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16. Abstract

This research developed, tested, evaluated, and recommended improved methods for communicating with drivers at both active and passive highway-railroad grade crossings to accomplish the study objectives. A driver comprehension survey of highway-railroad grade crossing traffic control devices, an in-vehicle observation of driver behavior at highway-railroad grade crossings, an evaluation of experimental passive sign systems previously installed at highway-railroad grade crossings, and the development of enhanced traffic control devices are documented in this report.

The driver comprehension survey found a lack of driver understanding related to requirements and responsibilities at passive and active grade crossings. Drivers initiated more looking behavior at passive crossings during the in-vehicle driver observation study. The implementation of the YIELD sign with a supplementary message plate containing the words TO TRAINS and the yellow supplementary message sign that read LOOK FOR TRAINS led to speed reductions at the highway-railroad grade crossing on some approaches. None of the experimental sign systems tested in the closed-course driving study, including the strobe light enhanced system, resulted in any adverse driver reaction. Driver ranking of the effectiveness of the three sign systems showed that both the standard flasher and strobe light enhanced systems were preferred to the standard railroad advance warning (W10-1) sign.

Based on the results of this research, a field test of a vehicle-activated strobe light mounted above the railroad advance warning sign (W10-1) was recommended for further study.

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ENHANCED TRAFFIC CONTROL DEVICES AND RAILROAD OPERATIONS FOR HIGHWAY-RAILROAD GRADE CROSSINGS: SECOND-YEAR ACTIVITIES

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IMPLEMENTATION STATEMENT

This report describes activities completed during the second year of a three-year study focusing on improving safety at highway-railroad grade crossings. The activities completed during the first year included a review of published literature on driver behavior at highway-railroad grade crossings; an assessment of railroad operating practices at grade crossings, including audible warning devices and locomotive conspicuity measures, and requirements for their use; an assessment of basic train detection technologies used at active highway-railroad grade crossings; and a statewide accident study.

In the second year of the study, the following activities were completed: driver comprehension surveys of highway-railroad grade crossing traffic control devices; in-vehicle observations of driver behavior at highway-railroad grade crossings; field study of YIELD TO TRAINS and LOOK FOR TRAINS signs; and development and evaluation of the vehicle-activated strobe enhancement to the advanced warning sign. Implementation of the researchers' recommendations may be accomplished through the distribution of public education materials and installation of the enhanced traffic control devices.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts, opinions, findings, recommendations, and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT) or the Federal Highway Administration (FHWA). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Daniel B. Fambro, P.E. No. 47535 (Texas).

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TABLE OF CONTENTS

Section		Page
LIST OF FIGURES		xiii
LIST OF TABLES		xv
SUMMARY		xvii
1.0	INTRODUCTION	1
	1.1 Problem Statement	1
	1.2 Research Objective	2
	1.3 Organization	2
2.0	DRIVER COMPREHENSION	5
	2.1 Introduction	5
	Objective	6
	2.2 Driver Knowledge and Misconceptions	6
	2.3 Study Design	8
	Methodology	8
	Survey Instrument	8
	Survey Distribution	9
	2.4 Analysis Procedures	9
	Driver Experience	9
	Demographic Factors	10
	Solicitation of Ideas	10
	2.5 Study Results	11
	Survey Questions and Responses	11
	Driver Comments	14
	Analysis of Research Hypotheses	18
	2.6 Summary	20
3.0	DRIVER BEHAVIOR	23
	3.1 Introduction	23
	Objective	23
	3.2 Driver Behavior at Grade Crossings	23
	Safe Driving Behavior at Highway-Railroad Grade Crossings	24
	Previous Research on Driver Behavior at Highway-Railroad Grade Crossings	26
	Factors That Contribute to Less Desirable Driving Behavior	27
	Observational Measures of Driver Performance	30
	3.3 Study Design	32
	Methodology	32
	Solicitation of Drivers	33
	Selection of Test Course	34
	Recording Observations of Driver Behavior	34

TABLE OF CONTENTS (Continued)

Section **Page**

Survey Instrument 35
3.4 Study Results 36
Observations at Active Crossings 38
Observations at Passive Crossings 42
Observations at the Closed Crossing 43
Motives for Deceleration Maneuvers 45
Effect of Defensive Driving Training 46
Effect of Legal History and Awareness 47
Effect of Frequency of Crossing Activity 48
Misconceptions Identified from Driver Comments and Survey Responses 49
3.5 Summary 53

4.0 EXPERIMENTAL PASSIVE SIGN SYSTEMS 55
4.1 Introduction 55
Objective 55
4.2 Safety at Railroad Crossings 55
4.3 Standard Sign Systems 56
4.4 Measures of Driver Performance 58
Driver Looking Behavior 58
Speed-Based Measures 58
Previous Laboratory Study of Experimental Signs 59
4.5 Study Design 59
Measures of Effectiveness 60
Driver Looking Behavior 60
Spot Speed Measurements 60
Driver Exit Survey 60
Sample Size Goals 61
YIELD TO TRAINS Sign System 61
LOOK FOR TRAINS Sign System 61
Site Selection 61
4.6 Study Results 63
Data Analysis 63
Field Tests 63
Driver Looking Behavior 63
Driver Approach Speed 66
Driver Survey 70
4.7 Summary 70

5.0 ENHANCED TRAFFIC CONTROL DEVICES 71
5.1 Introduction 71

TABLE OF CONTENTS (Continued)

Section **Page**

Objective 71
5.2 Background 72
5.3 Standard and Enhanced Sign Systems 74
Supplementary Flashing Beacon 75
Supplementary Strobe Light 75
Study Performance Measures 77
5.4 Study Design 77
Driver Study 78
Pilot Study 79
5.5 Analysis Procedure 80
5.6 Study Results 81
Driver Behavior 82
Driver Head Movement 82
Braking Reactions 82
Questionnaire Results 83
Focus Group Discussions 85
Passive Advance Warning versus Active Advance Warning 86
Enhanced Signs 86
Additional Concerns 87
5.7 Summary 88
5.8 Further Studies 88

6.0 SUMMARY OF FINDINGS 89
6.1 Driver Comprehension 89
6.2 Driver Behavior 90
6.3 Recommendations for Improving Driver Behavior 91
6.4 Evaluation of Experimental Passive Sign Systems 92
6.5 Enhanced Traffic Control Devices 92

REFERENCES 95

APPENDIX A: DRIVER COMPREHENSION SURVEY: SURVEY INSTRUMENT (ENGLISH VERSION) 99

APPENDIX B: DRIVER COMPREHENSION SURVEY: PARTICIPANT CHARACTERISTICS 115

APPENDIX C: DRIVER COMPREHENSION SURVEY: RESPONSES TO SURVEY QUESTIONS 119

TABLE OF CONTENTS (Continued)

Section **Page**

APPENDIX D: DRIVER COMPREHENSION SURVEY:
SUGGESTIONS FOR NEW SIGNS 129

APPENDIX E: DRIVER BEHAVIOR STUDY:
DESCRIPTIONS OF TEST COURSE CROSSINGS 133

APPENDIX F: DRIVER BEHAVIOR STUDY:
DATA COLLECTION FORM EXAMPLE
AND CODING INSTRUCTIONS 145

APPENDIX G: DRIVER BEHAVIOR STUDY:
DEBRIEFING STATEMENT AND SURVEY INSTRUMENT 151

APPENDIX H: EXPERIMENTAL PASSIVE SIGN SYSTEMS:
SPEED AND LOCATION DATA 159

APPENDIX I: ENHANCED TRAFFIC CONTROL DEVICES:
PARTICIPANT DEMOGRAPHIC DATA 171

LIST OF FIGURES

Figure	Title	Page
3.1	Observations of Looking Behavior at Active Crossings	39
3.2	Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions at Active Crossings According to Age Group	40
3.3	Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions at Active Crossings According to Gender	41
3.4	Percentage of Observations in Which Drivers Did Not Slow on the Approach to Active Crossings	41
3.5	Observations of Looking Behavior at Passive Crossings	42
3.6	Percentage of Observations in Which Drivers Looked Both Ways at Each Passive Crossing According to Age Group	44
3.7	Percentage of Observations in Which Drivers Looked Both Ways at Each Passive Crossing According to Gender	44
3.8	Percentage of Observations in Which Drivers Were Only Concerned with the Roughness of Crossing Surface While Initiating No Looking Behavior on the Approach	45
3.9	Percentage of Drivers Who Decelerated to Complete Stops or Rolling Stops at Each Passive Crossing	51
4.1	Standard Highway-Railroad Grade Crossing Sign System	57
4.2	The YIELD TO TRAINS Sign System Installed at a Test Crossing	62
4.3	The LOOK FOR TRAINS Sign System Installed at a Test Crossing	62
4.4	Driver Looking Behavior on the Northbound Approach to the F.M. 2131 Crossing	65
4.5	Driver Looking Behavior at the Baylor Street Crossing	66
4.6.	Mean Speed Reductions for YIELD TO TRAINS Experimental Sign System	67
4.7	Mean Speed Reductions for LOOK FOR TRAINS Experimental Sign System	67
4.8	Mean Speeds at the Crossbuck for YIELD TO TRAINS Experimental Sign System	68

LIST OF FIGURES (Continued)

Figure	Title	Page
4.9	Mean Speeds at the Crossbuck for LOOK FOR TRAINS Experimental Sign System	68
5.1	Advance Warning Signs for Highway-Railroad Grade Crossings	76
5.2	Map of the Closed Driving Course	79

LIST OF TABLES

Table	Title	Page
2.1	Frequency of Driver Comments	15
3.1	Stratification of Study Drivers	33
3.2	Crossing Classification Criteria	38
3.3	Percentage of Observations in Which Drivers Slowed Without Looking in Either Direction According to Exposure to Defensive Driving	46
3.4	Percentage of Observations in Which Drivers Looked in Direction(s) Obscured by Sight Obstructions According to Exposure to Defensive Driving	47
3.5	Percentage of Observations in Which Drivers Neither Looked Nor Slowed According to Exposure to Defensive Driving	47
3.6	Percentage of Observations in Which Drivers Did Not Look According to Frequency of Crossing Activity	50
3.7	Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions According to Frequency of Crossing Activity	50
3.8	Percentage of Observations in Which Drivers Neither Looked Nor Slowed According to Frequency of Crossing Activity	50
4.1	Summary of Data Collected at Test Sites	64
4.2	Results of the Chi-Square Test for Independence of the Driver Looking Behavior Data	65
4.3	Change in Speed Reduction	69
5.1	Age and Gender Distribution of Study Participants	81

SUMMARY

The objective of this research was to develop, test, evaluate, and recommend improved methods for communicating with drivers at both active and passive highway-railroad grade crossings. Four study methods were developed to accomplish this objective. First, a survey of driver comprehension of highway-railroad grade crossings was completed. This survey was followed by in-vehicle observations of driver behavior at highway-railroad grade crossings. A third study included the evaluation of experimental passive sign systems previously installed at several operational highway-railroad grade crossings. Driver reaction over an extended period of time to the LOOK FOR TRAINS and YIELD TO TRAINS signs were evaluated. Finally, the study looked at the development of other enhanced traffic control devices.

The driver comprehension survey found a lack of understanding of driver requirements and responsibilities at passive and active highway-railroad grade crossings. Drivers also showed a lack of understanding for the railroad advance warning sign and crossbuck. Twelve percent of the participating drivers said that driving around the gates at active grade crossings was acceptable if they could not see a train, and only 6 percent of the respondents have received a citation, or knew someone who had received a citation for driving improperly at a grade crossing. Most of the participating drivers said that they remembered instructions about grade crossings from either a driver's education or defensive driving course, operation lifesaver, or other educational campaign. However, participants suggested more public education would help improve safety at grade crossings.

Twenty-one drivers suggested that lights and gates should be present at every grade crossing, and these gates should extend completely across the roadway. They also suggested that many grade crossings are too rough and need to be made smoother. Drivers age 16 to 25 and drivers with less than five years of driving experience exhibited a lower level of comprehension related to traffic control devices and driver requirements at grade crossings than older, more experienced drivers. Living in large cities or rural areas did not affect driver comprehension of traffic control devices and driver requirements at grade crossings. Crossing frequency appeared to affect driver comprehension of traffic control devices at grade crossings; however, male and female drivers showed no differences in comprehension of traffic control devices and driver requirements at grade crossings.

Although responses reflected a general understanding of safe driving behavior at highway-railroad grade crossings, most drivers did not actually perform as they said they should or would when approaching the grade crossings along the test course. Furthermore, near miss experiences and association with those involved in tragic collisions did not necessarily produce noticeable changes in driving behavior at the grade crossings along the test course. Many drivers who initiated looking behavior in both directions did so within the hazard zone (within 5 m) of the grade crossing approach. Looking within this region may not allow enough time to avoid a potential collision, especially without speed reduction on the approach. Many drivers exhibit the desirable looking behavior without conscientiously looking for a train.

The implementation of the YIELD sign with a supplementary message plate containing the words TO TRAINS and the yellow supplementary message sign that reads LOOK FOR TRAINS may initially lead to larger speed reductions and lower speeds at the grade crossing on some approaches. Driver looking behavior may be significantly increased after the implementation of the YIELD TO TRAINS sign system. No evidence was found to suggest that this sign system would cause a significant decrease in looking behavior. The data suggests that drivers may have understood the YIELD TO TRAINS sign system better than the LOOK FOR TRAINS sign system. Drivers with the former sign system showed larger speed reductions and increases in looking behavior. The latter sign system did not have a significant impact on approach speeds and produced no significant improvement in looking behavior.

None of the three sign systems tested in the closed-course driver study, including the strobe light enhanced system, resulted in adverse driver reaction. The strobe light and standard flasher signing system did, however, solicit more braking than the standard sign. Head movement at each of the three signs was not statistically different. Drivers clearly preferred the standard flasher enhancement to the strobe light. Additionally, the strobe light was preferred to the standard sign. Both the strobe light and the standard flasher were said to have better attention gaining qualities than the standard sign, causing drivers to exhibit greater caution at a grade crossing. While some drivers did not like the strobe light, only three drivers said it startled them. Most of the startling reactions experienced were due to the novelty of the strobe and the fact that they were trying to decide what was flashing with such an irregular pattern. Of the three signing systems presented to the drivers, none caused adverse driver reactions in the form of rapid deceleration, sudden head movements or erratic steering maneuvers.

Drivers preferred the railroad advance warning sign supplemented with the standard flasher to gain the attention of daydreaming drivers and to alert drivers that a passive grade crossing was ahead. Driver ranking of sign system effectiveness showed that both of the enhanced systems were preferred to the standard railroad advance warning sign. All drivers understood the meaning of the standard advance warning sign but became confused by its meaning upon the addition of the supplemental flashing lights. Confusion about whether a train was present when the lights were flashing was greater with the standard flasher than with the strobe light.

Based on the results of this research, a field test of the vehicle-activated strobe light mounted above the railroad advanced warning (W10-1) sign has been recommended.

1.0 INTRODUCTION

According to 1993 Federal Highway Administration (FHWA) reports, the state of Texas had 13,235 public highway-railroad grade crossings. This number is greater than in any other state; Illinois ranks second with 10,364 grade crossings. Approximately 4,500 (34 percent) of Texas' public grade crossings are classified as "active" crossings. Active crossings provide warning of the approach or presence of a train. A detection circuit in the railroad track senses the presence of an approaching train and activates the warning devices at the crossing. Examples of active warning devices include mast- and cantilever-mounted flashing light signals, automatic gates, wigwag signals, and bells. Grade crossings that lack train-activated warning devices are classified as "passive" crossings. Passive crossings employ signs and markings to identify the location of the crossing and direct the attention of the driver, bicyclist, or pedestrian toward it. Passive devices provide static messages; the message conveyed by the signs or markings remain constant regardless of the presence or absence of a train. Both types of crossings use the same advance warning signs and pavement markings to alert roadway users that a highway-railroad grade crossing is nearby.

In its simplest form, a highway-railroad grade crossing is nothing more than an intersection that handles two conflicting streams of traffic; however, the grade crossing is unique in the transportation system in that two different modes of transportation compete for the same physical space. This attribute and the different operating characteristics of highway vehicles and trains create a potential safety problem at highway-railroad grade crossings. For example, the operating characteristics of trains inhibit their ability to stop quickly. Unlike cars, trains move on a fixed path or guideway and cannot swerve to avoid an impending crash. Therefore, cars must yield right-of-way to trains at highway-railroad grade crossings or conflicts will occur. Texas law clearly states that the driver should always "slow, look, and listen, and be prepared to yield the right-of-way to an approaching train" at a highway-railroad grade crossing.

1.1 PROBLEM STATEMENT

Driver error is frequently cited as a factor in highway-railroad grade crossing crashes. Driver error may result from failure to perceive that a train is in hazardous proximity to the crossing. Alternatively, the driver may detect the train but decide erroneously that adequate time is available to clear the crossing ahead of the train. There are many reasons that drivers fail to detect the train or make faulty decisions. It has been suggested that a leading cause of bad decisions is violation of driver expectancy. If a driver is only familiar with active highway-railroad grade crossings, he or she may not understand his or her responsibilities at a passive crossing. Further, the driver who has had experience at a highway-railroad grade crossing with infrequent trains may not pay adequate attention at unfamiliar locations with higher train volumes.

Another possible source of confusion at highway-railroad grade crossings is the current system of visual communication. The advance warning sign and railroad crossbuck sign do not differentiate between active and passive crossings, thereby complicating the drivers' decision-making task. National statistics show that more than 50 percent of all collisions between motor vehicles and trains occur at active crossings, which in theory should have substantially fewer crashes or no crashes at all. One potential explanation is that the warning device technologies and the warning time they provide may contribute to the frequency of crashes at these grade crossings. Further, higher train and traffic volumes at active crossings may also be contributors to crashes. Nevertheless, methods for improving communication between railroad advance warning signs and the driver are needed to reduce driver confusion, minimize violations of driver expectancy, and improve overall safety at highway-railroad grade crossings.

1.2 RESEARCH OBJECTIVE

The objective of this study was to develop, test, evaluate, and recommend improved methods for communicating with drivers at both active and passive highway-railroad grade crossings. Recommended devices should demonstrate compliance with the *Manual on Uniform Traffic Control Devices* (MUTCD), high conspicuity and target value, adequate comprehension by the Texas driver population, and relatively low implementation cost versus alternative measures. To accomplish the research objective, the research team formulated a work plan consisting of nine tasks:

1. Assess driver behavior and causes of driver error;
2. Assess warning device activation technologies;
3. Assess railroad operating rules and practices;
4. Conduct a statewide grade crossing crash study;
5. Monitor experimental passive sign systems at test crossings;
6. Develop and evaluate enhanced traffic control devices;
7. Create and convene a public education advisory committee;
8. Develop a comprehensive plan for highway-rail safety awareness; and
9. Prepare and submit a final report documenting the research findings and recommendations.

This report documents the results from the study's second-year activities - Tasks 5 through 9. Observations of driver behavior as prescribed in Task 1 were also completed.

1.3 ORGANIZATION

This report documents the activities and findings of research activities completed in the second year of this three-year study. The report on first-year activities contained a review of the literature on driver behavior at highway-railroad grade crossings, a study of train detection-technologies for highway-rail grade crossings, a study of railroad operating rules and practices at highway-railroad grade crossings, and an analysis of factors contributing to grade crossing crashes in Texas.

This report on second-year research activities contains six sections, including this introductory section. Sections 2 through 6 discuss the following research activities completed during the second year of the study:

- Survey of driver comprehension of highway-railroad grade crossings;
- In-vehicle observations of driver behavior at highway-railroad grade crossings;
- Evaluation of experimental passive sign systems; and
- Development and evaluation of enhanced traffic control devices.

Section 2.0 discusses findings from a driver comprehension survey of grade crossing traffic control devices. Section 3.0 discusses findings from in-vehicle observations of driver behavior at highway-railroad grade crossings. Section 4.0 presents findings from long-term monitoring of experimental passive sign systems previously installed at test grade crossings. Driver reaction, over an extended period of time, to LOOK FOR TRAINS and YIELD TO TRAINS signs are discussed. Section 5.0 describes development of enhanced traffic control devices for passive highway-railroad grade crossings. A focus group study of drivers' reactions to these enhanced traffic control devices is discussed. Further studies planned for the vehicle-activated strobe light system are also discussed. Section 6.0 summarizes key findings from the second-year activities.

2.0 DRIVER COMPREHENSION

2.1 INTRODUCTION

Highway-railroad grade crossings represent the intersection of different modes of transportation. Two types of control are used to identify the location of the grade crossing and/or warn drivers of the presence of a train. *Passive* traffic control systems, consisting of signs and pavement markings, identify and direct attention to the location of the grade crossing. Passive grade crossings contain a railroad advance warning (W10-1) sign and railroad crossing (crossbuck) sign. *Active* traffic control systems inform drivers and pedestrians of the approach or presence of trains at highway-railroad grade crossings. In addition to warning signs, crossbucks, and pavement markings, active crossings have flashing lights to warn the driver of an approaching train. Active grade crossings may include bells and automatic gates, in addition to the flashing lights.

Driver requirements differ at active and passive crossings. Active warning devices attempt to reduce driver workload by simplifying the decision-making process. Drivers must observe the flashing light signal, determine if the lights are flashing, and then decide whether it is safe to pass over the grade crossing. Conversely, drivers at passive crossings are responsible for recognizing the grade crossing, determining whether a train is approaching, and judging the speed and distance of an approaching train. After completing the evaluation of these variables, the driver must then decide if crossing the tracks is safe.

The current system of visual communication fails to differentiate between passive and active highway-railroad grade crossings. The same advance warning signs and pavement markings are used to inform, instruct, warn, and guide drivers in two very different driving situations. At active crossings, the driver has different requirements than at passive crossings, yet no distinction is made between the two. The driver is unaware if the crossing is active or passive until it is within view. The determination is made when the observance of a flashing light signal leads to the assumption that the grade crossing is active. The distinction between crossing types is more difficult at night and during periods when weather conditions make the grade crossing less conspicuous.

This lack of distinction may result in driver confusion at passive highway-railroad grade crossings that can lead to driver error. Incorrect actions and actions not taken can result in one of three events: a collision, a near collision, or no event. Collisions between trains and vehicles usually result in fatalities.

Over the past 20 years, more than $2 billion have been allocated for the improvement of highway-railroad grade crossings. Many passive grade crossings have been upgraded with active protection which has decreased the number of collisions at grade crossings each year. Even so, collisions at grade crossings are still a major concern. To continue improving safety at highway-railroad grade crossings, driver comprehension and attitudes pertaining to traffic control devices requires additional investigation.

Objective

The objective of this task was the investigation of driver comprehension, attitudes, and misconceptions concerning grade crossing traffic control devices. The research team accomplished this objective through a literature review and driver survey. After reviewing the literature, the research team developed several hypotheses related to driver comprehension. Survey responses were used to refute or verify these assumptions.

This section is organized into several subsections that describe driver comprehension research. This first section introduces the problems surrounding drivers' comprehension of traffic control devices used at highway-railroad grade crossings. The second section discusses key findings in the literature that relate to surveys of drivers comprehension of traffic control devices at highway-railroad grade crossings. The third section describes the study methodology and procedures for assessing driver comprehension at highway-railroad grade crossings. The fourth section details the findings from the driver comprehension survey and the statistical analysis of the research hypotheses. The fifth section summarizes the key findings of this task.

2.2 DRIVER KNOWLEDGE AND MISCONCEPTIONS

This section discusses driver knowledge and misconceptions surrounding traffic control devices at highway-railroad grade crossings from the many drivers who do not understand or fully comprehend the meaning of these traffic control devices. In some situations, the number of drivers who do not understand the meaning of the devices is small, but the severity of the train-vehicle collision is such that only a small fraction of the driving population making improper decisions can lead to death and serious injury. Therefore, it becomes important to use proper traffic control devices at grade crossings and educate drivers on the proper driving behavior at these locations. The three E's of traffic engineering (engineering, education, and enforcement) are important at highway-railroad grade crossings.

Tidwell and Humphreys administered a survey and found that driver knowledge and/or understanding of traffic control devices used at grade crossings was inadequate *(1)*. Furthermore, more than 50 percent of all respondents believed that all grade crossings, except those rarely used by trains, have active warning signals to alert the driver of an approaching train. Most drivers were unaware of the differences in responsibilities at active and passive crossings. The researchers concluded that drivers' knowledge and/or understanding of grade crossing traffic control devices was inadequate and may be due, in part, to drivers' misconception that traffic laws are not enforced at grade crossings.

Womack et al. conducted a study investigating driver understanding of the railroad advance warning (W10-1) sign and found that 42 percent of the drivers surveyed did not know the railroad advance warning sign was circular, 60 percent did not know it was yellow, and 64 percent believed it was placed at the grade crossing *(2)*. The study also revealed that 70 percent of the drivers surveyed did not expect to see the crossbuck after the railroad advance warning sign and 17 percent said they would "stop and look for trains" upon seeing the railroad advance warning sign. Critics of the survey results claim the large difference between intent and response requires additional verification.

Expectancies often contribute to misunderstanding and misconception of the meaning and use of traffic control devices. Many studies have addressed driver understanding of traffic control devices and associated traffic laws at highway-railroad grade crossing. Sanders, Kolsrud, and Berger found deficiencies in driver understanding as 15 percent of drivers surveyed believed that all highway-railroad grade crossings have active warning devices (*3*). Fambro and Heathington evaluated drivers' comprehension and understanding of standard active traffic control devices and determined that 12 percent of drivers thought that flashing light signals were present at all grade crossings (*4*). Richards administered a similar survey, finding that 22 percent of the drivers held this same misconception (*5*). These percentages are alarming and reflect that some drivers have false expectancies pertaining to grade crossing traffic control and/or they do not fully comprehend the passive traffic control strategy.

As mentioned, Fambro and Heathington studied drivers' understanding of warning devices at highway-railroad grade crossings. When drivers were asked what to do when approaching a grade crossing without a railroad signal (i.e., a passive crossing), 84 percent thought they should stop, look, and listen for a train at the grade crossing. The researchers noted that although this behavior is not necessarily unsafe, the correct response when approaching a passive crossing is to be ready to stop for a train (i.e., a complete stop is not required at passive crossings) (*4*). Field observations of driver behavior at both active and passive crossings revealed that although drivers claim to stop, look, and listen in response to driver surveys, actual driving habits are not consistent with this response.

Urbanik evaluated drivers' attitudes concerning hazards at highway-railroad grade crossings, citizens' appraisal of priorities for improving grade crossing safety, driver evaluation of possible warning systems for grade crossings, and the general design and development of a proposed railroad advance warning system (*6*). This research found that the respondents considered highway-railroad grade crossings more hazardous than other highway hazards. Improving safety at highway-railroad grade crossings was given high priority by the respondents.

Driver attitudes at highway-railroad grade crossings are often influenced by the credibility of the traffic control devices. Research has shown that drivers disregard traffic control devices at grade crossings more than other traffic control devices (*7*). Active crossings with flashing lights and gates are susceptible to credibility problems in two ways: activation when no train is present, and excessive warning times. Drivers lose confidence in the traffic control device after they have witnessed a signal failure. Active warning devices are operated on fail-safe mode, which means that in case of a problem, the device will be activated. This problem can be serious when routine signal failures occur and drivers who are familiar with the grade crossings expect the equipment to fail and regularly ignore the signals.

Passive crossings have a different type of credibility problem. Most passive crossings are found in rural areas with both low volumes of trains and vehicles. Statistically speaking, the chance of a train and vehicle arriving at a grade crossing at the same time is relatively small. Drivers who frequently use passive crossings become accustomed to the absence of a train, and the warning signs become less credible.

2.3 STUDY DESIGN

Crashes at highway-railroad grade crossings in Texas involving vehicles and trains are generally more severe than all other crash types (*8*). Due to the frequency of these crashes, understanding drivers' comprehension of the existing traffic control devices is essential. The goal of this component of the research is to address the issue of driver comprehension through a literature review and driver survey. This section describes the survey design and analysis procedures used to study driver comprehension of grade crossing traffic control devices.

Methodology

The research team developed a survey to test drivers' understanding of traffic control devices and drivers' responsibilities at highway-railroad grade crossings. A self-administered survey instrument allowed the research team to reduce interviewer bias. The research team was careful to provide clarifications to questions raised by the participating drivers, rather than interpretation of the survey questions. Assuring that the research team had consistent interpretation related to driver comprehension of grade crossing traffic control devices also helped reduce interview bias (*9*).

Survey Instrument

A notebook containing photographs of traffic control devices was given to each driver. The objective of the survey was to present the highway-railroad grade crossing devices as realistically as possible. Each participating driver was provided an answer sheet to record his or her responses to the survey questions. A copy of the driver comprehension survey is provided in Appendix A.

The driver comprehension survey contained 15 questions consisting of four different types: true or false, multiple choice, open/free answer, and demographic information. Each of these question types can be further described as follows:

True or False: The questionnaire contained two true/false type questions. The respondents could choose true, false, or not sure.

Multiple Choice: Most of the questions were multiple-choice type questions. For each question, the respondent had multiple answers to choose from, or they could choose not sure.

Open/Free Answer: One question asked whether the driver had any comments or suggestions for improving safety at highway-railroad grade crossings. It was also suggested that the driver use the space provided to sketch a drawing if necessary. The responses were recorded and later categorized for data reduction purposes. The primary advantage of using an open-ended question was to allow drivers to respond freely without being influenced by required choice selection. Open-ended questions required a coding system for reduction and analysis of the data.

Demographic Information: Demographic information pertaining to drivers' age, gender, residency, driving experience, education level, and family background was requested in the survey. This information was used to ensure that the surveys collected were a representative sample of the Texas population. In addition, the following questions were included:

- Have you or anyone you know ever received a traffic citation (ticket) for driving improperly at a railroad crossing?
- Have you completed a Driver Education or Defensive Driving course within the past year?
- In your driving, how often do you encounter railroad crossings?

Survey Distribution

The research team distributed the survey to a large, diverse sample representative of the Texas driving population. The research team utilized the Houston Auto Show, the Texas/Mexico Hunting and Fishing Expo in Laredo, and the Nacogdoches Multi-Cultural Festival for the distribution sites. These locations allowed researchers to survey both rural and urban populations.

The survey was available in either English or Spanish. Participating drivers were informed that the survey was created for a research project on highway-railroad grade crossings sponsored by the Texas Transportation Institute (TTI) and the Texas Department of Transportation (TxDOT). Drivers were told to read the instructions on the first page of the survey and then mark their responses on the sheet provided. All responses were kept confidential. Upon completion of the survey, participating drivers were given a Texas State Highway Map, compliments of TxDOT.

2.4 ANALYSIS PROCEDURES

Several studies on grade crossing crashes and driver behavior were examined as part of the literature review for this research. After reviewing the literature, the research team developed six hypotheses concerning driver comprehension of grade crossing traffic control devices. The survey was designed to determine the accuracy of these hypotheses. The hypotheses will be discussed as they relate to driver experience and demographic factors.

Driver Experience

Four hypotheses were developed to identify the effects of driving experience on drivers' comprehension of grade crossing traffic control devices. First, the research team hypothesized that young drivers would not exhibit as high a comprehension of traffic control devices as older drivers who participated in the survey. This hypothesis was generated from the notion that young drivers are usually less experienced with driving tasks and environments than older drivers. This hypothesis was tested by comparing the number of correct responses for the young drivers (less than five years experience) with the responses of the other drivers.

Second, the research team hypothesized that drivers who had taken a Defensive Driving course or Drivers Education course within the last year might show a better understanding of traffic control devices associated with highway-railroad grade crossings. To test this hypothesis, the responses of those who had taken a driving course were compared with those who had not.

Third, those drivers who live in urban areas were expected to display a better understanding of active traffic control devices while those drivers living in small cities and rural areas were expected to be more familiar with the passive crossing devices. To test this hypothesis the researchers compared the survey responses of those living in large cities with the responses of those living in small cities and/or rural areas.

The fourth hypothesis evaluated the effect of familiarity with grade crossings. Because experience with the grade crossing leads to familiarity, drivers who cross railroad tracks more than once a day should do better than drivers with less exposure. Conversely, drivers who rarely cross railroad tracks were expected to display a lower level of comprehension of grade crossing traffic control devices. This hypothesis was tested by comparing the responses from those who pass over grade crossings daily to those who pass over grade crossings on a less frequent basis.

Demographic Factors

Two hypotheses were developed to identify the effects of demographic factors on driver comprehension of grade crossing traffic control devices. First, female respondents were expected to show a higher level of comprehension since they are involved in fewer collisions at highway-railroad grade crossings. This hypothesis was tested by comparing the responses of female drivers with the responses of male drivers.

Similarly, because Caucasian and Hispanic male drivers are involved in more collisions at highway-railroad grade crossings, the researchers wanted to determine whether a measurable difference in comprehension was present between different ethnic backgrounds. This hypothesis was tested by comparing the responses of the Hispanic drivers with those of the Caucasian drivers.

Solicitation of Ideas

One survey question asked the drivers if they had any comments or suggestions for improving safety at highway-railroad grade crossings. It was suggested that the driver use the space provided for comments and to draw a sketch if necessary. These comments were coded into the following categories:

- Operating Practices;
- Signs;
- Maintenance;
- Public Education/Enforcement;
- New Ideas; and
- Railroad Responsibilities.

2.5 STUDY RESULTS

This section presents the results of the analysis of the driver comprehension survey. A total of 1,010 surveys were collected. Some participating drivers did not answer all of the questions; therefore, the total responses pertaining to each question does not add up to 1,010. Incomplete surveys were used where applicable; however, for the hypotheses testing, only complete surveys were used. Appendix B provides characteristics of the study participants. The ethnic breakdown of the survey drivers was 63 percent Caucasian, 28 percent Hispanic, 4 percent African-American, and 3 percent Asian. These percentages are similar to the ethnic breakdown of the Texas driving population (i.e., 61 percent Caucasian, 26 percent Hispanic, 12 percent African-American, and 1 percent Asian). Appendix C contains the responses to the survey questions. An asterisk denotes the correct response to each question. Percentages were rounded to the nearest whole number. Therefore, some totals will not add to 100 percent. The percentages of each response are included next to each answer.

Survey Questions and Responses

Questions 1 and 2: All railroad crossings have flashing signals. All railroad crossings that are used by trains have flashing signals.

Participants could respond by choosing true, false, or not sure to these questions. The response to question 1 were 12 percent true, 86 percent false, and 3 percent not sure. The potential effect of incorrect responses to this question is quite serious. Approximately 15 percent of the drivers believe that all grade crossings are active or they are not sure. This uncertainty could be very dangerous when these drivers approach a passive crossing expecting it to be active.

Question 2 produced similar results as question 1, 20 percent true, 74 percent false, and 6 percent not sure. Again, incorrect responses indicated potentially dangerous effects. If 15 to 25 percent of drivers expect active signals at every grade crossing, they may not be looking for trains.

These findings agree with those by Sanders et al. in which 15 percent of the drivers stated that all grade crossings have active protection (*3*); however, Tidwell et al. showed that approximately 50 percent of the respondents believed that all grade crossings, except those rarely used by trains, have active warning signals (*1*). Despite the percentage of drivers who agree with this study, the fact remains that some drivers believe that all grade crossings are actively protected.

Question 3: Do you recall any specific instructions about safe driving at railroad crossings from any of the following sources?

The purpose of this question was to learn where the driving public is receiving information pertaining to highway-railroad grade crossings. The largest percentages of responses (33 percent) identified a Driver Education or Defensive Driving course as their primary source of information. Operation Lifesaver received 27 percent of the responses and other safety campaigns received 20 percent of the responses.

The high response rate to this question suggests that most drivers remember something from public education campaigns and that they are worthwhile. Only 4 percent of the drivers did not recall any specific instructions about safe driving at highway-railroad grade crossings.

Questions 4 and 5: At what type of crossing (active or passive) are the crossbuck and advance warning sign used?

These questions were designed to test drivers' comprehension of signing at highway-railroad grade crossings. Questions 4 and 5 pertained to the location of the crossbuck and railroad advance warning sign, respectively. For both of the signs, approximately 70 percent of the drivers identified the correct location. Only 50 percent said that these signs were used at both active and passive crossings.

These responses are somewhat better than the results of other studies. Womack et al. found that 64 percent of drivers thought that the railroad advance warning sign appears at the grade crossing (2); however, this study revealed the same response for only 25 percent of drivers. The current findings are also similar to a study by Tidwell et al. in which 21 percent of drivers believed that the railroad advance warning sign is located at the grade crossing (*1*). Responses to these questions reveal a lack of understanding of the railroad advance warning sign and crossbuck.

Question 6: What is the meaning of this (advance warning) sign?

Again, the responses to this question revealed that many drivers do not comprehend the meaning of the advance warning sign. Approximately 70 percent of the participating drivers responded correctly; however, 16 percent of the drivers marked the answer: "There is a highway-railroad grade crossing within 5 m (15 ft) of the sign. Stop, look, and listen for an approaching train." This percentage is less than the results from Fambro and Heathington's study in which 91 percent of the drivers selected the correct response and 9 percent selected the answer: "you will have to stop at the grade crossing" (*4*). This misunderstanding may lead to potentially dangerous behavior if the driver actually did stop within 5 m (15 ft) of the sign or at the grade crossing. Other drivers would not be expecting a vehicle to stop, which could lead to a rear-end collision.

Question 7: The railroad crossing shown below has a "Railroad Crossing" sign, but it does not have signals. What should you do at a railroad crossing that does not have signals?

Approximately 30 percent of the respondents answered this question correctly: maintain a safe speed, look for a train, and be ready to yield the right-of-way if a train is approaching the grade crossing. An additional 66 percent of the drivers chose a "less correct" response: "stop before crossing the track, and look and listen for a train." While this response is not completely wrong, (this action will result in safe viewing of the tracks) it may result in a potentially dangerous situation. Other drivers on the roadway may not be expecting the preceding vehicle to stop, possibly resulting in a rear-end collision.

The responses to this question are both positive and negative. The fact that a combined 96 percent of the participants chose an answer that would prevent a train-vehicle collision shows a high level of the understanding of the dangers associated with grade crossings; however, the fact that 66 percent of the responses were incorrect, and could result in a rear-end collision, shows that the driving public does not fully comprehend the traffic control devices at passive grade crossings. These results suggest that drivers do not always do what they say they will do. A study of driver behavior may reveal different findings.

Question 8: The railroad crossing shown below has a "Railroad Crossing" sign, in addition to signals and gates. What should you do at this railroad when the signals are not flashing and the gates are not lowered?

The results to this question are similar to question 7. Approximately 23 percent of the participants chose the correct answer: maintain a safe speed and proceed through the grade crossing without stopping. An additional 57 percent chose a "less correct" answer: "slow down, look, and listen for a train." Approximately 18 percent of the participants chose the answer: "stop at the grade crossing and look and listen for a train." These responses suggest that drivers have a good understanding of the hazards of a train-vehicle collision, but do not fully understand driver responsibility at active grade crossings. The responses of 69 percent of the participants could result in vehicle-vehicle collisions.

Question 9: The railroad crossing shown below has a "Railroad Crossing" sign, in addition to signals and gates. What should you do at this railroad crossing when the signals are flashing and the gates are lowered?

Most of the participants, 86 percent, responded correctly to this question: "stop at the crossing and do not continue across the tracks until the signals stop flashing and the gates are raised." The percentage of correct responses shows a good understanding of the traffic control devices at active highway-railroad grade crossings.

Ten percent of the participants thought it was "okay" to drive around the gates after either slowing down, or stopping to look for a train. Two percent of the participants selected the response: "when the signals are flashing and the gates are lowered, it is usually because they are malfunctioning. Continue through the crossing without stopping." These responses may show a disrespect for traffic control devices at active crossings; drivers not knowing that driving around gates is illegal, may exhibit risky behavior, or may disregard the signals.

Question 10: What does the sign shown below (experimental advance warning sign) mean?

This sign is an experimental sign intended to improve the existing signing system at passive crossings. It is placed between the standard railroad advance warning sign and the crossbuck. Results for this question were not very good. Approximately 9 percent of the participants selected the correct response to this question: "there is a railroad crossing without flashing signals or gates ahead. Slow down, look, and listen for an approaching train." An additional 25 percent of the drivers chose an acceptable answer: "there is a railroad crossing ahead. Slow down, look, and listen for an approaching train."

Two of the potential choices have dangerous implications. Due to the nature of the icon, 23 percent of the participants said that the sign meant that a historic locomotive is ahead, as in a city park. These drivers would not be looking for a grade crossing on the approach to a crossing. In addition, 12 percent said that: "there is a railroad ahead with slow-moving trains. Slow down, look and listen for an approaching train." This response could be potentially hazardous if the driver is not expecting a fast-moving train, and misjudges whether it is safe to cross the tracks.

The research team noted that this question produced many participant comments. A large number of drivers, 25 percent, were not sure of the correct answer. After completing the survey, many drivers wanted to know the correct meaning of this sign. A frequent comment was that this sign was *cute*, and it looked like the signs they have at amusement parks for the kiddie trains.

The sign shown in question 10 is intended to be used at passive crossings as a supplement to the standard railroad advance warning sign. A supplemental LOOK FOR TRAINS sign directly underneath the warning sign is also intended to be used with this sign. The results from this survey show that the sign is not well understood and may produce different results when used in this manner.

Questions 11 and 12: At which type of crossing would you expect to see the sign shown below (crossbuck and advance warning sign)?

These two questions explained the meaning of the terms "active" and "passive" railroad grade crossings and then asked at which type of grade crossing the crossbuck and railroad advance warning signs are used. The responses to these questions are discouraging. Only 66 percent of the participants said that the crossbuck was used at all highway-railroad grade crossings, and only 49 percent said the railroad advance warning sign was used at all highway-railroad grade crossings. Since participants had just viewed pictures in the survey in which the crossbuck is visible on both types of grade crossings, better results were expected. Again, responses to these questions show a lack of understanding of the crossbuck and railroad advance warning sign.

Question 13: What is the meaning of the sign shown below ("Yield to trains" experimental sign)?

Overall, this sign produced positive results. Approximately 82 percent of the drivers identified the correct meaning of the sign: "yield the right-of-way if a train is approaching a crossing." Three percent of drivers selected an extremely hazardous response: "trains at the railroad crossing must yield the right-of-way to highway traffic." These responses show some understanding of the sign, yet show evidence of serious misunderstanding by a small percentage of drivers.

Driver Comments

Participating drivers were asked whether they had any comments or suggestions to improve safety at highway-railroad grade crossings. Table 2.1 gives a summary of the comments from the surveys. The 325 comments were divided into six different categories: operating practices, signs, maintenance, public education/enforcement, new ideas, and railroad responsibilities. The comments within each category are discussed in the following sections.

Table 2.1. Frequency of Driver Comments

	FREQUENCY
GENERAL COMMENTS	
Liked this survey--good job	6
The signs are fine, people are just not always careful, drivers should stay alert	6
OPERATING PRACTICES	
Put gates and lights at every grade crossing	56
Build more overpasses, all crossings should be grade-separated	4
Timing should be right	3
Better lights on rural roads, and all grade crossings	2
SIGNS	
Make signs brighter	2
Mark multiple tracks	1
New sign design	13
Use icons for people who can't read English	1
Place signs at and well in advance of the grade crossing	2
Standardize and use one type of sign	5
MAINTENANCE	
General Maintenance Gates, lights should work 24 hours a day Clear vegetation so you can see down the tracks Develop a method to determine if the signals are not working Require railroads to maintain the track mats Use new technology to maintain grade crossings Update old equipment, repaint lines, check signals	41
Have a 1-800 number to call for maintenance problems	3
Make grade crossings smoother, maintain road surface condition	20
Remove traffic control devices from abandoned tracks	2

Table 2.1. Frequency of Driver Comments (Continued)

	FREQUENCY
PUBLIC EDUCATION / ENFORCEMENT	
This survey made the driver realize how much they do not know	16
Public Education Stress Railroad Crossing Information in drivers' education classes Increase Operation Lifesaver activity Information on noise levels inside the car Use (more) commercials on television Have a mandatory refresher course to renew drivers' license Use graphic movies of grade crossing crashes for television and drivers education Provide information in English and Spanish	53
Enforcement: Make it illegal to drive around gates, increase enforcement, higher fines	9
NEW IDEAS	
Use steel arms instead of wood	4
Install gates that you cannot drive around	21
Other Ideas Parallel grade crossings should have a turning lane for vehicles waiting to cross Use raised reflectors or speed bumps in advance of the grade crossing Have a steel wall rise from the ground when a train approaches Add "stop here" signs and pavement markings Put a traffic signal at all grade crossings Use spikes that will flatten tires if someone drives around the gates Make lights more like the lights on police vehicles so they are more visible Have an alarm to make the driver pay attention Use changeable message signs to warn of train presence and avoid traffic jams There should be a signal in advance and a few meters in front of the grade crossing Use reflective material on traffic control devices	28
RAILROAD RESPONSIBILITIES	
Train should use horn, use a louder horn	7
Trains should not block grade crossings	13
Trains should not run through cities during rush hour, route trains around city	5
Trains should run at night to avoid traffic problems	1
Trains should go slower through the grade crossings	3
Trains should not run at night	1
Use reflectors on the sides of trains	2

A total of 65 comments were categorized as "operating practices" issues. The comment with the greatest frequency (56) was: "Put lights and gates at every grade crossing." The other comments included building more grade-separated grade crossings, using consistent timing at active crossings to reduce delay. One comment suggested using better lighting at all highway-railroad grade crossings, especially rural grade crossings. These comments suggest that passive grade crossings are viewed as a problem.

Signs

The comments in this category concern the use of signs at the highway-railroad grade crossings. Five participants suggested standardizing and using one type of sign at all grade crossings. Other suggestions were to make the signs brighter, mark multiple tracks, and to place signs in advance of the grade crossing. In addition, drivers suggested 12 new sign designs that are included in Appendix D.

Maintenance

This category included 65 comments that dealt with maintenance issues. The most frequent comment (41) was: "The lights and gates should work 24 hours a day." Another frequent comment regarding the condition of the tracks was that the grade crossings need to be smoother.

These comments suggest that drivers have a negative perception of active crossings and may explain why some drivers go around the gates. Question 9 of the survey supports this comment: "What should you do at this crossing when the signals are flashing and the gates are lowered?" Approximately 2 percent of the participants chose the response: "When the signals are flashing it is usually because they are broken or malfunctioning, continue through the crossing without stopping." Eleven percent said that it was "okay" to drive around the gates if a train is not approaching. These results indicate that a percentage of the drivers do not trust the signals at active crossings.

Public Education/Enforcement

This category included all of the comments that dealt with public education and the enforcement of traffic laws at highway-railroad grade crossings. Sixteen of the participants said that this survey made them realize how much they did not know about grade crossings. The public education comments were the second highest category with a total of 53 comments. The types of comments in this category included:

- Stressing grade crossing information in drivers education classes;
- Increase Operation Lifesaver activity;
- Educate on the importance of keeping a safe noise level in the vehicle;
- Use public service announcements on television;
- Have mandatory refresher courses to renew drivers' licenses;

- Use graphic videos of train/vehicle collisions on TV commercials and in driver education courses; and
- Provide information in English and in Spanish.

The enforcement category contains nine comments regarding enforcement of traffic laws at highway-railroad grade crossings. The following are examples of these comments: "make it illegal to drive around the gates, increase enforcement, make enforcement stricter, and increase the fines for violating traffic laws at highway-railroad grade crossings."

These comments signify the importance of public education and increased enforcement of traffic laws at highway-railroad grade crossings.

New Ideas

Many participants came up with some new ideas to increase safety at grade crossings. The most common suggestion was to create gates that drivers could not drive around. A suggestion was also made that gates should be made of steel rather than wood so that it would act as a deterrent: a vehicle would be damaged if driven into the gates. Another suggestion was to have a steel wall rise from the ground so that drivers could not go around it, and spikes that would flatten tires if the driver drove around the gates. These types of comments show that the public is aware that driving around the gates is a problem; however, these drivers see the problem as a design problem, and not a driver behavior problem.

Railroad Responsibilities

The last category was labeled railroad responsibilities because the comments suggested ways that the railroads could increase safety. The most frequent suggestion in this category was that trains should not block the grade crossings. This comment is helpful in showing that drivers get frustrated waiting for trains. This comment also may explain why drivers familiar with the grade crossing try to beat the train. If a grade crossing is frequently blocked, drivers may be more likely to try to beat the train to avoid being delayed.

Six participants suggested that trains use a louder horn, which agrees with the literature in that the horn should only be used as an extra precaution. Although most trains blow their horns at every grade crossing, drivers may not always notice it.

The comment that trains should use louder horns and the comments about more public education on automobile noise levels agrees with the literature suggesting that the noise level in many vehicles prevents the driver from hearing the train's horn.

Analysis of Research Hypotheses

This section presents the hypothesis results relating driver experience and demographic factors on comprehension of grade crossing traffic control devices. A table is provided within Appendix C that summarizes the percentages of correct responses according to driver type (e.g., young driver, rural driver, male driver, Caucasian driver). The significance of the findings was evaluated using a Chi-Square test at a 95 percent confidence level.

Results of Driver Experience Factors

The researchers were interested in learning whether a significant difference in the comprehension of grade crossing traffic control devices between younger drivers (less than five years of driving experience) and older drivers exists. The young age group did not do as well on questions 1, 2, 4a, 6, 7, and 9. The results for the inexperienced group were similar. They did not do well on questions 1, 2, 5b, 6, 9, and 13. Similar results were expected since the two groups are generally consistent; drivers between 16 and 20 years of age will have less than five years of driving experience (both groupings were used, so as not to assume older drivers could not be in this group). Overall, the young and the inexperienced drivers displayed less comprehension of grade crossing traffic control devices than other drivers.

The research team hypothesized that those respondents who had taken a Defensive Driving or Drivers Education course within the last year might exhibit a better understanding of the traffic control devices associated with highway-railroad grade crossings. Analysis of the responses to the survey did not show a significant difference between the drivers who had taken a Drivers Education or Defensive Driving course in the past year and those who had not.

Participants living in urban areas were expected to exhibit a better understanding of active crossing traffic control devices while those living in small cities and rural areas were expected to be more familiar with the passive grade crossing scenario. The only significant finding was that the drivers who live in large cities did better on the first survey question (all railroad grade crossings have flashing signals) which may be considered a passive crossing question. Naturally, drivers in a large, urbanized area will be familiar with active crossings. The results did not show a significant difference for any other questions, or for any of the rural drivers' responses to the questions. Therefore, the drivers place of residence did not significantly affect responses.

Because experience with grade crossings leads to familiarity, the drivers who cross railroad tracks more than once a day should do better than the drivers with less exposure. Conversely, the drivers who rarely cross grade crossings were expected to display a lower level of comprehension of grade crossing traffic control devices. The drivers who cross tracks more than once a day did better on question 2 (all grade crossings used by trains have flashing signals), whereas the drivers who rarely cross tracks did worse on the same question. In addition, the drivers who rarely cross tracks did worse on question 6 (what is the meaning of the railroad advance warning sign). Questions 2 and 6 may be considered "experience" type questions. A driver who has never observed a passive crossing probably will not answer. The more experience a driver has, the better he or she will do on this question. The same is true for question 6; drivers will know what the railroad advance warning sign means the more they see them at grade crossings.

Results of Demographic Factors

Because male drivers are involved in more collisions at highway-railroad grade crossings, female respondents were expected to show a higher level of comprehension. Responses to question 2 (all railroad grade crossings used by trains have flashing signals) were statistically different for males and females. The female group had a lower correct response rate than the male group. Both groups performed equally well on the remainder of the questions.

Because Caucasian and Hispanic male drivers are involved in more collisions at highway-railroad grade crossings, the researchers wanted to test whether a measurable difference existed in the comprehension between different ethnic backgrounds. The Caucasian group did better on questions 1, 2, and 5a. The African-American group did not do as well on questions 2, 4b, 5b, 9, and 10. The Hispanic group did not do well on questions 1, 2, 4a, 5a, 11, and 12. The Asian group did not do well on questions 1, 2, 4a, 5a, 6, and 10.

Further analysis was performed on the ethnic data to determine why ethnic background appears to affect the performance. No significant differences were found among the age, gender, or education level, or whether or not the driver had taken a driving course within the past year, place of residency, or crossing frequency. It was concluded that an insufficient number of African-American and Asian groups were included in the survey. Another possible explanation may be that the survey questions could be confusing for non-English speaking drivers.

2.6 SUMMARY

The following section summarizes the findings from the driver comprehension survey.

- Respondents expressed a lack of understanding of driver requirements at passive and active grade crossings. For both types of grade crossings, most of the drivers said that the correct action was to stop at the grade crossing, look, and listen for trains (66 percent for passive crossings and 18 percent for active crossings). While these responses are helpful in avoiding train-vehicle collisions, they have the potential to cause vehicle-vehicle collisions.
- Drivers showed a lack of understanding for the railroad advance warning sign. Approximately 30 percent of participating drivers thought that the sign was located at the grade crossing. In addition, only 70 percent of the drivers correctly identified the meaning of the railroad advance warning sign. Furthermore, 50 percent of the drivers did not know that the sign is used at both active and passive crossings.
- Drivers expressed a lack of understanding of the crossbuck meaning and location. Only 71 percent of the participating drivers correctly identified the location of the crossbuck. In addition, 34 percent of the drivers do not know that it is used for both active and passive crossings.
- Previous research shows that compared to other states, Texas drivers are involved in more crashes in which the causal factor was listed as "drove around the gates". The following findings may explain this problem:
  - Twelve percent of the participating drivers said that driving around the gates at active crossings was acceptable if they could not see a train;
  - Only 6 percent of the drivers have received a citation, or knew someone who had received a citation at a grade crossing which might suggest that drivers do not know that driving around gates is illegal; and
  - A frequent comment on the survey was that the gates and lights should function 24 hours a day. This comment suggests that drivers may not trust active traffic control devices and frequently disregard them.
- Most of the participating drivers said that they remembered instructions about highway-railroad grade crossings from either a Drivers Education, Defensive Driving, Operation Lifesaver, or other educational campaign. In addition, 53 comments suggested more

public education would improve safety at grade crossings. These comments suggest that public education is an effective way of improving safety at grade crossings; however, hypothesis testing did not show any improvement in the responses from drivers who have taken a Drivers Education or Defensive Driving course in the past year. This finding suggests that these courses need to be reevaluated to incorporate more material concerning grade crossing safety.

- Twenty-one drivers suggested that lights and gates should be present at every grade crossing, and these gates should go all the way across the road so that drivers could not go around them.
- When asked for comments or suggestions for improving safety at highway-railroad grade crossings, 20 drivers suggested that grade crossings are too rough and need to be made smoother. These comments suggest that rough surfaces (like rumble strips) command the attention of the driver. Literature regarding the use of rumble strips has produced mixed results, furthermore, these comments support recommendations for further research in the area.
- Drivers age 16 to 25 and drivers with less than five years of driving experience exhibited a lower level of comprehension of traffic control devices and driver requirements at highway-railroad grade crossings than older, more experienced drivers.
- Living in large cities or rural areas did not affect driver comprehension of traffic control devices and driver requirements at grade crossings.
- Crossing frequency (how often a driver crosses the tracks) may affect driver comprehension of traffic control devices at grade crossings. Drivers who drive across tracks at least once a day did better on question 2, and drivers who rarely drive across tracks performed worse on question 6.
- Comprehension of traffic control devices and driver requirements at grade crossings between male and female drivers showed no differences.
- This survey gives an indication of what drivers say, and given multiple choices, shows how they would react at highway-railroad grade crossings. How drivers react under normal driving conditions may be entirely different. A observational study under normal driving conditions might be helpful in better understanding driver behavior.

3.0 DRIVER BEHAVIOR

3.1 INTRODUCTION

Highway-railroad grade crossing safety research has focused on improving the engineering, education, and enforcement issues surrounding the grade crossing scenario. Multiple focus group studies, questionnaires, field observations, and crash records reflect a lack of appreciation for the highway-railroad grade crossing as a critical intersection between two distinctly different modes of transportation. Driver behavior at highway-railroad grade crossings shows the perceived risk that many drivers acknowledge.

Objective

A misconception of the risks and a misunderstanding of driver responsibilities can contribute significantly to driver error. The consequences of driver error at highway-railroad grade crossings may be dire, resulting in a collision between a vehicle and train. Furthermore, collision statistics often fail to focus on the real causes of collisions at highway-railroad grade crossings. They focus on *what* happened rather than *why* the collision happened. In-vehicle observations of driving behavior at highway-railroad grade crossings are needed to provide insight about why train-vehicle collisions are occurring. At-risk driving behaviors can then be better targeted in grade crossing safety education campaigns and enforcement programs.

The topic of driver behavior at highway-railroad grade crossings has been studied by transportation engineers, traffic safety specialists, and human factors experts for many years. Researchers have postulated the effects of driver attitude, compliance, familiarity, comprehension, experience, and expectancy as they relate to the perception of risk at grade crossings using field observations and survey responses.

This section is organized into several subsections that describe driver behavior research. This first section introduces the subject of driver behavior at highway-railroad grade crossings while stating the research problem and objective. The second section discusses safe driving behavior at highway-railroad grade crossings, actual driving behavior as recorded in collision records and previous research findings, factors that contribute to at-risk driving behavior at highway-railroad grade crossings, and observational measures of driver performance at highway-railroad grade crossings. The third section describes the research methodology and procedures for observing driver behavior at grade crossings. The fourth section details the findings from the in-vehicle observations of driver behavior, as well as the responses from the questionnaire. The final sections summarize findings and offer recommendations for improving driver behavior at highway-railroad grade crossings.

3.2 DRIVER BEHAVIOR AT GRADE CROSSINGS

Before evaluating driver behavior at highway-railroad grade crossings, safe driving behavior must be defined for this critical intersection. The discussion of safe driving behavior will then serve as a comparison to observed driver behavior and survey responses from previous research studies.

Several factors influence and compete for driver attention, potentially contributing to less desirable driving behavior at grade crossings. These factors include perceptual limitations, emotional state/attitudes, social influences, expectancies regarding trains and crossings, and inattention. Each of these factors will be discussed as they relate to driver behavior at highway-railroad grade crossings.

Safe Driving Behavior at Highway-Railroad Grade Crossings

When approaching highway-railroad grade crossings, safe driving behavior should involve reducing speed enough so the driver can look both ways and listen for potential activity along the track. Some grade crossings are equipped with warning devices to signal the approach of a train. These devices attempt to reduce driver workload, improve safety, and maintain normal traffic flow by reducing the need for each driver to stop at the grade crossing to judge whether continuing through the crossing is safe.

The degree of positive guidance common to both active and passive crossings involves the installation of a railroad advance warning sign (W10-1) on the approach and a crossbuck (R15-1) at the crossing (*10*). Active crossings are further characterized by warning systems such as flashing light signals, automatic gates, cantilever flashing light signals, wigwag signals, and bells activated by the detection of an approaching train. Installation costs of detection track circuitry and the appropriate active warning devices are between $80,000 and $300,000 depending on the crossing design and complexity (*11*).

Often, low traffic volumes and limited funding do not warrant installing an active warning system. A passive grade crossing results when the presence of a grade crossing (rather than the presence of a train) is indicated by a railroad advance warning sign (W10-1) on the approach and a crossbuck (R15-1) at the grade crossing. At a passive grade crossing, no additional warning is provided to the driver when a train is approaching.

The driver, therefore, has different responsibilities when approaching a highway-railroad grade crossing depending on whether the crossing is active or passive. Neither the railroad advance warning sign on the approach to the crossing nor the crossbuck at the crossing provides any indication as to the type of warning system at the crossing. Upon approaching a highway-railroad grade crossing, the driver must first determine whether the crossing is equipped with additional warning devices that alert the driver of train activity on the track. Upon recognizing that no warning devices will be activated by an approaching train (i.e., a passive crossing), the driver must look carefully in both directions along the track and listen to determine whether a train is approaching. The driver should approach a passive crossing at a speed such that the vehicle can be stopped safely if a train is approaching or occupying the crossing.

The driver is responsible for achieving safe passage through passive crossings because no warning devices alert the driver of approaching trains. Laws (as found in the Uniform Vehicle Code or UVC) concerning the driver's responsibilities at passive grade crossings do not require a driver to stop at a passive crossing under all circumstances (*12*). The law also does not specifically require that a driver stop if a train is heard or visible from the grade crossing. A driver who *hears* a train must stop if that train is an "immediate hazard," and a driver who *sees* a train must stop if the train is "in hazardous proximity to such crossing." At least one court has concluded that "immediate hazard" and "hazardous proximity" have the same meaning (*13*).

If the highway-railroad grade crossing is equipped with flashing light signals, automatic gates, cantilever flashing light signals, wigwag signals, and/or bells (i.e., an active crossing), the driver should carefully observe the warning devices. This involves looking and listening for signals to be activated. Obedience to signals that indicate the approach of a train is outlined in most state motor vehicle laws. Specific legal requirements are outlined in UVC Section 11-701 for obedience to a signal indicating the approach of a train (*12*). Most states use this code to develop state motor vehicle laws concerning highway-railroad grade crossings. Unfortunately, not all states adopt laws that are consistent with the UVC. A study conducted in the late 1970s found that at least nine states did not expressly prohibit driving under or around a lowered gate arm. At least two of these states, Louisiana and Missouri, actually permitted a driver to maneuver around a lowered gate arm when it was safe to do so. This study also found that South Carolina had not adopted any portion of UVC Section 11-701 and thus did not specifically require drivers to stop for trains or signals indicating the approach of a train.

In the early 1980s, another compilation of state laws and regulations on matters affecting highway-railroad grade crossings found that Louisiana had since updated their motor vehicle laws to reflect the UVC ban on driving through, around, or under any gate or barrier while it is closed or while it is being opened or closed (*14*). Missouri still differed from the UVC by allowing driving through, around, or under a gate or barrier when it is safe to do so. By the mid 1980s, South Carolina still did not have a law expressly requiring a driver to stop when electrical or mechanical signal devices warn of an approaching train. South Carolina had laws comparable to UVC Subsection 11-201 (a) requiring drivers to comply with any "official traffic control device." Therefore, South Carolina, through its adherence to other sections of the UVC, may require stopping when a gate is lowered on the assumption that a gate is a traffic control device. The inconsistency in driver responsibility at highway-railroad grade crossings weakens the drivers' expectations of what they should do when approaching a grade crossing.

Texas Motor Vehicle Laws

Texas state law requires obedience to a signal indicating the approach of a train. The Texas Motor Vehicle Law (Article XI, Section 86 of the Uniform Act) was recently amended (effective September 16, 1995) to outline requirements more clearly for obedience to a signal indicating the approach of a train (*15*).

> **Subsection (A)** states that: "Whenever a person driving a vehicle approaches a highway-railroad grade crossing, the driver of the vehicle will stop within 15 m (50 ft) but not less than 5 m (15 ft) from the nearest rail of that railroad if:
>
> - a clearly visible railroad signal warns of the approach of a railroad train;
> - a crossing gate is lowered or a human flagman warns of the approach or passage of a railroad train;
> - the driver is required to stop by:
>   - other law;
>   - a rule adopted under a statute;

    - an official traffic-control device; or
    - a traffic-control signal;
- a railroad engine approaching within approximately 450 m (1500 ft) of the highway crossing emits a signal audible from such distance and such engine, due to its speed or nearness to such crossing, is an immediate hazard; or
- an approaching railroad train is plainly visible and in hazardous proximity to such crossing.

Subsection (B) The driver of a vehicle required to stop at a railroad crossing as provided by Subsection (A) of this Section (86) will remain stopped until the driver is permitted to continue safely through the crossing.

Subsection (C) The driver of a vehicle commits an offense if the person drives the vehicle around, under, or through a crossing gate or a barrier at a railroad crossing while the gate or barrier is closed, being closed, or being opened.

Subsections (D) In a prosecution under Subsection (A) (5) of this section, proof that at the time of the offense a train was approaching the grade crossing and that the train was visible from the crossing is prima facie evidence that proceeding was not safe for the driver.

Subsection (E) A person convicted of a violation of this section will be punished by a fine of not less than $50 or more than $200."

Previous Research on Driver Behavior at Highway-Railroad Grade Crossings

Empirical research on highway-railroad grade crossing crashes has primarily used collision reports to identify factors that contribute to vehicle-train crashes. Crash history also plays a role in most priority indices used to decide which grade crossings should be considered for improvements (i.e., upgraded from passive to active warning systems). This approach to improving safety at highway-railroad grade crossings is somewhat "reactive" in nature. The observation of driver behavior at grade crossings presents a "proactive" approach (i.e., prior-to-collision) toward identifying factors (misconceptions, attitudes, complacency) which may contribute to a potential vehicle-train collision. Risky and less desirable driving behavior can then be better targeted in grade crossing safety education campaigns and enforcement programs, as a proactive strategy to prevent collisions.

Relatively few studies have directly observed driver behavior at highway-railroad grade crossings to identify the cause of vehicle-train collisions. Michael, Russell, and Butcher (*16*); Sanders (*17*); Shinar and Raz (*18*); Wigglesworth (*19*); and Wilde, Cake, and McCarthy (*20*) analyzed driver speed on the approach to highway-railroad grade crossings. Some of these studies also recorded the apparent looking behavior of the drivers as observed from the field.

Meeker and Barr observed driver behavior at a highway-railroad grade crossing with flashing lights only (i.e., no gates) as trains approached (*21*). They noted that two thirds of the observed drivers crossed the tracks despite the activated warning flashers and the approaching train. This percentage was higher than in the study reported by Shinar and Raz, where 40 percent of the drivers crossed (*18*). Meeker and Barr concluded that this activity was not limited to a few drivers, and that the activated warning flashers were not perceived as a signal that the risk was so great that the driver should stop to wait for the train to pass. This finding was consistent with Leibowitz's view that "active" protection systems merely cue drivers of the need to decide whether to cross, rather than the need to wait for a train to clear the crossing (*22*).

Motor vehicle laws state that if warning signals are activated, the driver should stop and not continue through the grade crossing until it "is safe to do so." Texas law further defines that conditions are not considered "safe to proceed" if an approaching railroad train is plainly visible and in hazardous proximity to the crossing. Meeker and Barr observed that drivers exercised their own judgement about whether to cross in front of an approaching train despite activated warning flashers (*21*).

Heathington, Fambro, and Richards evaluated innovative active warning devices using a before-and-after study approach (*23*). The active warning devices evaluated in their study included four-quadrant gates with skirts and flashing light signals, four-quadrant flashing light signals with overhead strobes, and highway traffic signals with white bar strobes in the red lenses. They concluded that the three innovative devices were technically feasible and practical, and all three devices were accepted and understood by the driving public. Two of the systems, the four-quadrant gates with skirts and the highway traffic signals, were found to significantly improve crossing safety at the test crossings. The third system, four-quadrant flashing lights with strobes, did not produce measurable improvements in safety at the test crossing. The researchers also concluded that train predictors (and the constant warning time they provide) can have positive effects on safety at grade crossings where flashing light signals or highway traffic signals are used.

Factors That Contribute to Less Desirable Driving Behavior

The perceptions of drivers form the basis for making judgements while engaged in the driving task. These include perceptual judgements of speed and spacing which influence the subjective evaluation of risk (*24*). Many factors contribute to less desirable driving behavior at highway-railroad grade crossings. These include the driver's emotional state, attitude, exposure to social influence, expectancies regarding trains and grade crossings, attention, and limitations due to perceptual judgements. Each of these will now be discussed as they contribute to the perception of risk at highway-railroad grade crossings.

Risk Perception

Risk-taking refers to the willingness to accept a certain potential for harm, for whatever benefits derive from the action (*25*). The perception of risk refers to a person's ability to perceive the potential for harm because of the action. Risk perception is not static, but is constantly influenced by a variety of factors. In fact, two drivers who perceive the same level of risk, or even the same driver perceiving a given level of risk at different times, may decide differently about whether to accept that risk (*25*). To understand driver risk-taking at highway-railroad grade crossings, understanding how people view the risk and what factors contribute to accepting the risk of a potential vehicle-train collision are important.

Emotional State: The emotional state of the driver can influence their perception of risk and contribute to at-risk behavior at highway-railroad grade crossings. Frustrations from traffic conditions or from daily work activities can lead to impatient and aggressive driving behavior (*26*). These drivers may subject themselves to higher risks at highway-railroad grade crossings either consciously to save time or unconsciously due to preoccupation. There are also those drivers whose driving behavior reflects an underlying aggressive personality.

Social Influences: The behavior of drivers at highway-railroad grade crossings is also influenced by the presence and actions of others. Drivers generally decide more cautiously when passengers are in the vehicle, unless a male driver is accompanied by a male passenger, in which case decisions may be more risky (*25*). Social norms within communities often dictate driver reactions and acceptance of risk. Young male drivers are highly represented among those collisions in which the driver apparently "tried to beat the train." The aggressive driving behavior typically exhibited by this population exemplifies the powerful effect of peer pressure as a social influence that could contribute to unsafe driving behavior at highway-railroad grade crossings. Drivers' respect for grade crossing traffic control devices is weakened when they observe other drivers violating rules (driving around a lowered gate). Furthermore, drivers are more likely to copy this behavior if they perceive no immediate consequences, such as enforcement measures.

Driver Expectancies Regarding Trains and Crossings: Drivers respond not only to what is physically present in the driving environment, but also to what is anticipated based on experience. Driver expectancies about the likelihood of trains and their probable speeds, the nature of the warning devices, the warning time provided by the flashing signals, the delay caused by waiting for the train, etc., will determine how much risk is perceived on the approach to grade crossings. After conducting field studies of undesirable driver actions at active crossings, Richards concluded that expectancies and tolerance levels associated with warning times at active grade crossings may contribute to unsafe driving behavior at these locations (*27*).

Driver Attention: Experienced drivers learn how to distribute their attention more efficiently than novice drivers, maximizing performance and minimizing effort (*28*). Shinar, McDonald, and Treat further note that "even among experienced drivers, differences in the ability to distribute their attention effectively may be an important determinant of their driving safety" (*28*). In fact, the familiarity of many drivers with the overall driving task often contributes to drivers who are inattentive to traffic control devices such as warning signs.

Recognizing that the attention of even the most alert driver is distributed across a variety of navigational and operational subtasks is important. Consideration of the likelihood of a train, or its closing rate, is never the driver's sole concern. Other ideas compete for the attention of the driver. For example, avoiding conflicts with other vehicular and pedestrian traffic, negotiating the tracks themselves (rough crossing surface), compensating for effects of inclement weather, and monitoring standard traffic control devices at adjacent signalized intersections can divert driver attention from other crossing-related decision making (i.e., recognition of an approaching train). Distractions within the vehicle from radio and/or other passengers (e.g., young children) affect attention to the driving task.

Viewing a driver's actions as risk-taking is not meaningful without the appreciation that a risk exists; however, driver inattention and/or distraction from competing thoughts reduce perception of risk at highway-railroad grade crossings. Robinson and Desai considered the control of attention during the driving task as a function of risk and risk preference, influenced by variable inputs from the driving environment provided with the most information (*29*).

Perceptual Limitations of the Driver

The driver's perception of risk and subsequent behavior at highway-railroad grade crossings is influenced by many factors such as their emotional state, exposure to social influence, expectancies, and attention. When drivers disregard information from grade crossing warning systems, they are relying on other decision-making strategies. Sensory and perceptual decision-making techniques become critical tools for these self-appointed, risk assessment roles. Judgement of train speed and distance is essential for determining the safe time for crossing railroad tracks. A driver's perspective of his or her vehicle's operating characteristics is usually accurate and under the driver's control; however, the driver's judgement of train speed and distance is subject to several systematic biases that will now be discussed.

Leibowitz identified several human factor issues related to a drivers' assessment of risk at highway-railroad grade crossings (*22*). This study pointed out that drivers' decisions to cross may be made more hazardous by inaccurate judgements of train speed and distance due to perceptual illusions. These include the illusion of velocity and size, the illusion of perspective, and the deceptive geometry of collisions. When determining risk, most drivers are not aware of the effects that these illusions have on their perception of safe passage at this critical intersection.

Illusion of Velocity and Size: The illusion of velocity and size results from the fact that, the bigger the object, the slower it appears to be moving. This phenomenon can be observed at airports by observing the apparent landing speeds of different-sized aircraft. Despite awareness of the typical velocities of different-sized aircraft, even experienced pilots succumb to this illusion in which the larger aircraft appear to be traveling more slowly. This illusion is created by the required effort of the human eye to "pursue" the object being tracked. The effort required to make a pursuit eye movement is determined by the actual velocity and contour of the object being tracked. The net result is that, for equal velocities, larger objects are perceived to be moving slower than smaller objects.

The illusion of velocity and size affects driver behavior at highway-railroad grade crossings because drivers may overestimate the safe time for crossing the tracks ahead of an approaching locomotive. That is, drivers may perceive that the train is moving slower than it actually is. This overestimation may give the driver the impression that he or she has enough time to cross before the approaching locomotive reaches the intersection.

The cues available to estimate the speed of the train will depend primarily on the degree to which the train is visible and the angle of view that is afforded the driver (*30*). Although drivers can make moderately good estimates of the speed and distance of an approaching train if the front of the locomotive can be seen clearly, the driver's opinion of speed and distance of an approaching train is less accurate if the driver's view is mainly of the front of the train rather than of the side. Furthermore, at a distance of 1,500 m (5,000 ft), a locomotive subtends a vertical angle of only 0.17 degrees and only 0.86 degrees at 300 m (1,000 ft) (*30*).

Illusion of Perspective: The illusion of perspective involves learned responses to monocular cues to depth (two-dimensional cues that can be appreciated with one eye generate a strong impression of depth). The perception of size and distance is not innate, but rather is learned because of perceptual and perceptual-motor experience. The monocular cues operate unconsciously to signal depth relationships in the surrounding environment. Several of these cues are normally present when a driver views an oncoming train (e.g., the tracks converge to a point due to linear perspective, the texture gradient of the ballast or stone is more distinct near the grade crossing and is less detailed when looking down the tracks, and sometimes, rows of telephone poles or trees that shrink in size depending on their distance from the crossing). Leibowitz contends that the effect of these cues is a perceived increase in the train's distance from the grade crossing and would, thus, contribute to an overestimation of the time available for safe passage across the tracks.

Deceptive Geometry of Collisions: The deceptive geometry of collisions is created by the fact that, if two objects traveling in straight lines at constant velocities are on a collision course, their relative positions in the visual field remain constant. This deceptive phenomenon is created when relying on the expansion pattern of the visual angle for the perception of risk. Since there is no lateral motion, the principal cue to velocity is the increase in size of the visual angle subtended (i.e., the expansion pattern). Schiff refers to this phenomenon as "looming" (*31*). The deceptive geometry of collisions is especially dangerous at highway-railroad grade crossings because the expansion pattern is increasing slowly just when the driver is determining whether to cross (i.e., assuming that both the train and the vehicle are moving at nearly constant velocities). The slow expansion pattern presents the illusion that the train is traveling slower, when in fact, the train will approach the grade crossing much faster than expected. This perception may also lead to an overestimation of the time available for safe passage across the tracks.

Observational Measures of Driver Performance

The *Texas Drivers Handbook* advises drivers always to "slow, look, listen, and be prepared to yield the right-of-way to an approaching train" (*32*). These driver actions can be evaluated by observing looking behavior and deceleration on the approach to the highway-railroad grade crossing.

Crossing Zones

The *Railroad-Highway Grade Crossing Handbook* divides the approach to a grade crossing into three zones: the approach zone, the non-recovery zone, and the hazard zone (*33*). Driver responsibilities and information processing will be discussed for each zone. These zones are adapted from the information handling zones defined in *A User's Guide For Positive Guidance* by Post, Alexander, and Lunenfeld (*34*). Positive guidance refers to information provided to the driver in advance of a unique highway feature. These features might include a sharp turn, dip in the roadway, or critical intersection. Providing positive guidance before these features allows the drivers to begin processing the information to formulate appropriate decisions and responses.

The approach zone is the area in which drivers first begin to formulate actions needed to avoid colliding with trains. The railroad advance warning sign (W10-1) is found within this zone and should be placed at a distance upstream of the highway-railroad grade crossing such that the driver is provided sufficient time to alter vehicle speed and take appropriate action. The start of the approach zone is loosely defined. In theory, the approach zone begins when a driver can first detect the highway-railroad grade crossing. Information may be gathered from visual, auditory, or tactile observations on the approach. Visual observations include detection of the railroad advance warning signage, pavement markings, and/or grade crossing itself as these components come within the field of view. Auditory detection of the whistle of an approaching train may also alert the driver to the presence of a highway-railroad grade crossing. Tactile indicators include rumble strips and alert the driver of a critical intersection between the railroad and the highway. Literature on driver perception has shown that the use of redundant sensory stimulation (visual, auditory, and tactile) generally increases the likelihood of detecting an event (an approaching grade crossing and/or train).

When approaching a highway-railroad grade crossing, the next zone is the non-recovery zone. This zone begins at the point along the roadway where drivers must decide if they need to stop to avoid a collision with a train at the grade crossing. That is, the non-recovery zone is within the area defined by the stopping sight distance (based on the approach speed) required to avoid a collision at the grade crossing.

The hazard zone is the rectangular area formed by the width of the highway and a distance of 5 m (15 ft) measured along the highway from either side of the closest and farthest rail. The hazard zone is the area where stopped or approaching vehicles can collide with stopped or approaching trains. Drivers who detect activated warning devices or approaching trains should stop before the hazard zone and wait for the approaching train to clear the grade crossing.

Looking Behavior

Looking behavior is the action by drivers to look for warning signs, identify the location of the highway-railroad grade crossing, and determine if a train is approaching or is present when the driver approaches a crossing. Movements of the driver's head and/or eyes quantify the looking behavior of the driver. Detection of eye movements requires researchers to accompany the driver in the vehicle and observe their looking behavior. Head movements can be measured in the field without necessarily riding with the driver.

Distinguishing between motives for initiating looking behavior is difficult when evaluating driver behavior in the field. Drivers may initiate looking behavior (on the approach to the crossing) that is not directed toward detecting potential activity along the track(s). Field observation of driver behavior typically shows the percentage of drivers looking left, right, or in both directions on the approach to highway-railroad grade crossings. Few studies, if any, verify that looking behavior was directed toward detecting potential activity along the track. A better assessment of the motivation behind observed looking behavior and deceleration can be achieved through observation of driver behavior while riding with the driver.

Furthermore, some field studies conclude that the absence of a head movement on the approach to a highway-railroad grade crossing shows "unsafe" looking behavior. However, if the view on the approach to a grade crossing is free from sight obstructions, the driver can probably view the crossing clearly and determine whether the warning devices are activated (at an active grade crossing) or whether a train is approaching (at a passive grade crossing) without making a noticeable head movement.

Deceleration

Approach speed profiles, speed changes, and deceleration are all speed-based measures of driver performance at highway-railroad grade crossings. Speed profiles illustrate the changes in speed on the approach to a crossing. Speed profiles of drivers who are unfamiliar with a particular crossing may suggest when and where the driver first detects a highway-railroad grade crossing.

Speed data are generally easier to gather in the field and to quantify than field observations of looking behavior; however, interpreting the motives behind field-observed deceleration is difficult. Changes in speed may be due to the warning device, alignment of the roadway near the grade crossing, prior knowledge of the existence of an upcoming grade crossing (before the railroad advance warning sign), anticipated roughness of the grade crossing, or in response to slower vehicles. In-vehicle observations allow the researcher to distinguish between deceleration initiated clearly out of concern for potential activity on the track(s) and those initiated only out of concern for roughness of the crossing surface.

3.3 STUDY DESIGN

This section describes the design of the in-vehicle driver behavior study. The methodology, solicitation of drivers, selection of a test course, description of highway-railroad grade crossings, and data collection procedures will be discussed.

Methodology

The criteria for determining safe driving behavior at highway-railroad grade crossings was established as the degree of looking behavior and deceleration on the approach to the crossing. This study involved a unique method (within the field of transportation engineering) of observing these driver behaviors. Rather than observing the behavior of random drivers as they approached a particular grade crossing, the researcher accompanied drivers in his or her vehicle. Drivers were invited to participate in a transportation study. Before they began the study, they were asked to drive throughout the course as he or she would normally drive. The driver was also informed that no situations that he or she might encounter during the study had been arranged or prepared in advance by the research team. No indication was given that the researcher would be observing driver behavior at highway-railroad grade crossings. The researcher guided the driver along the predetermined route while engaging in casual conversation.

Many advantages were recognized when employing this methodology. The researcher could observe the behavior of the same driver at a variety of highway-railroad grade crossing scenarios. While riding in the vehicle with the driver, the researcher observed the driver's motives for initiating looking behavior and deceleration. Observing looking behavior and deceleration from outside the vehicle requires the researcher to speculate whether these actions were motivated by a desire to assess potential track activity. In-vehicle observation of driver behavior allowed the researcher to differentiate behaviors directed toward activity along the track from those behaviors where the attention of the driver was actually directed elsewhere.

At the conclusion of the driving portion of the study, the researcher administered a questionnaire to better understand any misconceptions regarding highway-railroad grade crossing warning devices, driver responsibilities, and related traffic laws. After debriefing the driver as to the purpose of the study, the researcher verbally discussed the observed driver behavior and addressed apparent misconceptions about the driver's responsibilities at both active and passive grade crossings.

Solicitation of Drivers

Drivers were recruited through direct person-to-person contact and telephone solicitation. Recruitment was open to all interested individuals with a valid driver's license and proof of insurance for the personal vehicle used during the test. The ethnic distribution of a large Texas city (Houston) was used as a model in that the population consists of 60 percent Caucasian, 20 percent Hispanic, 19 percent African-American, and 1 percent Other. The sample size was distributed equally among the following age groups: 18-25 (young drivers), 30-45 (middle-aged drivers), and 55+ (older drivers). Half of the drivers were male and half were female. The behaviors of these 30 people were observed as they traversed many highway-railroad grade crossings in the Bryan/College Station area. Table 3.1 stratifies the study drivers by ethnicity, gender, and age.

Table 3.1. Stratification of Study Drivers

Ethnicity	**Caucasian**		**African-American**		**Hispanic**		**Other**		**Total**
Gender	M	F	M	F	M	F	M	F	
Younger (18-25)	3	3	1	1	1			1	10
Middle-Aged (30-45)	3	3	1	1	1	1			10
Older (55+)	3	3	1	1	1	1			10
Total Drivers	9	9	3	3	3	2	0	1	30

Selection of Test Course

A test course was established which exposed the drivers to a variety of active and passive crossings in both urban and rural settings. The test course included seven active, three passive, and one closed highway-railroad grade crossing within the cities of Bryan and College Station, Texas. Crossings incorporated within the test course included those with a variety of grade crossing signage, warning equipment, approach angles, sight obstructions, crossing profiles, approach speed limits, and various traffic control devices.

The seven active grade crossings were equipped with flashing light signals and gate arms. Two of the active grade crossings had additional flashing light signals mounted on cantilevers over the travel lanes. Of the three passive grade crossings, one had a stop sign installed near the crossing while the other two were marked only by a crossbuck. A highway-railroad grade crossing that is no longer in service was also included within the test course. Railroad tracks once crossed the highway at a 45-degree angle and a moderately high profile. A crossbuck remains at the crossing on the southbound approach; however, the rails have been covered with asphalt and, a chain-link fence paralleling the roadway crosses the tracks providing an indication that the track no longer services trains.

A description and drawing of each crossing scenario within the test course are provided in Appendix F. An arrow within each figure depicts the path of the vehicle along the test course. The Texas Crossing Summary Database was used to obtain the train volume per day, maximum allowable timetable speed, Average Daily Traffic (ADT), and crash history for each grade crossing used in the test course (*35*). The database was last updated in December of 1995.

Recording Observations of Driver Behavior

The researchers decided to manually record the degree of looking behavior and deceleration at each highway-railroad grade crossing. Other researchers used eye-tracking equipment to monitor looking behavior and instrument the vehicle to detect deceleration maneuvers; however, equipping drivers with cumbersome eye-tracking equipment might make the driver uncomfortable and could potentially influence their driving behavior. Likewise, the researcher wished to conduct the observations within the real-world driving environment. Use of eye-tracking equipment would also limit observations of driver behavior to a controlled or restricted course that might not accurately represent the actual conditions that drivers encounter when approaching highway-railroad grade crossings. Since drivers are most comfortable operating a vehicle with which they are familiar, each driver was asked to use his or her personal vehicle during the study. Each vehicle could not be instrumented to detect deceleration without the owner's consent and without potentially influencing the behavior of the drivers.

The researcher took great care when recording the observations to not influence driving behavior. Each driver encountered 11 highway-railroad grade crossings over a period of 30 minutes to reduce the likelihood that the driver might identify the objective of the study. While conducting the in-vehicle observation of driver behavior, the researcher noted whether the driver was operating the lead vehicle or was within a platoon of vehicles when approaching a crossing. Traffic conditions at each crossing were recorded as light traffic (no other cars), moderate traffic (one or two other cars near the crossing), or heavy traffic.

The researcher also recorded looking behavior and deceleration within each of the three zones (i.e., approach zone, non-recovery zone, and hazard zone) as the driver approached each grade crossing. Head or eye movements directed toward potential activity on the track qualified as looking behavior. The researcher simultaneously recorded the sequence of all looking behavior when approaching the grade crossing. Corresponding decelerations were noted as they occurred on the approach to the crossing. Deceleration included no decrease in speed, significant decrease in speed, rolling stop, and complete stop. The researcher was careful to note the driver's motive for these maneuvers (i.e., was the driver focusing attention on the roughness of the crossing surface or was the driver looking/scanning for approaching trains). The same researcher recorded all observations for each driver. An example of the data collection form is provided within Appendix G. Appendix H provides instructions for coding the data collection form.

Survey Instrument

At the conclusion of the driving portion of the study, the researcher explained the purpose of the study and the expected benefits. The informed consent form, debriefing statement, and survey instrument are provided in Appendix I. The survey instrument was designed to detect other potential variables that might influence the driver's behavior at highway-railroad grade crossings.

First, the driver was asked to indicate how often he or she usually encountered highway-railroad grade crossings (i.e., once a day, four times per week, rarely). The purpose of this question was to compare the actions of drivers who frequently cross highway-railroad grade crossings with those who rarely do so. The driver was then provided the following description of active and passive grade crossings:

> Highway-railroad grade crossings are classified as active or passive depending on the ability of the warning system to show the presence of an approaching train. For example, an active crossing will have flashing light signals, automatic gates, or bells that activate when a train is approaching. A passive crossing uses signs to show where the railroad tracks cross the roadway. No additional warning is provided when a train is approaching.

Given this description of the difference between an active and passive grade crossings, the driver was asked to write what he or she should do when approaching each type of crossing. The responses were used to compare what actions the drivers felt they should do, to what they actually did when encountering the crossings on the test course.

To understand what cues the driver relies on, the driver was also asked what *first* makes he or she aware that a highway-railroad grade crossing is ahead. The driver was encouraged to choose only one of the following choices:

- When I feel the vibration of my tires on the tracks.
- When I see the advance warning sign on the approach to the grade crossing.
- When I see flashing signals and/or lowering gates.
- When I see the pavement markings just before the grade crossing.
- Other (please specify) ______________________________

The driver then identified his or her first concern when approaching a highway-railroad grade crossing. The purpose of this question was to learn how many drivers' first concern was about whether or not a train was approaching the crossing. The driver was also asked whether he or she had completed a driver's education course within the past year to show any differences in driver behavior.

The next question asked of the drivers was if they had ever driven under lowering gates or around lowered gates at a highway-railroad grade crossing. The driver was asked to describe the reason he or she engaged in such an activity. The driver was then asked whether he or she was aware that driving around or under a crossing gate is against the law. The last two questions were asked specifically in this sequence to avoid putting the driver in a defensive mode, perhaps reducing the validity of the responses. The final question asked was that of how many moving citations (excluding parking violations) the driver had received within the last three years. The number of tickets received and the reason for the tickets was requested on the survey instrument.

A driver information form was also included within the survey to ensure that a broad representation of the Texas driving population was represented. The driver indicated his or her age, years of driving experience, occupation, highest level of school completed, and vehicle information (make, model, year, type of transmission). In addition, the drivers indicated whether they preferred to drive during the day or night.

After the driver completed the survey, the researcher verbally asked the following questions:

- How would *you* (the driver) characterize your husband's/wife's/close friend's driving behavior?
- How would your husband/wife/close friend characterize *your* driving behavior?

The researcher did not attempt to influence the response of the driver. Only when the driver had difficulty understanding or answering the question did the researcher present typical responses such as "cautious," "excellent," "aggressive," "inattentive," "fast." Responses to these questions might provide further insight into the typical driving behavior exhibited by the driver.

3.4 STUDY RESULTS

Ideally, drivers should look in both directions when approaching any highway-railroad grade crossing; however, the degree of looking behavior which one can *expect* to observe at a grade crossing ultimately depends upon the warning devices installed at the crossing and the sight obstructions on the approach to the crossing. For analysis purposes, the test course grade crossings were classified according to the degree of looking behavior required to view potential activity along the railroad track (i.e., in the direction obscured by sight obstructions).

Categories of Type 1, 2, and 3 were used to compare driver behavior at highway-railroad grade crossings with similar warning devices and sight obstructions. When approaching active grade crossings, the driver should be listening for an audible warning and looking at the signals to see whether they are activated. Whereas at a passive grade crossing, the driver must carefully look and listen in both directions to decide whether a train is approaching since no warning devices will be activated by an approaching train.

A broad overview of each "type" of highway-railroad grade crossing, as classified within this study, is necessary before discussing the observed driving behavior. A Type 1 grade crossing classification characterizes an *active* crossing in which sight is not obstructed on the approach. Substantial head movement is not necessarily needed at a Type 1 crossing to perceive whether a train is approaching the crossing since no sight obstructions block the view of potential track activity. Type 2 refers to those *active* crossing scenarios where sight obstructions limit the view of potential track activity in one direction as the driver approaches the crossing. Type 2 grade crossings are further divided into Type 2R and Type 2L showing the direction blocked by sight obstructions. Type 3 refers to grade crossing scenarios in which sight obstructions limited the view of potential track activity in both directions on the approach to the crossing and/or the crossing is passive. Active grade crossings meeting the Type 3 specifications are categorized as Type 3A. All passive grade crossings are classified as Type 3P.

Table 3.2 stratifies the types of highway-railroad grade crossings according to the sight obstructions and the looking behavior necessary to view potential track activity due to these sight obstructions on the approach to the crossing. As mentioned previously, grade crossings equipped with active warning devices that signal the approach of a train do not necessarily require the driver to look for trains in both directions along the track. On the contrary, the desirable looking behavior for a passive crossing scenario involves carefully looking in both directions along the track for potential train activity since no warning devices are installed at the crossing to signal the approach of a train.

As a driver approaches a highway-railroad grade crossing, he or she gathers information within his or her field of view and auditory range. The visual field narrows as the speed of the vehicle increases (*24*). The driver subconsciously filters out what is deemed "irrelevant" information as he or she continues to gather additional information. When approaching a grade crossing, the driver may be able to clearly view potential track activity in one or both directions along the track. Upon observing no critical activity along the track, the driver may not initiate additional looking behavior (head or eye movement) before traversing the crossing because he or she has already assessed the conditions while approaching the intersection. An observer is, therefore, less likely to detect noticeable looking behavior (head or eye movement) in a direction that the driver can clearly view while approaching the grade crossing.

For example, if sight obstructions in the right quadrant limit the driver's view of potential track activity in this direction, the driver would ideally initiate rightward looking behavior (head or eye movement) to better determine whether a train is approaching. An observer would not expect to detect noticeable looking behavior directed toward the left since this view is not obstructed when approaching the crossing. An early assessment of potential track activity in this direction (left) is possible because no sight obstructions block the driver's view. Therefore, an observation that a driver did not (noticeably) look both ways before traversing this crossing is not necessarily indicative of poor driving behavior.

Table 3.2. Crossing Classification Criteria

Crossing Type		Sight Obstructions	Looking Behavior	Test Course Crossings
Active	Type 1	No sight obstructions on approach	Looking behavior not necessarily needed in either direction	0
	Type 2R	Sight obstructions block right view	Look right	3
	Type 2L	Sight obstructions block left view	Look left	2
	Type 3A	Sight obstructions block both views	Look both directions	2
Passive	Type 3P	Sight obstructions block both views	Look both directions	3

Observations at Active Crossings

Looking behavior is not necessarily required at grade crossings classified as Type 1 active crossings because visibility is not obstructed on the approach to the crossing. That is, drivers can clearly scan the tracks for potential train activity without substantial head movement. No grade crossings within this study met this qualification. Physical landmarks or overgrown vegetation obstructed the driver's line of sight in at least one direction at all of the grade crossings. Very few highway-railroad grade crossings within a developed area will meet the criteria for a Type 1 crossing.

All active grade crossings within the study satisfied the criteria established for a Type 2R, Type 2L, or Type 3A crossing. Sight obstructions block the right view at a Type 2R crossing, the left view at a Type 2L crossing, and both views at a Type 3A crossing. Therefore, to obtain a clear view of potential train activity at the crossings, a driver would need to look right at a Type 2R crossing (i.e., in the direction obscured from view by sight obstructions), look left at a Type 2L crossing, and look both ways at a Type 3A crossing. As illustrated in Figure 3.1., less than 50 percent of the drivers looked in the direction(s) obscured by sight obstructions when approaching the active grade crossings along the test course.

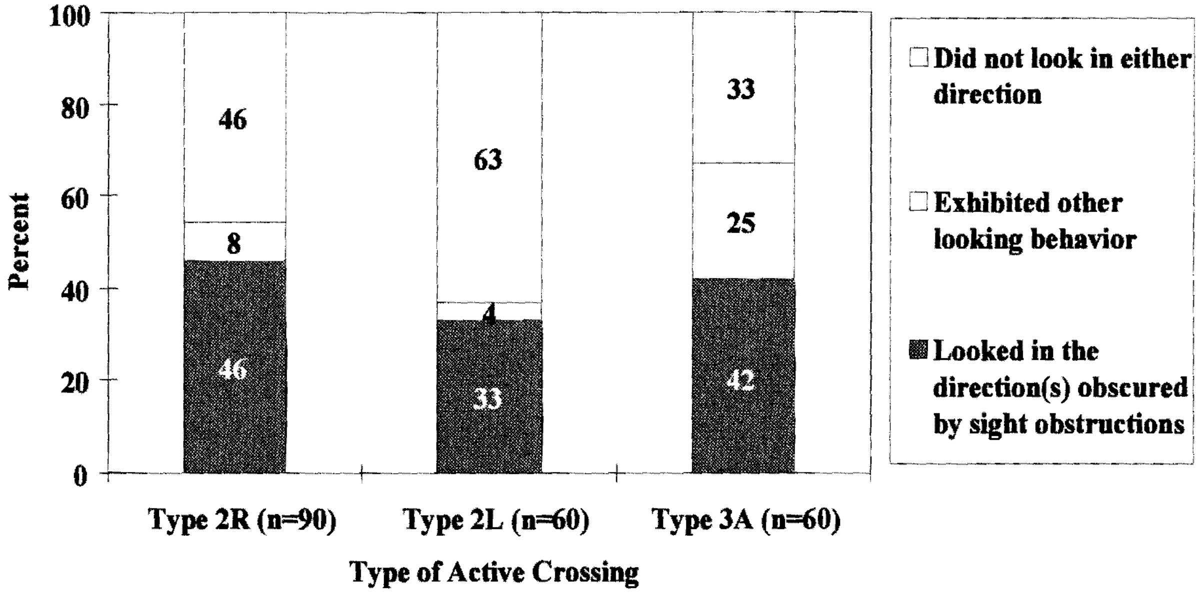


Figure 3.1. Observations of Looking Behavior at Active Crossings

Within Figure 3.1, those who "exhibited other looking behavior" show the percentage of observations where drivers only looked left at Type 2R crossings (i.e., in the direction that was clearly visible on the approach), only looked right at Type 2L crossings, or only looked in one direction at Type 3A crossings where sight obstructions prevented clear views of potential train activity in both directions. Those drivers who initiated looking behavior at the active crossings were more likely to exhibit looking behavior in the direction(s) obscured by sight obstructions as is evident by the smaller percentage of observations in which drivers exhibited other looking behavior. Large percentages of the observations resulted in no looking behavior in either direction on the approach to the active crossings along the test course. Not looking left or right on the approach to an active crossing is not necessarily considered unsafe or at-risk behavior. Drivers approaching active crossings should be observing the warning devices installed at the crossing to decide whether they are actively signalizing the approach of a train.

Within this study, the Type 2L subgroup characterized the oblique angled crossing in which the railroad track crossed the roadway surface at a 45-degree angle. The two crossing scenarios included in Type 2L were the northbound and southbound approach to the College Avenue crossing near 32nd Street. The sharp approach angle allowed the driver to view potential track activity from one direction clearly (right); however, the driver would need to look backwards over their left shoulder to look for approaching trains in the other direction. Although this behavior seems desirable since the driver is checking along the track for potential train activity, the substantial turn of the head and a careful search for activity along the track requires the driver to shift the focus of his or her attention from the roadway ahead.

One-third of the looking behavior observations at Type 2L crossings reflected substantial head movement, looking backwards across the left shoulder, for potential activity along the track. Overall, no noticeable differences were found in the degree of looking behavior or deceleration maneuvers between the two approaches to the College Avenue crossing; however, 27 percent of drivers (8 of 30) varied their driving behavior on opposite approaches to the crossing. Two of these differences were attributed to train activity at the crossing. Younger drivers were more likely to change the focus of their attention to look backwards over their left shoulders when traveling northbound, while older drivers were more likely to exhibit this behavior when traveling southbound. Observations at the Type 2L crossings reflect the inconsistent behavior of drivers at active crossings with virtually identical geometric characteristics.

Both of the highway-railroad grade crossings that satisfied the criteria for a Type 3A crossing had cantilever mounted flashing light signals (besides flashing light signals and gates) because sight obstructions block both the right and left view of potential track activity and/or the curvature of the roadway makes it difficult to view standard post-mounted flashing light signals. Observations at Type 3A crossings revealed an increase in looking behavior though not always in both directions. Figure 3.2 and Figure 3.3 show only slight differences in the percentages of observations in which drivers looked in the direction(s) obscured by sight obstructions according to age group and gender.

Figure 3.4 shows the percentage of observations in which drivers did not slow on the approach to the active grade crossings. The percentage of instances when the driver neither slowed nor looked on the approach to the crossing is shaded within the figure. Drivers who exhibited this behavior did not seem to realize they had just traversed a grade crossing. Drivers appeared to be more apt to slow and look at Type 3A crossings.

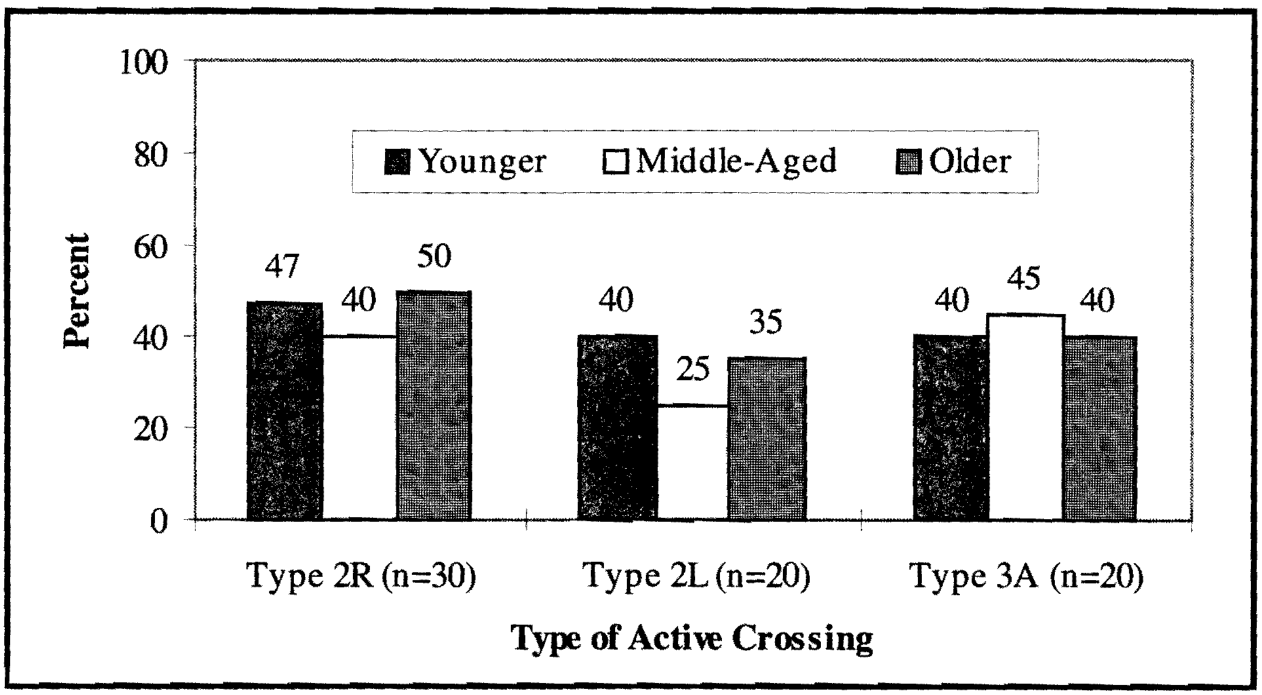


Figure 3.2. Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions at Active Crossings According to Age Group

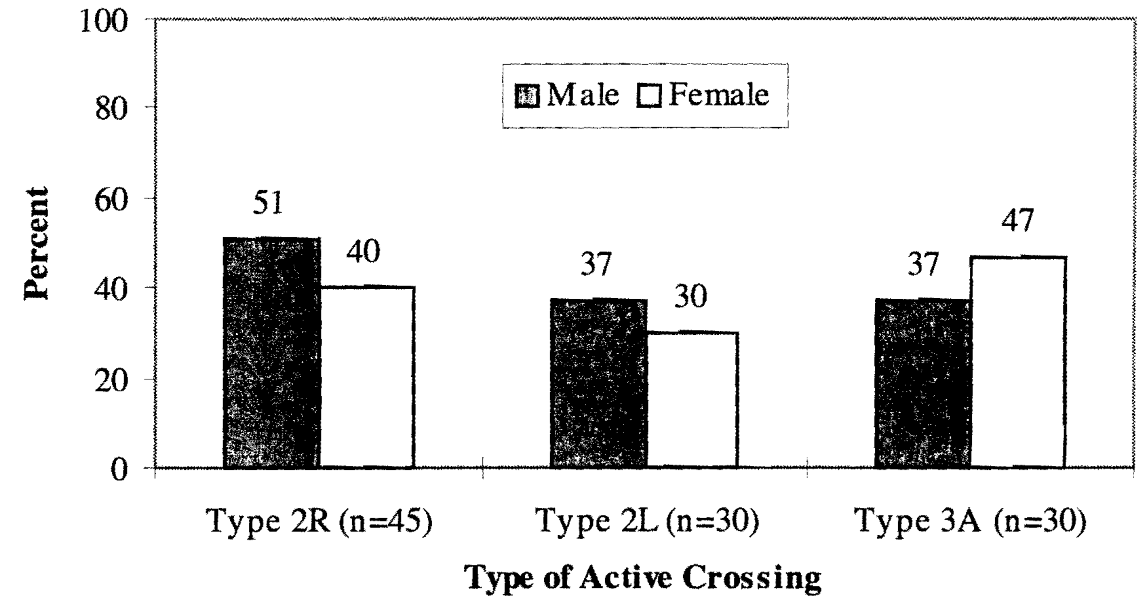


Figure 3.3. Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions at Active Crossings According to Gender

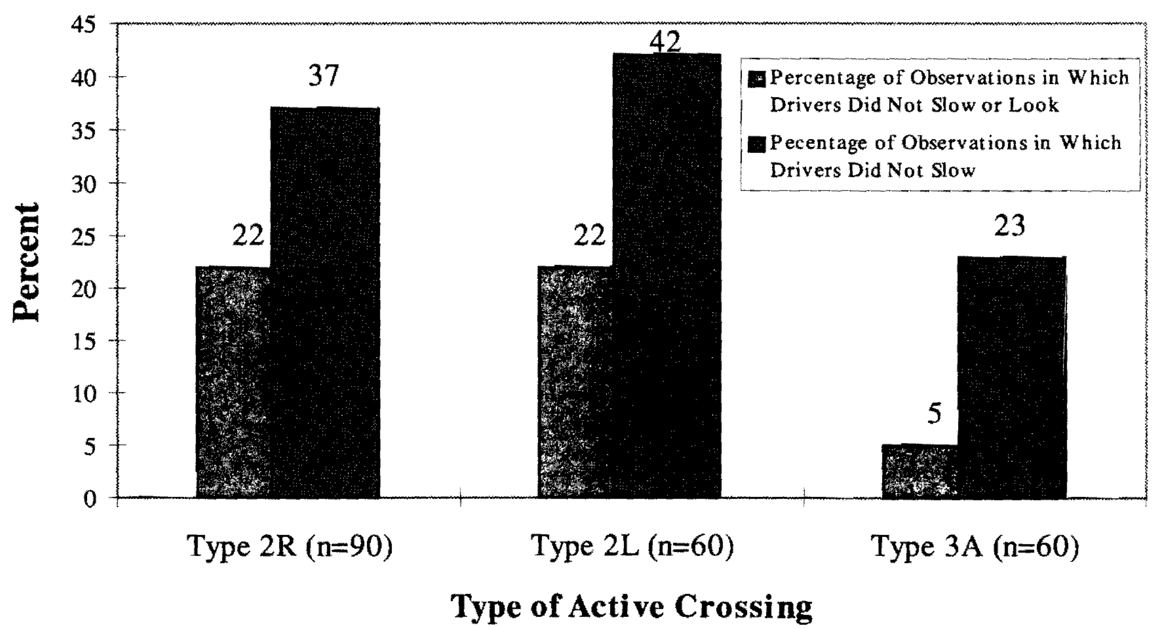


Figure 3.4. Percentage of Observations in Which Drivers Did Not Slow on the Approach to Active Crossings

Observations at Passive Crossings

The three passive grade crossings within the test course were grouped together as Type 3P crossings; however, the unique features of each passive grade crossing warranted individual analyses. Observations of looking behavior and deceleration for each passive grade crossing will be discussed following a brief description of each passive grade crossing. The Dodge Street passive grade crossing near Fountain Avenue is located only 15 m (50 ft) from an active grade crossing that was also included in the test course (i.e., Dodge Street Crossing at Finfeather Road - Type 2R). No railroad advance warning sign is provided on the approach to the industrial spur track. Only crossbucks mark the location of the tracks. Sight obstructions severely limit a driver's view when approaching the grade crossing. The passive grade crossing at Randolph Street lies between two one-way streets that form West 27th Street. A stop sign controls the intersection of Randolph Street and West 27th Street. Next to the stop sign is a crossbuck. The tracks intersect the roadway at a very high profile, blocking the view of oncoming traffic. Large houses block the view in all four quadrants on the approach to this crossing. The passive grade crossing at 20th Street is not controlled by a stop sign. Only a crossbuck marks the location of the tracks. Sight obstructions severely limit the view in both directions.

Looking behavior in both directions and significant reduction in speed is especially recommended at Type 3P (passive) crossings because no warning devices are activated when a train is approaching the crossing. The driver is responsible for achieving a safe passage through this critical intersection. Figure 3.5 shows the percentages of drivers who looked both ways (as desired), looked only in one direction (although both views were obstructed on the approach), or did not look in either direction for each passive crossing included in the test course.

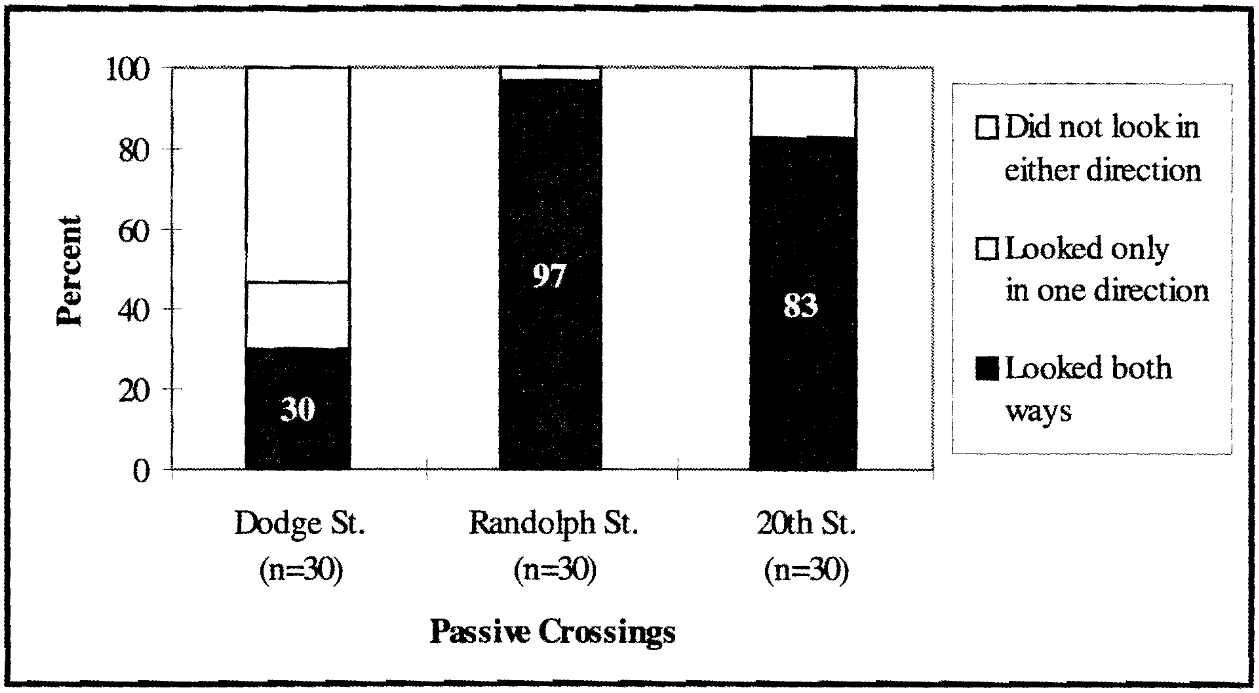


Figure 3.5. Observations of Looking Behavior at Passive Crossings

More than half of the drivers did not look in either direction on the approach to the Dodge Street crossing. This industrial spur track is used infrequently according to the Texas Crossing Summary Database (i.e., through train volume is listed as zero trains per day) (*35*). The researchers hypothesized that the degree of familiarity with the low train volume might influence the driver's perception of risk and subsequent driving behavior at this passive crossing. Further analysis revealed that half the drivers were unfamiliar with this street and that younger drivers made up a large percentage (60 percent) of the unfamiliar drivers. One would expect those who were unfamiliar with the low train volume at the crossing to react more cautiously; however, a majority (53 percent) of these unfamiliar drivers did not slow or look when traversing the crossing.

Observations at the other two passive crossings revealed more desirable behavior. Drivers exhibited slightly better looking behavior at the crossing where a stop sign controlled the approach to the intersection (Randolph Street) compared with the 20th Street crossing where the only traffic control devices within the hazard zone were crossbucks marking the location of the tracks. Note that 17 percent of the drivers did not look both ways before crossing at the 20th Street crossing.

Further analysis of the observations at the stop-controlled intersection (Randolph Street crossing) revealed that only one out of 30 test drivers did not look both ways before traversing this crossing. This driver witnessed a train at the crossing and proceeded to look only in the opposing direction before crossing after the train cleared the crossing. Only three of the 30 drivers did not stop at the stop sign although they each slowed on the approach to the grade crossing. One third of the drivers came to a rolling stop as opposed to a complete stop at the crossing. Finally, Figures 3.6 and 3.7 show only slight differences in the percentages of observations with desirable looking behavior (i.e., looking both ways) according to age group and gender, respectively.

Observations at the Closed Crossing

Analysis of the observations at the closed or out-of-service highway-railroad grade crossing produced interesting results. Railroad tracks once crossed the roadway at a 45-degree angle and a moderately high profile. A crossbuck remains at the crossing on the southbound approach; however, the rails have been covered with asphalt and, a chain-link fence paralleling the roadway crosses the tracks providing an indication that the track no longer services trains. The test course used the northbound approach to this crossing.

In analyzing the observations of driver behavior, the drivers were first divided into those familiar with this highway-railroad grade crossing and those unfamiliar with this crossing. This differentiation is important because those familiar with the highway-railroad grade crossing may have previously detected that the crossing is no longer in service (despite the presence of the crossbuck and the moderately high profile). That is, these "familiar" drivers may not exhibit any looking behavior or deceleration when approaching the closed crossing. Half the 30 drivers were considered "unfamiliar" with this particular highway-railroad grade crossing because they had either rarely or never traversed the crossing before their participation in this study. Sixty percent of those who were not familiar with this crossing were younger drivers.

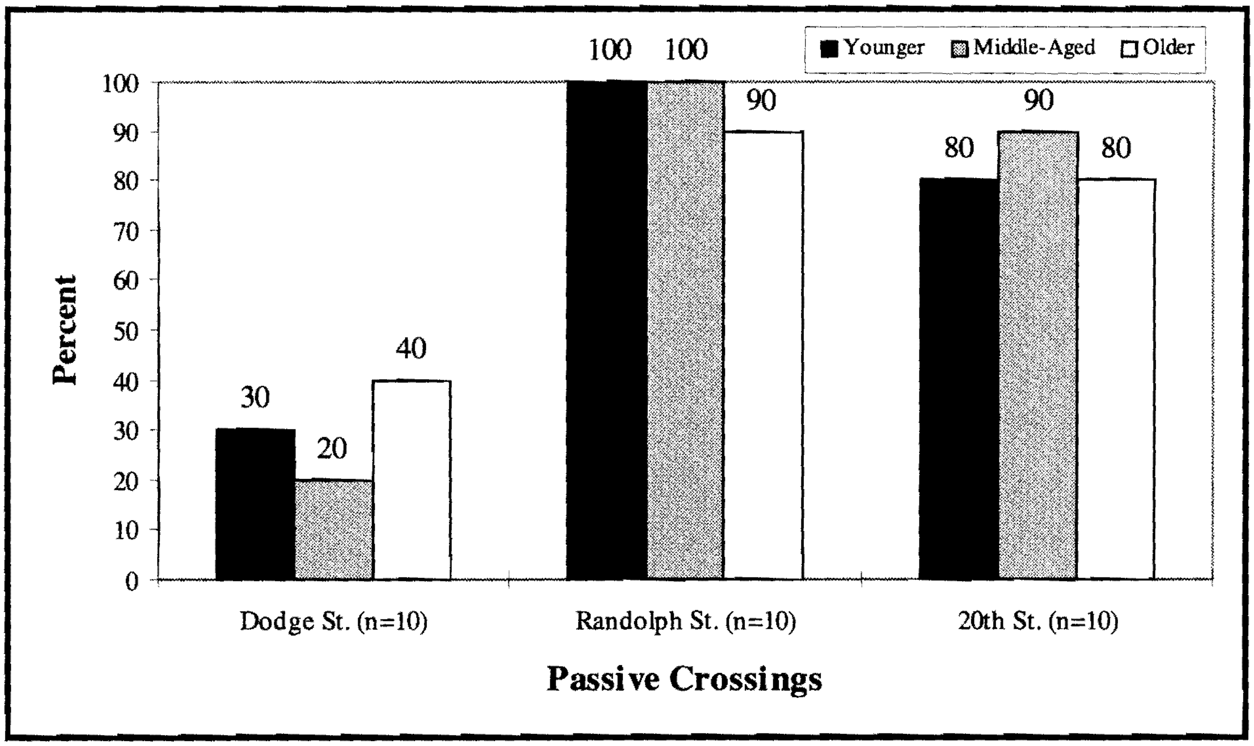


Figure 3.6. Percentage of Observations in Which Drivers Looked Both Ways at Each Passive Crossing According to Age Group

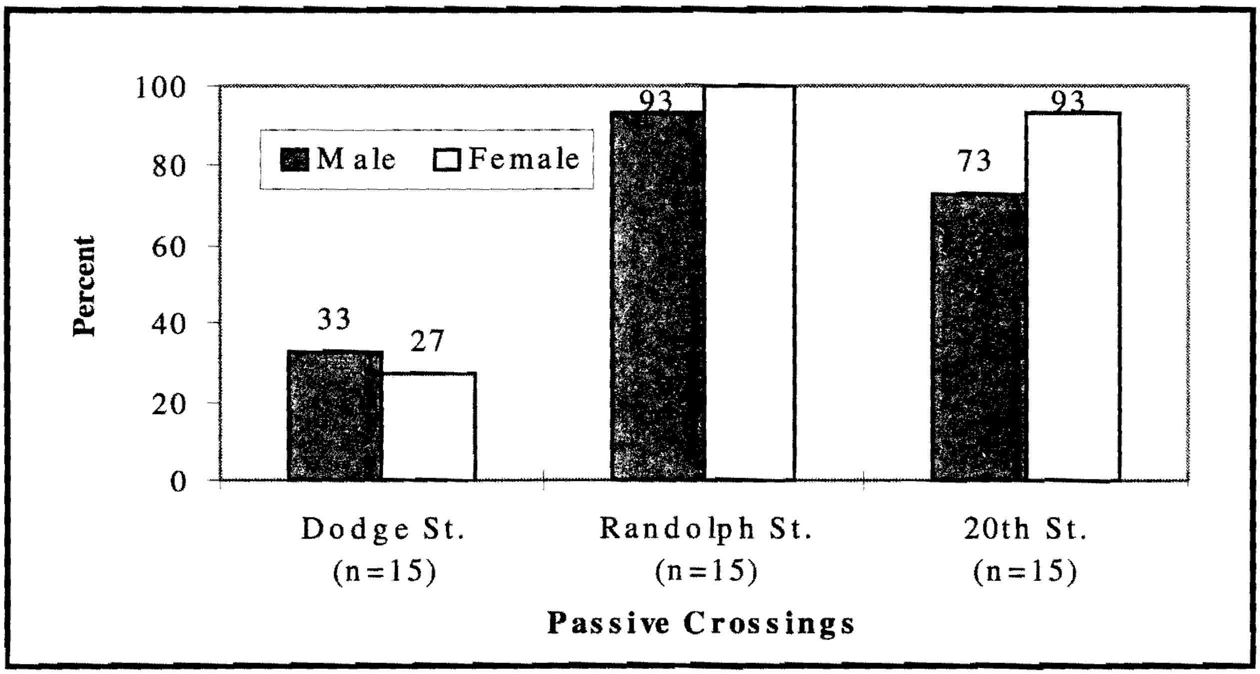


Figure 3.7. Percentage of Observations in Which Drivers Looked Both Ways at Each Passive Crossing According to Gender

As anticipated, the looking behavior of unfamiliar drivers was more extensive than that of familiar drivers; however, only one of the unfamiliar drivers appeared to slow out of concern for detecting potential activity along the track. More familiar drivers (40 percent) than unfamiliar drivers (30 percent) slowed out of concern for the roughness of the grade crossing surface, without initiating any looking behavior on the approach.

Motives for Deceleration Maneuvers

Carefully observing the behavior of the drivers while riding in the driver's vehicle, the researcher can deduce the motive of the deceleration exhibited. The researcher noted whether the driver focused his or her attention on the potential roughness of the highway-railroad grade crossing surface as opposed to a concern for looking for potential activity along the track.

Figure 3.8 shows the percentage of observations where the driver's initiative for decelerating was motivated by a concern for the roughness of the highway-railroad grade crossing surface (without looking in either direction) as opposed to detecting whether a train was approaching. The fact that any percentage of drivers is more concerned about the roughness of the surface at a passive crossing (i.e., Dodge Street industrial spur track) than their responsibility to look and listen for trains is disturbing.

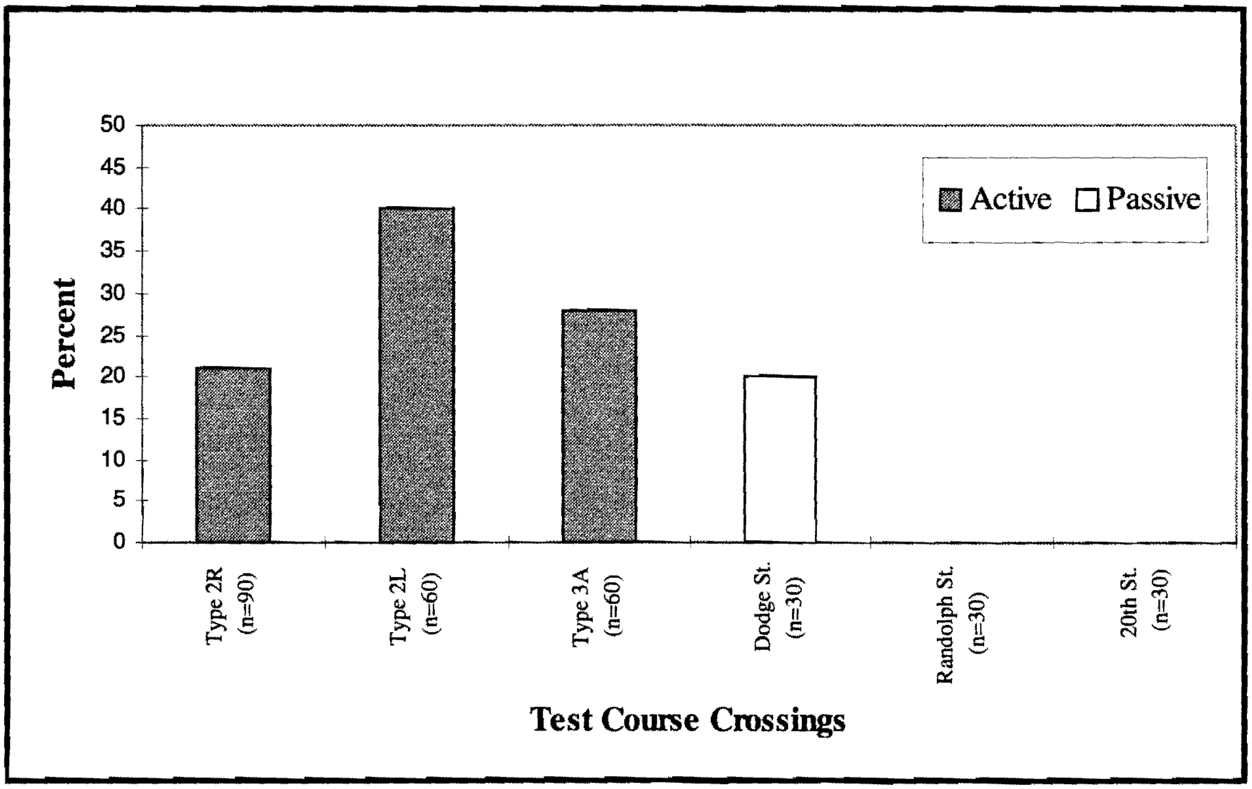


Figure 3.8. Percentage of Observations in Which Drivers Were Only Concerned with the Roughness of Crossing Surface While Initiating No Looking Behavior on the Approach

Effect of Defensive Driving Training

Only six of the 30 drivers had received Defensive Driving training within the past year. Five of these drivers were younger drivers and one was middle-aged. Comparisons were made between the behaviors of those drivers who had completed a Defensive Driving Course within the past year to the behavior of those who had not. The researcher was interested in determining whether exposure to a Defensive Driving Course yielded different driving behavior among the drivers. Those who had received training within the last year were expected to do better (initiate appropriate looking behavior and deceleration for each type of highway-railroad grade crossing) than those who had not recently received training.

Table 3.3 stratifies the percentage of observations in which drivers did not look in either direction for approaching trains when they encountered highway-railroad grade crossings along the test course, according to exposure to Defensive Driving and type of crossing. The six drivers who had recently received training were less likely to slow out of concern for the roughness of the crossing surface without looking in either direction, than those who had not recently received training; however, this difference was not significant at the 95th percent confidence level when comparing two binomial proportions.

When both views were obstructed, drivers who had received training exhibited more looking behavior (in both directions) than those who had not received training as shown in Table 3.4. On the contrary, five of the six drivers who took a Defensive Driving Course neither looked nor slowed on the approach to many of the crossings as shown in Table 3.5.

Analysis of the effectiveness of exposure to Defensive Driving on behavior at highway-railroad grade crossings could not be determined from the data recorded during this study. The effectiveness of Defensive Driving training is subject to many variables, such as the ability of the trainer to captivate the attention of the trainees and provide a quality training session, the quality and breadth of the curriculum, and the interest/attention that a trainee devotes to the training process. All but one of the six drivers who had received training had also received a speeding ticket within the last three years. Texas drivers can apply for permission to enroll in a Defensive Driving Course to remove a speeding ticket from their permanent driving record.

Table 3.3. Percentage of Observations in Which Drivers Slowed Without Looking in Either Direction According to Exposure to Defensive Driving

Crossing Type		Completed Defensive Driving within the Previous Year			
		Yes (6/30)		No (24/30)	
Active	Type 2R	17	(3/18)	22	(16/72)
	Type 2L	25	(3/12)	44	(21/48)
	Type 3A	25	(3/12)	27	(13/48)
Passive	Type 3P	0	(0/18)	8	(6/72)

Table 3.4. Percentage of Observations in Which Drivers Looked in Direction(s) Obscured by Sight Obstructions According to Exposure to Defensive Driving

Crossing Type		Completed Defensive Driving within the Previous Year			
		Yes (6/30)		No (24/30)	
Active	Type 2R	39	(7/18)	24	(17/72)
	Type 2L	42	(5/12)	31	(15/48)
	Type 3A	50	(6/12)	15	(7/48)
Passive	Type 3P	67	(12/18)	71	(51/72)

*Shaded entries show those differences that are significant at the 95th percent confidence level.

Table 3.5. Percentage of Observations in Which Drivers Neither Looked Nor Slowed According to Exposure to Defensive Driving

Crossing Type		Completed Defensive Driving within the Previous Year			
		Yes (6/30)		No (24/30)	
Active	Type 2R	44	(8/18)	15	(11/72)
	Type 2L	25	(3/12)	21	(10/48)
	Type 3A	8	(1/12)	4	(2/48)
Passive	Type 3P	22	(4/18)	7	(5/72)

*Shaded entries show those differences that are significant at the 95th percent confidence level.

Effect of Legal History and Awareness

Nine of the 30 drivers indicated that they had received one or more moving citations (i.e., excluding parking violations) within the last three years. Speeding tickets were the most common citation listed. Seven of the nine who had received tickets within the last three years were younger drivers. Furthermore, seven of the 30 drivers were not aware that driving around or under a crossing gate is against the law. All older drivers stated that they were aware that this activity was illegal, while fewer middle-aged and younger drivers were aware of the legal implications of this activity.

Sixty percent of the drivers indicated that they had driven under lowering gates or around lowered gates at a highway-railroad grade crossing at least once; two-thirds of those knew they were engaging in an illegal activity when they traversed the tracks under these circumstances. More younger and middle-aged subjects (23 percent each) had engaged in this type of activity than older drivers (13 percent). The drivers offered the following reasons about why they initiated this (illegal) behavior:

- No train in sight (10);
- Equipment malfunction - gates broken, "signals stuck" (5);
- Train stopped near crossing (5);
- Late for meeting (1);
- Train was switching tracks (1); and
- Followed others since no train in sight (1).

Comparisons were made between the behaviors of those drivers who had previously driven under lowering gates or around lowered gates to those who had not. The researchers were interested in observing whether drivers who had never driven under lowering gates or around lowered gates yielded different driving behavior than those who had initiated this (illegal) activity. Those who had never driven under lowering gates or around lowered gates were expected to exhibit more respect for the critical intersection between the roadway and railroad tracks; therefore, this subgroup was also expected to exhibit more desirable driver behavior (i.e., appropriate looking behavior and deceleration for each type of highway-railroad grade crossing).

Analysis of the results revealed no significant differences between the observed driving behavior of those who had never driven around lowered or under lowering gates and those who had previously engaged in this activity. During a slightly higher percentage of time (33 percent compared with 30 percent), those who *had* previously traversed the crossing illegally, slowed only out of concern for roughness and did not initiate the recommended looking behavior for the type of crossing (Type 2L, 2R, 3A, 3P). Likewise, this subgroup neither slowed nor looked in either direction when approaching each type of crossing during a slightly higher percentage of time (16 percent compared with 13 percent for those who had never illegally traversed a crossing). Therefore, drivers who do not violate railroad traffic control devices are no more likely to exhibit the desirable looking behavior and deceleration maneuvers on the approach to the highway-railroad grade crossings than drivers who decide to cross despite activated warning devices.

Effect of Frequency of Crossing Activity

Following the driving portion of the study, each driver was asked to indicate how often he or she usually encountered highway-railroad grade crossings (i.e., once a day, four times per week, rarely). The purpose of this question was to evaluate the actions of those drivers who regularly cross highway-railroad grade crossings as compared with those who occasionally do so. "Occasionally" was defined as no more than five times per week. Seventy-five percent of the drivers who participated in this study encountered grade crossings "occasionally," while the remaining 25 percent encountered highway-railroad grade crossings regularly, ranging from the three to 10 times per day.

Wigglesworth noted that most highway-railroad grade crossing crash victims are familiar with the area, and even the particular crossing (*36*). Sanders, Kolsrud, and Berger found that driver looking behavior and speed reductions were inversely correlated with the frequency of using the highway-railroad grade crossing (*3*). According to the literature, as drivers become more familiar with a particular crossing, they exhibit fewer cautionary measures of looking behavior and speed reductions.

Table 3.6 stratifies the percentage of observations according to the frequency of crossing activity and type of crossing in which drivers did not look in either direction for approaching trains when they encountered the highway-railroad grade crossings along the test course. Only one type of highway-railroad grade crossing (Type 2L) resulted in significant differences (at the 95th percent confidence level when comparing two binomial proportions) in this behavior between those who occasionally or regularly encounter crossings. The Type 2L subgroup contained the oblique angled crossing in which the railroad track crossed the roadway surface at a 45-degree angle. The driver would need to look backwards over the left shoulder while a clear view of rightmost track activity was available on the approach to the crossing without initiating noticeable head movement to the right to look for approaching trains. Eighty-one percent of those who regularly encountered crossings showed no attempt to initiate this type of head movement, compared with 32 percent of those who only occasionally encountered crossings. Roughly one-half of both groups did not look in either direction upon approaching the industrial spur track crossing at Dodge Street.

Table 3.7 stratifies the percentage of observations in which drivers looked in the direction obscured by sight obstructions for each type of crossing according to the frequency of crossing activity. Those who regularly encountered crossings were less likely to initiate this looking behavior. The shaded entries show those crossing scenarios in which significant differences were observed between those who occasionally encounter crossings and those who regularly encounter crossings (i.e., significant at the 95th percent confidence level when comparing two binomial proportions).

The percentage of observations where drivers did not look in either direction or slow on the approach to the highway-railroad grade crossings is stratified, according to type of crossing and frequency of crossing activity, in Table 3.8. Whereas Table 3.6 and Table 3.7 suggest that those who occasionally encounter crossings exhibit more desirable looking behavior, Table 3.8 suggests that most of those who occasionally encounter crossings neither slowed nor looked in either direction on the approach to the crossing when compared with the behavior of those who regularly encounter crossings. This difference was significant at the 95th percent confidence level for the Type 2R crossing classification when comparing the two binomial proportions. More observations would be required to make more conclusive statements as to the significance of the findings for the other crossing classifications.

Misconceptions Identified from Driver Comments and Survey Responses

Survey Responses vs. Observed Driver Behavior

At the completion of the driving portion of the study, the drivers were told the difference between an active and a passive crossing within the subsequent questionnaire (see Appendix I). Most of the drivers had never considered the highway-railroad grade crossing scenario from the perspective of the different traffic control devices present at active and passive crossings. Within the subsequent survey instrument, the drivers were asked to explain what they should do when approaching an active crossing. The same question was then asked concerning what they should do when approaching a passive crossing.

Table 3.6. Percentage of Observations in Which Drivers Did Not Look According to Frequency of Crossing Activity

Crossing Type		Encounter Grade Crossings...			
		Occasionally (22/30)		Regularly (8/30)	
Active	Type 2R	45	(23/51)	46	(18/39)
	Type 2L	50	(17/34)	81	(21/26)
	Type 3A	32	(11/34)	35	(9/26)
Passive	Dodge Street	53	(9/17)	54	(7/13)
	Randolph Street	0	(0/17)	0	(0/13)
	20th Street	0	(0/17)	0	(0/13)

*Shaded entries show those differences that are significant at the 95th percent confidence level.

Table 3.7. Percentage of Observations in Which Drivers Looked in the Direction(s) Obscured by Sight Obstructions According to Frequency of Crossing Activity

Crossing Type		Encounter Grade Crossings...			
		Occasionally (22/30)		Regularly (8/30)	
Active	Type 2R	47	(24/51)	44	(17/39)
	Type 2L	47	(16/34)	15	(4/26)
	Type 3A	53	(18/34)	27	(7/26)
Passive	Dodge Street	35	(6/17)	23	(3/13)
	Randolph Street	94	(16/17)	100	(13/13)
	20th Street	82	(14/17)	85	(11/13)

*Shaded entries show those differences that are significant at the 95th percent confidence level.

Table 3.8. Percentage of Observations in Which Drivers Neither Looked Nor Slowed According to Frequency of Crossing Activity

Crossing Type		Encounter Grade Crossings...			
		Occasionally (22/30)		Regularly (8/30)	
Active	Type 2R	29	(15/51)	10	(4/39)
	Type 2L	24	(8/34)	19	(5/26)
	Type 3A	9	(3/34)	0	(0/26)
Passive	Dodge Street	35	(6/17)	23	(3/13)
	Randolph Street	0	(0/17)	0	(0/13)
	20th Street	0	(0/17)	0	(0/13)

*Shaded entries show those differences that are significant at the 95th percent confidence level.

When Wigglesworth reviewed the potential for safety improvements at open level crossings in Australia (*37*), he agreed with other authors that although the expectation of traffic authorities and designers of highway-railroad grade crossings is that drivers will look in both directions to see if a train is approaching, and will slow to a speed that enables them to stop if necessary, most drivers do not do so. Comparison between the survey responses and the observed driving behavior within the present study also revealed that drivers are not actually doing what they say they should do when approaching highway-railroad grade crossings.

For example, the responses of more than 85 percent of the drivers reflected an appreciation for defensive driving procedures when approaching an active crossing. The most common responses included references to looking both ways before crossing and reducing speed on the approach in case a train was detected; however, as evident in Figure 3.1, observed behavior of drivers at active crossings along the test course did not correspond with what drivers said they should or would do at active crossings. That is, most drivers did not look both ways and/or reduce their speed on the approach to the active crossings. Likewise, half the drivers responded that they would always stop at passive crossings; however, observations at the passive crossings along the test course revealed that very few drivers came to complete or rolling stops as Figure 3.9 shows.

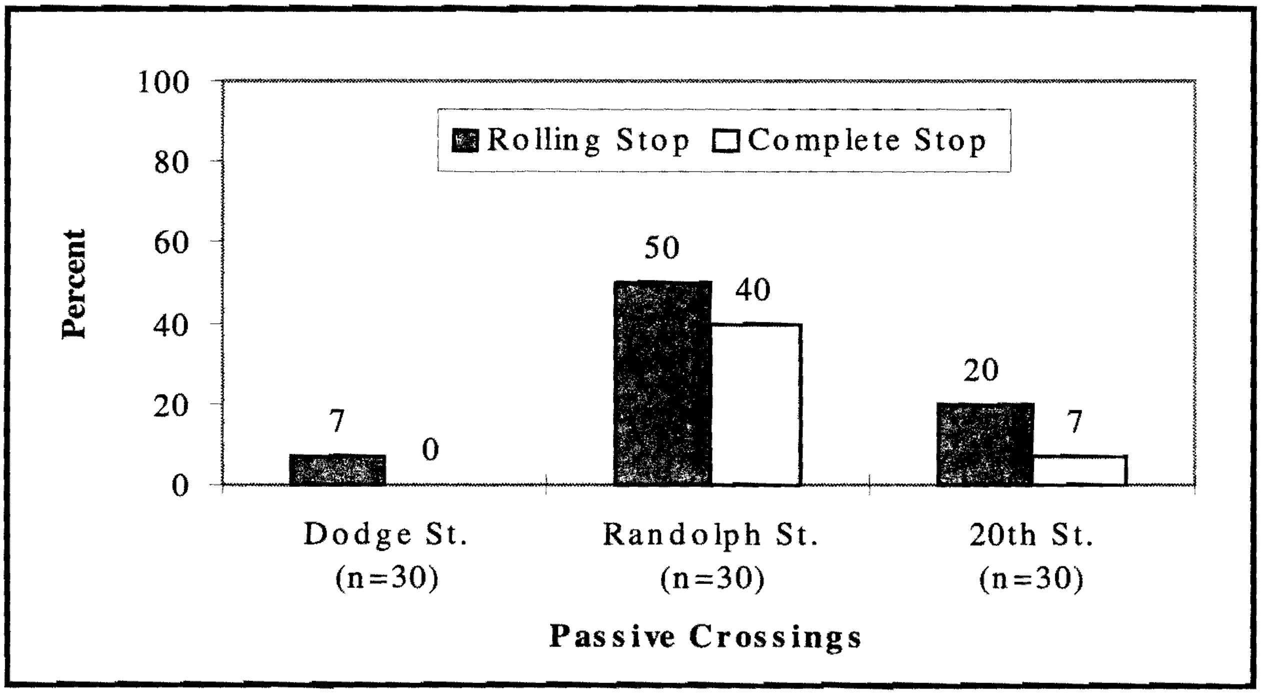


Figure 3.9. Percentage of Drivers Who Decelerated to Complete Stops or Rolling Stops at Each Passive Crossing

Understandably, drivers may not need to initiate looking behavior in both directions to achieve safe passage at active crossings nor are drivers required to stop before traversing passive crossings. The contrasts between what drivers say they would or should do and what drivers actually do when traversing highway-railroad grade crossings is important to recognize when analyzing survey responses. Conclusions drawn from survey responses of previous studies may not accurately reflect drivers' understanding of highway-railroad grade crossing traffic control devices.

Perceptual Cues

To understand what cues the driver relies on, the drivers were asked when they first became aware of a highway-railroad grade crossing. Note that no reference was given to crossing type (active or passive). The driver was encouraged to select only one of the multiple choices provided. The majority responded "when I see the railroad advance warning sign on the approach to the crossing" (47 percent) or "when I see the pavement markings on the roadway just before the crossing" (30 percent). Thirteen percent rely on "humps" in the road to identify highway-railroad grade crossing areas. Ten percent responded reactively "when I see flashing signals and/or lowering gates." These responses show that many drivers assume all highway-railroad grade crossings have active warning devices to warn of approaching trains. In fact, when a young female driver was traversing the high profile, passive crossing along Randolph Street, she asked, "Is this a real crossing? I always get nervous around the ones without gates!" Her reaction implied that if this highway-railroad grade crossing was used by trains (i.e., "real"), gates and signals would accompany the signage at the crossing.

The drivers were then asked to identify their first concern when approaching a highway-railroad grade crossing. Again, no reference was made to the crossing type (active or passive). Only 50 percent of drivers stated that their first concern was whether or not a train was approaching the crossing. Seventeen percent were not concerned unless they detected lights flashing and/or gates lowering.

Driver Comments

The researcher recorded the comments of each driver while traveling through the test course. One driver commented, "I have seen enough videos and television footage about collisions. If there are not gates, I stop and look." This comment was made as the driver continued across the passive crossing on Dodge Street. The driver looked left and right as he approached the crossing but did not stop as he stated he would.

Another driver voiced a similar comment; "If there are not gates, I stop and look both ways. I have seen too many accidents"; however, observation of this driver's behavior revealed that neither a complete stop nor a rolling stop was initiated at any of the passive crossings within the test course. Although a reduction in speed was achieved, the driver failed to stop at the stop sign next to the passive crossing at Randolph Street. This driver later stated, "It is the driver's responsibility to get safely across these tracks" referring to the passive crossing at 20th Street. Therefore, a contrast in what drivers say they would do and what drivers actually do may not necessarily be indicative of misunderstanding of driver responsibilities at highway-railroad grade crossings.

Upon being debriefed regarding the study's purpose, many drivers relayed stories regarding near miss experiences and tragic collision experiences of both acquaintances and close friends at highway-railroad grade crossings; however, observations of their driving behavior at the active and passive crossings along the test course did not reflect a concern for crossing safety as did their description of the seriousness of these previous incidents. One particular driver described a situation in which she noticed, once on top of a highway-railroad grade crossing at the plea of her concerned child in the passenger seat, that a train was within a hundred meters of the crossing. Although she said that this experience really taught her a lesson, the researcher did not observe corresponding cautious behavior or noticeable respect for the crossing scenarios encountered along the test course.

3.5 SUMMARY

The following summarizes the findings from the in-vehicle investigation of driver behavior at highway-railroad grade crossings.

- When analyzed according to driver age and gender, there were only slight differences in the percentages of observations in which drivers looked in the direction(s) obscured by obstructions at active crossings and in both directions at passive crossings.
- Less than 50 percent of the drivers looked in the direction(s) obscured by sight obstructions when approaching the active crossings along the test course.
- Those drivers who did initiate looking behavior at the active crossings were more likely to exhibit the desirable looking behavior (in the direction(s) obscured by sight obstructions) as is evident by the smaller percentage of observations in which drivers exhibited other looking behavior; however, large percentages of the observations resulted in no looking behavior in either direction on the approach to the active crossings.
- One-third of the looking behavior observations at the oblique angled grade crossings (i.e., the railroad track crossed the roadway surface at a 45- or 135-degree angle) resulted in substantial head movement, looking backwards across the left shoulder, for potential activity along the track.
- Observations at active crossings in which both views were obstructed on the approach revealed an increase in looking behavior though not always in both directions.
- The deceleration exhibited at active crossings were primarily a function of the perceived roughness of the grade crossing surface.
- Drivers did not always look both ways at the passive crossings along the test course. More than half of the drivers did not look in either direction as they approached and traversed the industrial spur track crossing. Even most of those who were unfamiliar with this particular crossing did not look in either direction or slow before crossing the industrial spur track.
- At the industrial spur track crossing, 20 percent of the drivers slowed only out of concern for the roughness of the crossing surface (without looking in either direction). Although, this percentage decreased to zero at the other two passive crossings, the fact that any driver is more concerned about the roughness of the crossing surface at a passive crossing, than their responsibility to look and listen for trains, is disturbing.
- More desirable driver behavior was observed at the passive crossing that had a stop sign near the crossing than at the passive crossing with no stop sign on the approach.
- As expected, the looking behavior of those unfamiliar with the closed or out-of-service grade crossing was more extensive than that of drivers who were familiar with the

crossing; however, only one of the unfamiliar drivers slowed out of concern for detecting potential activity along the track (i.e., to look for trains).

- The sight or sound of a train at a nearby grade crossing (visible, but not included in the test course) did not necessarily produce more cautious driving behavior at the next crossing on the test course.
- Drivers seemed less likely to notice the railroad advance warning sign or pavement markings when they were following another vehicle as opposed to operating as the lead vehicle or the only vehicle approaching the crossing.
- The effectiveness of Defensive Driving training could not be determined from the data recorded during this study. The effectiveness of a training program ultimately depends on the capabilities of the trainer, the quality and breadth of the curriculum, and the interest/attention devoted by the trainee.
- The drivers who had intentionally engaged in undesirable behavior (e.g., driven around or under lowered or lowering gates) generally did not perceive that their actions were hazardous although two-thirds understood that this activity was against the law.
- Those who encounter highway-railroad grade crossings regularly were less likely to look in the direction(s) obscured by sight obstructions. Most of those who occasionally encounter highway-railroad grade crossings neither slowed nor looked in either direction on the approach to the crossings.

4.0 EXPERIMENTAL PASSIVE SIGN SYSTEMS

4.1 INTRODUCTION

Where the paths of any two vehicles meet, steps must be taken to minimize the potential for collisions occurring when one vehicle fails to yield to the other. At highway-railroad grade crossings, the results of such a collision can be especially catastrophic due to the large difference in both size and speed of the vehicles involved. While crash rates have been on the decline, the potential for crashes at grade crossings has been increasing as a result of higher train and automobile volumes. Thus, new methods to enhance the safety of highway-railroad grade crossings are constantly being sought.

While 25 percent of all highway-railroad grade crossings have some form of active control, such as gates and flashing lights, the majority of highway-railroad grade crossings do not have active devices. These passively controlled crossings place the burden of detecting a train, and judging whether it is safe to cross the tracks, upon the driver. While active controls provide clear instructions to the driver at a crossing, passively controlled crossings do not convey such a message. Thus, drivers often do not understand exactly what actions are required of them as they approach a passively controlled crossing.

Many highway-railroad grade crossings continue to be converted to active control, yet there are factors that discourage such conversion at all crossings. First, the minimal funds available for conversion limit the number of new active controls that can be installed each year. Also, grade crossings that operate only during the day or with low train speeds or volumes can operate safely with only passive controls if the driver reacts to such controls in the appropriate manner.

With the high costs associated with each highway-railroad grade crossing crash, it is desirable to increase the level of safety at passively controlled crossings by enhancing the current standard traffic control devices at these crossings. Even a slight decrease in crash rates at a grade crossing would justify the expense of enhancing the traffic.

Objective

The objective of this component of the study was to examine the effects that enhancements to standard traffic control devices at passively controlled highway-railroad grade crossings had on the level of safety at the crossing. The results of the analysis of data collected both before and after the enhancements were made will show if there has been an increase in safety at the crossing. It will also be important to demonstrate that the addition of the new warning devices did not have an adverse effect on driver behavior at the crossing.

4.2 SAFETY AT RAILROAD CROSSINGS

The highway-railroad grade crossing brings together two distinct modes of transportation: the automobile and the train. In the past when vehicle speeds were limited and sight distance extended for many miles, highway users had ample time to recognize the existence of a grade crossing and react to an approaching train. Since the train cannot stop quickly or change directions, it is always given the right-of-way at these crossings. Thus, maintaining the safety of the grade crossing is mostly the responsibility of the highway vehicles. As vehicle speeds and volumes increased and land was developed near grade crossings, delays and crashes at the crossings began to increase. This forced many states, cities, and towns to pass laws mandating that "the railroads eliminated some crossings and provide safety improvements at others" (*33*).

"Traffic and highway engineers can assist drivers in their task by providing proper highway design and traffic control devices" (*33*). Early attempts to improve safety at railroad-grade crossings resulted in the placement of "a wide variety of signs, holding no particular conformity to standard" at many grade crossings throughout the country (*38*). Drivers were often confused by the different signs and were unsure as to what response was required. To alleviate some of these problems, in 1924, the American Association of State Highway Officials (AASHTO) adopted the use of the railroad advance warning sign with black lettering on a yellow background for warning drivers of the existence of a railroad grade crossing (*39*). This railroad advance warning sign is still required by the *Manual on Uniform Traffic Control Devices* (MUTCD) (*10*).

4.3 STANDARD SIGN SYSTEMS

The standard sign system required by the *Texas Manual on Uniform Traffic Control Devices* (*40*) at passively controlled highway-railroad grade crossings is depicted in Figure 4.1. The warning sign used as part of this sign system is located 230 m (750 ft) in advance of the grade crossing in rural areas. In urban areas, the railroad advance warning sign is placed at a position determined by approach speed and available sight distance. The MUTCD (*10*) specifies the placement of the railroad advance warning signs in both urban and rural areas based on approach speed. In cases where the railroad advance warning sign is placed closer than the required 230 m (750 ft) in advance of the grade crossing, intersecting roadways and the geometry associated with the approach have most likely influenced its placement.

According to the 1980 MUTCD, the placement of the pavement marking used in the current sign system should be at a distance from the crossing dependent upon the approach speed; however, the 1988 MUTCD requires that the pavement marking be placed the same distance from the crossing as the railroad advance warning sign. As previously mentioned, the position of this sign depends on the approach speed and the available sight distance. Pavement marking is to be present at all paved approaches to actively controlled crossings and at all other crossings where the approach speed is 65 km/h (40 mph) or greater.

The crossbuck is located immediately prior to the railroad tracks adjacent to the roadway. Crossbuck signs are a double-sided white "X"-shaped sign with the words RAILROAD CROSSING spelled across its arms. Since the *Texas Drivers Handbook* (*32*) instructs drivers to slow and prepare to yield to approaching trains, many feel that "in effect, the . . . crossbuck is a YIELD sign and drivers have an obligation to so interpret it" (*33*). However, others feel that the crossbuck only alerts drivers to the existence of a grade crossing and thus more information should be conveyed to drivers to instruct them how to properly respond.

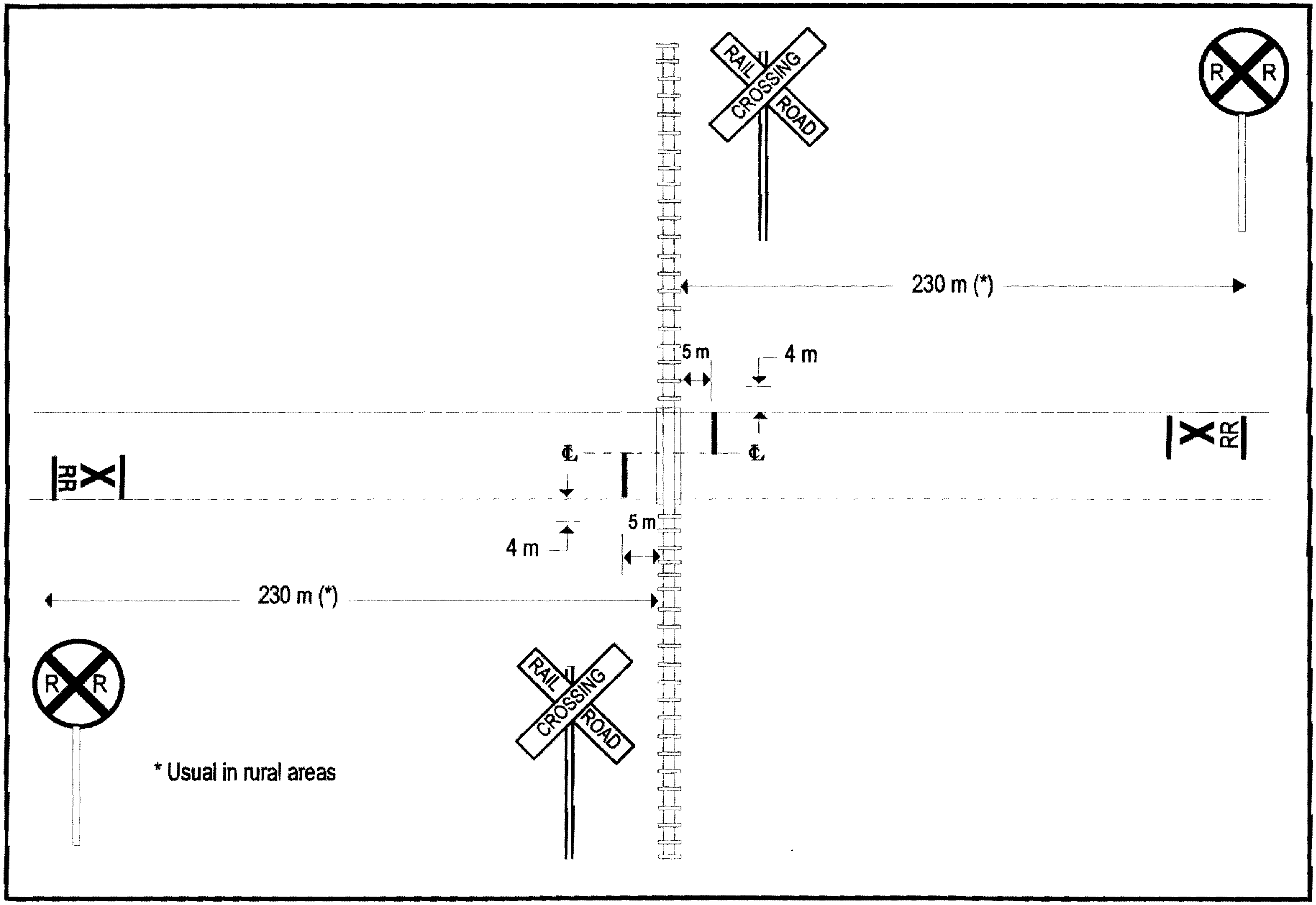


Figure 4.1. Standard Highway-Railroad Grade Crossing Sign System

4.4 MEASURES OF DRIVER PERFORMANCE

The goal of any improvements at highway-railroad grade crossings is to improve the safety at the crossing for the operators of both the train and motor vehicle. An increase in safety can be directly measured by noting a decrease in the number of crashes at a grade crossing. However, as found in several studies conducted in the past, measuring a change in the crash rate at a grade crossing would require that the duration of the study be quite long and include an extremely large sample size (*41*). Thus, a direct measurement of crash reduction is not feasible for most studies.

An observation of certain driver behavior at highway-railroad grade crossings can be used to determine the effect that an improvement will have on the safety at a grade crossing. It can be inferred that those who operate in a safer manner will be less likely to be involved in a crash at the crossing. Two such behaviors that can be indicative of safety at the grade crossing are driver looking behavior and approach speed.

Driver Looking Behavior

As a driver approaches a grade crossing, he or she must analyze the surroundings and decide whether it is safe to proceed across the tracks. This analysis includes noting any warning devices, the grade crossing location, and the presence of any approaching trains. The primary action that the driver takes to perform this analysis is defined as the looking behavior of the driver. The measurement of driver looking behavior is conducted by observing the head movements of the driver near the grade crossing. Measurements based on head movements can be difficult to obtain due to tinted windows, sun glare, angle of approach, or lack of available sunlight. Using either an "in-vehicle" camera or binoculars can help overcome some of these difficulties. Also, for grade crossings with longer sight distances, it may be possible for the driver to observe the crossing without making any discernible head movements (*3*). Several studies focusing on driver looking behavior at highway-railroad grade crossings have been discussed in a previous chapter.

Speed-Based Measures

Driver performance at the grade crossing can also be measured by observing the speed of the drivers on the approach. Speed-related measurements include the approach speed profile and the mean speed reduction on the approach to the crossing. It is intuitive that slower approach speeds can lead to improved safety at the grade crossing since the required stopping distance would be less, and thus the driver would have more time to react if a train is detected. Using radar guns, loop detectors, or other speed measuring devices makes speed measurements easier to obtain than measurements of looking behavior.

The speed-based measurement can be used to detect a change in driver behavior due to a modification at the grade crossing, such as the installation of a new warning device (*25*). However, it is very hard to isolate the exact cause of approach speed differences due to other factors that also influence speed. These factors include the anticipated roughness of the grade crossing, the alignment of the roadway near the crossing, knowledge of the existence of an upcoming crossing before the railroad advance warning sign is passed, and the response to preceding slower vehicles (*23*). Other studies have found that reduction in speed on the approach to the grade crossing is often a better measurement than the use of the mean speed profile along the approach.

Although the use of driver looking behavior and speed measurements has limitations, these measures can provide knowledge about the effectiveness of an experimental sign system at the crossing. As long as the shortcomings of these measures are accounted for in the study, the information gained through the observations can form the basis for recommending the use of an experimental sign system at other grade crossings.

Previous Laboratory Study of Experimental Signs

A laboratory study examining the current standard sign system and three experimental sign systems was conducted at the Texas A&M University Riverside campus. The first experimental sign system simply replaced the standard crossbuck with a Canadian crossbuck. The Canadian crossbuck is a white X-shaped sign with no lettering and a reflective red border. The second experimental sign system combined two test signs with the standard railroad advance warning sign and the Canadian crossbuck. The first test sign was diamond-shaped with a symbol of a locomotive and an advisory plate with the words LOOK FOR TRAINS. The third test sign combined a standard size YIELD sign with a TO TRAINS advisory plate. The final experimental sign system was identical to the third except that the standard crossbuck was used in place of the Canadian crossbuck (*38*).

Driver approach speeds and looking behavior were the measures of effectiveness used to study each sign system. The results of the study did not suggest that the observation of a particular sign system had a particular effect on speed at the crossbuck. However, an increase in looking behavior for the experimental sign systems was noted and may have been due to other factors, such as test group sampling differences. Comments from drivers in the study indicated that they understood all of the signs involved in the study with the exception of the Canadian crossbuck. The study recommended further testing of the two test signs in conjunction with the standard crossbuck (*38*).

4.5 STUDY DESIGN

The study design for this research facilitated the measurement of those behaviors that are indicative of safe driving behavior at highway-railroad grade crossings. The study provides a comparison between the response due to the current sign system and that due to two experimental sign systems. The experimental design for this study is a *before* and *after* or longitudinal study. This type of study compares data taken at a particular study area at different times. This differs from a cross-sectional study which compares an experimental grade crossing to a control crossing at the same point in time. The latter approach would require finding two grade crossings that were exactly alike; otherwise, it would be very hard to isolate the experimental sign system as the only variable causing changes in driver behavior.

Since there was a period of time between each study period, conditions may have changed at the grade crossing which would cause a measurable difference in driver behavior that was not attributable to the experimental sign system. The changes could include changes in vegetation, traffic volumes, or the angle of the sun. Further study was halted at those crossings where any of the signs on an approach had been damaged or removed since the previous study periods. Thus, it is assumed that changes detected in driver behavior in this study are due to the experimental variable, although the differences mentioned above may have also contributed to the behavioral changes.

Measures of Effectiveness

The most accurate measure of improved safety at highway-railroad grade crossings would be a decrease in the crash rate at the crossing. However, in order to directly observe a change in the low expected crash rate, it would be necessary to study a location for many years. Thus, increases in driver looking behavior and mean speed reduction from the railroad advance warning sign to the crossbuck will be used as an indirect measure of increased crossing safety. While these measures do not correlate one-to-one with crossing safety, it can be inferred that an increase in safer driver behavior at a grade crossing will lead to a decrease in the crash rate at that crossing.

The research hypothesis for this study was that the installation of the experimental sign systems at the highway-railroad grade crossings would cause an increase in driver looking behavior that is inferred to create a safer driving environment. With respect to the measures of effectiveness used in this study, the research hypothesis is that driver looking behavior and mean speed reduction will increase after the experimental signs are installed.

Driver Looking Behavior

The looking behavior of drivers was observed to determine if the existence of enhanced warning devices at railroad-grade crossings has a positive effect on the looking behavior of drivers. It is inferred that an increase in driver looking behavior will result in increased safety. The number of drivers who looked to the left, right, or both, as well as the number of drivers that did not experience any significant looking behavior within 45 m (150 ft) of the grade crossing was recorded.

Spot Speed Measurements

Spot speed measurements were made in three locations as vehicles approached the grade crossing. These locations were as follows:

- The standard railroad advance warning sign;
- The beginning of the advance R X R pavement marking; and
- The grade crossing itself.

The mean difference in speed from the railroad advance warning sign to the grade crossing was calculated to determine if speeds reduced or increased on the crossing approach. Once again, one can infer that greater reductions in speed on the approach will result in a safer crossing. The mean and variance of the speeds at the three locations were calculated.

Driver Exit Survey

During the initial poststudy, drivers were stopped downstream from the grade crossing and presented with a survey to determine their understanding of the experimental sign system. Drivers were asked demographic questions and questions related to how well they remembered and understood the meaning of the signs at the grade crossing. Drivers were also asked if they felt the sign system was effective.

Sample Size Goals

It was necessary to collect a minimum number of observations in order to conduct the required statistical analysis. Thus, the goal of 100 spot-speed and looking behavior observations at each test crossing was established. At those grade crossings with very low volumes, the goal was set to the number of speed observations that could be observed in one day.

YIELD TO TRAINS Sign System

The first experimental sign system tested consisted of a standard size YIELD sign with a supplementary message plate containing the words TO TRAINS. As shown in Figure 4.2, this sign was located at the highway-railroad grade crossing near the crossbuck. While there has been a considerable argument against the use of YIELD signs at grade crossings, the addition of the TO TRAINS sign clearly distinguishes this experimental sign from the standard YIELD sign. Thus, the effectiveness of the standard YIELD sign at other locations should not be affected by this sign system.

LOOK FOR TRAINS Sign System

The second experimental sign system consists of a 0.9 m (36 in) yellow high intensity backed diamond warning sign with a black train locomotive symbol. The sign also contains a yellow supplementary message sign that reads LOOK FOR TRAINS. The LOOK FOR TRAINS sign is placed on the approach to the grade crossing between the railroad advance warning sign and the crossbuck, as shown in Figure 4.3. At most of the test sites, the sign was placed next to the beginning of the advanced pavement marking. At those sites where the pavement marking and railroad advance warning sign were at the same distance, the LOOK FOR TRAINS sign was placed 15 m (50 ft) from the pavement marking distance specified in the 1980 TMUTCD.

Site Selection

The experimental sign systems were installed at passive highway-railroad grade crossings in four Texas counties. The YIELD TO TRAINS sign system was installed at two grade crossings in Grimes County and three grade crossings in Coleman County. The LOOK FOR TRAINS sign system was installed at three grade crossings in San Patricio County. This latter sign system was also installed at some grade crossings in Nacogdoches County; however, vandalism of the signs prohibited the collection of data in that county. Several factors were considered when choosing the test site locations. While each highway-railroad grade crossing is different, those with the greatest number of desired characteristics were included in the study. These characteristics included:

- Train volume of at least two (2) trains per day;
- Train speeds of at least 48 km/h (30 mph);
- Vehicular volumes of between 300 and 2000 average daily vehicles;
- Vehicular speeds of at least 48 km/h (30 mph);
- Smooth grade crossing and paved approach surfaces; and
- Crossings void of peculiar geometric features or sight distance limitations.

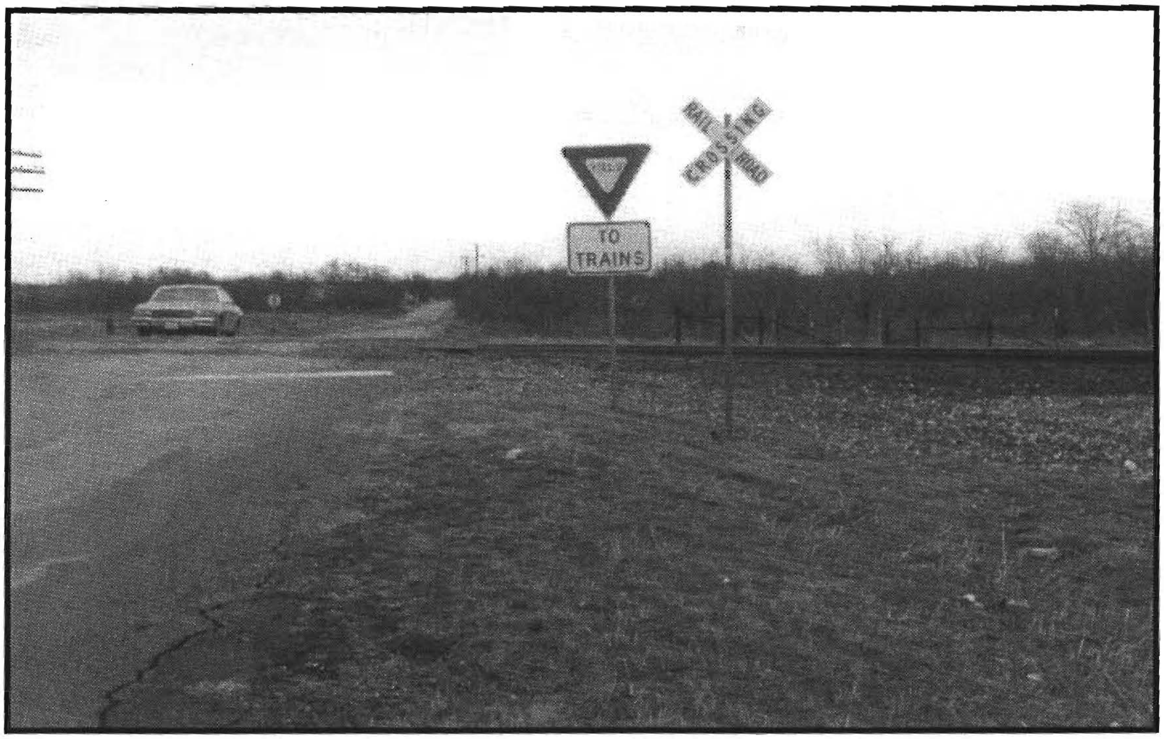


Figure 4.2. The YIELD TO TRAINS Sign System Installed at a Test Crossing

Figure 4.3. The LOOK FOR TRAINS Sign System Installed at a Test Crossing

4.6 STUDY RESULTS

Data Analysis

The results of this study are based on statistical analysis techniques used to determine whether any differences in the data were significant. A significance level of 0.05 was used in all the statistical tests. A Chi-square test of independence was performed to determine if the research hypothesis (that new signs improved the looking behavior of drivers) was accurate. This test was performed on the recorded totals of four types of head movement: no discernible movement, movement to the left only, movement to the right only, and movement in both directions.

A two sample t-test was performed on the speed data collected at each grade crossing to determine if there was a significant change in mean speed reduction. The reduction in speed for each observation was calculated by taking the difference between the speed at the crossbuck and the speed at the railroad advance warning sign. The null hypothesis is that there was no change in speed reduction on the approach. The research hypothesis was that mean speed reduction increased on the approach. Additional studies after the installation of the experimental sign system will help to show the impact of novelty effects of the new signs.

Field Tests

Data was collected in three counties for each experimental sign system being tested. YIELD TO TRAINS signs were installed at test sites in Coleman and Grimes Counties and LOOK FOR TRAINS signs were installed at test sites in San Patricio County. Data was collected once before the experimental signs were installed to serve as a control condition for the longitudinal study. Data was collected between two and four times after the experimental sign system was installed. The amount of data collected at each test site for the two measures of effectiveness are listed in Table 4.1. Detailed results of the studies are included in Appendix H.

Some problems with signs being removed by vandals were encountered throughout the study. Data at Hidden Acres Rd. and Baylor St. in San Patricio County were limited to one approach due to missing or damaged signs on the other approach. The Poststudy III data collected at Courtney Road in Grimes County contains only the northbound approach as the railroad advance warning sign for the southbound approach was missing at the time the data was collected. The County Road 304 and Parker Street crossings were also only studied in one direction due to geographic constraints at the crossing. The remaining grade crossings include data for both approaches during each study period. Attempts were also made to collect data at sites in Nacogdoches County equipped with the LOOK FOR TRAINS sign system. However, some of the experimental signs had been removed from these grade crossings thus resulting in questionable data that will not be discussed in this study.

Driver Looking Behavior

The driver head movements within 45 m (150 ft) of the grade crossing were also observed. Drivers' head movement is inferred to indicate the level of looking behavior of the driver. Head movements were placed in four categories: no discernible head movement, movement to the right only, movement to the left only, and movement in both directions. A Chi-square test of

Table 4.1. Summary of Data Collected at Test Sites

County (Sign System)	Crossing	Measure of Effectiveness	Prestudy (8/92)	Poststudies I (3/93)	Poststudies II (7/93)	Poststudies III (2/95)	Poststudies IV (6/96)
San Patricio (LOOK FOR TRAINS)	Hidden Acres Rd.	Looking	14	97	38	48	--
		Speed	80	114	42	51	--
	Baylor St.	Looking	65	81	94	75	--
		Speed	67	98	101	78	--
Nacogdoches (LOOK FOR TRAINS)	Fredonia St.	Looking	104	162	--	--	
		Speed	107	184	--	–	
Coleman (YIELD TO TRAINS)	Parker St.	Looking	49	41	24	25	--
		Speed	50	37	26	27	--
	FM 2131	Looking	120	62	107	85	--
		Speed	133	79	83	108	--
	Vale St.	Looking	36	111	108	--	--
		Speed	28	107	56	--.	–
Grimes (YIELD TO TRAINS)	C. R. 304	Looking	77	65	59	22	37
		Speed	78	70	70	33	45
	Courtney Rd.	Looking	97	98	97	26	--
		Speed	101	109	138	37	--

independence was performed on the data to determine if there had been a significant change in driver looking behavior. A significance level of 0.05 was used to test the null hypothesis that looking behavior did not change throughout the study. The alternative hypothesis was that looking behavior had changed as a result of the placement of the experimental signs at the crossings. An increase in driver looking behavior is inferred to increase safety at the highway-railroad grade crossing since increased looking behavior is taken to be a characteristic of safer drivers.

To account for the small sample sizes, the first three categories (no looking, left only, and right only) were combined to form one "No looking" category. The category of movement in both directions was not combined with any of the other categories. The results of the statistical analysis are presented in Table 4.2. As can be seen from Table 4.2, there was a significant increase in looking behavior at only one crossing, FM 2131. Figure 4.4 shows that the looking behavior on the northbound approach to FM 2131 significantly increased in the first Poststudy and continued to be higher that the Prestudy levels throughout the remainder of the studies. This grade crossing had the YIELD TO TRAINS sign system installed. Analysis of the Vale St. data was inconclusive due to small sample sizes. The Baylor St. grade crossing indicated a significant difference in looking behavior over time. However, as Figure 4.5 points out, looking behavior has actually been worsening over time. Thus, according to the analysis there has been a significant decrease in looking behavior at the Baylor St. crossing.

Table 4.2. Results of the Chi-Square Test for Independence of the Driver Looking Behavior Data

Sign System	Test Site	Train Volume (trains per day)	Quadrant Site Restrictions	Significant Increase in Looking Behavior
YIELD TO TRAINS	Co. Road 304	7	None	
	Courtney Rd. NB	8	None	
	Courtney Rd. SB	8	None	
	Parker St.	16	1 (Structure)	
	Vale St. NB	16	1 (Structure)	?
	Vale St. SB	16	1 (Vegetation)	?
	FM 2131 NB	2	None	✓
	FM 2131 SB	2	1 (Vegetation)	✓
LOOK FOR TRAINS	Baylor St.	2	1 (Structure)	★
	Hidden Acres Rd.	4	2 (Brush)	

✓ = Reject H_0 (significant increase in looking behavior)

? = Questionable analysis due to small sample size

★= Reject H_0 (significant <u>decrease</u> in looking behavior)

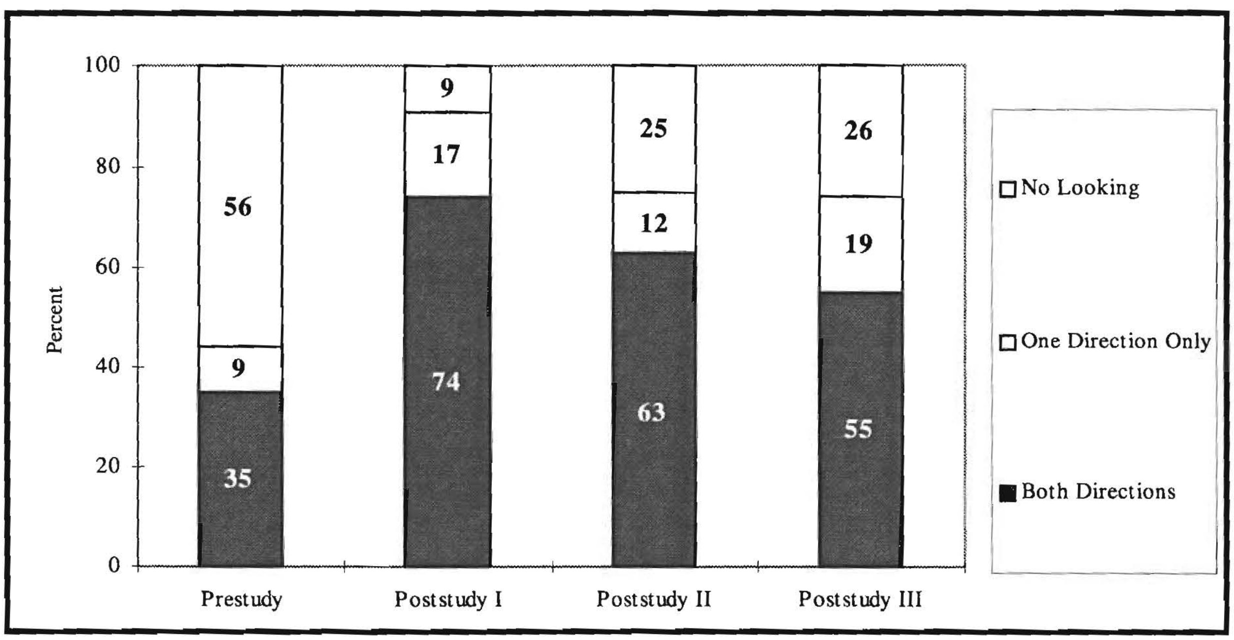


Figure 4.4. Driver Looking Behavior on the Northbound Approach to the F.M. 2131 Crossing

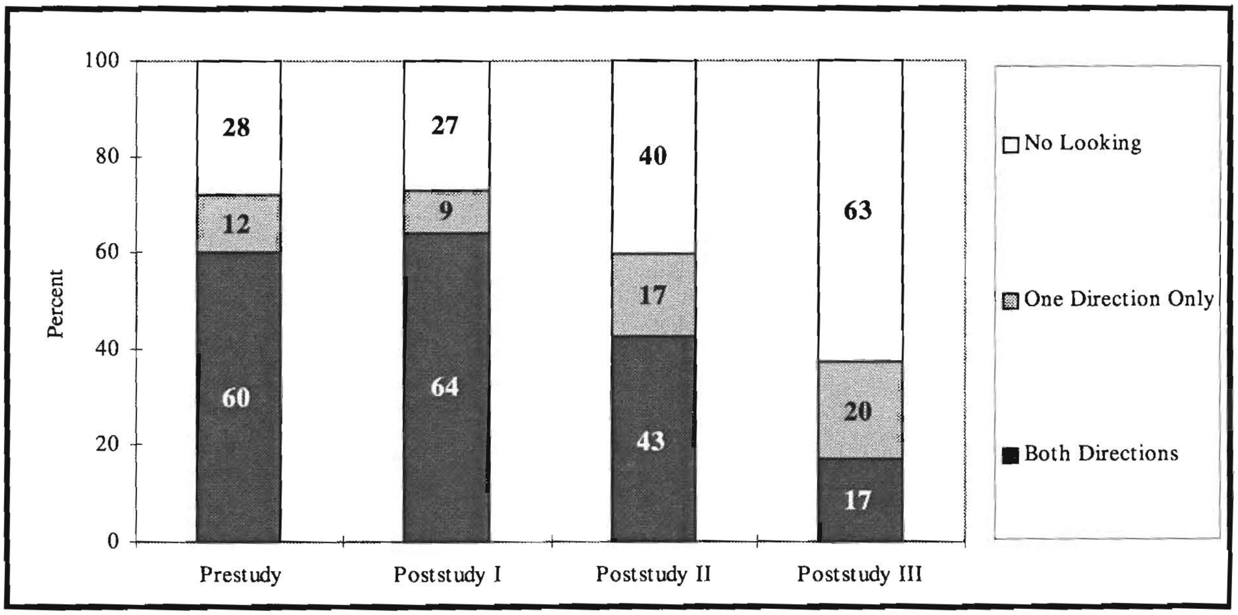


Figure 4.5. Driver Looking Behavior at the Baylor Street Crossing

Driver Approach Speed

Three spot-speed measurements were made for each vehicle as it approached the crossing. The first measurement was taken as the vehicle passed the railroad advance warning sign. The second speed measurement was made at the advanced pavement marking. The final speed observation was taken at the crossbuck. These measurements were taken before and after the installation of the experimental sign system to determine if the sign system being tested had any effect on speed reduction between the railroad advance warning sign and the crossbuck at the crossing. An increase in the speed reduction might be an indication that the new signs have a positive impact on driver behavior at the crossing. This positive impact indicates drivers are reducing speed more as they approach the crossing and might indicate an increase in safety at the crossing.

To collect the necessary speed data, a radar gun was used. Some of the radar guns used in the experiment would not indicate speeds less than 15 km/h (10 mph). In instances where vehicles slowed to less than 15 km/h (10 mph) but did not stop, a speed of 10 km/h (5 mph) was recorded. If it was observed that the vehicle came to a complete stop, a value of zero was recorded for the speed.

The mean speed reduction from the railroad advance warning sign to the crossbuck for each grade crossing and study period was calculated from the data. A higher mean speed reduction indicates that vehicles are slowing more as they near the crossing. A plot of the mean speed reductions can be seen in Figure 4.6 for the grade crossings with the YIELD TO TRAINS signs, and in Figure 4.7 for the grade crossings with the LOOK FOR TRAINS signs. The mean speeds at the crossbuck for these test crossings are shown in Figures 4.8 and 4.9, for the YIELD TO TRAINS signs and LOOK FOR TRAINS signs respectively.

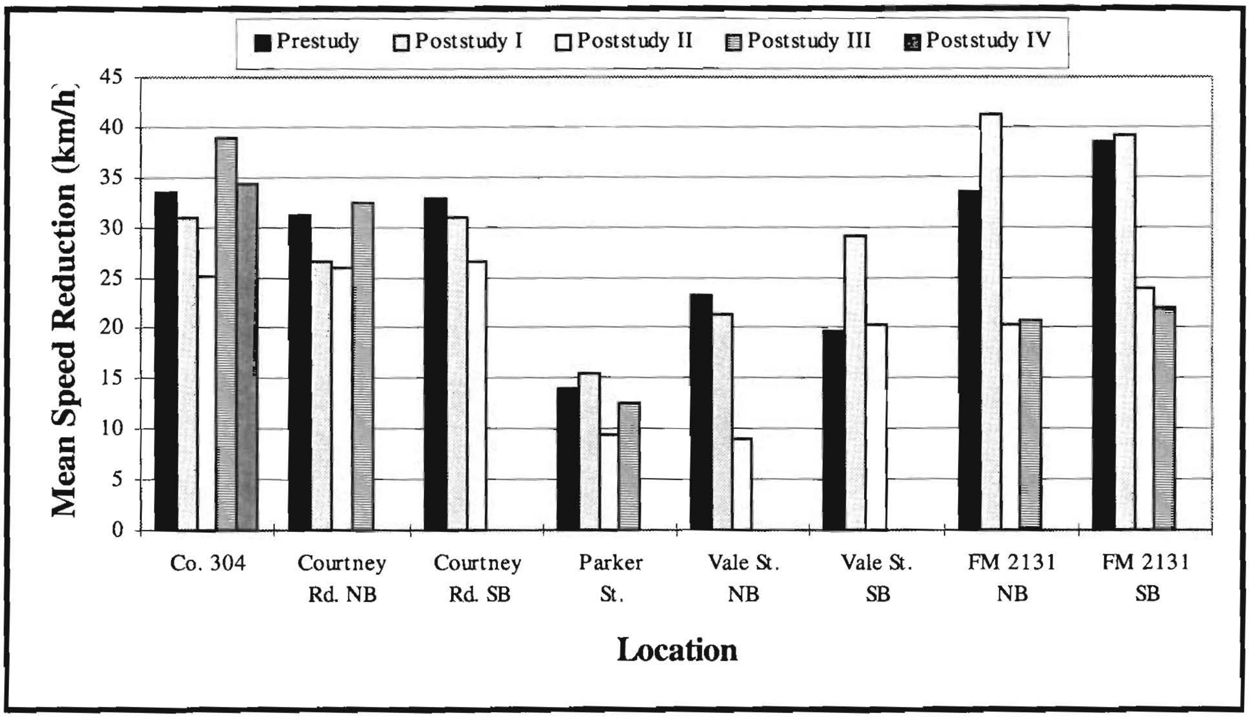


Figure 4.6. Mean Speed Reductions for YIELD TO TRAINS Experimental Sign System

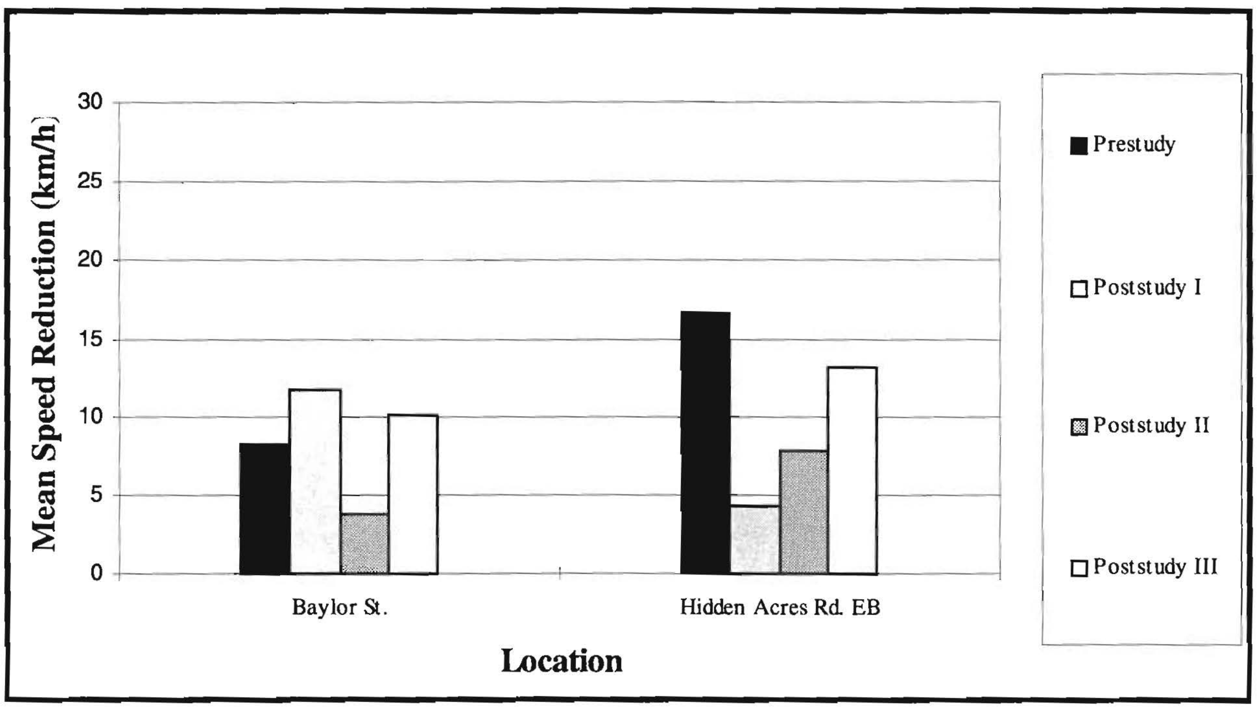


Figure 4.7. Mean Speed Reductions for LOOK FOR TRAINS Experimental Sign System

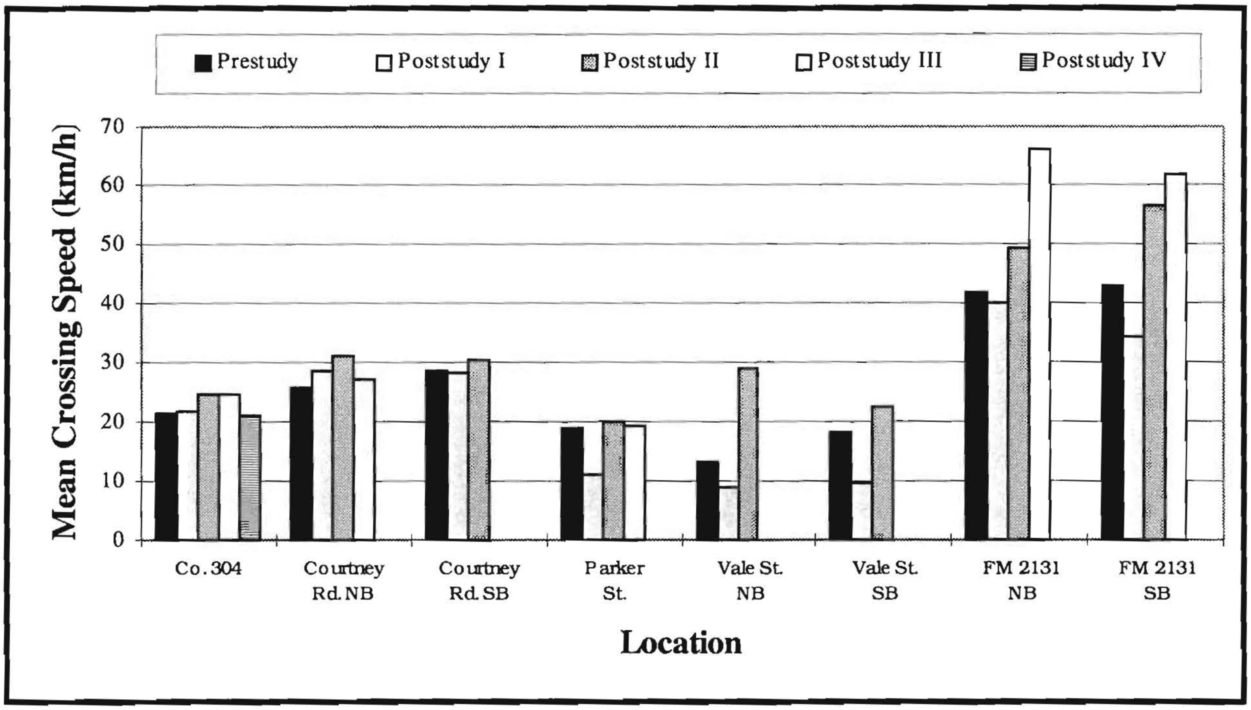


Figure 4.8. Mean Speeds at the Crossbuck for YIELD TO TRAINS Experimental Sign System

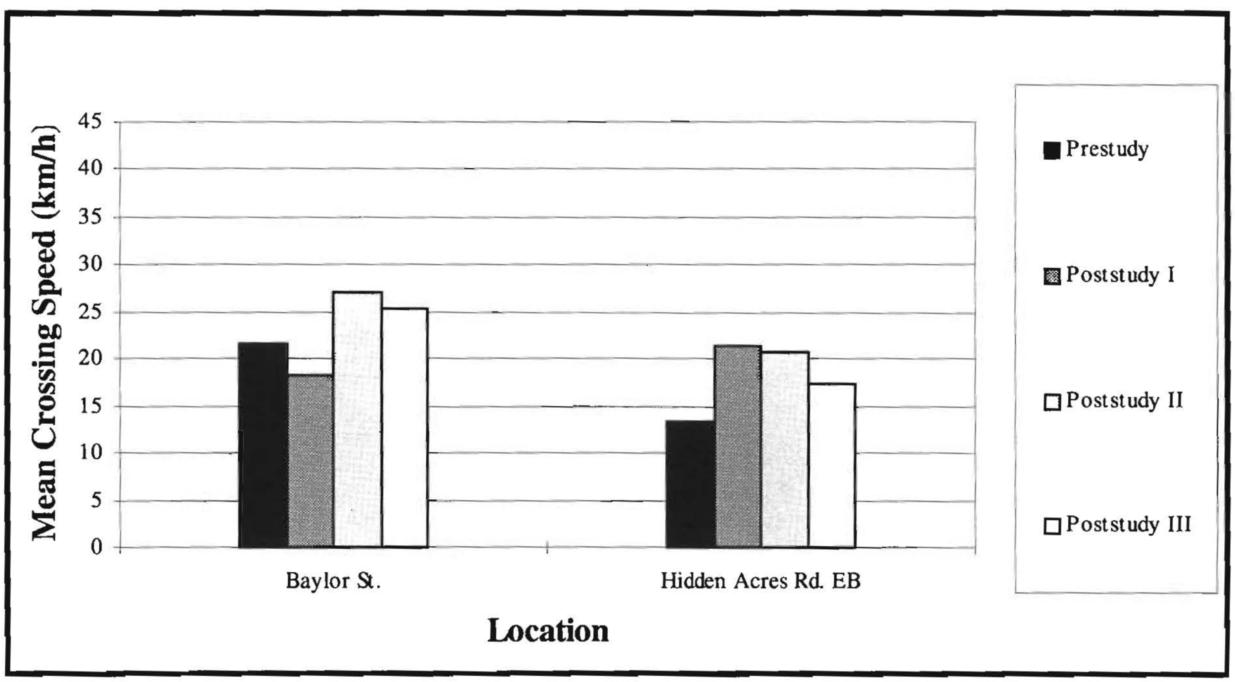


Figure 4.9. Mean Speeds at the Crossbuck for LOOK FOR TRAINS Experimental Sign System

As can be observed from these graphs, the mean speed reduction varied greatly over the evaluation period at each grade crossing. To determine if the differences noted by the graphs are significant, a two-sample t-test was performed on the data. This test compared the mean speed reduction of each Poststudy (after experimental signs were installed) to the Prestudy. The null hypothesis (H_0) was that there was no difference in mean speed reductions while the alternative hypothesis was that mean speed reductions were greater. A 0.05 significance level was used for each test. Table 4.3 summarizes the results.

Only three test locations experienced a significant decrease in speed reduction at some time during the test period. Most sites did not show any significant change in speed reduction in Poststudy I. However, most of the grade crossings experienced a significant decrease in speed reduction during Poststudy II. This may indicate that cars are not slowing as much as before the experimental signs were installed at the crossing. A significant decrease in mean speed reduction is an indication that the signs have very little impact or perhaps the opposite effect on driver behavior.

Very little data was available for the Vale St. highway-railroad grade crossing before the installation of the experimental signs. This could negatively affect the analysis since it is difficult to accurately prove statistical significance when a sample is small and has a large variance. The data for Hidden Acres Rd. may also be unreliable due to questionable Poststudy data. It appears from the data that the analyst collecting the Poststudy data at this site was incorrectly positioned to make the speed measurements.

An examination of the mean speeds at the crossing indicates that every grade crossing that had a significant decrease in speed reduction also experienced higher mean speeds at the crossing. While these results may seem to indicate that drivers are responding negatively to the new signs, it is important to remember that other aspects of the grade crossings can also affect the driver speed. For example, if the grade crossing has been resurfaced, drivers may have been able to cross over the tracks at a higher speed. Also, the change in vegetation or foliage on the side of the road at the grade crossing could change between studies affecting the sight distance of drivers which would explain some of the results of the analysis.

Table 4.3. Change in Speed Reduction

Test Site	Poststudy I	Poststudy II	Poststudy III	Poststudy IV
Co. Road 304	No Change	Decrease	INCREASE	No Change
Courtney Rd. NB	Decrease	Decrease	No Change	
Courtney Rd. SB	No Change	Decrease		
Parker St.	No Change	Decrease	No Change	
Vale St. NB	No Change	Decrease		
Vale St. SB	INCREASE	INCREASE		
FM 2131 NB	No Change	Decrease	Decrease	
FM 2131 SB	No Change	Decrease	Decrease	
Baylor St.	INCREASE	Decrease	No Change	
Hidden Acres Rd.	Decrease	Decrease	Decrease	

Driver Survey

Drivers were stopped downstream of the grade crossing during the Prestudy and first Poststudy and asked some questions related to their understanding of the experimental sign system, their recollection of the warning signs, and whether they felt the sign system was effective. The results of the survey found that drivers remembered more of the warning signs after the installation of the experimental sign system than before its installation. The drivers' response to the questions regarding their understanding of the current sign system indicated that drivers would benefit from the addition of a warning sign that provided them with more information. Finally, the questions regarding the effectiveness of the experimental sign system revealed that drivers felt both of the sign systems would effectively increase safety at the crossing. There was no preference for one sign system over the other.

4.7 SUMMARY

The research documented in this section analyzed two experimental sign systems to be installed at passively controlled highway-railroad grade crossings. Though a reduction in crashes could not be measured directly, two surrogate measures of effectiveness were observed to determine the effectiveness of both sign systems. The following conclusions can be drawn from the results presented in the previous section:

- The implementation of either sign system may initially increase speed reductions and decrease speeds on the approaches to some grade crossings; however, the data suggests that over time drivers will return to their previous behavior after the signs have been installed.
- Driver looking behavior may be significantly increased after the implementation of the YIELD TO TRAINS sign system. There is no evidence to suggest that this sign system would cause a significant decrease in looking behavior.
- The data suggests that drivers may have understood the YIELD TO TRAINS sign system better than the LOOK FOR TRAINS sign system. Drivers with the former sign system showed greater speed reductions and some significant increases in looking behavior. The latter sign system did have as great an impact on approach speeds and produced no significant improvement in looking behavior.

5.0 ENHANCED TRAFFIC CONTROL DEVICES

5.1 INTRODUCTION

When approaching a highway-railroad grade crossing, drivers must be aware of the crossing's presence. Awareness can be enhanced by providing railroad advance warning signs or markings, and with visual observation of the grade crossing or a train. The critical point for drivers occurs when approaching a grade crossing and deciding whether to stop if a train is approaching, or continue across the tracks. At this point, a driver needs to be able to see the approaching train at passive crossings or the active controls at an active crossing. The previous statement also assumes that the driver has reduced the approach speed so if a train is observed, the driver has enough time to bring the vehicle to a safe stop (*23*). Consequently, it is important that drivers be made aware of the highway-railroad grade crossing through conspicuous railroad advance warning signs as they approach the crossing.

The visibility of signs in the traffic environment and the resulting communication with the driver is dependent upon detection, identification, and legibility. Each of these factors has special importance as the sign is approached, each requiring an adequate degree of visibility to insure effectiveness (*42*). Detection of the sign is very important if the other two requirements (identification and legibility) are to be met. All too often, drivers become complacent in the driving task and do not notice the traffic control devices, including railroad advance warning signs, that are important parts of a safe and efficient transportation network.

Advance warning signs at passive railroad crossings need to be enhanced so that the sign is more conspicuous to a passing driver. A traffic engineer with the Texas Department of Transportation (TxDOT) in the Lufkin District proposed the use of a supplemental strobe light on the railroad advance warning sign at highway-railroad grade crossings. To make the sign more conspicuous than it is currently, the strobe light flashes only in the presence of a motor vehicle. The use of strobe lights as traffic control devices in the state of Texas are limited. Therefore, measures must be taken to insure that the flashing strobe light will not cause adverse driver reaction prior to field implementation of the experimental sign system.

Objective

The objective of this component of the research was to find out if adding a strobe light to a railroad advance warning sign preceding a passive crossing would cause adverse driver reactions, such as hard braking or erratic steering maneuvers. Approaching vehicles detected by a motion sensor activated a strobe light that flashed until the vehicle was at a point where the railroad advance warning sign was visible and in the driver's cone of vision. The enhanced sign system was evaluated in a closed driving course at the Texas A&M University Riverside Campus. Each driver drove through the course in the same vehicle with an in-vehicle observer that recorded sudden head movement, steering reactions, and/or braking reactions to the sign system. A focus group discussion was also conducted to determine drivers' opinions of the experimental signing system and whether the enhanced sign system was more conspicuous than the standard sign system, or a railroad advance warning sign supplemented with a standard flashing beacon. Both qualitative and quantitative measures were taken regarding driver reaction to the enhanced signing system. The study design includes a description of the standard highway-railroad grade crossing sign system and the two supplemental devices included in the study, the study elements, the field study and procedures, and the data analysis procedures.

5.2 BACKGROUND

While available information concerning the use of strobe lights at passive crossings is limited, studies have been done to evaluate the use of strobe lights at actively controlled highway-railroad grade crossings. In most of these studies, strobe lights were used supplementary to the standard signing system at the grade crossings.

Two basic considerations are involved in the effectiveness of train-activated warning devices: credibility and conspicuity. A study performed by Ruden et al. focused on increasing the attention getting property of active crossing warning systems using a supplementary approach as opposed to an approach of substituting new warning devices for the standard, in-place system (*43*). The add-on approach was chosen to avoid restraints on what colors could be used (amber and red), based on the driver's perception of the use of certain colors, as well as constraints on the uses of certain colors defined in the MUTCD. Additionally, the research team did not want to alter the basic integrity of the active warning device because many state laws and regulations refer to certain physical features of the warning devices. A final consideration was that the improved, add-on device should not destroy the basic integrity of the existing system by focusing so much of the drivers' attention to the add-on device that they fail to see and comprehend the meaning of the remainder of the system with which they are familiar (*43*).

Typically, white lights are used for illumination while colored lights are used to attract a driver's attention both on and off the roadway. If the driver's attention is diverted from other colored lights, flashing or steady, then the size or brightness of the colored array can be increased to gain additional conspicuity; therefore, where safety is a major concern, a non-filtered flashing white light source may be ideal in gaining drivers' attention. A white light can easily overcome attention diverting properties of colored lights at a lower rate of power consumption by the intensity of the flashing white warning lights. In areas where other non-flashing white lights are present and compete for the drivers' attention, a flashing light can better attract a driver's attention (*43*).

After laboratory and field tests, Ruden et al. concluded that increased conspicuity can be gained by increasing the flash rate to two or more flashes per second; however, the strobes added to an existing active warning device will consume additional electrical power. After the installation of the strobes, earlier deceleration on the approach to the crossing was observed during daytime. The use of white xenon strobe lights as supplements to the standard red railroad flashers add significantly to the conspicuity of this array. Furthermore, two strobes were found to be better than one, and three strobes were even better than two. Finally, it was concluded that the add-on white strobes as tested in the laboratory and in the field showed the most promise for improving attention getting properties of grade crossing warning systems. This research shows that a color difference (white), flash rate increase (strobe), and the use of multiple (three) signal faces are correlated with increased conspicuity in a competing signal environment (*43*).

Hopkins and Holstorm concluded that their analysis, laboratory measurements, and field tests strongly suggest that the use of xenon flash lamps (a type of strobe) at highway-railroad grade crossings can significantly increase the effectiveness of warning the driver of an approaching train. The primary benefit accrues through the increased alerting effectiveness and conversion efficiency associated with short-duration flashes which makes it possible to use a broad beam pattern. Installation of such lights as supplements to the standard system is technically simple, economical, and should not have serious liability implications (*44*).

The Illinois Department of Transportation (IDOT) studied the effectiveness of strobe lights as supplemental warning devices at actively controlled grade crossings. The strobe lights were mounted inside signal housings near the conventional flashing lights on signal standards or mast arms depending on the location. The light was tested behind clear lenses and flame orange lenses. The flame orange lenses, when illuminated, produced a color very close to the traditional red lenses. The units were adjusted to produce a flash rate of 60 flashes per minute resulting in a flash rate of 120 flashes per minute for the alternate heads in each installation. This rate is well below the flash rate of 600 to 1,200 flashes per minute identified by the Epilepsy Foundation of America as the crucial trigger point for reflex or photosensitive epileptics. The strobe lights were controlled by a photoelectric cell that reduced the light intensity from an energy output of 15 joules during daylight to four joules after dark (*45*).

The study results, with respect to the use of strobe lights as supplemental warning devices at actively controlled grade crossings, concluded that:

- At locations with strobe lights, approximately two thirds of the drivers using the grade crossing recalled a difference in the lights;
- Drivers did not find the strobe lights distracting or annoying;
- A substantial number of drivers that noticed the strobe lights reported that they exercised greater caution at or near the grade crossing after seeing the strobe lights;
- Strobe lights with clear or flame orange lenses can be seen further from the grade crossing than conventional flashing lights;
- The visibility of properly installed and operated strobe lights equals or exceeds the visibility of the conventional flashing lights; and
- Strobe lights have a higher relative visibility from an angle than do the traditional flashing lights (*45*).

Other modifications to active warning systems besides the use of strobe lights were investigated by Heathington, Fambro, and Rochelle in 1984 (*46*). Two versions of each of three experimental warning devices were evaluated in an outdoor laboratory: a four-quadrant gate system with and without skirts, a four-quadrant flashing light signal system with and without overhead red strobe lights, and a highway signal system with one and with three white bar strobes. The supplementary strobe lights were not mounted near the standard flashers as was done in the previously mentioned research but were centered over each lane of traffic.

Perception brake reaction time (PBRT) and maximum deceleration rate were recorded as each of the test drivers approached three crossings at which the various warning systems were installed. The prediction was that more conspicuous warning devices would be associated with faster PBRTs and a larger number of comfortable deceleration rates. Driver behavior was observed in both day and night time conditions. Actuation distance, the distance between the motor vehicle and the warning device when the device was activated, was also manipulated. The control situation used for this research was driver behavior that occurred when the vehicle was at the crossing when the warning device was activated. Driver response was observed at actuation distances of 100, 130, and 200 m (30, 40, and 61 ft).

When PBRTs were analyzed, the trends of the data differed depending on the actuation distance; however, the four-quadrant gates with skirts consistently had the fastest PBRTs. Likewise, the two versions of the highway traffic signals were always among the slowest conditions. In the control condition and at an actuation distance of 200 m (650 ft), the four-quadrant gates and the four-quadrant flashing lights did not produce significantly different PBRTs, although both versions of each of these two warning devices produced faster PBRTs than the highway traffic signals. At the actuation distance of 130 m (450 ft), four-quadrant gates were associated with much faster PBRTs than the four-quadrant flashing lights or the highway traffic signals; however, at this distance, the four-quadrant flashing lights and the highway signals did not result in significantly different PBRTs. In summary, at the short and medium actuation distances, four-quadrant gates with skirts produced faster PBRTs than the other systems, but in the control condition and at long distances, this system has no apparent advantage over the four-quadrant flashing lights in being detected earlier, thereby creating faster PBRTs. Both the PBRTs and the deceleration rate varied between day and night viewing conditions at the medium and long actuation distances. The complex interactions between these data indicate the many parameters that must be taken into account when evaluating the effectiveness of active warning devices (*46*).

In a follow-up study, Heathington, Fambro, and Richards performed a field evaluation of three of the warning devices mentioned above; four-quadrant gates with skirts, four-quadrant flashing lights with overhead strobes, and highway traffic signals with white strobes in front of each of the red lenses (*23*). When flashing light signals were used in the experimental device, the standard flashers with 20 cm (8 in) roundels were changed to 30 cm (12 in) roundels. In this research, unlike previous studies, each system was compared with the existing two-quadrant standard active warning system at the same grade crossing in a before-and-after methodology. This study was searching for indications that the system prototypes would result in earlier detection; therefore, Heathington evaluated PBRT, speed profiles, and maximum deceleration rate. Two of the grade crossings had limited visibility of the crossing and the two-quadrant system; therefore, the features of the experimental systems such as the four-quadrant positioning, the larger flashers and overhead strobes, or the cantilevered highway traffic signals, were expected to increase the conspicuity of the crossing. Any increase in the detectability of the grade crossing was not reflected in decreases of PBRTs, decreases in average approach speed or more gradual deceleration rate. No significant difference was noted between the before and the after evaluation of any of the three parameters at any of the grade crossings (*23*).

5.3 STANDARD AND ENHANCED SIGN SYSTEMS

1. The current standard signing system required by the *Texas Manual on Uniform Traffic Control Devices* (*40*) at passively controlled highway-railroad grade crossings consists of two signs and pavement marking. The crossbuck at the grade crossing is double-sided. The other sign used as part of this signing system is the railroad advance warning sign seen in Figure 5.1a and located 230 m (755 ft) ahead of the grade crossing in rural

areas. In urban areas, the railroad advance warning sign is placed at a position determined by approach speed and available sight distance. The MUTCD specifies the placement of the railroad advance warning signs in both urban and rural areas based on approach speed (*10*). In cases where the railroad advance warning sign is placed closer than the specified 230 m (755 ft) ahead of the grade crossing, intersecting roadways and the geometry associated with the approach have most likely influenced its placement.

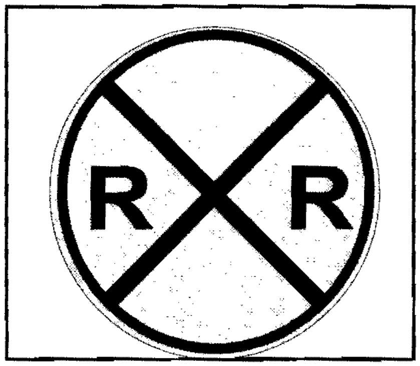
The placement of the pavement marking used in the current sign system, according to the 1980 MUTCD, should be placed at a distance from the grade crossing dependent upon the approach speed; however, the 1988 MUTCD requires that the pavement marking be placed the same distance from the grade crossing as the railroad advance warning sign. This position depends on approach speed and available sight distance as previously mentioned. The pavement marking is to be present at all paved approaches to actively controlled grade crossings and at all other crossings where the approach speed is 65 km/h (40 mph) or greater.

Supplementary Flashing Beacon

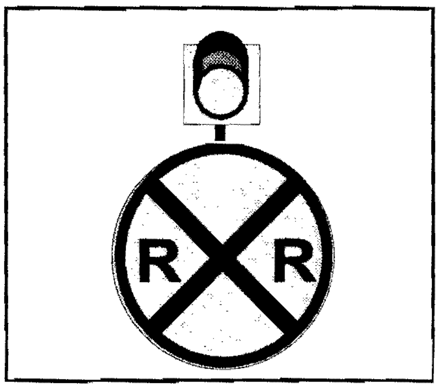
According to the MUTCD, a hazard identification beacon is one or more sections of a standard signal head with a flashing CIRCULAR YELLOW indication in each section. One typical application of flashing beacons cited in the MUTCD is the use of the flashing beacon supplemental to railroad advance warning signs. The MUTCD also requires that the flashing beacon be used only as a supplement to appropriate signs and will not be located within the border of the sign. The flashing beacon used for this study was yellow and had a diameter measuring 300 mm (12 in). As required by the MUTCD, the flashing beacon was clearly visible to all drivers under normal weather conditions for at least an approach distance of 400 m (1,312 ft). The beacon was mounted on the same post as the railroad advance warning sign above the sign as shown in Figure 5.1b. The light was powered by a generator.

Supplementary Strobe Light

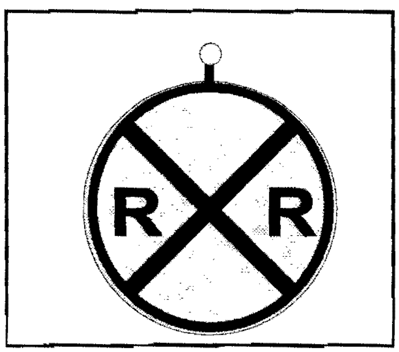
The supplementary strobe light evaluated in this research was 65 mm (2 ½ in) in diameter and can be seen in Figure 5.1c. It flashed at a rate of 1.4 flashes per second, well under the flash rate reported to trigger epileptic seizures in photosensitive epileptics. The 65 mm (2 ½ in) size light was chosen because of the intensity of the light emitted by a strobe. Originally, the strobe light was mounted on the sign post with the railroad advance warning sign but below the sign. The strobe flashed four to six times and paused while the driver had an opportunity to look at the railroad advanced warning sign and recognize it before driving past it. The preliminary design of this signing system changed due to expert opinion as will be discussed in a later section of this section.



a). Standard Railroad Advance Warning (W10-1) Sign



b). Railroad Advance Warning Sign with Flashing Beacon



c). Railroad Advance Warning Sign with Strobe Light

Figure 5.1. Advance Warning Signs for Highway-Railroad Grade Crossings

The mechanism used for vehicle detection in this study was a motion sensor that emitted an infrared beam that struck a reflector placed across the road from the sensor. The reflector then echoed the beam back to the motion sensor. The strobe light did not flash if the beam remained unbroken. Once the beam was broken by an object passing through it such as a vehicle, the strobe light began to flash. Based on the assumed approach speed of 60 km/h (35 mph), a distance of 60 m (200 ft) from the warning sign was chosen as the appropriate location of the motion sensor. This distance was chosen because it allowed the driver to see five or six flashes of the strobe light before passing the railroad advance warning sign without startling the driver to the point of adverse reaction. Drivers were aware that the light was not continuously flashing, but triggered by their presence. Additionally, this activation distance was chosen such that the driver would not see the strobe light flashing from a long distance ahead of the railroad advance warning sign. Just as the sign design changed, so did the location and theory of the placement of the motion sensor as will also be discussed later in this section.

Study Performance Measures

This study was conducted to determine if the supplemental strobe light used with the railroad advance warning sign at a highway-railroad grade crossing would result in any adverse driver reactions. Therefore, the measures of performance that were evaluated included driver head movement, braking reaction, and steering reaction. An in-vehicle observer accompanied drivers in their vehicles as they drove through the course and were exposed to three railroad advance warning signs, each with a different supplemental device. The in-vehicle observer simply recorded whether each driver reacted to the sign and if so, whether the reaction was severe and potentially dangerous. The observer also recorded if the driver made any type of comment or acted startled by the traffic control device. Before each driver began the driving course, the in-vehicle observer recited the same directions to each driver to insure that each driver was aware of the conditions under which they would be driving. However, the observer did not tell the drivers what to expect as to the types of signs that they would see.

To determine if driver comprehension of the experimental sign system was consistent with its intended meaning, study drivers were asked to participate in a group discussion of the experimental devices. Their responses, as well as and the rationale behind their thoughts and opinions, were recorded. Because strobe lights are not widely used in Texas as supplements to traffic control devices, drivers were also asked their opinions on the strobe light and whether they preferred the sign with the strobe light enhancement, the standard continuous flashing beacon enhancement, or the railroad advance warning sign with no enhancement. A more detailed account of the focus group discussion format is in the following section.

5.4 STUDY DESIGN

The study design for this research consisted of three parts: a driver study, a completed questionnaire, and a focus group discussion. The data collection was conducted over a period of five nights with one focus group being conducted each night. Data collection was done at night because researchers believed that most severe driver reactions would occur at times when the road had very little natural and ambient lighting. Therefore, the contrast between the driving environment and the intensity of the strobe would be at its greatest. Focus groups ranged from four to six drivers and were selected to closely reflect the average driver in Texas. Each night, a different group of drivers was represented with the first night being primarily used as a pilot study. The drivers in the first focus group had vast experience in transportation-related issues including expertise in traffic control devices, geometric design, human factor issues, and railroad research. Their comments and suggestions regarding their concerns about the way in which the signs were displayed to the driver were taken into account and integrated into the study procedure for the remainder of the focus groups.

The second group was also made up of drivers with transportation backgrounds, but with less experience than the previous group. The second group of transportation professionals served as a group of drivers educated about transportation and traffic control related areas. Researchers thought that including this group of drivers was important due to the controversial nature of the strobe light. The third focus group consisted of drivers under the age of 25. Group four included Hispanic drivers over the age of 18. The fifth and final focus group consisted of drivers over the age of 55. Efforts were made to insure equal representation of both males and females, and drivers that feel uncomfortable driving at night, and those that experience little trouble driving after dark.

Each night, as the drivers arrived, they were given a vague description of the research that was being conducted so as not to influence what they were expecting to see. For liability and other related concerns, each driver was asked to sign a consent form agreeing to participate in the study. Attached to the consent form was a written summary of what they should expect during the evening. Upon signing the consent form, each driver filled out a Participant Information Form (Appendix I) that gave the researchers information regarding race, age, years of driving experience, etc. Also on this sheet, each driver was assigned an identification number that allowed the researchers to track individual drivers throughout the study, while maintaining a certain degree of anonymity.

Driver Study

Upon completion of the consent form and Participant Information Form, the driver drove through a closed driving course with an in-vehicle observer. A map of the driving course is shown in Figure 5.2. The course had only two entry points to allow for two different orders of presentation of the signs. Besides the three railroad advance warning signs (one standard sign, one supplemented with a flashing beacon, and one supplemented with the strobe light), there were also distractor signs along the driving course. Each of these cardboard distractor signs had strips of reflective tape in the shape of numbers. The in-vehicle observer instructed each of the test drivers to watch for these distractor signs and read each number aloud. The purpose of this exercise was to keep the drivers busy by requiring their attention on more than just looking for the next sign being tested and dividing the drivers' attention as often happens under normal driving conditions.

The in-vehicle observer gave each driver the same instructions before entering the driving course. The primary purpose of the observer was to observe driver reactions to each sign and record on a data sheet what type reactions were made and if they were severe or potentially dangerous. These data sheets were each marked with the identification numbers the drivers were assigned on their respective Participant Information Form. The observer was recording data with respect to head movement, braking reactions, and steering maneuvers.

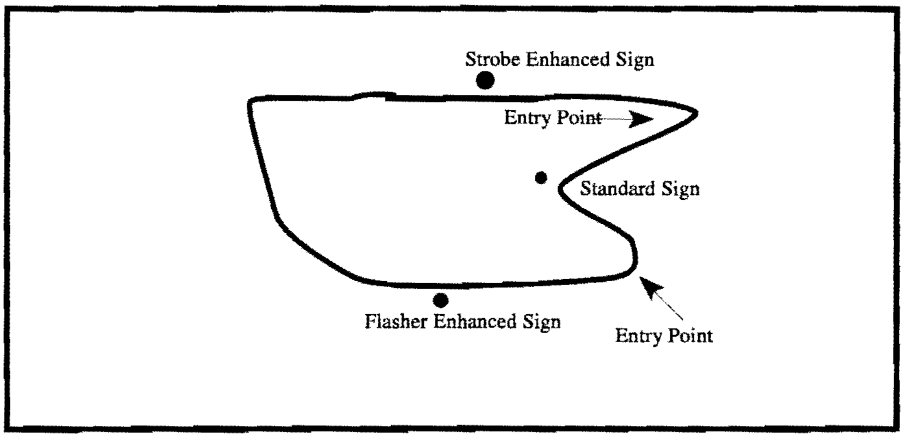


Figure 5.2. Map of the Closed Driving Course

Additionally, the observer recorded whether the drivers appeared startled by any of the signs presented to them. While on the driving course, the in-vehicle observer did not discuss what the drivers saw but reserved all discussion for such time as all of the drivers had completed the driver study and answered the questions on their questionnaire.

As previously mentioned, each driver completed a questionnaire immediately after they returned from the driving course. The intention of the questionnaire was to help drivers remember what they thought or felt as they observed each sign. Additionally, the questionnaires were marked with drivers' identification numbers so that their responses could be compared with their reactions on the driving course. Completion of the questionnaire was also done so that the drivers all had a chance to record their opinions without them being tainted or swayed by what other members of the group thought of the three different railroad advance warning signs. The questionnaires were used by the researchers to answer some questions omitted from the discussion and served as a written record of the drivers' opinions.

After each driver completed the driving task, they were asked not to discuss what they had seen or their opinions about each of the signing systems until all of the drivers had completed the course and their questionnaires. After all drivers had completed the driving course and their questionnaire, a discussion was facilitated by the focus group leader. The facilitator discussed several topics with the group each night, including whether the strobe light startled anyone, what each driver thought each sign meant, and which sign each driver preferred. Because the dynamics of each of the focus groups varied, the discussions did too. However, each group covered the topics that the researchers determined were pertinent to this research as mentioned earlier.

Pilot Study

As previously discussed, the first focus group consisted of transportation professionals with expertise in traffic control devices, grade crossing safety, human factor issues, and geometric design. This group of drivers drove through the driving course and made comments regarding not only their opinions of the different treatments of the sign, but the manner in which each sign was presented to them. The expert panel assembled in this group determined that to create a safer and more efficient driving course and more positive enhancements to the railroad advance warning sign, the following steps be taken. All these measures were incorporated into the driving portion of the study before the drivers of the second focus group began driving the course the following night.

The first concern was with respect to the placement of the strobe light under the sign. It was recommended that the strobe light be placed above the sign as the standard flasher was mounted. The pilot study drivers agreed that a bright light at that height (approximately equal to driver eye height) was not expected by drivers and may startle them. Because the common practice is to place supplemental lighting devices above signs, it was thought that drivers may totally miss the railroad advance warning sign and only see the strobe light if the light remained below the sign.

Secondly, due to limitations in the equipment used to operate the strobe system, the strobe light was not activated until the drivers were approximately 30 m (100 ft) to 45 m (150 ft) away from the sign. This activation distance required that the driver look out of the right side of the windshield as opposed to straight ahead when approaching the railroad advance warning sign. Traffic control devices are commonly placed within the drivers' cone of vision to allow them to continue to keep their attention focused on the roadway ahead and not have to turn their heads to see the signs along the roadway. By allowing the drivers to see the sign within their cone of vision without have to turn their heads, more attention can be placed on the driving task, the meaning of the sign just seen, and the proper response to such a sign. Therefore, the panel recommended that the activation distance of the strobe be further away from the sign than was originally used.

A third recommendation of the pilot study dealt with the brightness of the standard flashing beacon as it appeared in this driving study. The flashing beacon mounted above the railroad advance warning sign was 30 cm (12 in) in diameter and was the same type flasher that commonly accompanies the School Zone Speed Limit sign. The bulb originally used in the flasher and seen by the drivers in the pilot study was 165 watts and much too bright; therefore, the bulb was changed to a 69-watt bulb. Similarly, the drivers complained of a glare on the sign that did not allow them to see the face of the sign. Some drivers in the focus group acknowledged that if they had not known what sign it was, they would have been unable to discern it. It was suggested that the flasher be mounted further above the sign face to help reduce the glare on the sign; therefore, the flasher was moved to a distance of 15 cm (6 in) above the sign.

5.5 ANALYSIS PROCEDURE

Data analysis addressed both quantitative and qualitative issues. The information analyzed included driver head movement, braking reactions, steering reactions, and driver rankings assigned to each of the three signing systems that the drivers observed.

The in-vehicle observer recorded whether each driver turned their head to look at the signs, removed their foot from the accelerator and applied the brakes, and/or performed some type of steering reaction upon seeing the signs along the driving course. The percentage of drivers responding in such manners was determined. The research hypothesis tested was that using the supplemental device with the railroad advance warning sign would not affect the driver's response to the sign. The Chi-square test was performed to test the null hypothesis that the sign system seen would affect driver behavior. A significance level of 0.05 was used.

Within the questionnaire, drivers were asked to rank each of the sign systems with respect to their ability to attract a driver's attention safely and redirect their attention to the driving task. The sign with the highest attention attracting quality received a ranking of "1." The rankings for the three sign systems were evaluated based on the average rank for each system. The sign system with the lowest rank was considered the most effective in drawing driver attention to itself.

The Friedman test was used to detect significant differences in the sign system preferences. The research hypothesis showed significant differences in preference for at least two of the sign systems, while the null hypothesis showed an equal preference for the three sign systems. Again, a significance level of 0.05 was used.

The focus group format with both the questionnaire and the group discussion, yielded many diverse driver thoughts and opinions. These sets of data were categorized by topic and further evaluated to determine the best form of presentation of the material. Topics ranged from likes and dislikes of each of the sign systems to which sign system would best redirect a driver's attention to the task of driving.

5.6 STUDY RESULTS

Study results involving human drivers are dependent upon how well the study drivers reflect the population as a whole. Because of this, researchers desired that drivers used in this study reflect the characteristics of the general Texas driver. The age and gender distributions of the study drivers are shown in Table 5.1 along with the age distribution of Texas drivers. Note that the distribution of drivers' ages closely represents the distribution of the Texas drivers in each age group. It should be noted that each focus group had a particular sector of the population that was trying to be represented. In other words, the first focus group represented drivers under 25 years of age, the second one represented drivers over 55, etc.

While the participation in the study closely represents the driver population of Texas in terms of age distribution, the drivers did not match the state's ethnic backgrounds. Approximately 85 percent of the drivers were white and 15 percent were Hispanic. No African-American drivers participated in the study; therefore, this ethnic group was not adequately represented.

Table 5.1. Age and Gender Distribution of Study Participants

Age	Texas Driver Population[1]	Study Participants		
		Male	Female	Total
< 25	21.7%	4	3	7 (26.95%)
25 - 54	53.8%	9	3	12 (46.1%)
55 +	24.5%	4	3	7 (27.0%)

[1] Texas State Data Center, Department of Rural Sociology, Texas A&M University

Considering the educational level of the study drivers is also important. In this study, many highly educated drivers participated. Considering that the first two groups were employed as transportation professionals, this is not surprising. Of the drivers, the lowest level of education included high school or equivalent, and this included only 12 percent of the drivers. As previously mentioned, many drivers (42 percent) had a graduate degree, while 15 percent had graduated from college, and 31 percent had completed some college. Therefore, the various educational levels of the Texas driver population were not represented adequately.

The drivers in this study appear to approximate the Texas driver population with respect to age; however, the sample did not adequately represent the population in terms of gender, ethnicity or education. Complete demographic data can be found in Appendix I.

Driver Behavior

The primary objective of this research was to learn if enhancing the railroad advance warning sign at a highway-railroad grade crossing with a vehicle-activated strobe light would cause any adverse driver reaction; therefore, an in-vehicle observer rode with the drivers as they each drove through the course to observe their reactions to the three signs. The fact that no drivers exhibited severe reactions to any of the signs is important. Additionally, only one driver made erratic steering maneuvers; however, this driver steered erratically throughout the driving course. His steering maneuvers were not considered a reaction to any of the displayed signs. Because no other drivers reacted to the signs by steering away from the signs or toward the sign, steering reactions were eliminated as a means to discern a difference in the three signing systems.

Driver Head Movement

As previously mentioned, no driver exhibited any severe or potentially harmful reactions to the three sign systems; therefore, the observed head movements are indicative of drivers looking at the signs and used primarily as a method for measuring the attention-gaining property or conspicuity of the three signs. The results of the survey showed that 10 (38.5 percent) drivers exhibited head movements at the strobe sign, while 11 (42.3 percent) and 8 (30.8 percent) drivers exhibited head movements at the flasher and standard signs, respectively. This suggested that the driver head movements were not dependent on the sign system.

Braking Reactions

Like head movements, no drivers exhibited any severe braking reactions such as slamming on the brakes or rapid deceleration. However, many drivers did apply their brakes when approaching the three signs. The results of the survey showed that 14 (53.8 percent) drivers exhibited braking reactions at the strobe sign, while 14 (53.8 percent) and 5 (19.2 percent) drivers exhibited braking reactions at the flasher and standard signs respectively. The braking reaction approaching the various signing systems on the course was assumed to be a measure chosen by the driver trying to be more careful during that portion of the driving task than during parts of the driving course where no signs were present.

Because the strobe light sign and the standard flasher signs were altered after the first group had seen the systems, a second Chi-square analysis was performed on the remaining data to determine if the sign system affected driver braking reaction for the remainder of the study drivers. The indications were that the sign system observed by the drivers affected driver braking reactions.

Questionnaire Results

The questionnaire was used as a tool by the focus group leaders to obtain the drivers' first reactions to the sign before any discussion regarding the three signs they had seen along the driving course. Additionally, it allowed all drivers to express their opinions without the fear of being ridiculed by others.

The first question dealt with retention and recollection. This study was not designed to test for driver recollection; this question was asked simply to make drivers think about and recall what they had seen moments earlier while they were driving and what their initial thoughts were. Most of the drivers did, however, recall all three signs previously observed, in addition to the construction barrels and numbered distractor signs. In the instances where drivers recalled only two of the signs, they typically forgot seeing the standard sign and remembered the two enhanced signs.

Drivers were next asked what each sign meant to them and what message they thought the signs were trying to convey. All 26 drivers recognized the standard sign as an advance warning that a grade crossing was ahead. Additional comments were written by drivers such as "slow down" and "approach with caution." Five drivers (19 percent) responded in this manner to the standard sign, seven (27 percent) to the strobe-enhanced sign and 10 (38 percent) to the sign enhanced with the standard flasher.

A concern that drivers would misinterpret the flashing lights (strobe or beacon) as an indicator that a train was at the grade crossing was also important in this study. Only three drivers thought that the strobe-enhanced sign was trying to convey that a train was ahead while nine drivers (35 percent) thought that the flashing beacon indicated the presence of a train. While this is a "fail-safe" misunderstanding, one concern is that drivers at passive crossings with railroad advance warning signs enhanced with a flashing light source who do not see trains will begin to disrespect railroad advance warning signs intended to warn drivers that a train is present. It should be noted that the railroad advance warning signs with two beacons, one mounted above the sign and the other below the sign, flash alternately when a train is present are supplemented with a TRAIN PRESENT WHEN FLASHING plaque.

Additional comments made about the signs with respect to their meaning included statements such as "the strobe did not add any meaning to the sign. It was used to attract attention." A few drivers also thought that the flashing lights indicated a passive crossing, or a nearby crossing with poor visibility or limited sight distance, or had a higher frequency of train crossings than at crossings with just the standard railroad advance warning sign.

When asked what they liked and disliked about the standard sign, drivers said that they liked the clear and understandable message and the brightness of the sign. It should be noted the signs used in this study had an engineering grade sheeting making them retroreflective. Others liked the size of the sign and the fact that it was a standard sign. Drivers also said that they thought the sign was too passive and plain. They felt that the sign needed a supplemental device to attract more attention. One person thought the sign was easy to ignore while four people said they liked the sign.

Conspicuity was the number one sighted characteristic of the strobe-enhanced sign that drivers noted. Thirteen drivers (50 percent) responded in this manner. Additionally, six people liked the sign because it conveyed a message that they should be careful at this grade crossing. On the other hand, some drivers (seven of them) found the strobe light confusing. They commented that they had trouble identifying the light source. A primary problem drivers experienced with the strobe system was that the strobe light was too weak, not bright enough, or too small. Thirteen drivers answered in this manner. While four drivers found nothing that they disliked about the sign, three drivers thought that the strobe light distracted driver attention from the sign itself and the driving task and placed it on the light.

The sign with the standard flashers was most popular due to the large flasher and its brightness. Conspicuity was sited by 11 drivers as one thing they liked about the flasher sign. Again, drivers said that they liked the fact that the flashing light suggested a situation where more caution should be used. Like the strobe light, some drivers found the flasher-enhanced system to be confusing. Of the 26 drivers, 11 of them found the system confusing. However, eight drivers found nothing that they disliked about this signing system.

Drivers were then asked to choose which sign they thought best alerted or reminded a driver that a passive highway-railroad grade crossing was ahead. Only four (15.4 percent) of the drivers chose the standard sign, while five (19.2 percent) chose the strobe-enhanced sign and 19 (73.1 percent) chose the flasher-enhanced sign. It should be noted that the sum of the percentages does not equal 100 because some drivers responded saying that two of the signs were good choices.

The drivers that chose the standard sign as the best choice for alerting the driver to a passive railroad crossing did so because they found it to be less confusing than the other two and it caused them no agitation. The drivers that chose the strobe-enhanced sign did so because it gained attention better than the standard sign but was not confusing like the flasher-enhanced sign. Some drivers also said that they liked the strobe because it was not as bright as the flasher-enhanced sign. The drivers that selected the flasher-enhanced sign attributed their choice to the sign's increased conspicuity and the fact that it had a large light that illuminated the sign face. Additionally, drivers liked the fact that the flasher-enhanced sign conveyed a message of greater caution than the other two signs. The flasher was also selected because it was a standard type of traffic control device and many of the drivers participating in this study had never seen a strobe used with any traffic control device.

The primary objective of the strobe-enhanced sign was to attract the attention of all drivers that pass the sign including those drivers that pass it at least once a day. Therefore, the drivers were asked which sign they thought would best alert or remind a daydreaming driver of the approaching grade crossing. Again, most of the drivers (22 or 84.6 percent) selected the sign supplemented with the standard flasher. The standard sign was selected by one (3.8 percent) person, while the strobe-enhanced sign was selected by three (11.5 percent) persons. The drivers attributed their choice to the fact that they found the flasher to be more effective in attracting their attention and that it made them want to be careful. Additionally, some of these drivers selected the flasher-enhanced sign because of the size of the flasher. They thought that the strobe light was so small it looked out of proportion to the railroad advance warning sign itself. Those that chose the strobe-enhanced sign did so because they liked the pulsating pattern and its attention gaining power. One person chose the standard sign because he found the flasher to be too bright and the strobe light to be too odd.

To find out which sign drivers preferred the most, each driver was asked to rank each sign based on its ability to attract driver attention. The number "1" represented the sign that best attracted driver attention. The average ranking that each sign received was 2.85 for the standard sign, 1.96 for the strobe-enhanced sign and 1.19 for the flasher-enhanced sign. The sign supplemented with the standard flasher received the lowest average ranking suggesting that it had the best attention gaining qualities of the three signs tested. The strobe-enhanced system received the second lowest ranking while the standard sign received the highest ranking of the three signs. It should be noted that the strobe light was ranked by at least one driver in all three positions while the standard flasher was never ranked a "3" and the standard sign never received a "1."

The final two questions referred to how the lights (strobe and flasher) affected a driver's ability to read the sign. Most drivers (20 of 26) had no problems reading the signs with either of the light sources. The light emitted by the standard flasher was a problem for four drivers while the strobe only caused problems for two drivers. Similarly, the final question of the survey asked if the strobe light startled the driver; 20 of 26 drivers said it did not affect them while only six people said it startled them. Of the six drivers who were startled by the strobe, three commented that they were as startled by the strobe as they were distracted by it, trying to decide where the light was coming from and if something was broken. Again, drivers thought the strobe should be larger and brighter but that it had a positive effect and gained driver attention.

Focus Group Discussions

After all drivers had completed the driving course and the questionnaire, the focus group leaders led a discussion that included some material covered in the questionnaire and other highway-railroad grade crossing related safety issues. During the discussion period, the goals and intentions of this study were revealed to the drivers. The comments made during the discussions have been classified into six categories discussed in this section.

As mentioned in the section on questionnaire results, all drivers recognized the sign as the advance warning to a highway-railroad grade crossing. The groups did not discuss the addition of the strobe or how it affected the meaning of the sign. When it was mentioned, drivers responded by saying, "it (the strobe-enhanced sign) has the same meaning to me as the standard sign but commands more attention." Others agreed saying that the strobe and flasher used with the standard sign could be conveying the message that the grade crossing it is preceding has an obscured view, limited visibility, or a higher crash rate. When questioned whether either of the enhanced sign systems could be interpreted as "train ahead" signs, several drivers said, "I didn't see that, but now that you mention it, I could see how someone would make that mistake." One driver stated that he "attributes beacons to nothing more than the identification of a situation that has a greater potential danger than those without beacons." Another comment regarding the signs' meaning was that as the light source got bigger and brighter she thought it represented different levels of severity.

Passive Advance Warning versus Active Advance Warning

Once it was established that the enhanced sign systems could be interpreted as a train ahead sign, the question arose regarding how this misinterpretation would affect the currently used "TRAIN AHEAD WHEN FLASHING" railroad advance warning sign. One comment was that instead of creating disrespect, the sign would cause confusion. The difference between a railroad advance warning sign supplemented with a continuously flashing beacon and an active railroad advance warning sign that is malfunctioning and flashes continuously, despite the presence of a train, was discussed. The average driver can discern this difference.

Most of the drivers said that the railroad advance warning sign alone does not demand enough attention, particularly on a dark rural road. Drivers agreed that the enhanced signs gained their attention and made them look at the sign. Similarly, one driver said, "it (the strobe) grabs your attention and makes you look twice - once to see where the light is coming from and again to see the sign."

Because of the continuous blinking of the flasher, drivers could see it from further away than the strobe light. One driver said that the flasher got his attention immediately when he was far enough away to react properly and in a timely manner. Another driver said of the flasher that it would definitely wake him up.

When comparing the attention gaining qualities of the strobe light and the standard flasher, one driver said that the message intended to be conveyed needs to be evaluated. He went on to say that the strobe lights most people are accustomed to seeing are on emergency vehicles and require an immediate response to get out of the path of the emergency vehicle. A flasher, on the other hand, did convey an extra meaning of caution, but in a more gradual manner.

Enhanced Signs

Study participants said that the standard railroad advance warning sign was "too common" and often "taken for granted." According to the study drivers, when lights are added to the existing sign, not only does the target value of the sign increase, but the attention that drivers give the sign also increases. The lights allow drivers to read the signs from a greater distance and prepare for the crossing. The flashing lights, as previously mentioned, also cautioned the driver approaching the grade crossing better than the standard sign. One driver said that if he were driving too fast on a rural road, the blinking of the strobe or flasher would better gain his attention than just the sign.

Due to the limitations of the equipment used in this study, the strobe light exhibited an irregular flash pattern in which it would blink four times, pause, then blink four more times when activated. Several drivers said that this irregular flash pattern agitated them. Others said they were bothered by the strobe because it was out of the normal or they had never seen one used with a traffic control device. The novelty effect of the strobe caused some problems for the drivers because they tried to look at the light source and not at the sign. One driver said she initially thought that the strobe light was a reflection and when she looked for it, it was gone. Other drivers simply did not like the strobe light at all. Approximately two-thirds of the focus group drivers said that the strobe was too small, not bright enough, or was out of proportion to the sign. A final problem some drivers had with the strobe was that it flashed white; however, of the 13 people that answered what color they saw flashing, five of them said they saw the strobe flash yellow.

The strobe system was cited as a definite attention gainer due to its novelty. It made the drivers aware of the sign. While the strobe did not severely distract any of the drivers, several drivers said that it did not provide adequate redirection of driver attention. The strobe was compared with the lights used in a construction zone that two drivers said make them slow down and proceed with caution.

Additional Concerns

During the focus group discussions, two important concerns arose that were not addressed. The first concern was regarding the height of the mounted light. It was mentioned that truck drivers often complain about flashing lights that are at their eye-level temporarily blinding them at night. The second concern dealt with how well these lights could compete for driver attention with the headlights of an opposing vehicle. It was thought by at least one driver that the combination of these two lighting sources may cause some drivers problems, especially on rural roads where the edge of the pavement is not defined very well.

Additional comments from both the questionnaire and the discussion groups included:

- It's hard for me to drive at night so I need signs like these to grab my attention.
- The lights got my attention.
- Flashing lights should be used at limited sight distance grade crossings, but not at all grade crossings.
- The strobe could be used at all grade crossings because it is small and demands attention.
- Strobe seems to be an effective means of gaining attention. After drivers have seen it for the first time, they should get use to it and not be distracted by it.
- Either of the lights are better than nothing.
- Strobe has long life, low energy, and excellent conspicuity.
- A YIELD TO TRAINS sign may work better.
- Use a warning sign that indicates the distance to the grade crossing and the number of tracks.
- All grade crossings should be active.
- Should use reflective tape on train cars so people can see them at night.
- Use the strobe light at grade crossings with limited sight distance or fog problems.
- The flasher may work great and even better if it were vehicle-activated like the strobe.
- I fear that, with the continuous flasher and the flat land in Texas, a driver may become dazed by the flashing light long before he sees the sign.
- Maybe you could just illuminate the signs at night like billboard lighting.
- Why not illuminate the grade crossing at night?
- It seems like we could use some optical sensor or prism that could bounce headlight light across the grade crossing to better illuminate it.

5.7 SUMMARY

Completion of the controlled testing of the proposed enhancements to the railroad advance warning sign at a highway-railroad grade crossings was an important step in identifying a better method to alert drivers of a nearby grade crossing and convey the message that extreme caution should be used when approaching this area. The evaluation process included both quantitative and qualitative analyses. Based on the findings of this research, the following conclusions were made:

- Of the three signing systems presented to the drivers, none of them caused any adverse driver reactions, such as slamming on the brakes, rapid deceleration, sudden head movements, or erratic steering maneuvers.
- No evidence was available to support that the sign system seen affected driver head movement or looking behavior.
- The sign system seen, however, did affect driver braking behavior, particularly at the flasher-enhanced sign and the strobe-enhanced railroad advance warning sign. Here, the braking reactions showed drivers exhibiting caution and preparing for the conditions that may lie ahead.
- Drivers preferred the railroad advance warning sign supplemented with the standard flasher to gain the attention of daydreaming drivers and as the sign that would best alert the drivers that a passive highway-railroad grade crossing was ahead.
- Driver ranking of the effectiveness of the three sign systems showed that both of the enhanced systems were preferred to the standard sign.
- All drivers understood the meaning of the standard railroad advance warning sign but became confused by its meaning upon the addition of the supplemental lights. Confusion about whether or not a train was present when the lights were flashing was greater with the standard flasher than with the strobe light.
- While some drivers simply did not like the strobe light, only three subjects said it startled them. Most startled reactions were due to the novelty of the strobe and the fact that drivers were trying to determine what was flashing in an irregular pattern.

5.8 FURTHER STUDIES

Based on the results of the pilot study, a field test of the vehicle-activated flashing strobe light mounted on the top of the railroad advance warning (W10-1) sign has been commissioned for further evaluation. Besides the strobe light, a supplementary sign plate stating LOOK FOR TRAIN AT CROSSING will be presented to provide additional information to drivers.

After reviewing many passive grade crossing locations, a passive grade crossing on Blackland Road in Temple, Texas, was chosen as the test site. A *before* and *after* study of the strobe-enhanced sign system is currently underway. The primary measure of performance chosen to evaluate the device is the effect the device has on the speed profile of vehicles approaching the crossing. Speed profiles on each approach to the grade crossing will be generated by collecting speed data at various distances from the grade crossing. A driver survey and driver observation study will also be included. The field tests should be completed in 1997.

6.0 SUMMARY OF FINDINGS

This research combined a number of studies to develop, test, evaluate and recommend improved methods for communicating with drivers at both active and passive highway-railroad grade crossings. The following sections provide a summary of the findings in this research.

6.1 Driver Comprehension

The driver comprehension survey found that drivers expressed a lack of understanding of requirements and responsibilities at passive and active highway-railroad grade crossings. For both types of grade crossings, most of the drivers said that the correct action was to stop at the crossing, look and listen for trains. While these responses are helpful in avoiding train-vehicle collisions, they have the potential to induce vehicle-vehicle collisions.

Drivers showed a lack of understanding for the railroad advance warning sign. Approximately 30 percent of participating drivers thought that the sign was located at the actual grade crossing. In addition, only 70 percent of the drivers correctly identified the meaning of the railroad advance warning sign and 50 percent of the drivers did not know that the sign is used at both active and passive crossings. Further, drivers expressed a lack of understanding of the meaning and location of the crossbuck. Only 71 percent of the participating drivers correctly identified the location of the crossbuck. Approximately 34 percent of the drivers did not know that it is used for both active and passive crossings.

Previous research shows that drivers in Texas are involved in more crashes in which the causal factor was listed as "drove around the gates" as compared with crashes nationwide. Twelve percent of the participating drivers said that driving around the gates at active crossings was acceptable if they could not see a train while only 6 percent of the drivers have received a citation, or knew someone who had received a citation for driving improperly at a grade crossing. A frequent comment on the survey was that the gates and lights should function 24 hours a day. This comment suggests that drivers may not trust active traffic control devices and frequently disregard them.

Most of the participating drivers said that they remembered instructions about grade crossings from either a Driver Education or Defensive Driving class, Operation Lifesaver, or other educational campaign. In addition, 53 comments suggested more public education would help improve safety at grade crossings. These comments suggest that public education is an effective way of improving safety at grade crossings. These comments suggest hypothesis testing did not show any improvement in the results of drivers who have taken a driver's education or defensive driving course in the past year to the overall results. This suggests that these courses need to be reevaluated to incorporate more material concerning grade crossings.

Twenty-one drivers suggested that lights and gates should be present at every grade crossing, and these gates should go all the way across the road so that drivers could not go around them. When asked for any comments or suggestions for improving safety at highway-railroad grade crossings, 20 drivers suggested that grade crossings are too rough and need to be made smoother. These comments suggest that rough surfaces (like rumble strips) command the attention of the driver. Literature regarding the use of rumble strips has produced mixed results; furthermore, these comments support other recommendations for further research in the area.

Drivers age 16 to 25 and drivers with less than five years of driving experience exhibited a lower level of comprehension of traffic control devices and driver requirements at grade crossings than older, more experienced drivers. Drivers living in large cities or rural areas did not affect driver comprehension of traffic control devices and driver requirements at grade crossings. Crossing frequency appeared to affect driver comprehension of traffic control devices at grade crossings; however, comprehension of traffic control devices and driver requirements at grade crossings between male and female drivers showed no differences.

6.2 Driver Behavior

Many advantages to observing driver behavior at highway-railroad grade crossings were recognized directly when riding with the driver. The researcher was able to observe the behavior of the same driver at a variety of crossing scenarios. While riding with the driver in the vehicle rather than observing from the field, the researcher could observe whether the attention of the driver was primarily focused on the perceived roughness of the grade crossing surface as opposed to looking at the warning devices or looking along the tracks for approaching trains. The following conclusions and recommendations were drawn from the in-vehicle observations of driving behavior at highway-railroad grade crossings.

The researcher observed differences in looking behavior and deceleration maneuvers at the active and passive crossings along the test course. Drivers initiated more looking behavior at the passive crossings except at an industrial spur track grade crossing. The observation of different driving behavior at active and passive crossings infers that the drivers apparently detected differences, either subconsciously or unconsciously, in the degree of warning installed at the grade crossing.

Many drivers were motivated to decelerate by the perceived roughness of the grade crossing surface, rather than out of concern for looking for approaching trains as they approached active crossings. Understandably, due to the nature of the warning devices installed at active and passive crossings, drivers may not necessarily need to initiate looking behavior in both directions to achieve safe passage at active crossings, nor are drivers necessarily required to stop before traversing passive crossings. Slowing without looking in either direction may be more risky than not slowing at all, due to the increase in exposure time at the crossing. One young female slowed, due to her perception that the grade crossing surface might be rough, almost to the point of stopping on the tracks without having looked in either direction on the approach to the active crossing. One cannot necessarily conclude that her behavior was risky for that assumption might imply that she inadvertently stopped on the tracks without regards to the potential for train activity. In approaching the active crossing, she may have subconsciously thought that the active warning devices were not activated and warning of approaching train activity, and thus chose to reduce her speed and focus her attention on negotiating the grade crossing surface to avoid damaging her vehicle.

Furthermore, survey responses may not accurately reflect driver understanding or behavior within the real world environment. Although most responses reflected a general understanding of safe driving behavior at grade crossings, most drivers did not actually perform as they said they should or would when approaching the grade crossings along the test course. Furthermore, near miss experiences and association with those involved in tragic collisions did not necessarily produce noticeable changes in driving behavior at the highway-railroad grade crossings along the test course.

6.3 Recommendations for Improving Driver Behavior

Observations of *good* or desirable looking behavior do not necessarily show that drivers will avoid collisions at highway-railroad grade crossings. Many drivers who initiated looking behavior in both directions did so themselves within the hazard zone which is within 5 m (1.5 ft) of the railroad tracks. Looking within this region may not allow enough time to avoid a potential collision, especially with no speed reduction on the approach. Furthermore, many drivers exhibit the desirable looking behavior without conscientiously focusing on what to look for. Safety educational programs should incorporate a list of precisely what drivers should be looking for when approaching a highway-railroad grade crossing.

- **Look** for approaching trains;
- **Look** for activity along a second track;
- **Look** for (and around) sight obstructions that block a clear view of potential track activity; and
- **Look** for ample clearance space on the far side of the tracks before proceeding across the tracks.

This list specifically targets certain tasks for the driver to initiate when approaching a grade crossing. This approach should improve the driver's expectancy of potential hazards at either passive or active grade crossings. Driver Education and Defensive Driving programs should also present various grade crossing scenarios and the respective driver responsibilities as they differ between active and passive crossings. Until the public recognizes the highway-railroad grade crossing scenario as a critical intersection, positive changes in driver behavior are not likely to result. Furthermore, drivers should develop a better mental picture of where railroad tracks run through their community. This system perspective should improve driver expectancy of a highway-railroad grade crossing and could potentially yield more desirable driving behavior.

The in-vehicle observations within this study were all performed during daylight conditions. Nighttime observations of driver behavior at active and passive crossings may yield further insight into the misconceptions drivers have regarding the highway-railroad grade crossing scenarios. For example, many drivers assume that most grade crossings used by trains have warning devices to alert the driver of approaching trains. This misconception is especially dangerous at night because the lights mounted on the crossbucks at active crossings are difficult to see due to the black casings. The casings are colored black to improve the conspicuity of the system during daylight conditions. Nighttime observations of driver behavior are thus recommended to further identify driver misconceptions regarding safe driving behavior when approaching active and passive highway-railroad grade crossings.

6.4 Evaluation of Experimental Passive Sign Systems

The objective of this component of the research was to study the effects that enhancements to the current standard traffic control devices at passively controlled railroad-highway grade crossings have on the level of safety at the crossing. The first experimental sign system tested consisted of a YIELD sign with a supplementary message plate containing the words "TO TRAINS." The second experimental sign consisted of a yellow high intensity backed diamond warning sign with a black locomotive symbol. The sign also contained a yellow supplementary message sign that read "LOOK FOR TRAINS."

Two surrogate measures of effectiveness were observed, namely driver approach speeds and looking behavior, to determine the effectiveness of both sign systems. The major findings are:

- The implementation of either sign system may initially increase speed reductions and decrease speeds at grade crossings on some approaches. However, the data suggests that over time drivers will approach their previous behavior after the signs have been installed.
- Driver looking behavior may be significantly increased after the implementation of the YIELD TO TRAINS sign system. No evidence was noted to suggest that this sign system would cause a significant decrease in looking behavior.
- The data suggests that drivers may have understood the YIELD TO TRAINS sign system better than the LOOK FOR TRAINS sign system. Drivers with the former sign system showed greater speed reductions and some significant increases in looking behavior. The latter sign system did not have as great an impact on approach speeds and produced no significant improvement in looking behavior.

6.5 Enhanced Traffic Control Devices

The objective of this component of the research was to determine if the addition of a strobe light to an railroad advance warning sign preceding a passive railroad crossing would result in adverse driver reactions, such as hard braking or erratic steering maneuvers. Approaching motor vehicles detected by a motion sensor activated a strobe light that flashed until the vehicle was at a point where the railroad advance warning sign was in the driver's cone of vision.

The measures used to evaluate the device included driver head movement, braking reaction, and steering reaction. None of the three sign systems, including the strobe-enhanced system, resulted in any adverse driver reaction. The strobe- and flasher-enhanced sign systems did, however, solicit more braking than the standard sign. Head movement at each of the three signs was not statistically different.

Drivers preferred the standard flasher enhancement to the strobe light. Additionally, the strobe light was preferred to the standard sign. Both the strobe light and the standard flasher were said to have better attention gaining qualities than the standard sign, causing drivers to exhibit greater caution.

While some drivers simply did not like the strobe light, only three drivers said it startled them. Most of the startling that they experienced was due to the novelty of the strobe and the fact that they were trying to decide what was flashing with such an irregular pattern.

The completion of the controlled testing of the proposed enhancements to the railroad advance warning sign to a highway-railroad grade crossing was an important step in identifying methods to better alert drivers of a nearby grade crossing and convey a message that extreme caution should be used when approaching this area. The evaluation process included both quantitative and qualitative analysis. Based on the findings of these studies, the conclusions of this research are as follows:

- Of the three signing systems presented to the drivers, none of them caused any adverse driver reactions in the form of slamming on the brakes, rapid deceleration, sudden head movements or erratic steering maneuvers.
- No evidence was available to support that the sign system seen affected driver head movement or looking behavior.
- The sign system seen did affect driver braking behavior, particularly at the flasher-enhanced sign and the strobe light-enhanced advance warning sign. Here, the braking reactions showed drivers exhibiting caution and preparing for the conditions that may lie ahead.
- Test drivers preferred the railroad advance warning sign supplemented with the standard flasher to gain the attention of daydreaming drivers and as the sign that would best alert the drivers that a passive highway-railroad grade crossing was ahead.
- Driver ranking of the effectiveness of the three sign systems showed that both of the enhanced systems were preferred to the standard sign.
- All drivers understood the meaning of the standard railroad advance warning sign but became confused by its meaning upon the addition of the supplemental lights. Confusion about whether a train was present when the lights were flashing was greater with the standard flasher than with the strobe light.

Based on the results of this research, a field test of the proposed vehicle-activated flashing yellow strobe light system mounted on the top of the railroad advanced warning (W10-1) sign has been recommended for further study.

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APPENDIX A

DRIVER COMPREHENSION SURVEY: SURVEY INSTRUMENT (ENGLISH VERSION)

RAILROAD CROSSING SURVEY

Sponsored by the
Texas Transportation Institute
and the
Texas Department of Transportation

INSTRUCTIONS

- Mark your answers on the **answer sheet provided.**
- Answer all questions in order, **do not go back and change previous answers.**
- This survey is confidential, do not put your name on the form.
- Some questions may have more than one correct answer, mark all that apply.
- If none of the answers are correct mark "none of the above."
- If you are unsure of the answer, you may mark "not sure."
- If you do not understand a question or other part of the survey, please ask one of the survey attendants for help.
- You will receive a **free highway map** when you have completed the survey.

Your comments and suggestions regarding railroad crossings are welcome. Please feel free to write comments or suggestions in the space provided on the answer page. Thank you for your time and participation.

PART I. TRUE/FALSE QUESTIONS

1. All railroad crossings have flashing signals.

   A. True.

   B. False.

   C. Not sure.

2. All railroad crossings that are used by trains have flashing signals.

   A. True.

   B. False.

   C. Not sure.

PART II. MULTIPLE CHOICE QUESTIONS

3. Do you recall specific instructions about safe driving at railroad crossings from any of the following sources? (Check only those sources you remember something from.)

   A. Safety Campaign (TV, Radio, Newspaper, Magazine, etc.).

   B. Driver Education Course or Defensive Driving course.

   C. Texas Driver's Handbook.

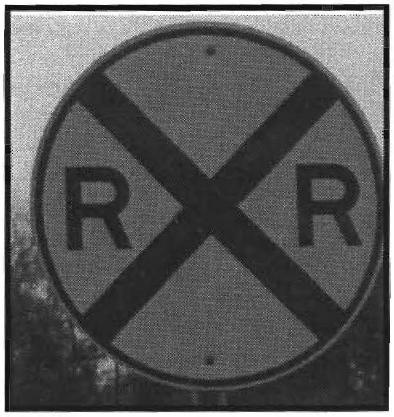
   D. Operation Lifesaver presentation.

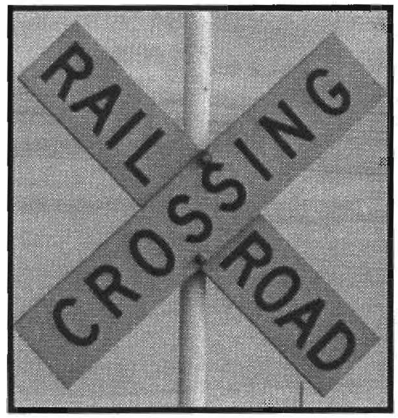
   E. Family member/relative.

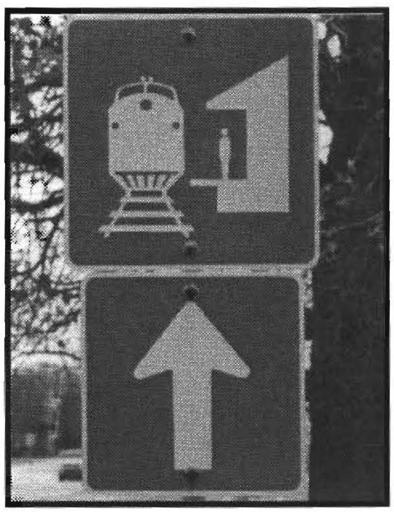
   F. Other (please describe:______________________________).

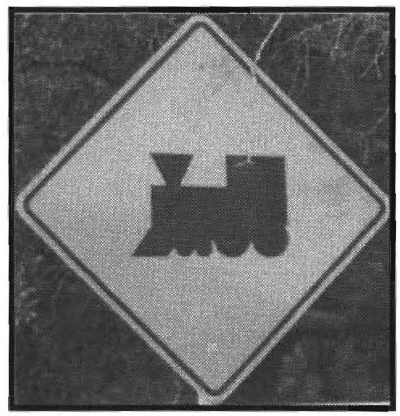
   G. I do not recall any specific instructions.

4a. Which of the signs shown below is placed just at the point where the railroad tracks cross the highway?









4b. The sign you selected in Question 4a is used at which of the following types of railroad crossings? (Please choose only one response.)

A. Only at crossings with flashing signals.

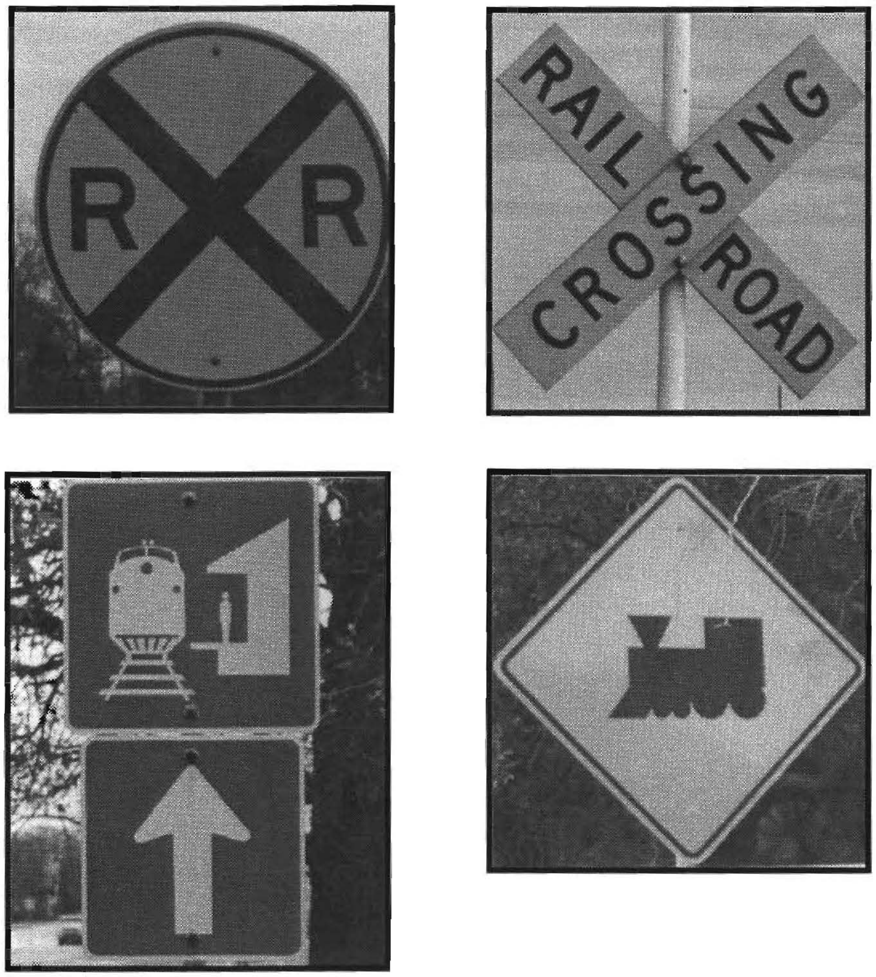
B. Only at crossings with flashing signals and gates.

C. Only at crossings that do not have flashing signals or gates.

D. The sign is used at all railroad crossings.

E. Not sure.

5a. Which of the signs shown below is usually located several hundred feet in advance of a railroad crossing?



5b. The sign you selected in Question 5a is used at which of the following types of railroad crossings? (Please choose only one response.)

A. Only at crossings with flashing signals.

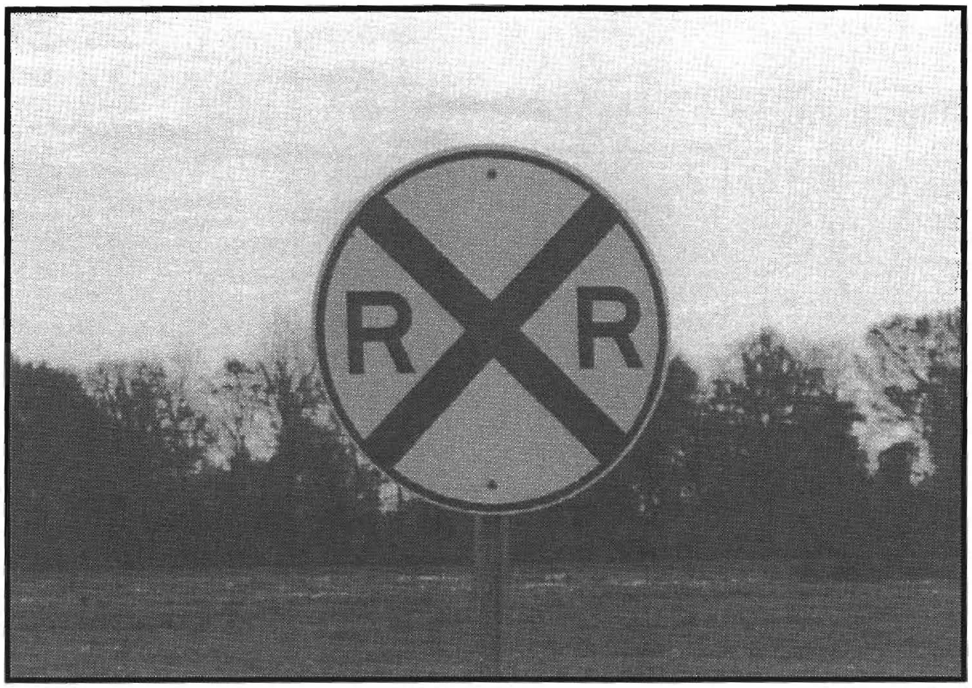
B. Only at crossings with flashing signals and gates.

C. Only at crossings that do not have flashing signals or gates.

D. The sign is used at all railroad crossings.

E. Not sure.

6. What does the sign shown below mean?



A. There is a railroad crossing within about 15 feet of the sign. Stop, look, and listen for an approaching train.

B. There is a railroad crossing with signals and gates ahead. Prepare to slow down and look and listen for an approaching train.

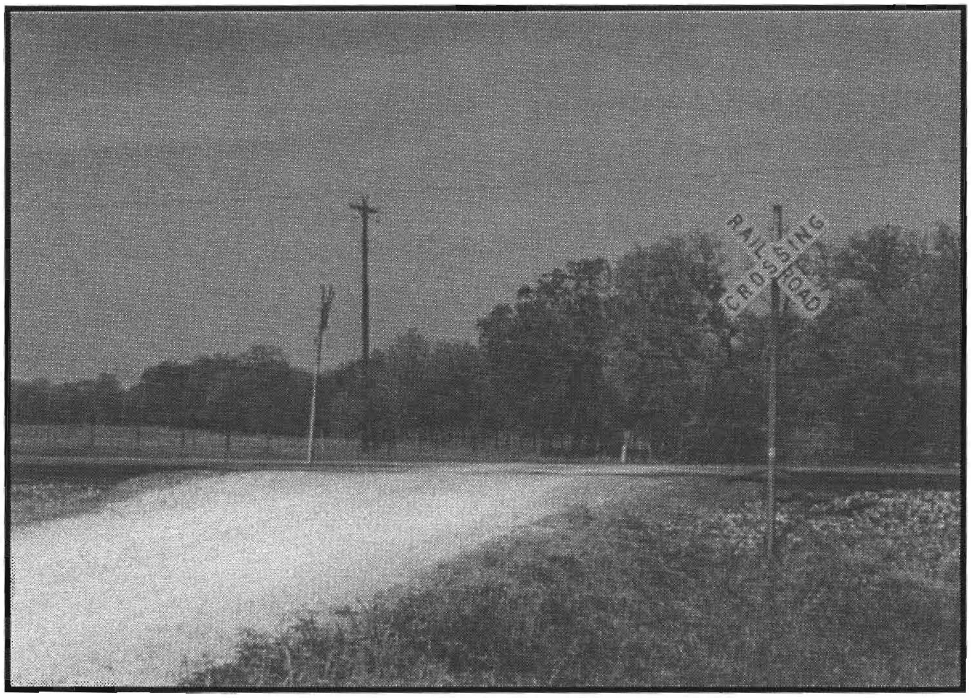
C. There is an intersection with a Ranch Road ahead. Be aware of turning traffic.

D. There is a railroad crossing ahead. Prepare to slow down and look and listen for an approaching train.

E. None of the above.

F. Not sure.

7. The railroad crossing shown below has a "RAILROAD CROSSING" sign, but it does not have signals. What should you do at railroad crossings that do not have signals?



A. Stop before crossing the track, and look and listen for a train.

B. Maintain a safe speed, look for a train, and be ready to yield the right-of-way if a train is approaching the crossing.

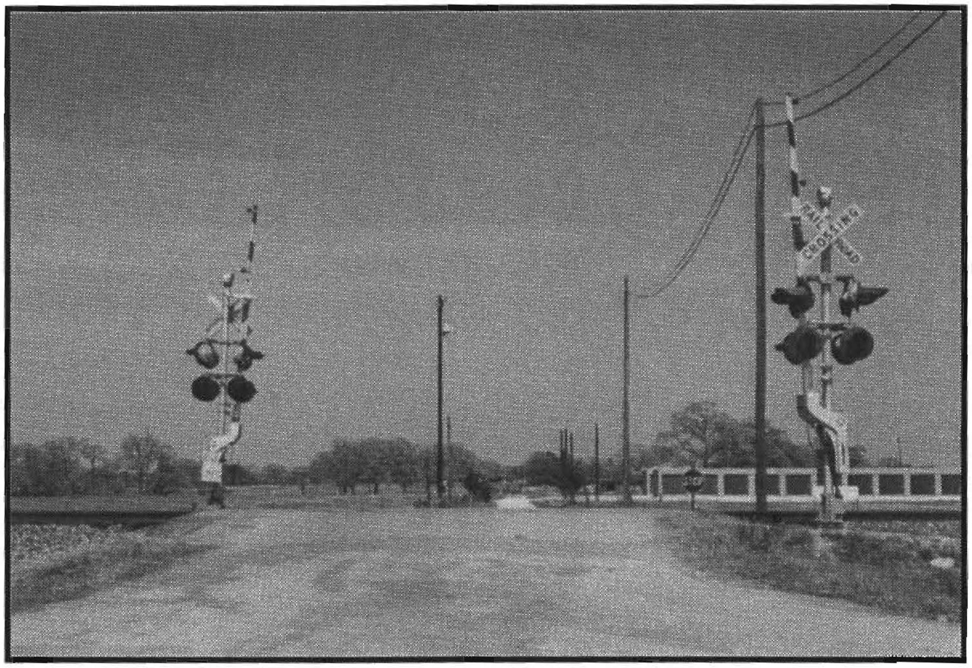
C. Speed up to get through the crossing quickly and avoid an accident.

D. Slow down because the crossing surface may be rough and may damage your vehicle.

E. None of the above.

F. Not sure.

8. The railroad crossing shown below has a "RAILROAD CROSSING" sign, plus signals and gates. What should you do at this railroad crossing when the signals are <u>NOT</u> flashing and the gates are <u>NOT</u> lowered?



A. Slow down, and look and listen for a train.

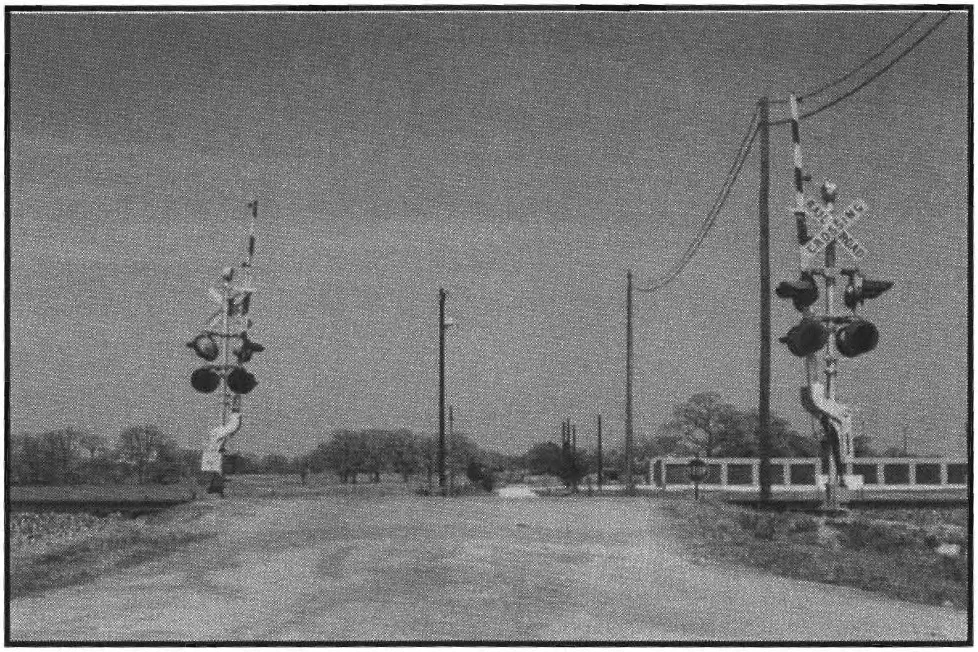
B. Stop at the crossing, and look and listen for a train.

C. Maintain a safe speed, and proceed through the crossing without stopping.

D. None of the above.

E. Not sure.

9. The railroad crossing shown below has a "RAILROAD CROSSING" sign, plus signals and gates. What should you do at this railroad crossing when the signals ARE flashing and the gates ARE lowered?



A. When the signals are flashing and the gates are lowered, it is usually because they are broken or malfunctioning. Proceed through the crossing without stopping.

B. Slow down and look and listen for a train. It is OK to driver around the gate if you do not see or hear a train.

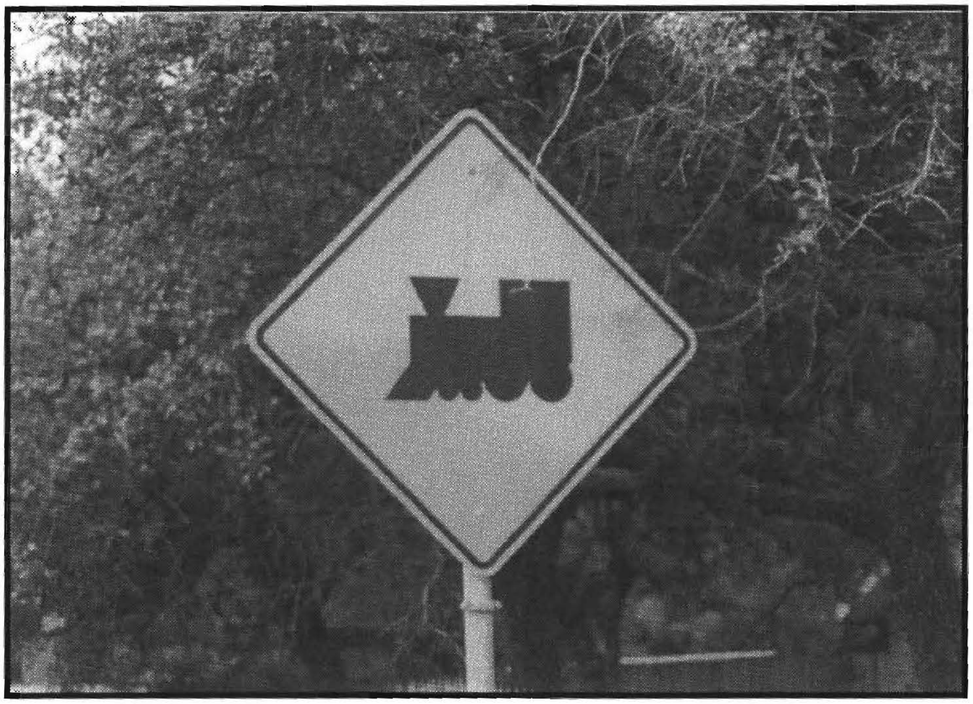
C. Stop and look and listen for a train. It is OK to driver around the gate if you do not see or hear a train.

D. Stop at the crossing, and do not proceed across the tracks until the signals stop flashing and gates are raised.

E. None of the above.

F. Not sure.

10. What does the sign shown below mean?



A. There is a railroad crossing ahead with slow-moving trains. Slow down and look and listen for an approaching train.

B. There is a railroad crossing without flashing signals or gates ahead. Slow down and look and listen for an approaching train.

C. There is a historic steam locomotive on display ahead (as at a city park).

D. There is a railroad crossing ahead. Slow down and look and listen for an approaching train.

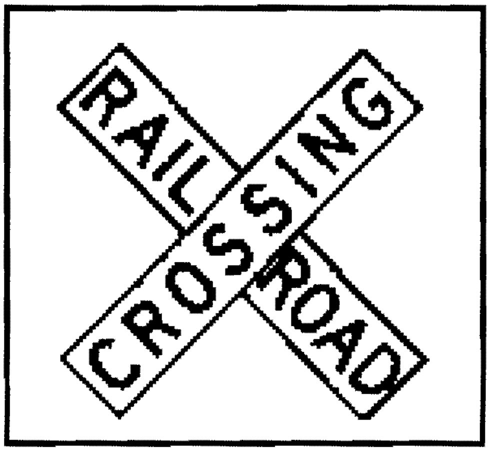
E. None of the above.

F. Not sure.

11. An **Active Railroad Crossing** has signals that warn you of an approaching train. Most active railroad crossings also have gates that are lowered to block the roadway when a train is approaching.

A **Passive Railroad Crossing** does not have any signals or gates to warn of an approaching train.

At which type of railroad crossing would you expect to see the sign shown below?



A. The sign shown is used at active railroad crossings only.

B. The sign shown is used at passive railroad crossings only.

C. The sign shown is used at both active and passive railroad crossings.

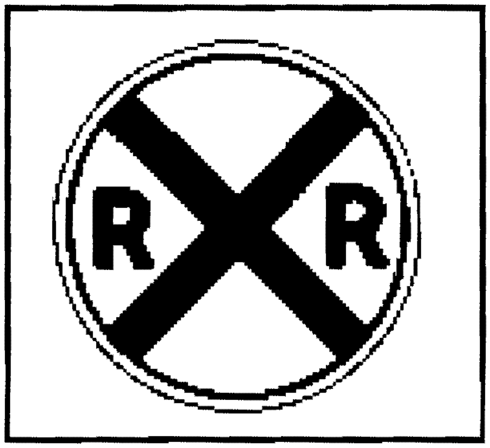
D. The sign shown is not used at either active or passive railroad crossings.

E. Not sure.

12. An **Active Railroad Crossing** has signals that warn you of an approaching train. Most active railroad crossings also have gates that are lowered to block the roadway when a train is approaching.

A **Passive Railroad Crossing** does not have any signals or gates to warn of an approaching train.

At which type of railroad crossing would you expect to see the sign shown below?



A. The sign shown is used at active railroad crossings only.

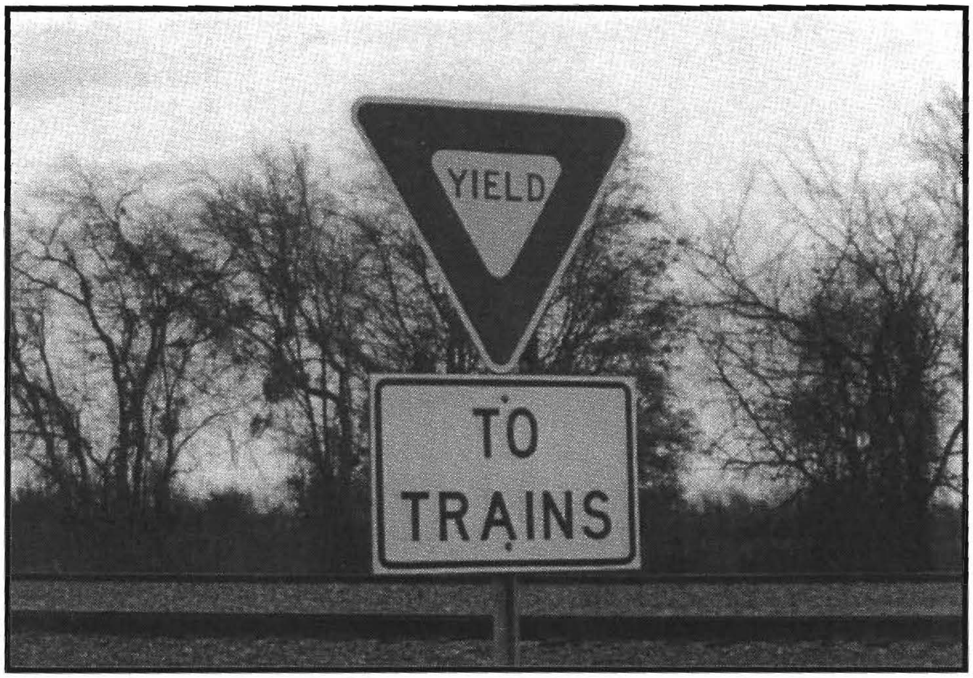
B. The sign shown is used at passive railroad crossings only.

C. The sign shown is used at both active and passive railroad crossings.

D. The sign shown is not used at either active or passive railroad crossings.

E. Not sure.

13. What is the meaning of the sign shown below?



A. There may be 2 trains at the railroad crossing.

B. Yield the right-of-way if a train is approaching the crossing.

C. Trains at the railroad crossing must yield the right-of-way to highway traffic.

D. None of the above.

E. Not sure.

PART III. COMMENTS AND SUGGESTIONS

We would like to know any comments or suggestions you may have for improving safety at railroad crossings. Please use the space provided on the response form to write any comments or suggestions, or to sketch or suggest new or different signs for railroad crossings.

PART IV. DEMOGRAPHIC INFORMATION

There are 10 demographic questions on the response form. The answers to these 10 questions are needed for comparison purposes. Please answer each question to the best of your knowledge. Your responses will remain confidential.

APPENDIX B

DRIVER COMPREHENSION SURVEY: PARTICIPANT CHARACTERISTICS

Table B-1. Driver Comprehension Survey Participant Characteristics

Participant Characteristics	Grouping	City		
		Houston	Laredo	Nacogdoches
		Number of Participants		
Age	16-20	88	25	3
	21-25	102	51	4
	26-34	130	68	11
	35-44	156	82	20
	45-59	103	59	20
	59+	30	11	2
Gender	Male	405	242	16
	Female	204	55	44
Driving Experience	Less than 5 years	30	10	1
	1-5 years	90	30	6
	5 + years	482	255	51
Education Level	Less than High School	55	15	2
	High School or Equivalent	114	48	7
	Trade or Vocational School	30	12	2
	Some College	196	99	18
	College Grad.	143	84	13
	Advanced Degree	63	35	16
Ethnic Background	African-American	37	2	2
	Anglo	447	109	48
	Hispanic	78	179	7
	Asian	26	0	3
	Other	14	7	0

Table B-1. Driver Comprehension Survey Participants Characteristics (Continued)

Participant Characteristics	Grouping	City		
		Houston	Laredo	Nacogdoches
		Number of Participants		
Have ever received or known someone who has received citation at a railroad grade crossing	Yes	45	12	2
	No	558	282	56
Area Type	Large City >500,000	424	186	4
	Medium City 50,000-500,000	118	70	46
	Small Town <50,000	39	22	6
	Rural Area Not in the City	23	18	3
Taken a driving course in the past year	Yes	196	79	20
	No	407	215	38
Crossing frequency	At least once per day	402	178	26
	At least once per week	128	69	18
	At least once per month	44	31	9
	At least once per year	22	9	5
	Never	8	7	0
Resident of Texas	Yes	577	278	58
	No	29	19	1

APPENDIX C

DRIVER COMPREHENSION SURVEY: RESPONSES TO SURVEY QUESTIONS

1. All railroad crossings have flashing signals?

A.	True	12%
B.	False	86%*
C.	Not sure	3%

2. All railroad crossings that are used by trains have flashing signals?

A.	True	20%
B.	False	74%*
C.	Not sure	6%

3. Do you recall specific instruction about safe driving at railroad crossings from any of the following sources? (Check only those sources you remember something from).

A.	Safety Campaign (TV, Radio, Newspaper, Magazine, etc.)	20%
B.	Driver Education Course or Defensive Driving Course	33%
C.	Texas Driver's Handbook	28%
D.	Operation Lifesaver Presentation	2%
E.	Family member/relative	11%
F.	Other (Please describe)	2%
G.	I do not recall any specific instructions	4%

4a. Which of the signs shown below is placed just at the point where the railroad tracks cross the highway?

A.	25%
B.	71%*
C.	1%
D.	3%

4b. The sign you selected in question 4a is used at which of the following types of railroad crossings? (Please choose only one response)

A.	Only at crossings with flashing signals.	10%
B.	Only at crossings with flashing signals and gates.	10%
C.	Only at crossings that do not have flashing signals or gates.	16%
D.	The sign is used at all railroad crossings	52%*
E.	Not sure.	13%

5a. Which of the following signs is usually located several hundred feet in advance of a railroad crossing?

A.	69%*
B.	12%
C.	7%
D.	12%

5b. The sign you selected in Question 5a is used at which of the following types of railroad crossings? (Please choose only one response).

A.	Only at crossings with flashing signals.	7%
B.	Only at crossings with flashing signals and gates.	8%
C.	Only at crossings that do not have flashing signals or gates.	14%
D.	The sign is used at all railroad crossings.	50%*
E.	Not sure.	22%

6. What does the sign shown below mean?

A.	There is a railroad crossing within 15 feet of the sign. Stop, look and listen for an approaching train.	16%
B.	There is a railroad crossing with signals and gates ahead. Prepare to slow down and look and listen for an approaching train.	10%
C.	There is an intersection with a Ranch Road ahead. Be aware of turning traffic.	2%
D.	There is a railroad crossing ahead. Prepare to slow down and look and listen for an approaching train.	69%*
E.	None of the above.	<1%
F.	Not sure.	4%

7. The railroad crossing shown below has a "RAILROAD CROSSING" sign, but it does not have signals. What should you do at a railroad crossing that does not have signals?

A.	Stop before crossing the track, and look and listen for a train.	66%
B.	Maintain a safe sped, look for a train, and be ready to yield the right-of-way if a train is approaching the crossing.	30%*
C.	Speed up to get through the crossing quickly and avoid an accident.	1%
D.	Slow down because the crossing surface may be rough and may damage your vehicle.	2%
E.	None of the above.	1%
F.	Not sure.	1%

8. The railroad crossing shown below has a "RAILROAD CROSSING" sign, plus signals and gates. What should you do at this railroad crossing when the signals are NOT FLASHING and the gates are NOT LOWERED?

A.	Slow down, look and listen for a train.	57%
B.	Stop at the crossing, and look and listen for a train.	18%
C.	Maintain a safe speed, and proceed through the crossing without stopping.	23%*
D.	None of the above.	1%
E.	Not sure.	1%

9. The railroad crossing shown below has a "RAILROAD CROSSING" sign, plus signals and gates. What should you do at this railroad crossing when the signals ARE FLASHING and the gates ARE LOWERED?

A.	When the signals are flashing and the gates are lowered, it is usually because they are broken or malfunctioning. Proceed through the crossing without stopping.	2%
B.	Slow down and look and listen for a train. It is OK to driver around the gate if you do not see or hear a train.	3%
C.	Stop and look and listen for a train. It is OK to drive around the gate if you do not see or hear a train.	7%
D.	Stop at the crossing, and do not proceed across the tracks until the signals stop flashing and gate are raised.	86%*
E.	None of the above.	1%
F.	Not sure.	1%

10. What does the sign shown below mean?

A.	There is a railroad crossing ahead with slow-moving trains. Slow down and look and listen for an approaching train.	12%
B.	There is a railroad crossing without flashing signals or gates ahead. Slow down and look and listen for an approaching train.	9%*
C.	There is a historic steam locomotive on display ahead (as at a city park).	23%
D.	There is a railroad crossing ahead. Slow down and look and listen for an approaching train.	25%
E.	None of the above.	5%
F.	Not sure.	26%

11. An **Active Railroad Crossing** has signals that warn you of an approaching train. Most active railroad crossings also have gates that are lowered to block the roadway when a train is approaching.

    A **Passive Railroad Crossing** does not have any signals or gates to warn of an approaching train.

    At which type of railroad crossing would you expect to see the sign shown below?

A.	The sign shown is used at active crossings only.	12%
B.	The sign shown is used at passive crossings only.	13%
C.	The sign shown is used at both active and passive crossings.	66%*
D.	The sign shown is not used at either active or passive crossings.	4%
E.	Not sure.	6%

12. An **Active Railroad Crossing** has signals that warn you of an approaching train. Most active railroad crossings also have gates that are lowered to block the roadway when a train is approaching.

    A **Passive Railroad Crossing** does not have any signals or gates to warn of an approaching train.

    At which type of railroad crossing would you expect to see the sign shown below?

A.	The sign shown is used at active crossings only.	16%
B.	The sign shown is used at passive crossings only.	18%
C.	The sign shown is used at both active and passive crossings.	49%*
D.	The sign shown is not used at either active or passive crossings.	5%
E.	Not sure.	11%

13. What is the meaning of the sign shown below?

A.	There may be 2 trains at the railroad crossing.	3%
B.	Yield the right-of-way if a train is approaching the crossing.	82%
C.	Trains at the railroad crossing must yield the right-of-way to highway traffic.	3%
D.	None of the above.	6%
E.	Not sure.	5%

DEMOGRAPHIC INFORMATION

There are 10 demographic questions on the response form. The answers to these 10 questions are needed for comparison purposes. Please answer each question to the best of your knowledge. Your responses will remain confidential.

1. What is your age?

Under 20	20%
20-25	16%
25-34	22%
35-44	27%
45-59	19%
Over 59	5%

2. What is your gender?

Female	31%
Male	69%

3. Are you a resident of Texas?

Yes	95%
No	5%

4. How long have you been driving?

Less than 1 year	4%
1-5 years	13%
More than 5 years	83%

5. What is the highest level of school you completed?

Less than high school	8%
High school graduate or equivalent	18%
Trade/Vocational school graduate	5%
Some college	33%
College graduate	25%
Advanced college degree	12%

6. What is your family background?

African-American	4%
Anglo (white)	63%
Hispanic	28%
Asian	3%
Other	2%

7. In what type of area do you live?

Large city (greater than 500,000)	64%
Medium city (50,000 to 500,000)	24%
Small city (less than 50,000)	7%
Rural area	5%

8. Have you or someone you know ever received a traffic citation (ticket) for driving improperly at a railroad crossing?

Yes	6%
No	94%

9. Have you completed a Driver Education or Defensive Driving course within the past year?

Yes	31%
No	69%

10. In your driving, how often do you encounter railroad crossings? (Estimate)

At least once per day	63%
At least once per week	23%
At least once per month	9%
At least once per year	4%
Never	2%

Table C-1. Percentage of Correct Responses by Driver Type

Question	Percentage of Correct Responses for Survey	Driver Type											
		Young	Inexperienced	Large City	Rural Area	Frequently Crosses Tracks	Rarely Crosses Tracks	Female	Male	African-American	Anglo	Hispanic	Asian
1	86	78	71	90	80	88	78	83	87	81	91	76	72
2	74	62	55	77	66	78	59	65	79	61	82	63	48
4a	70	68	71	68	66	71	67	70	70	63	74	64	35
4b	51	45	46	0.5	52	52	39	55	50	37	55	47	38
5a	74	73	69	74	68	76	66	72	75	63	78	67	59
5b	50	46	42	50	52	52	39	50	50	29	53	46	38
6	69	58	56	67	68	70	54	67	69	63	72	64	41
7	29	24	27	31	25	29	24	25	32	34	31	24	21
8	21	20	25	21	18	20	29	21	22	22	21	20	28
9	86	82	81	87	80	85	86	88	86	73	89	83	83
10	9	11	13	10	5	8	18	8	9	24	7	10	21
11	67	66	68	66	64	67	57	7	65	61	71	60	59
12	50	46	45	50	46	51	48	49	50	53	52	42	41
13	83	83	77	83	80	84	75	82	84	83	84	83	83

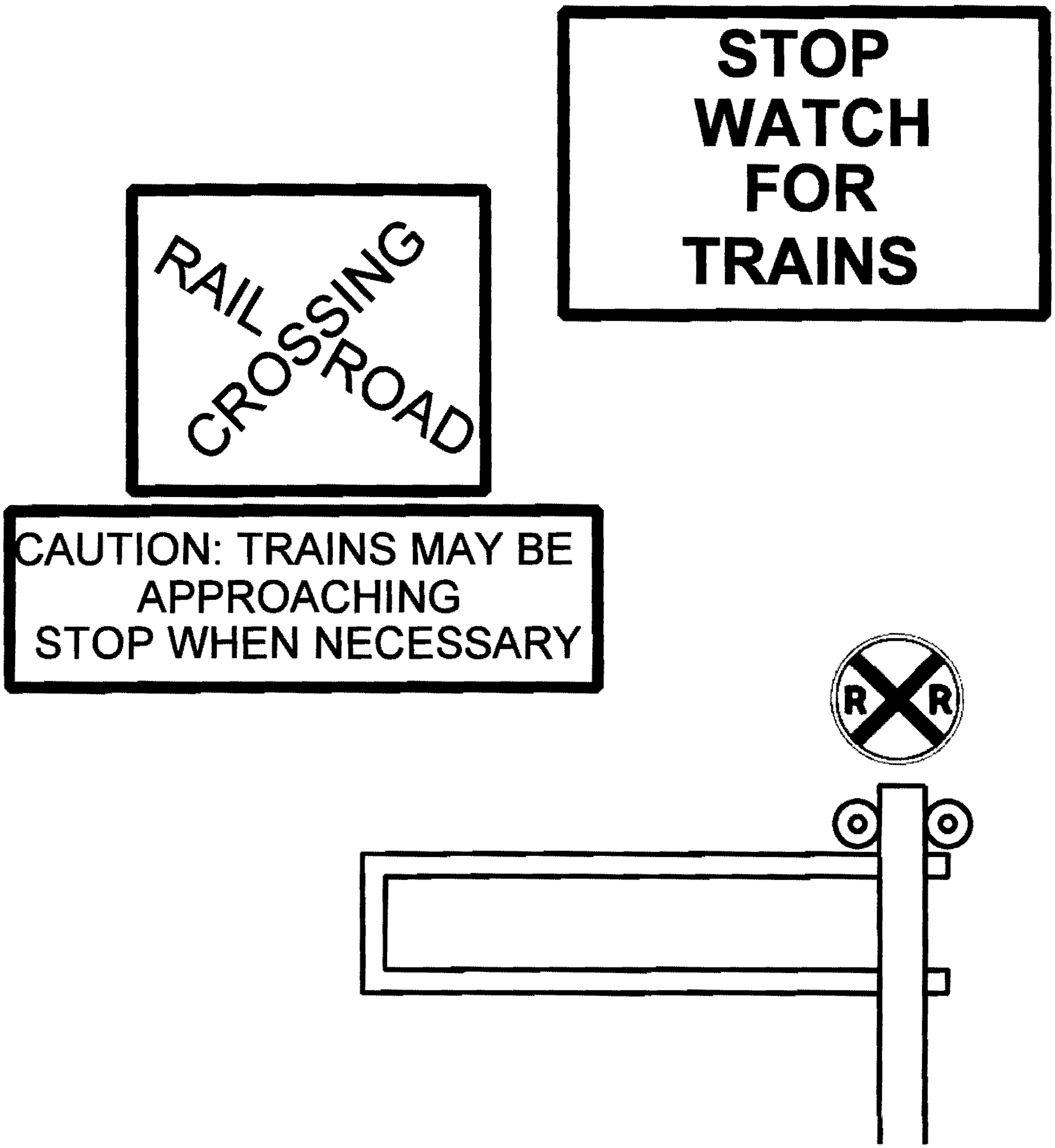
APPENDIX D

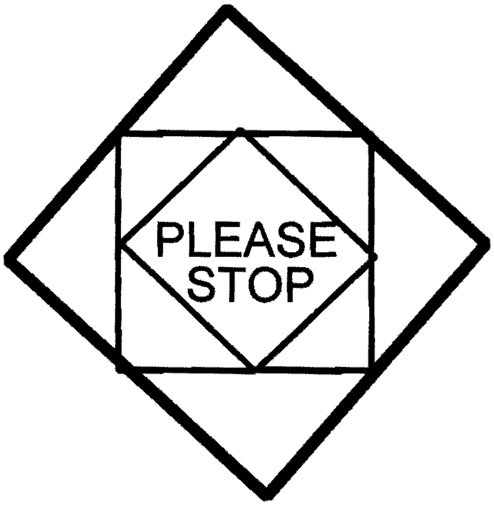
DRIVER COMPREHENSION SURVEY: SUGGESTIONS FOR NEW SIGNS

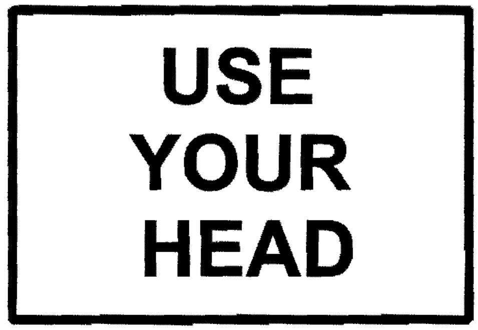
New Sign Ideas:

- Put a warning light 500-1000 yards (450-900 meters) before the track that flashes before a train gets too close.
- Look and Proceed with caution.
- Indicate how far away the crossing is on the sign.
- Look and Listen.

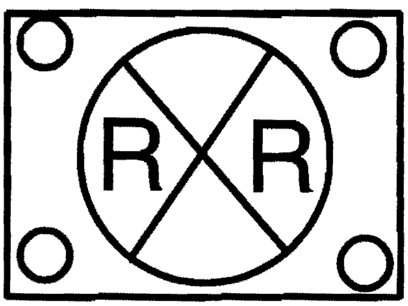
Sketches of New Sign Suggestions:

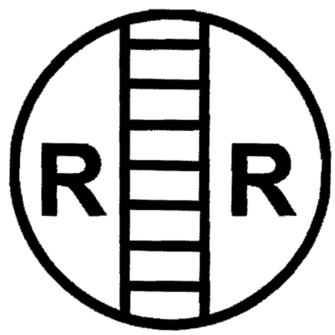


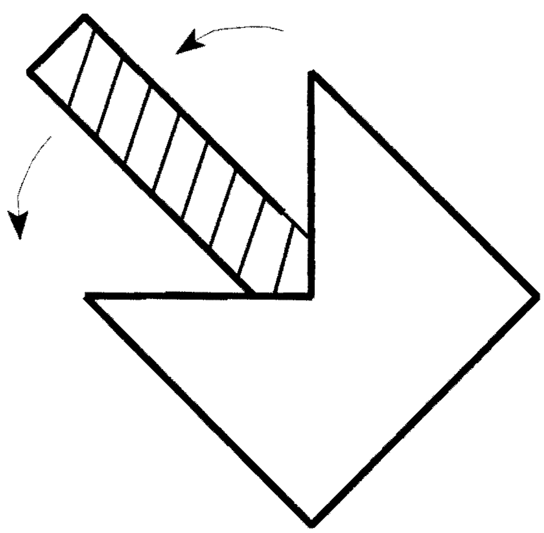




- Stop at This Sign
- Look and Listen for Trains
- If No Trains are Near, Proceed







Arm lowers when gate at crossing lowers

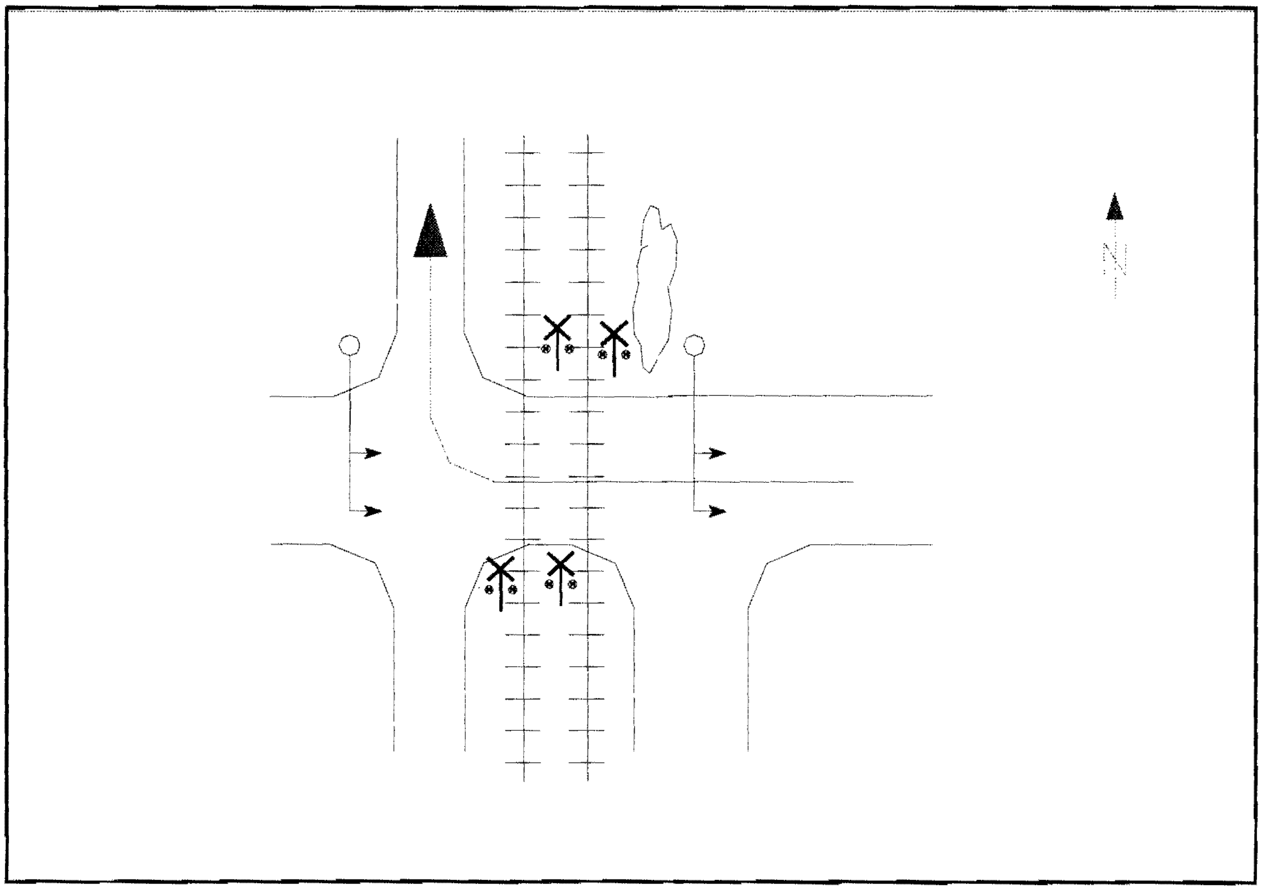
APPENDIX E

DRIVER BEHAVIOR STUDY: DESCRIPTIONS OF TEST COURSE CROSSINGS

Villa Maria Road
(USDOT No. 745060T)

The Villa Maria Road crossing is located within the signalized intersection of both Wellborn Road and Finfeather Road. Two tracks run parallel between Wellborn and Finfeather. Through train volume is 17 trains per day with a train speed limit of 40 km/h (25 mph). Vehicular volume is estimated to be 3,560 Average Daily Traffic (ADT). Only two of the seven accidents at this crossing involved a train. No fatalities have been reported. The westbound approach was utilized in the test course. An advance warning sign is visible on the approach. Flashing light signals and gates are installed at both tracks. The approach angle is 90 degrees. Sight obstructions lie within the northern quadrant as shown in Figure E-1. This crossing was classified as a Type 2R crossing because of the need to look right in order to obtain a clear view of potential track activity.

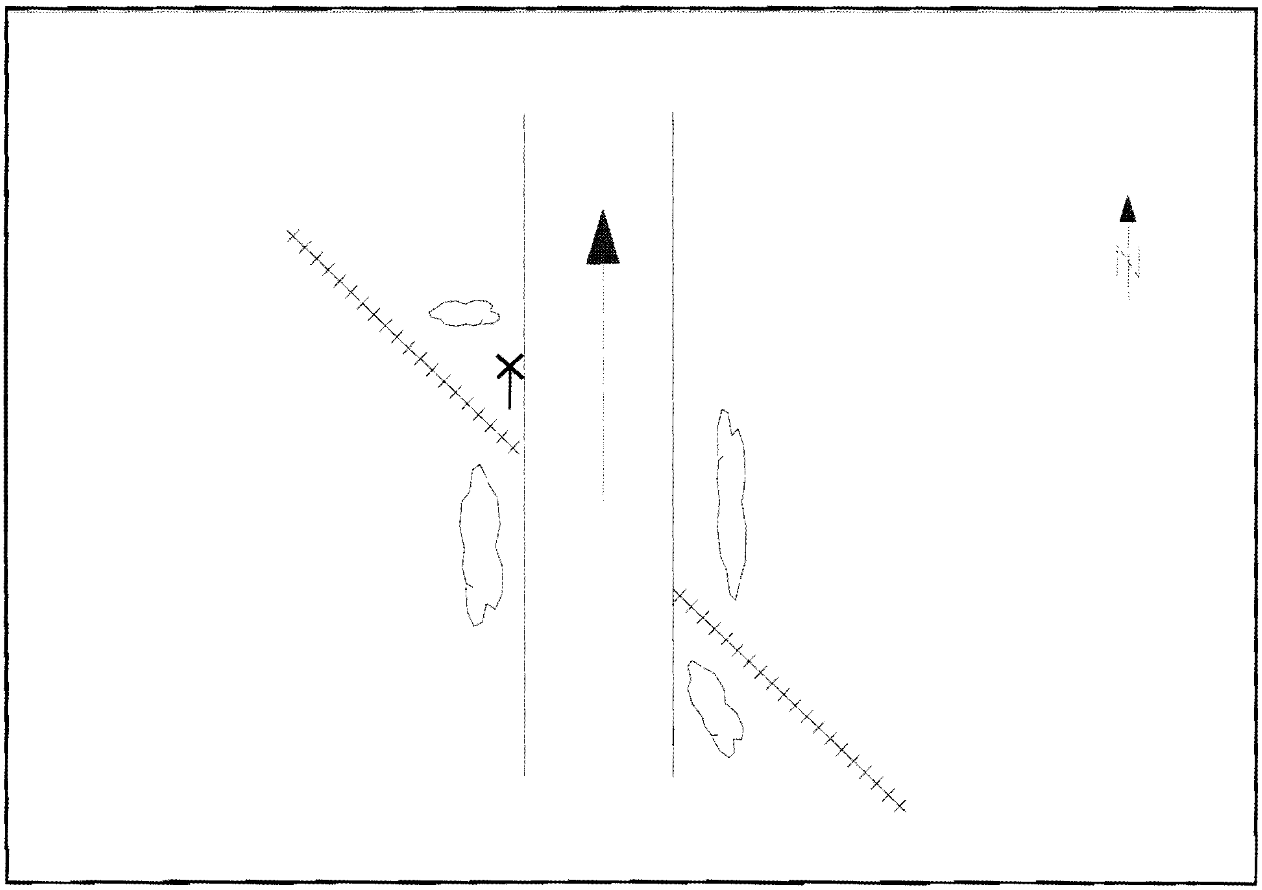
Figure E-1. Villa Maria Road Crossing



Finfeather Road
(Closed Crossing)

One closed crossing was included in the course which was located a quarter mile before the intersection of Finfeather Road and Carson Street. The railroad tracks once crossed the highway at a 45-degree angle and a moderately high profile. The crossing is now closed and the tracks have been sealed with asphalt. However, visual cues within the driver's immediate field of view are characteristic of a typical approach to a grade crossing. A crossbuck still remains at the crossing on the southbound approach. Likewise, the raised profile is indicative of some shared right-of-way (i.e., intersection, highway-railroad grade crossing, or utility easement). A fence line parallels each side of the highway and continues across the tracks. Vegetation is overgrown throughout the crossing area. Figure E-2 shows an aerial view of the crossing scenario.

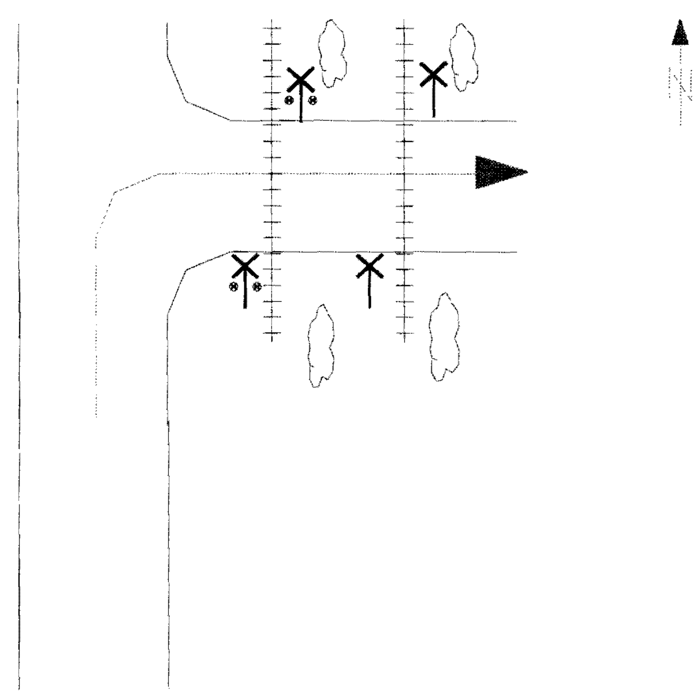
Figure E-2. Closed Crossing along Finfeather Road



Dodge Street at Finfeather Road
(USDOT No. 743204N)

The Dodge Street crossing is located at the intersection of Dodge Street with Finfeather Road. In approaching the crossing, the test subject has been driving parallel to the railroad tracks for approximately two miles. Through train volume is 25 trains per day with a train speed limit of 40 km/h (25 mph). Vehicular volume is estimated to be 3,990 ADT. Only one of the five accidents at this crossing involved a train. No fatalities have been reported. The eastbound approach was utilized in the test course. An advance warning sign is visible on the approach. Flashing light signals and gates are installed at the tracks and angled so that drivers may detect signal activation along Finfeather Road prior to turning onto Dodge Street. The approach angle is 90 degrees. Sight obstructions lie within the northern and southern quadrants as shown in Figure E-3. This crossing was classified as a Type 2R crossing because of the need to look right in order to obtain a clear view of potential track activity. While driving north on Finfeather Road, no additional head or eye movement is needed to observe potential activity down the left or (north-most) part of the track. Shown within Figure E-3 is the adjacent passive crossing along Dodge Street which will be further discussed on the next page.

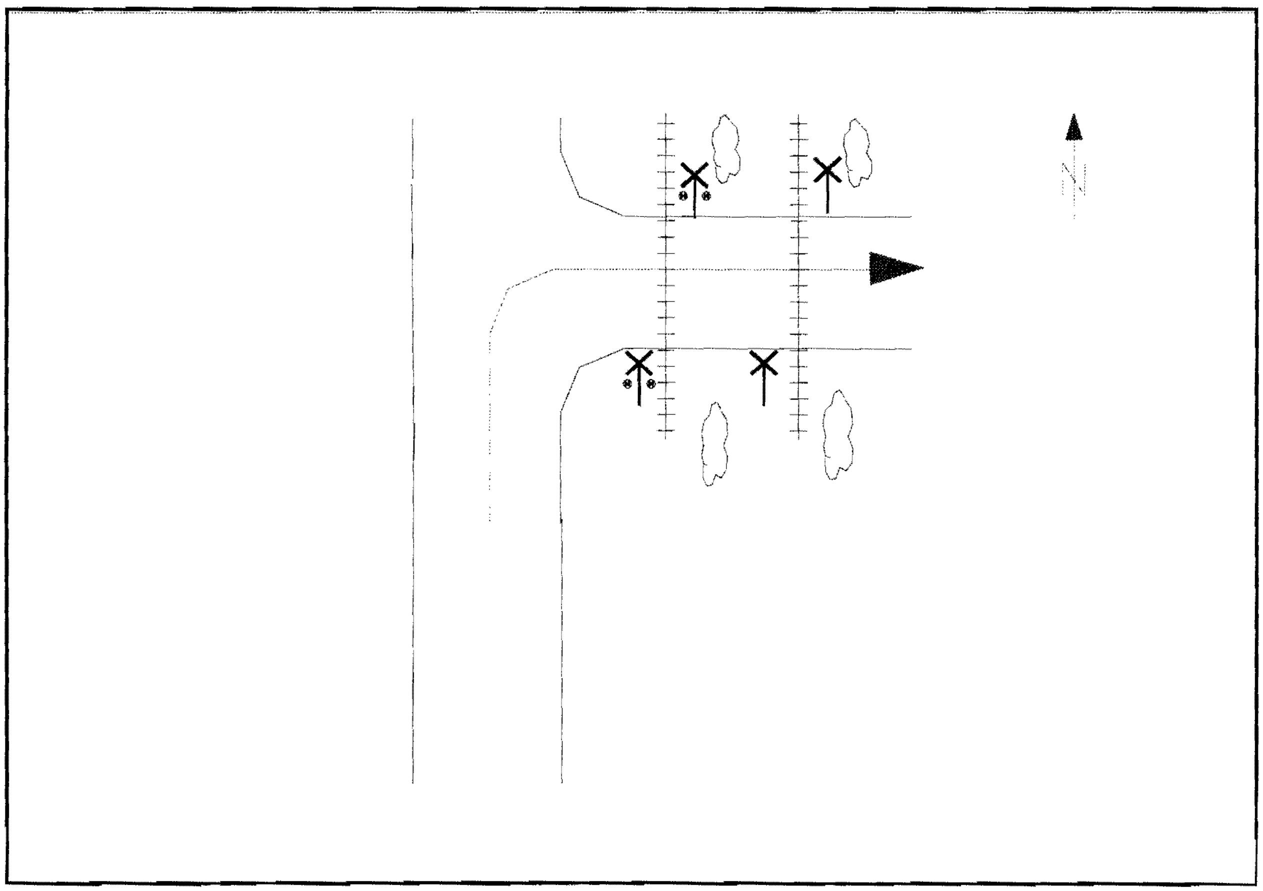
Figure E-3. Dodge Street Crossing (at Finfeather Road)



Dodge Street near Fountain Avenue
(USDOT No. 430155D)

An industrial spur track is located just east of the active Dodge Street crossing at Finfeather Road. The Texas crossing summary database lists the train volume per day as zero and a train speed limit of 15 km/h (10 mph). No advance warning sign is provided specifically for this passive crossing probably due to its close proximity to the preceding active crossing at Finfeather Road. Vehicular volume is estimated to be 4,060 ADT. Only one accident has been reported, and the accident did not involve a train. The eastbound approach was utilized in the test course. Crossbucks mark the location of the tracks. The approach angle is 90 degrees. Sight obstructions lie within all four quadrants as shown in Figure E-4 (identical to Figure E-3). This passive crossing was classified as a Type 3P crossing because the warning devices do not alert the driver of train activity along the track. Drivers must slow to look and listen in both directions for approaching trains.

Figure E-4. Dodge Street Crossing (near Fountain Avenue)



Dodge Street near College Avenue
(USDOT No. 430137F)

This crossing is located just prior to the intersection of Dodge Street and College Avenue. The moderately high profile and slight curve of the roadway at the crossing make it slightly difficult to see oncoming vehicles. However, the roadway width at the crossing includes two full lane widths significantly reducing any concern of colliding with an oncoming vehicle at the crossing. Through train volume is 7 trains per day with a train speed limit of 100 km/h (60 mph). Vehicular volume is estimated to be 4,060 ADT. No accidents have been reported. An advance warning sign is visible on the approach. Flashing light signals and gates are installed at the tracks along with flashing signals mounted on cantilevers which project over the travel lanes. The approach angle is slightly skewed from 90 degrees on the eastbound approach utilized in the test course. Sight obstructions lie within all four quadrants as shown in Figure E-5. This crossing was classified as a Type 3A crossing because of the need to look both directions in order to obtain a clear view of potential track activity.

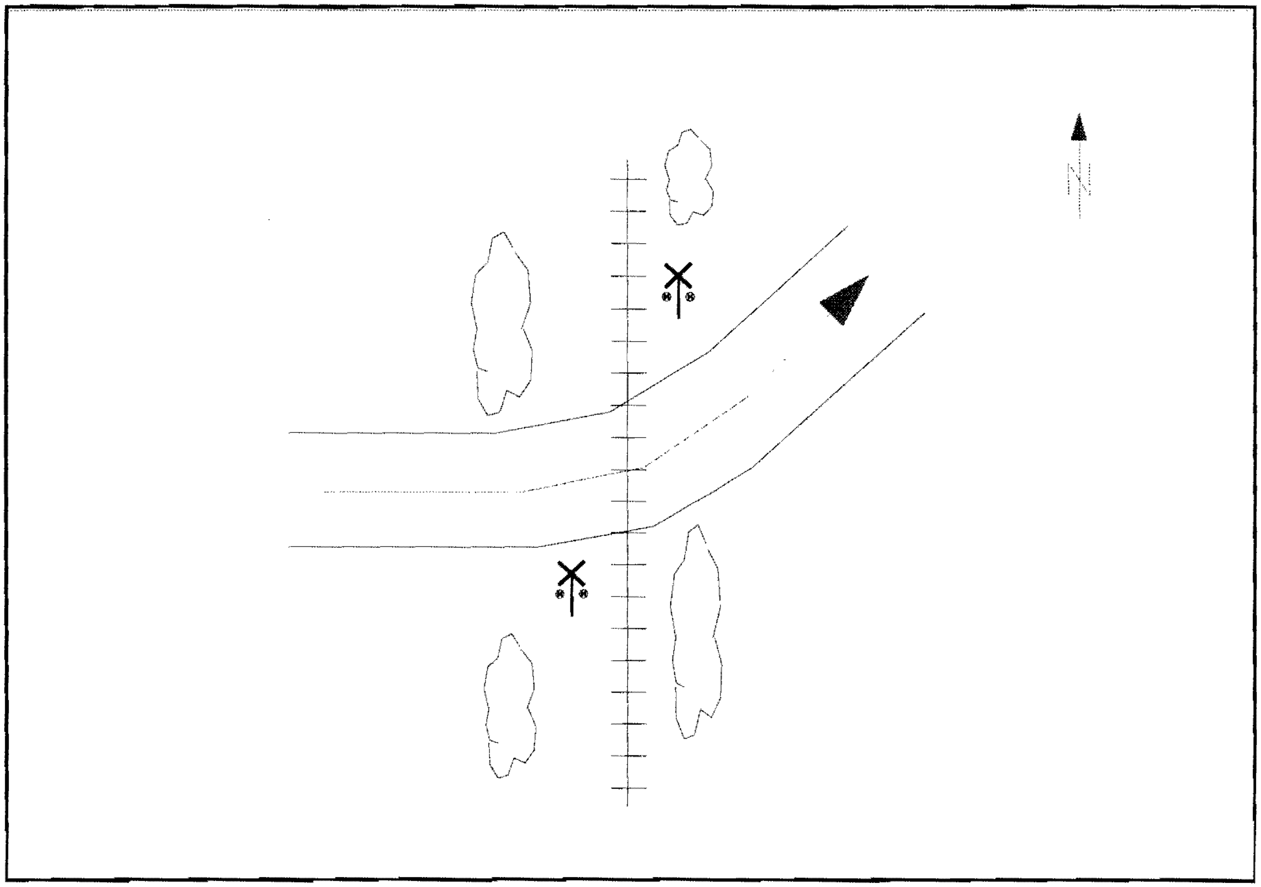
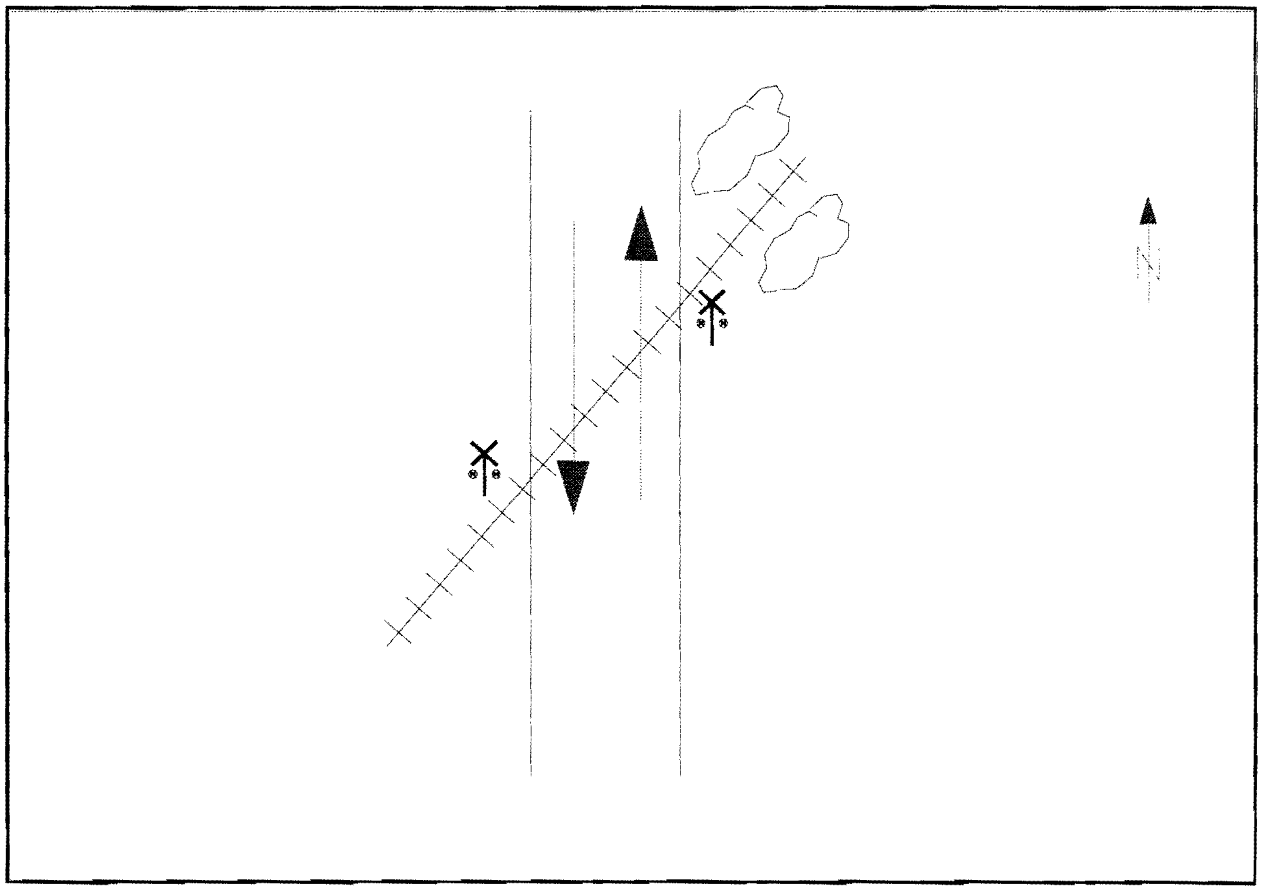


Figure E-5. Dodge Street Crossing (near College Avenue)

College Avenue - Northbound and Southbound
(USDOT No. 743201T)

The College Avenue crossing is located near 32nd Street. Through train volume is 25 trains per day with a train speed limit of 40 km/h (25 mph). Vehicular volume is estimated to be 13,620 ADT. Three of the seven accidents involved a train. No fatalities have been reported. Both the northbound and southbound approaches were utilized in the test course. Flashing light signals and gates are installed at the crossing. The roadway crosses the tracks at a 45- degree angle. No advance warning sign has been installed on either approach. A sign on the northbound approach does warn drivers to "look for vehicles backing." When the signals are activated at this crossing, many northbound vehicles will back up to use an alternate route that parallels rather than wait to cross the track. From the southbound approach, sight obstructions exist along the left side of the roadway as shown in Figure E-6. The sharp approach angle provides a clear view of potential track activity in one direction for each approach. This crossing was classified as a Type 2L crossing because of the need to look left in order to obtain a clear view of potential track activity.

Figure E-6. Northbound and Southbound Approach to College Avenue Crossing



Randolph Street
(USDOT No. 430149A)

This passive crossing is located within a residential area. The track lies between two one-way streets (27th Street). The intersection of Randolph and 27th is controlled by a stop sign on Randolph. Crossbucks are installed next to the stop sign. The high profile of the crossing makes it difficult to see oncoming vehicles. Through train volume is 15 trains per day with a speed limit of 100 km/h (60 mph). An advance warning sign is visible on the approach to the crossing. Vehicular volume is estimated to be 170 ADT. Only one accident has been reported, and this accident did not involve a train. The southbound approach was used in the test course. The approach angle is 90 degrees. Sight obstructions lie within all four quadrants as shown in Figure E-7. This passive crossing was classified as a Type 3P crossing because the warning devices do not alert the driver of train activity along the track. Drivers must slow to look and listen in both directions for approaching trains.

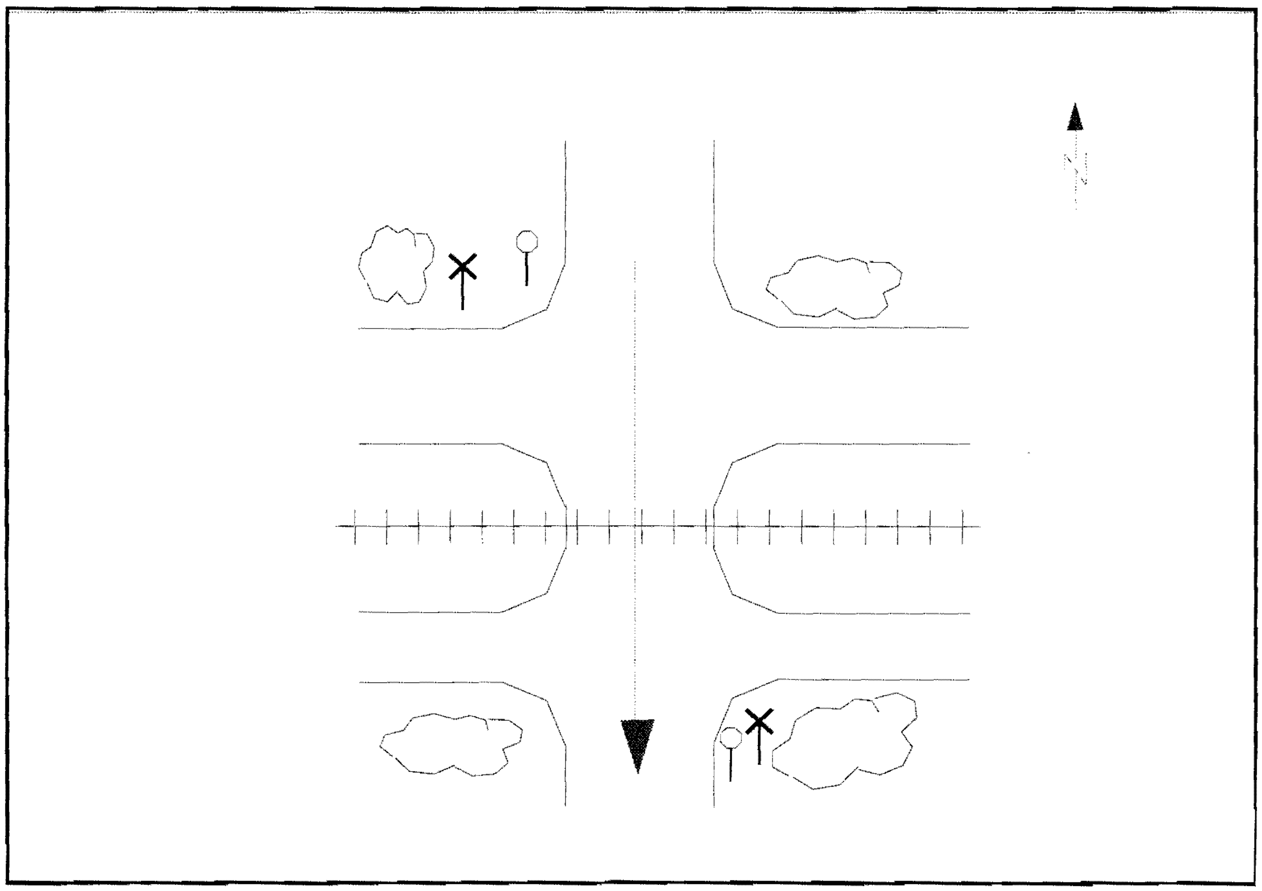


Figure E-7. Randolph Street Crossing

West 28th Street
(USDOT No. 43156K)

The West 28th Street Crossing is located in a rural area, a quarter mile south of the intersection of West 28th with State Highway 21. The test subject has been driving approximately two miles along West 28th Street when the tracks suddenly cross the highway at a sharp angle. An advance warning sign is visible on the approach; flashing light signals and gates are installed at the tracks. Sight obstructions exist along the right side of the approach as shown in Figure E-8. Through train volume is 15 trains per day with a train speed limit of 100 km/h (60 mph). Vehicular volume is estimated to be 740 ADT. Neither of the accidents at this crossing involved a train. No fatalities have been reported. This crossing was classified as a Type 2R crossing because of the need to look right in order to obtain a clear view of potential track activity. While driving west on West 28th Street, no additional head or eye movement is needed to observe potential activity down the left or (west-most) part of the track.

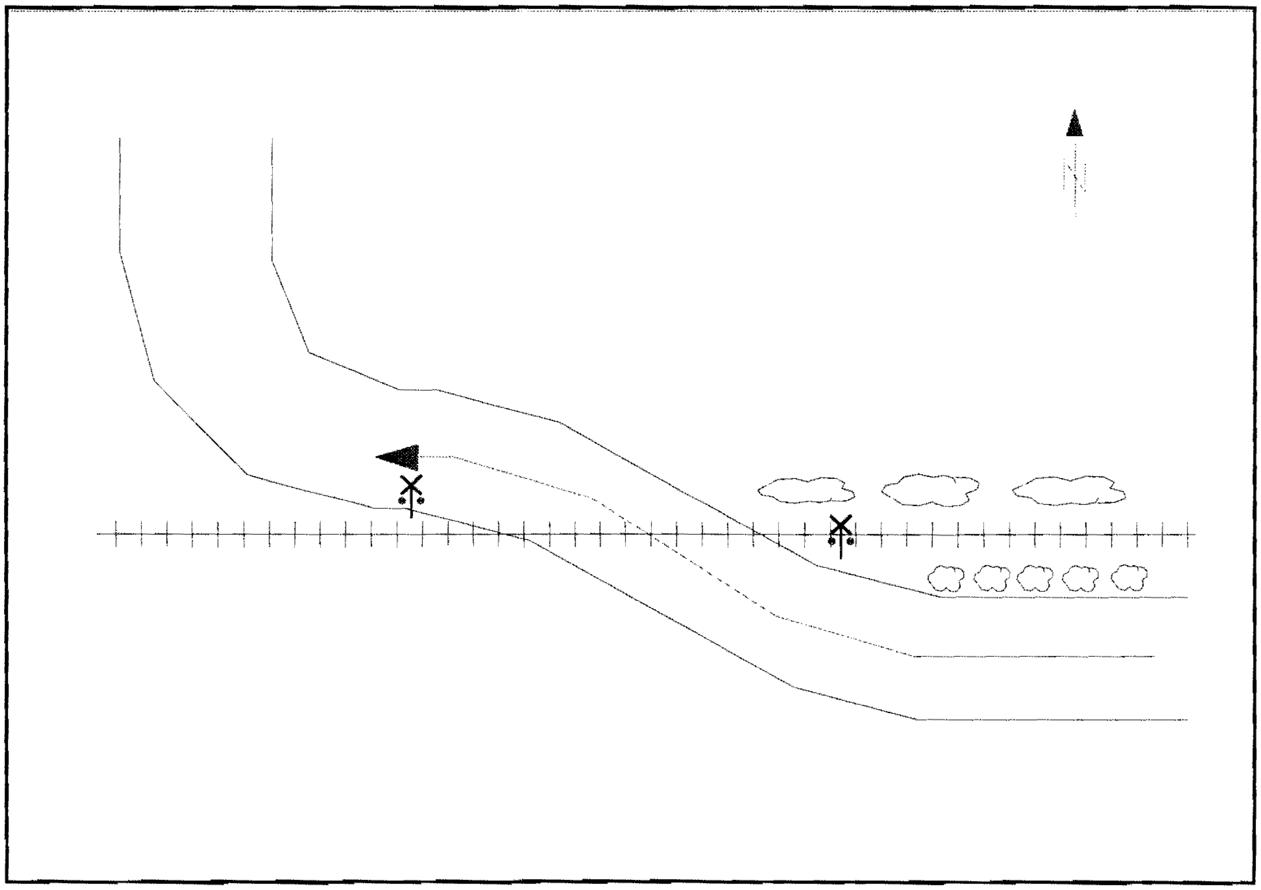


Figure E-8. West 28th Street Crossing

20th Street
(USDOT No. 743192W)

This passive crossing is also located within a residential area near Tabor Road. Crossbucks mark the location of the crossing. There is no stop sign on the approach to the crossing. Mounted on the crossbuck pole is a supplemental plaque indicating two tracks (R15-2). However, closer investigation of the crossing reveals only one railroad track. Through train volume is 22 trains per day with a speed limit of 40 km/h (25 mph). An advance warning sign is visible on the approach to the crossing. Vehicular volume is estimated to be 280 ADT. Only one accident has been reported; this accident involved a train but resulted in no fatalities. The eastbound approach was used in the test course. The approach angle is 90 degrees. Sight obstructions lie within all four quadrants as shown in Figure E-9. This passive crossing was classified as a Type 3P crossing because the warning devices do not alert the driver of train activity along the track. Drivers must slow to look and listen in both directions for approaching trains.

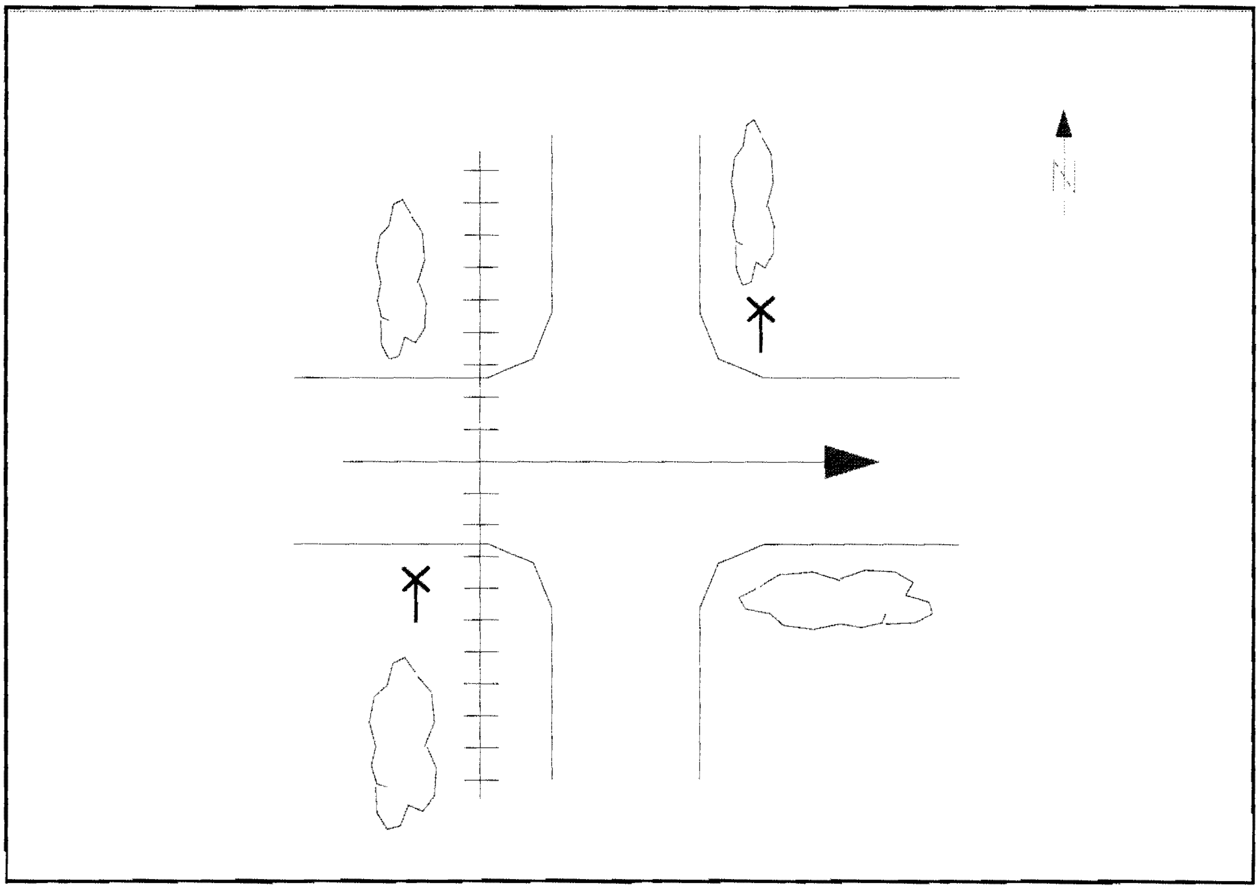


Figure E-9. 20th Street Crossing

West 29th Street
(USDOT No. 743200L)

This crossing is located just prior to the signalized intersection of West 29th Street and College Avenue. An advance warning sign is visible on the approach. Flashing light signals and gates are installed at the tracks along with flashing signals mounted on cantilevers which project over the travel lanes. Through train volume is 25 trains per day with a train speed limit of 40 km/h (25 mph). Vehicular volume is estimated to be 3,180 ADT. The approach angle is 90 degrees. Sight obstructions lie within all four quadrants as shown in Figure E-10. This crossing was classified as a Type 3A crossing because of the need to look both directions in order to obtain a clear view of potential track activity.

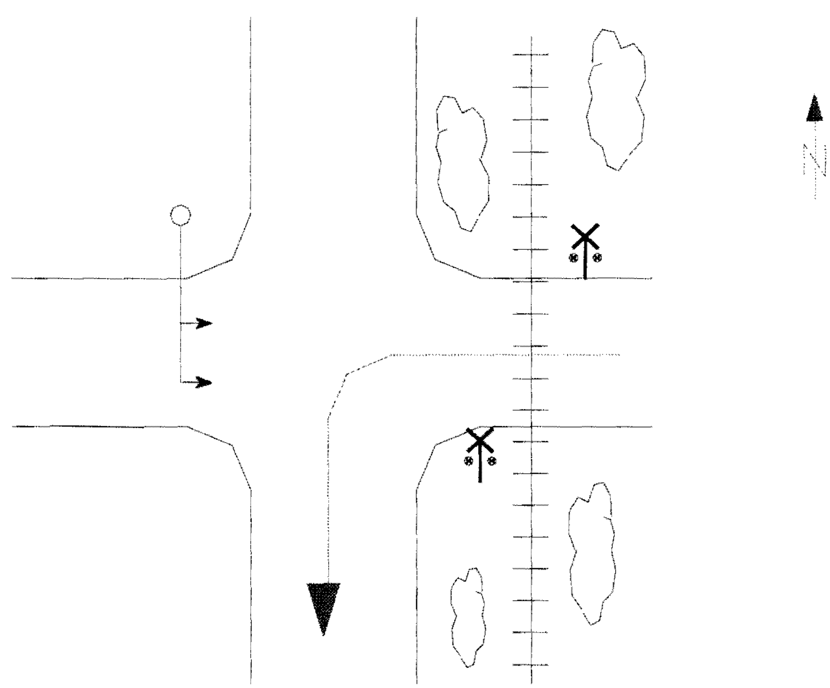


Figure E-10. West 29th Street Crossing

APPENDIX F

DRIVER BEHAVIOR STUDY: DATA COLLECTION FORM EXAMPLE AND CODING INSTRUCTIONS

Table F-1. Example of Driver Behavior Data Collection Form

No.	Crossing Location	Lead Veh.	Traffic Cond.	Looking Behavior	Brake/ Stop	Comments
1	Villa Maria Road	Yes No	Light Mod Heavy	N	N	
				N	N	
				N	N	
2	Finfeather Road (Closed/Out-of-Service)	Yes No	Light Mod Heavy	N	N	
				RL	N	
				N	N	
3	Dodge Street (T-Intersec.)	Yes No	Light Mod Heavy	N	N	
				N	N	
				N	N	
4	Dodge Street (Industrial Siding/Spur Track)	Yes No	Light Mod Heavy	N	N	
				N	N	
				N	N	
5	Dodge Street (Just Before Mn/College)	Yes No	Light Mod Heavy	ROLO	N	
				N	N	
				N	N	
6	Main/College Avenue (NB)	Yes No	Light Mod Heavy	N	N	
				L	D	
				N	N	
7	Randolph Street	Yes No	Light Mod Heavy	LR	R	
				LR	N	
				N	CS	
8	West 28th Street (Stop Sign Near X-ing)	Yes No	Light Mod Heavy	ROLO	N	
				N	D	
				N	N	

Table F-1. Example of Driver Behavior Data Collection Form (Continued)

No.	Crossing Location	Lead Veh.	Traffic Cond.	Looking Behavior	Brake/ Stop	Comments
9	20th Street (No Stop Sign)	Yes No	Light Mod Heavy	RLG	N	
				L	R	
				N	N	
10	29th Street	Yes No	Light Mod Heavy	N	N	
				LR	N	
				N	N	
11	Main/College Avenue (SB)	Yes No	Light Mod Heavy	L	N	
				R	N	
				N	N	

Note: Looking Behavior and Brake/Stop columns provide the behavior observed within each of the three zones. The bottom most row under these columns at each crossing represents the observations made within the approach zone. The middle row represents the observations made within the non-recovery zone. The top most row indicates the observations made within the hazard zone. "LR" within one zone indicates that the participant first looked left and then right within that particular zone.

Lead Vehicle

Is the driver operating the lead vehicle (not within a platoon of vehicles) when approaching the grade crossing?

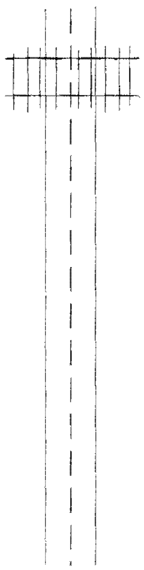
Y	=	Yes
N	=	No

Traffic Conditions

L	=	Light traffic
M	=	Moderate traffic
H	=	Heavy traffic

***Location* of Looking Behavior and Deceleration Maneuvers**

*** Only consider head or eye movements directed toward potential activity on the track**



C: **Hazard Zone**
(Within 15 feet of the nearside tracks)

B: **Non-Recovery Zone**
(Within the area defined by the stopping sight distance required by the vehicle speed to avoid a collision at tracks)

A: **Approach Zone**
(Within the area where the driver first begins to formulate actions needed to avoid colliding with trains; *Note*: the advance warning sign is located within this area)

***Type* of Looking Behavior**

*** Only consider head or eye movements directed toward potential activity on the track**

L	=	Left	**LO**	=	Looked left on tracks
R	=	Right	**RO**	=	Looked right on tracks
B	=	Both	**LG**	=	Glanced left
N	=	None	**RG**	=	Glanced right

***Type* of Deceleration Maneuvers**

R	=	Slowed due to roughness of crossing surface (not out of caution)
N	=	No decrease in speed
D	=	Decrease in speed
SO	=	Stop on top of tracks
RS	=	Rolling stop
CS	=	Complete stop

APPENDIX G

DRIVER BEHAVIOR STUDY: DEBRIEFING STATEMENT AND SURVEY INSTRUMENT

Informed Consent

This research is being conducted by the Texas Transportation Institute, part of the Texas A&M University System, to assist the Texas Department of Transportation in the development of public education materials regarding the driving environment. Further explanation as to the purpose of the study will be provided upon completion of the experiment. The experiment should take no more than 1½ hours to complete. Up to 90 people may participate in this study. The first part of the study involves approximately 30 minutes of driving along a predetermined route in the Bryan/College Station area. We ask that you drive your personal vehicle so that you are in an environment that is suited to your personal needs for the driving task. A researcher will accompany you during the study. The researcher will direct you along the course. We ask that you drive as you would normally drive. No situations that you might encounter during the study have been arranged or prepared by the research team along the predetermined route.

As a participant, I agree to:

- ☐ Provide proof of a valid driver's license before beginning the study.
- ☐ Provide proof of current insurance papers for the car that I will be driving during the study.
- ☐ Complete a participant information form which will provide relevant information needed for this study. I understand that I will be given a numerical code on the participant information form. I understand that confidentiality will be maintained because no attempt will be made to reference my records to my actual name or other personal information.
- ☐ Drive along the driving course as I would normally drive.
- ☐ Be compensated for participating in this study. I have been informed that I will receive $25 in cash immediately following my participation in the study unless I am an employee of the Texas Transportation Institute. I understand that participation is voluntary and that I will receive $5 if I withdraw prior to the completion of the driving portion of the experiment.

This research study has been reviewed and approved by the Institutional Review Board - Human Subjects in Research, Texas A&M University. For research related problems or questions regarding research subjects' rights, the Institutional Review Board may be contacted through Dr. Richard E. Miller, IRB Coordinator, Office of Vice President for Research and Associate Provost for Graduate Studies at (409) 845-1811. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. I have been given a copy of this consent form.

______________________________ ______________________________

Signature of Subject Date Signature of Researcher Date

If I have further questions, I may contact:
Dr. Dan Fambro (409) 845-1717 or Lee Anne Shull (409) 862-3553
Texas Transportation Institute, The Texas A&M University System, College Station, Texas

In-Vehicle Driver Behavior Study

Debriefing Statement

The purpose of this study is to observe driver behavior at highway-railroad grade crossing situations. A **grade crossing** is the intersection of a roadway and a railroad track at the same level. Texas has the most grade crossings in the nation with over 18,000 public and private crossings. Unfortunately, Texas also leads the nation in the number of grade crossing **collisions, deaths, and injuries**. Texas is, therefore, quite concerned about safety at grade crossings.

In an effort to decrease the tragedies at highway-railroad grade crossings, the Texas Department of Transportation is interested in how drivers are actually behaving at grade crossings. Driver behavior serves as an indicator of the perceived risk that the driver acknowledges. Once unsafe driving behaviors are identified, they can be better targeted in grade crossing safety education campaigns. Likewise, driver needs can be better addressed in the design of railroad traffic control devices and enforcement programs.

1. **How often do you usually encounter grade crossings?**

□ _______ (Number of times) per day/week (please circle)	(Occasionally)	73.3%
□ Rarely	(Regularly)	26.7%
□ Other (please specify) ____________________		

2. Highway-railroad grade crossings are classified as "active" or "passive" depending on the ability of the warning system to indicate the presence of an approaching train. For example, an "active" crossing will have flashing light signals, automatic gates, or bells that activate when a train is approaching. A "passive" crossing uses signs to indicate where the railroad tracks cross the roadway. No additional warning is provided when a train is approaching.

   Given this description of the difference between an "active" and a "passive" crossing, what should you, as the driver, do when approaching an "active" crossing?

   What should you, as the driver, do when approaching a "passive" crossing?

3. **I <u>first</u> become aware of a railroad grade crossing...**

□ When I feel the vibration of my tires on the tracks.	0.0%
□ When I see the advance warning sign on the approach to the crossing.	46.7%
□ When I see flashing signals and/or lowering gates.	10.0%
□ When I see the pavement markings on the roadway just before the crossing.	30.0%
□ Other (please specify) ____________________	13.3%

4. **My first concern when approaching a grade crossing is...**

Is a train coming?	50.0%
Are the lights flashing and gates lowering?	16.7%
Roughness of crossing surface	13.3%
Reducing speed to look and stop if necessary	10.0%
Getting across	3.3%
Is a clear view of track activity blocked by sight obstructions?	3.3%
Is the traffic stopped on the far side of the crossing?	3.3%
Look both ways at the crossing	3.3%
Look for sign	3.3%

5. Have you completed a driver's education course in the past year?

□ Yes (Defensive Driving, Driver's Education, Other ________)	20.0%
□ No	80.0%

6. Have you ever driven <u>under lowering gates</u> or <u>around lowered gates</u> at a railroad-highway grade crossing?

□ Yes (Please explain) ______________________________	60.0%
□ No	40.0%

7. How many moving citations (excluding parking violations) have you received within the last 3 years? (For example: speeding tickets, accident tickets, etc.)

Number____________________________________	(None)	70.0%
Reason____________________________________	(One or more)	30.0%

8. Are you aware that driving around or under a crossing gate is against the law?

□ Yes	76.7%
□ No	23.3%

Participant Information Form
For Ensuring Broad Representation of Texas Driving Population

1. **What is your age?**

□ 18-25	33.3%
□ 30-45	33.3%
□ 55+	33.3%

2. **How many years of driving experience do you have?**

□ Less than 1 year	0.0%
□ Between 1 and 5 years	13.3%
□ More than 5 years	86.7%

3. **What is your occupation?**

____

4. **What is the highest level of school you have completed?**

□ Less than high school	6.7%
□ High school graduate (or equivalent)	16.7%
□ Trade school graduate	3.3%
□ Some college	36.7%
□ College graduate	20.0%
□ Advanced degree	16.7%

5. **Do you prefer to drive during the day rather than at night?**

□ Yes, because...	
□ I am concerned for my safety when driving at night	26.7%
□ It is harder for me to see when driving at night	23.3%
□ Other (please specify) ______________	13.3%
□ Not necessarily	36.7%

6. **Please provide the following information about the car you are using today:**

Make______________________

Model______________________	Newer Model (1986-1996)	86.7%
	Older Model	13.3%
Year______________________		

Transmission:	Automatic	76.7%
	Manual	23.3%

ID # ______

Male	**Female**
50%	50%

In-Vehicle Driver Behavior Study
Participant Information Form

(to be **completed by the researcher** and
attached as a cover sheet to all data recorded for the participant)

Date ______________________________

M	T	W	R	F	Sat	Sun
10.0%	3.3%	33.3%	33.3%	16.7%	3.3%	0.0%

Start Time ______________

End Time ______________

Weather ______________

Ethnicity

□ African-American	16.7%
□ Caucasian	60.0%
□ Asian	3.3%
□ Hispanic	20.0%
□ Other (please specify)	______

Closing Questions
(to be asked **verbally** by the researcher **at the conclusion of the study**)

How would <u>you</u> characterize your husband's/wife's (or close friend's) driving behavior?

(**<u>If</u>** the participant is having trouble answering, present the following examples:
aggressive, day-dreaming, fast, cautious, excellent)

____

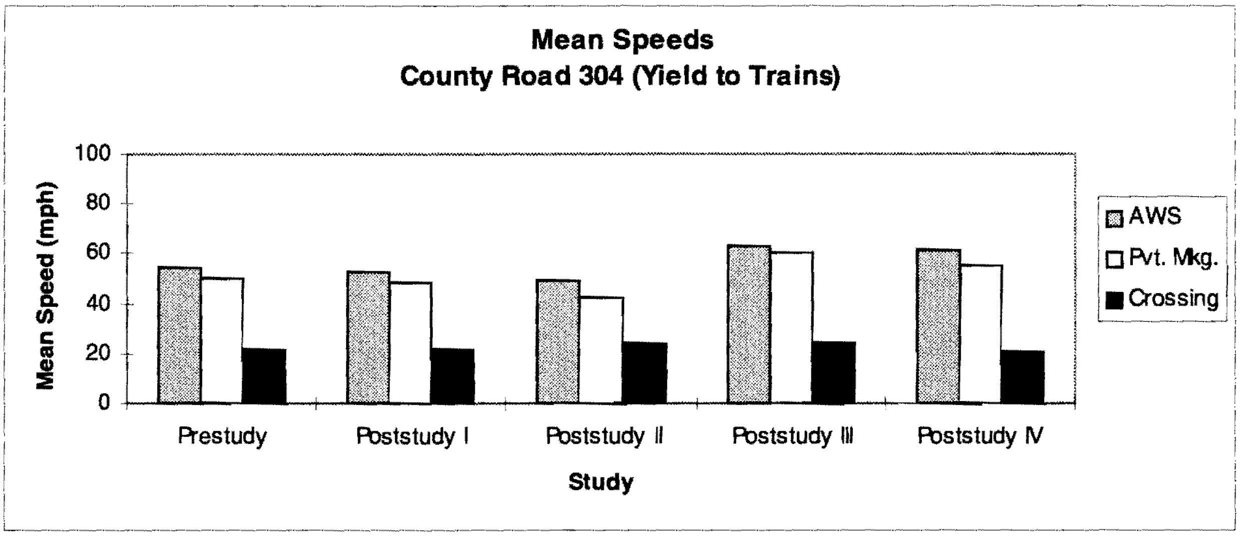
How would your husband/wife (or close friend) characterize <u>your</u> driving behavior?

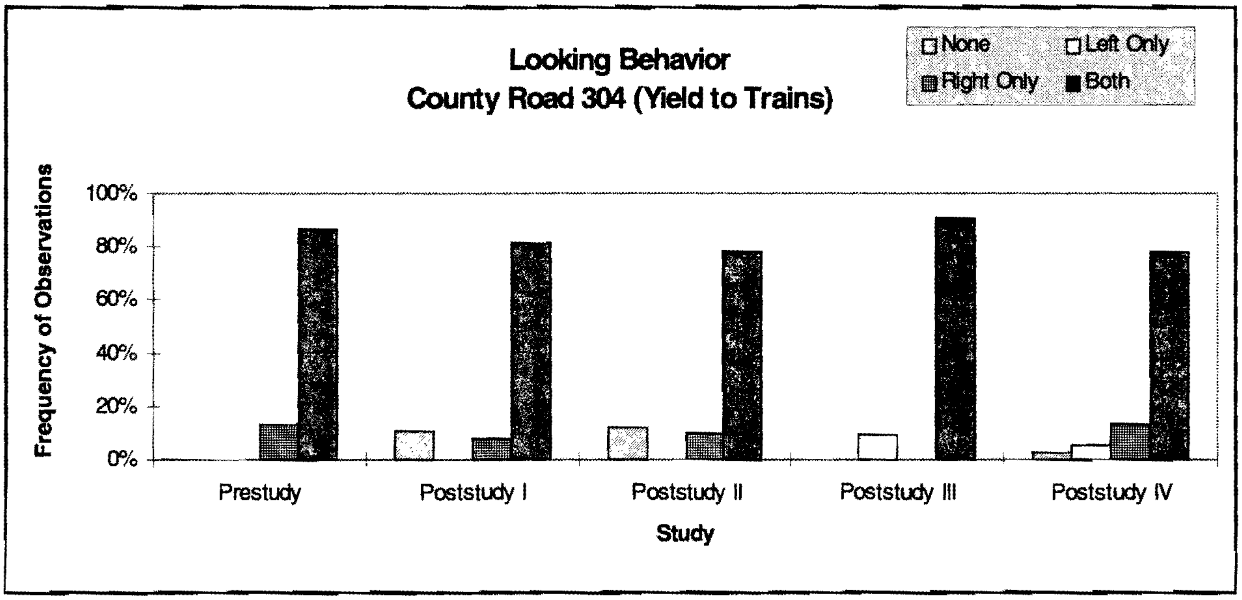
(**<u>If</u>** the participant is having trouble answering, present the following examples:
aggressive, day-dreaming, fast, cautious, excellent)

____

APPENDIX H

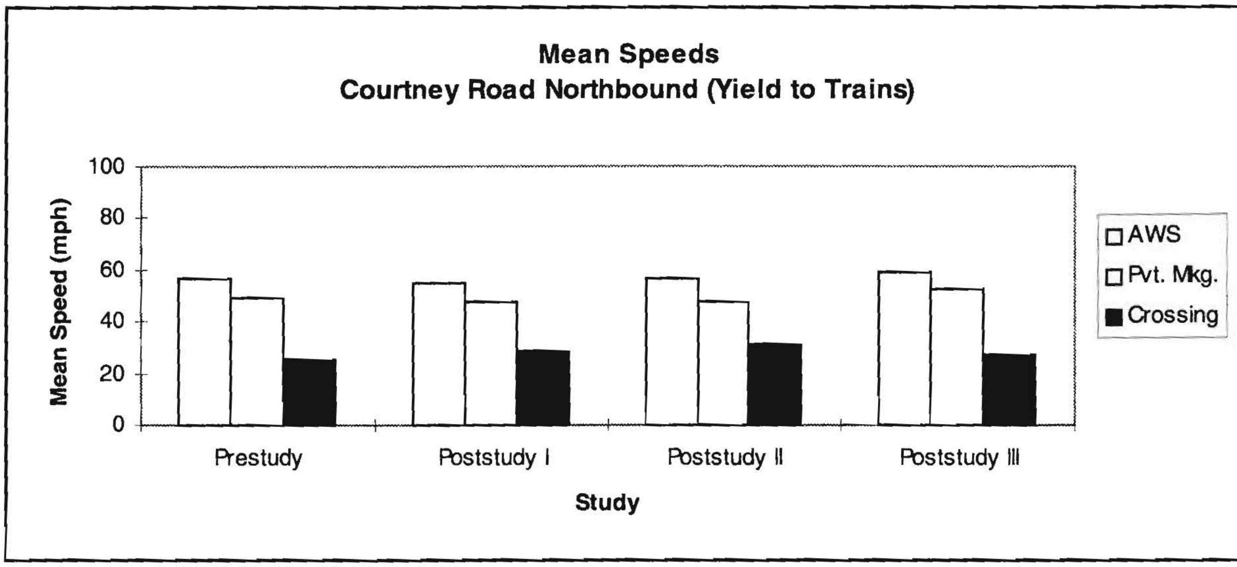
EXPERIMENTAL PASSIVE SIGN SYSTEMS: SPEED AND LOCATION DATA

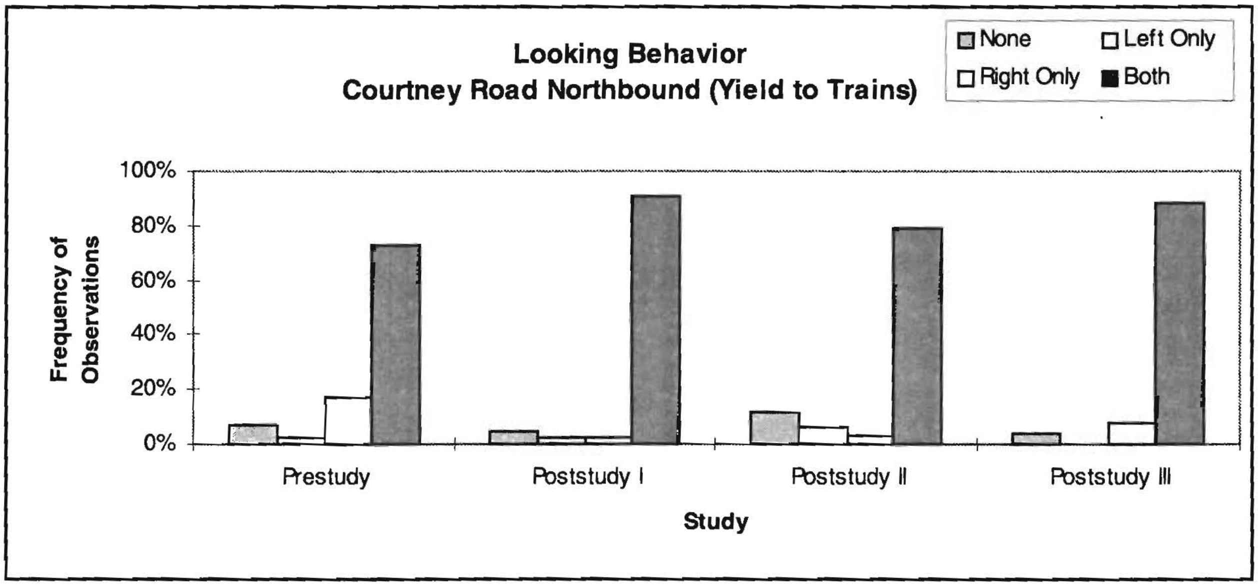




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III		Poststudy IV	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	54.67	12.16	52.34	9.81	49.39	9.01	63.12	12.34	61.06	8.8
Pvt. Mkg.	49.87	10.42	48.3	10.62	41.9	9.71	60.42	12.22	55.22	8.61
Crossing	21.3	6.7	21.5	11.28	24.37	8.34	24.48	12.62	21.06	11.74

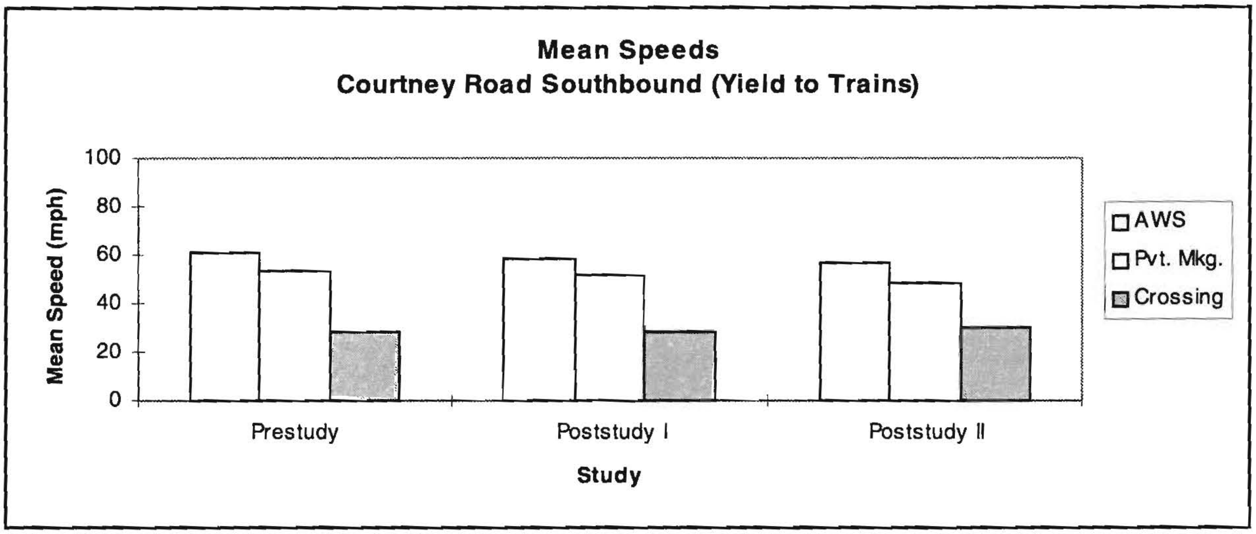
Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III		Poststudy IV	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	0	0.0	7	10.8	7	11.9	0	0.0	1	2.7
Left Only	0	0.0	0	0.0	0	0.0	2	9.1	2	5.4
Right Only	10	13.0	5	7.7	6	10.2	0	0.0	5	13.5
Both	67	87.0	53	81.5	46	78.0	20	90.9	29	78.4
Totals	77	100.0	65	100.0	59	100.0	22	100.0	37	100.0

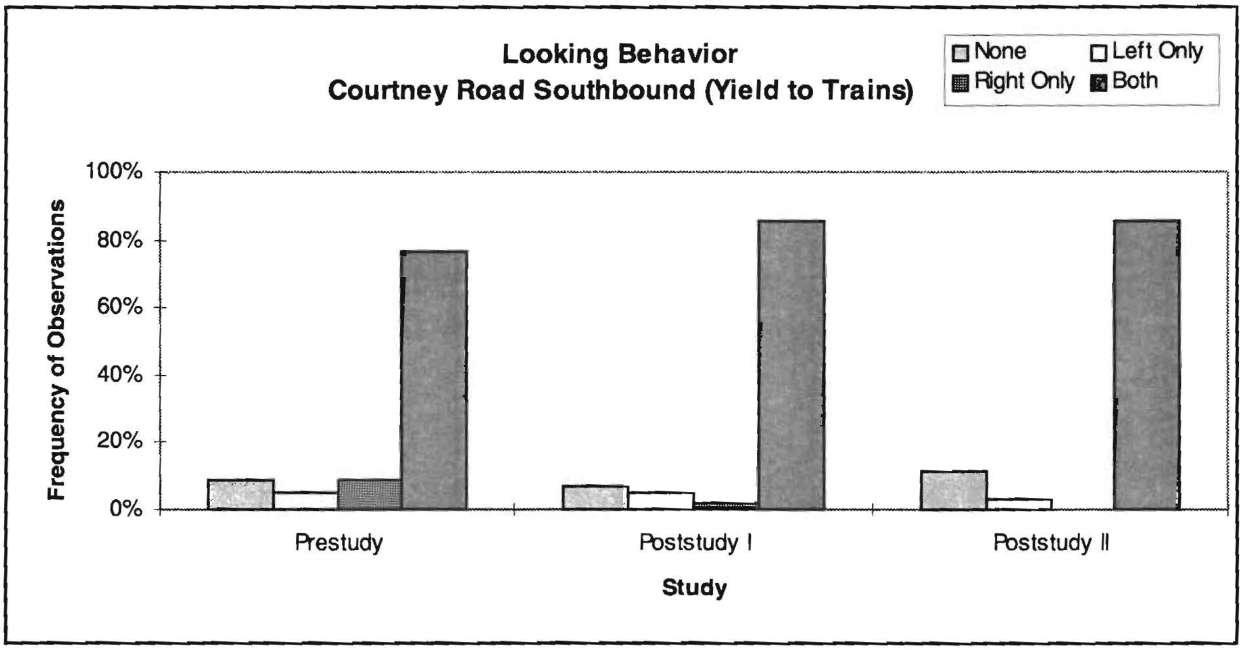




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	56.62	15.6	54.86	11.87	56.74	10.91	59.2	10.56
Pvt. Mkg.	49.25	15.81	47.5	12.06	47.78	11.18	52.58	8.64
Crossing	25.57	12.98	28.48	9.52	31.02	9.07	27.02	12.14

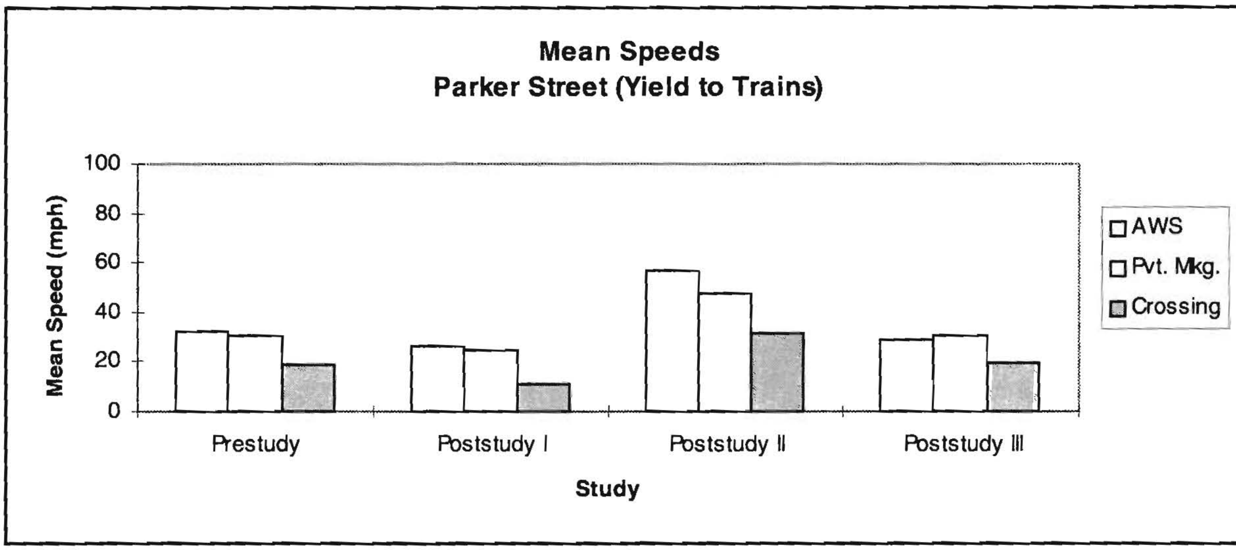
Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	3	7.3	2	4.8	7	11.3	1	3.8
Left Only	1	2.4	1	2.4	4	6.5	0	0.0
Right Only	7	17.1	1	2.4	2	3.2	2	7.7
Both	30	73.2	38	90.5	49	79.0	23	88.5
Totals	41	100.0	42	100.0	62	100.0	26	100.0

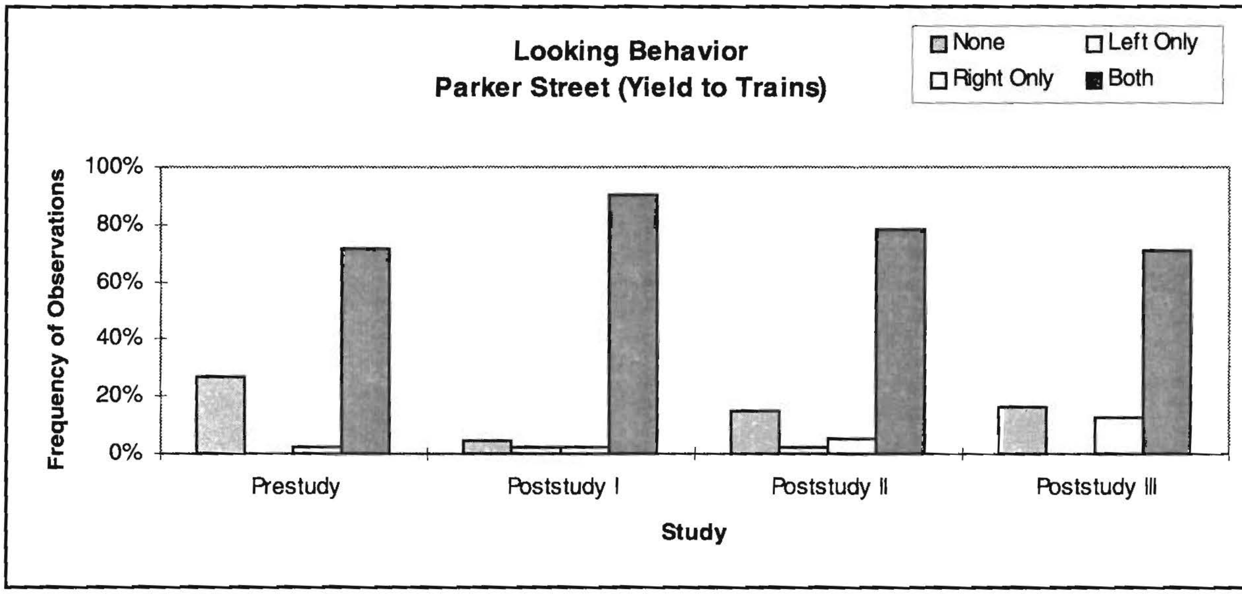




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	60.91	12.59	58.66	12.69	56.59	12.27
Pvt. Mkg.	53.62	11.44	51.31	11.26	48.35	12.16
Crossing	28.27	12.21	27.92	8.1	30.14	8.11

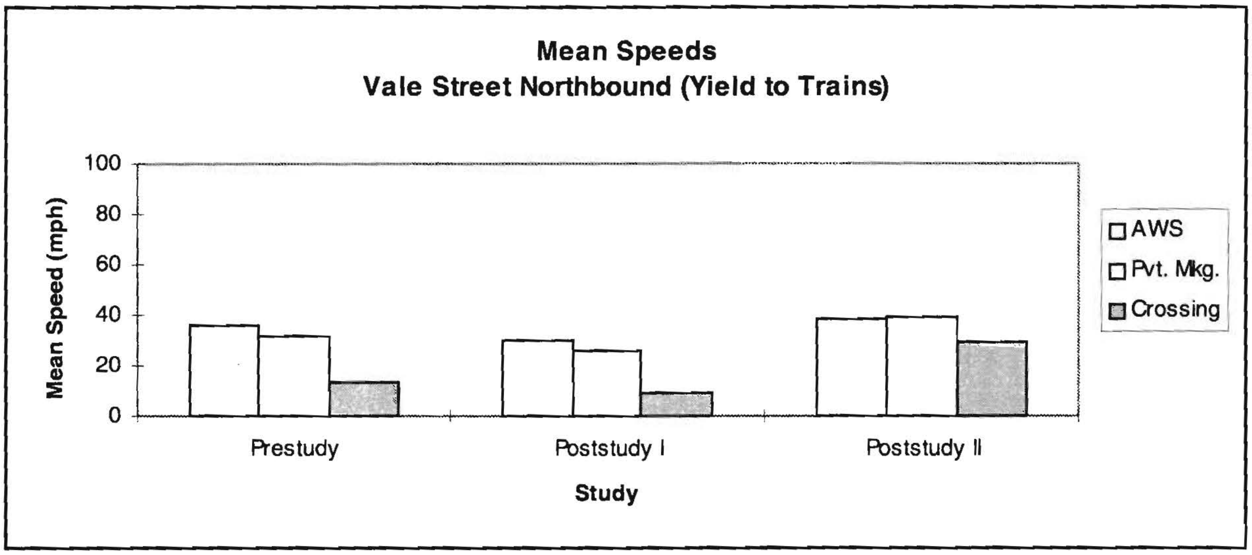
Looking Behavior	Prestudy		Poststudy I		Poststudy II	
	Number	Percent	Number	Percent	Number	Percent
None	5	8.9	4	7.1	4	11.4
Left Only	3	5.4	3	5.4	1	2.9
Right Only	5	8.9	1	1.8	0	0.0
Both	43	76.8	48	85.7	30	85.7
Totals	56	100.0	56	100.0	35	100.0

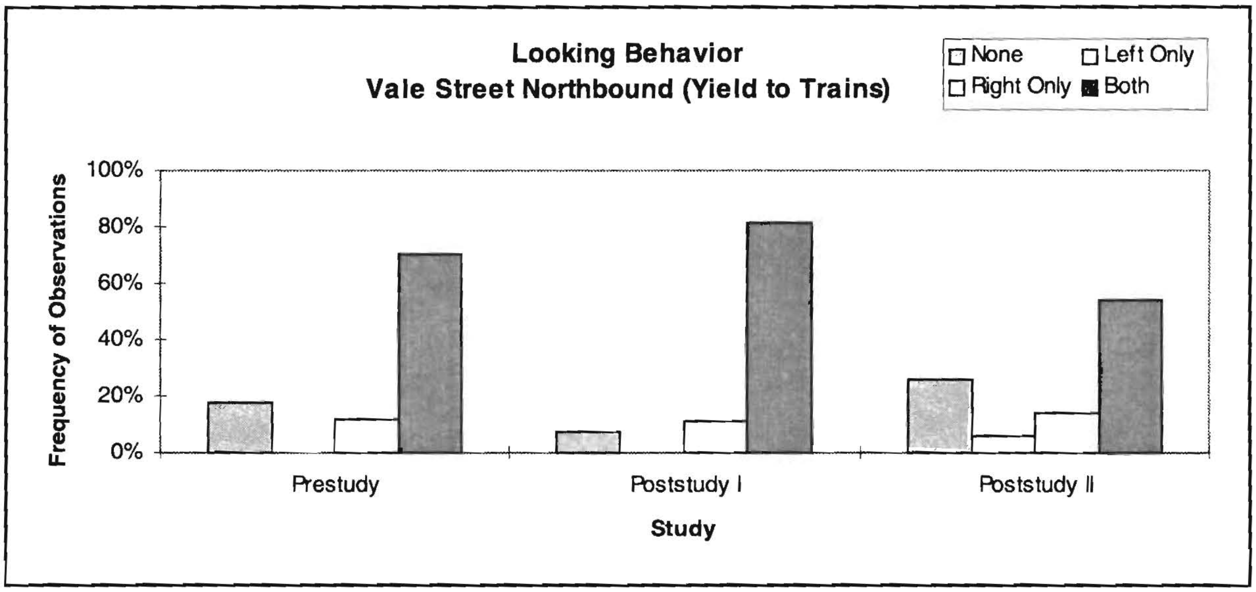




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	32.61	7.28	26.64	6.48	56.74	10.91	29.17	7.74
Pvt. Mkg.	30.78	6.72	24.22	7.66	47.78	11.18	30.27	7.65
Crossing	18.72	6.38	11.15	6.26	31.02	9.07	19.87	5.71

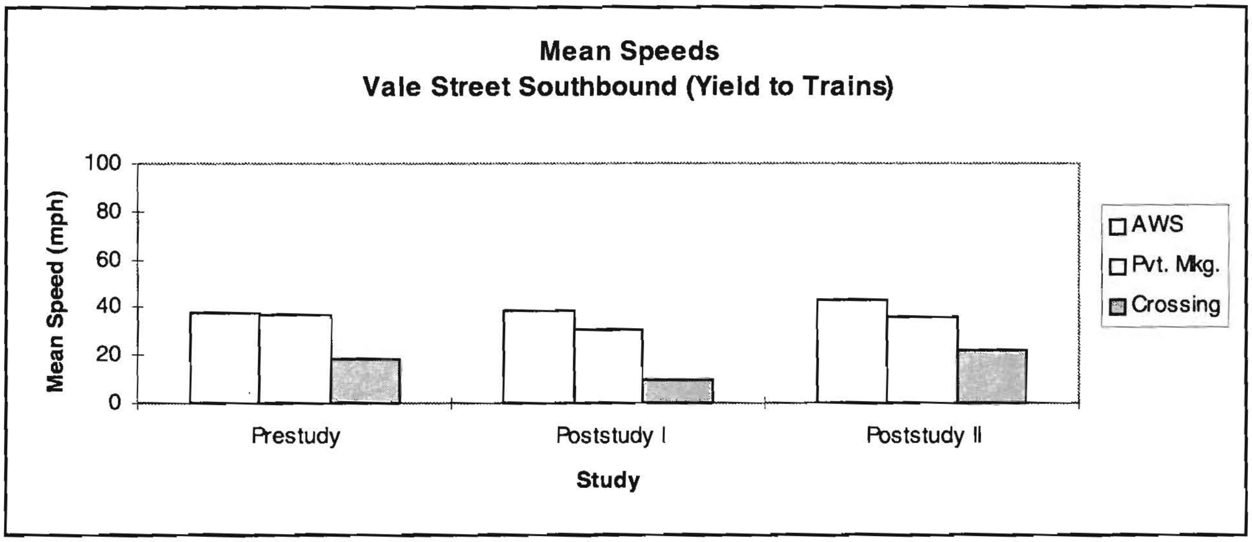
Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	13	26.5	2	4.8	6	14.6	4	16.7
Left Only	0	0.0	1	2.4	1	2.4	0	0.0
Right Only	1	2.0	1	2.4	2	4.9	3	12.5
Both	35	71.4	38	90.5	32	78.0	17	70.8
Totals	49	100.0	42	100.0	41	100.0	24	100.0

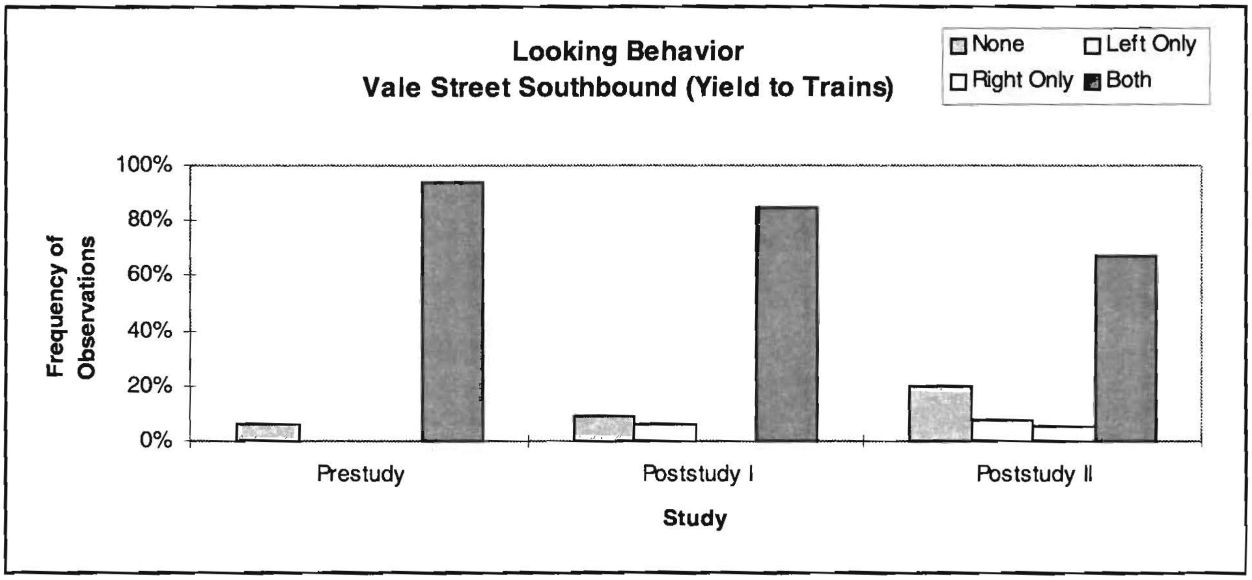




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	36.16	15.14	30.18	7.34	37.94	8.9
Pvt. Mkg.	31.57	11.98	26.16	6.21	39.14	9.9
Crossing	13.01	13.18	8.9	4.18	28.91	8.13

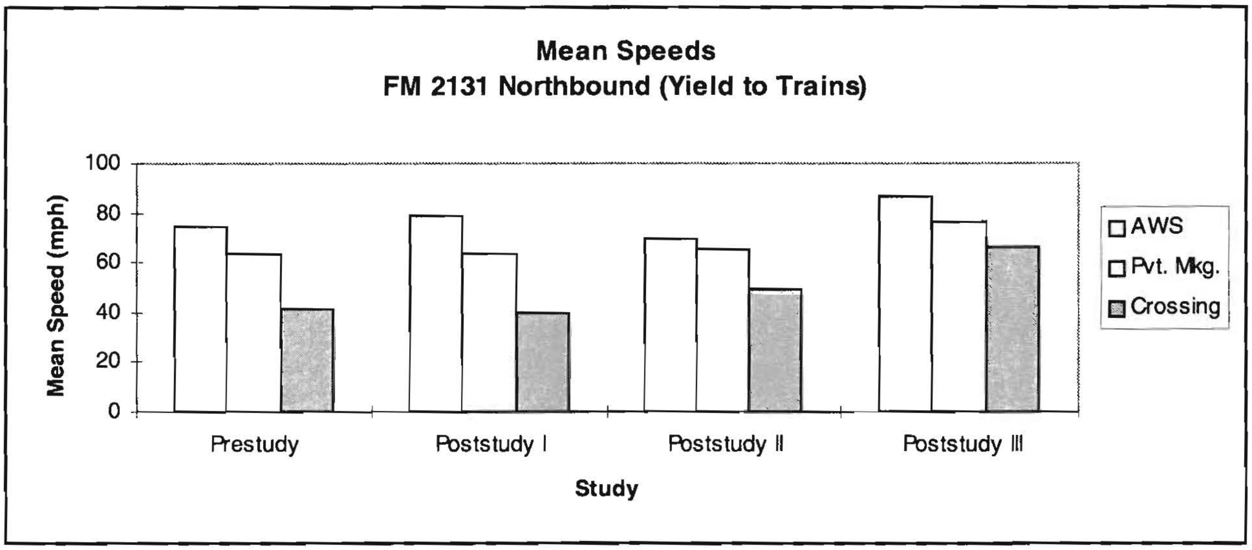
Looking Behavior	Prestudy		Poststudy I		Poststudy II	
	Number	Percent	Number	Percent	Number	Percent
None	3	17.6	2	7.4	17	26.2
Left Only	0	0.0	0	0.0	4	6.2
Right Only	2	11.8	3	11.1	9	13.8
Both	12	70.6	22	81.5	35	53.8
Totals	17	100.0	27	100.0	65	100.0

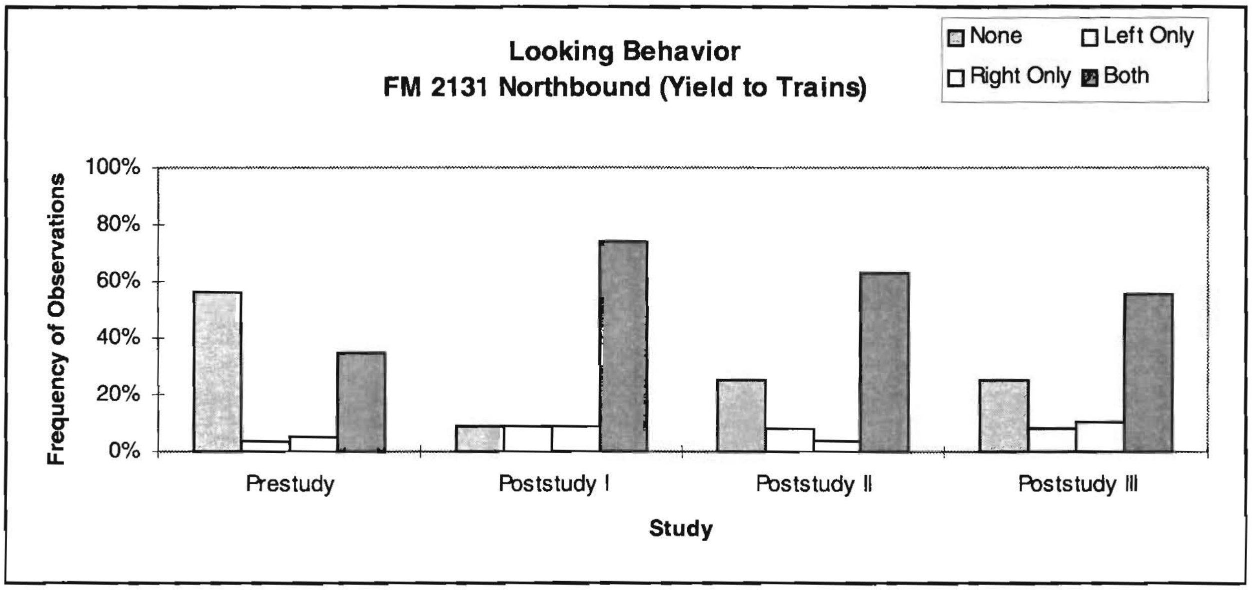




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	37.79	7.26	38.4	7.09	42.58	8.48
Pvt. Mkg.	36.56	9.68	30.35	6.64	36.11	6.83
Crossing	18.21	13.18	9.49	6.58	22.34	7.98

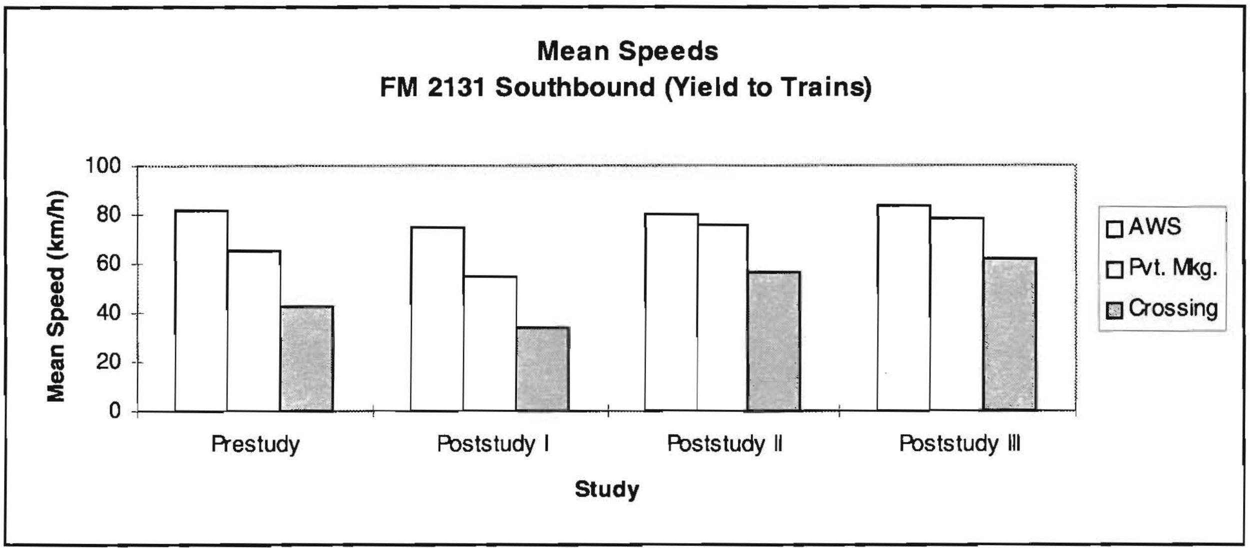
Looking Behavior	Prestudy		Poststudy I		Poststudy II	
	Number	Percent	Number	Percent	Number	Percent
None	1	5.9	3	9.1	8	20.0
Left Only	0	0.0	2	6.1	3	7.5
Right Only	0	0.0	0	0.0	2	5.0
Both	16	94.1	28	84.8	27	67.5
Totals	17	100.0	33	100.0	40	100.0

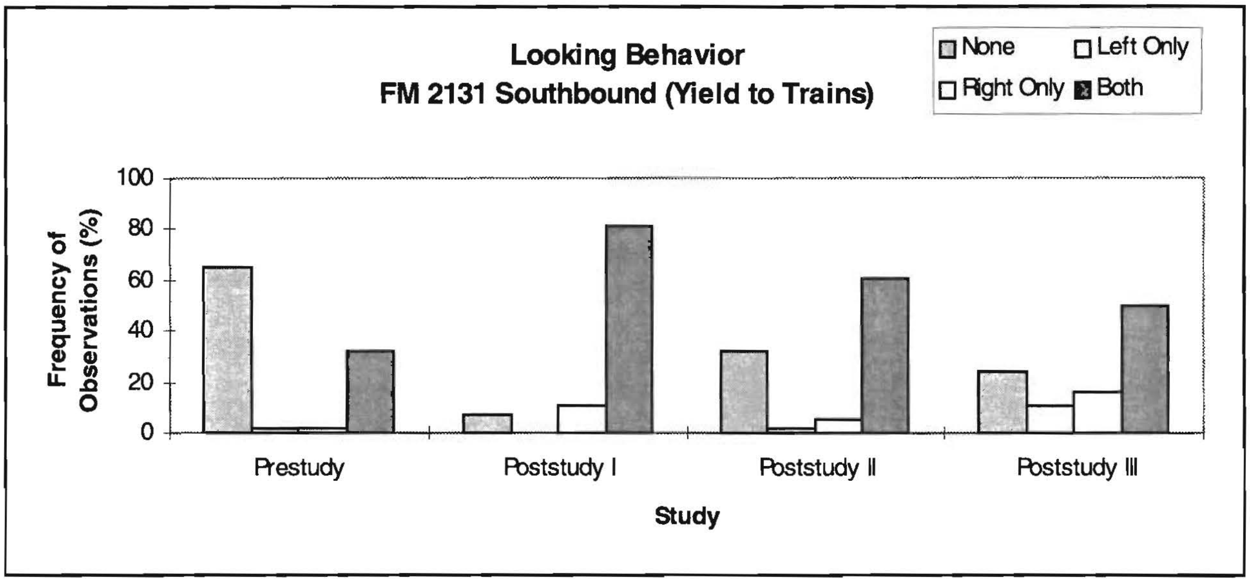




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	74.83	12.02	78.9	12.43	69.33	14.11	86.51	14.34
Pvt. Mkg.	63.97	13.79	63.26	13.9	65.01	12.83	76.24	16.38
Crossing	41.6	18.38	39.92	20.1	49.12	18.48	65.82	22.53

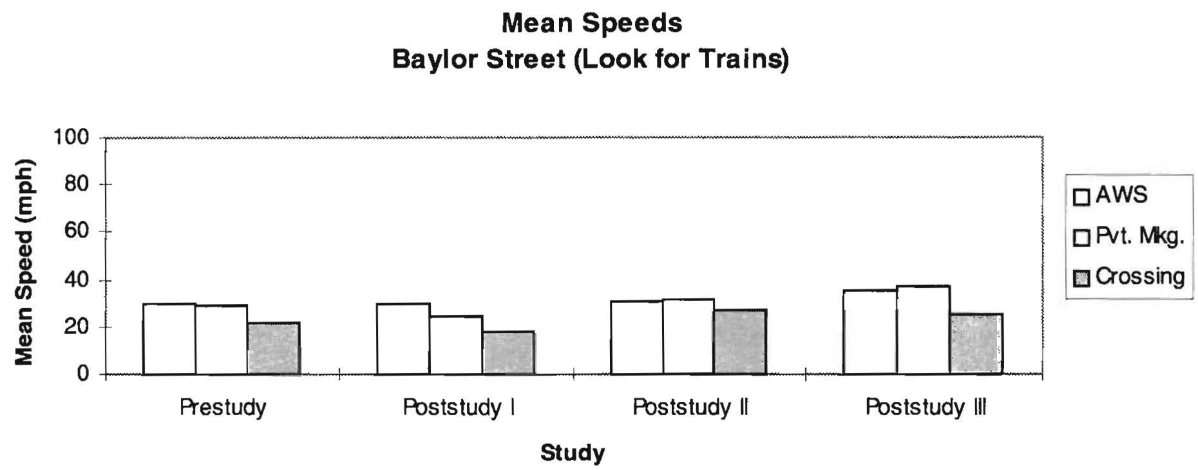
Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	32	56.1	3	8.6	15	25.4	12	25.5
Left Only	2	3.5	3	8.6	5	8.5	4	8.5
Right Only	3	5.3	3	8.6	2	3.4	5	10.6
Both	20	35.1	26	74.3	37	62.7	26	55.3
Totals	57	100.0	35	100.0	59	100.0	47	100.0

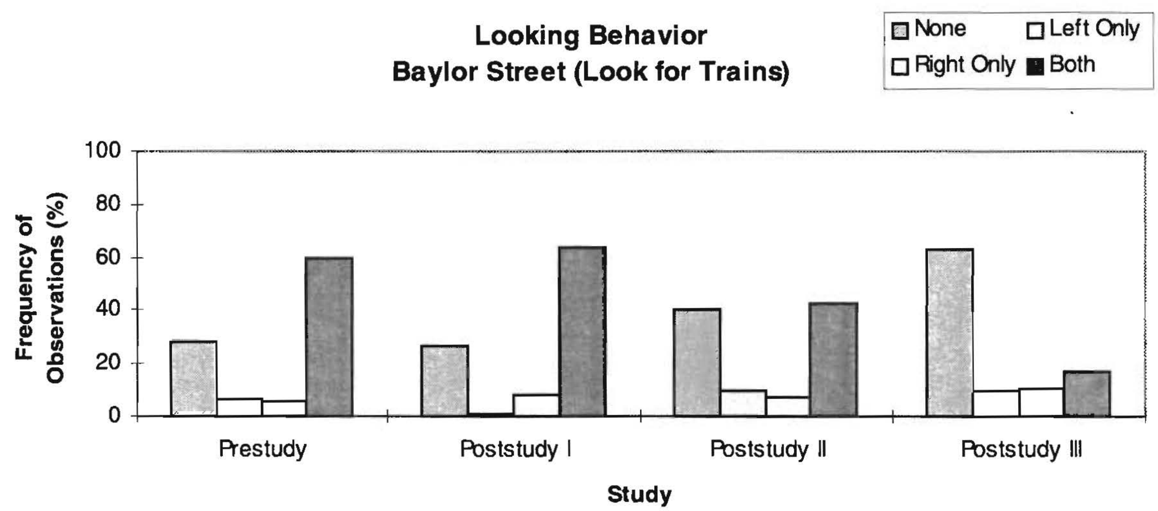




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	81.39	13.44	75.12	12.18	79.97	13.28	83.25	13.76
Pvt. Mkg.	65.38	13.17	54.69	12.64	75.34	14.03	78.32	14.38
Crossing	43.01	19.54	34.05	15.65	56.19	21.34	61.47	22.22

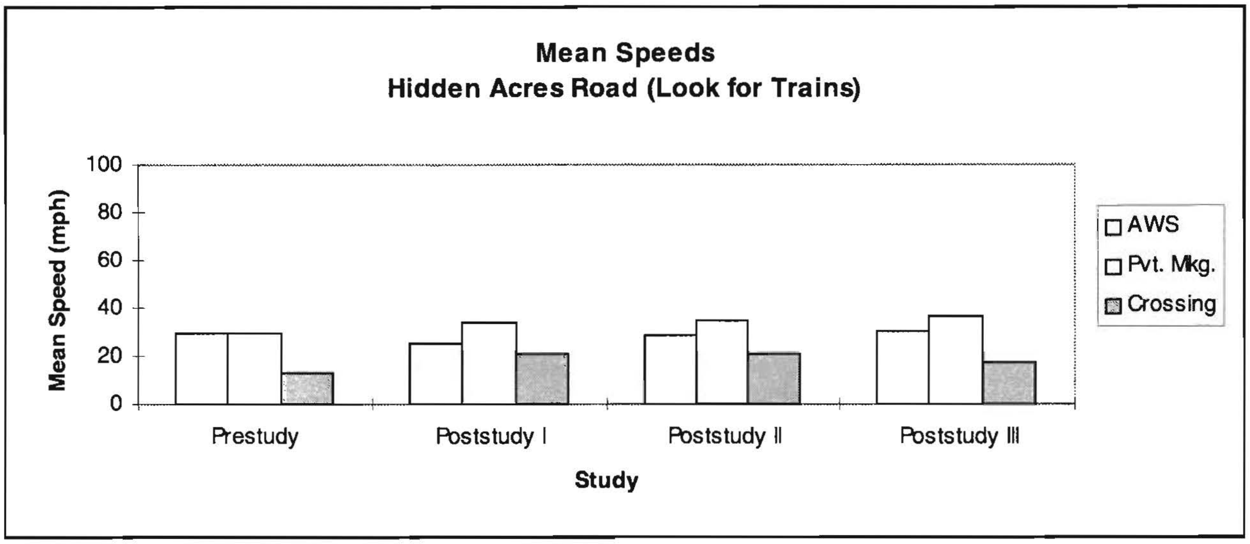
Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	41	65.1	2	7.4	17	32.1	9	23.7
Left Only	1	1.6	0	0.0	1	1.9	4	10.5
Right Only	1	1.6	3	11.1	3	5.7	6	15.8
Both	20	31.8	22	81.5	32	60.4	19	50.0
Totals	63	100.0	27	100.0	53	100.0	38	100.0

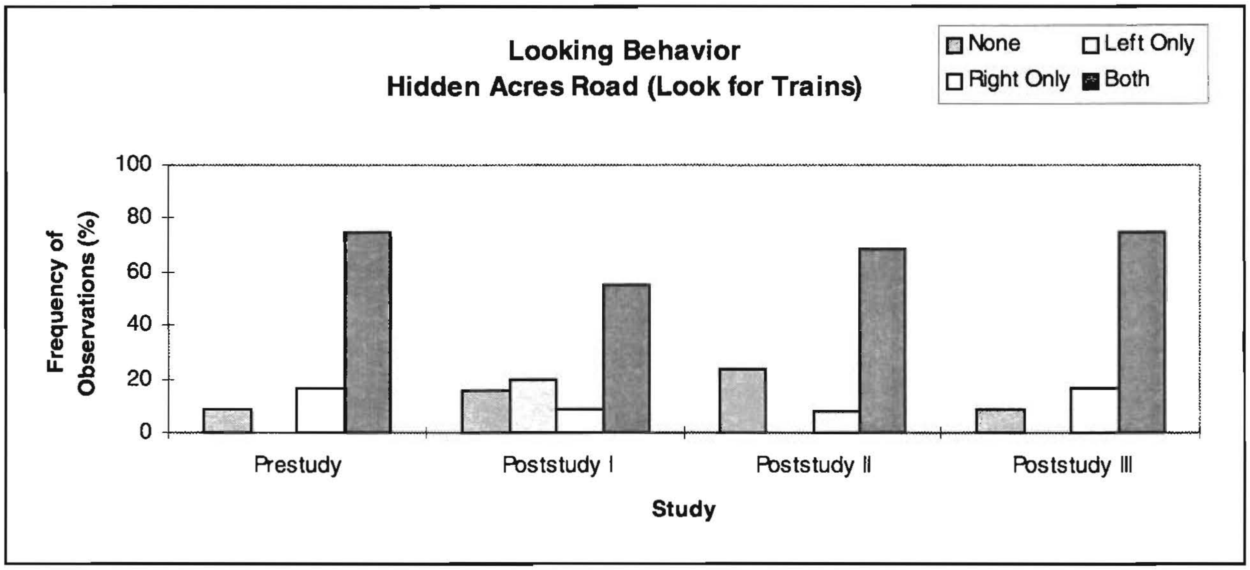




Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	29.73	5.31	29.9	6.46	30.8	6.64	35.14	5.44
Pvt. Mkg.	29.14	5.87	24.35	5.58	31.84	6.35	36.59	6.35
Crossing	21.58	8.59	18.26	7.46	26.61	7.25	25.15	8.46

Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	48	28.2	23	26.7	38	40.4	47	62.6
Left Only	11	6.5	1	1.2	9	9.6	7	9.3
Right Only	9	5.3	7	8.1	7	7.4	8	10.6
Both	102	60.0	55	63.9	40	42.6	13	17.3
Totals	170	100.0	86	100.0	94	100.0	75	100.0





Location of Speed Observation	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation	Mean Speed	Standard Deviation
AWS	29.84	4.7	25.52	5.28	28.27	5.58	30.37	6.53
Pvt. Mkg.	29.36	7.01	33.79	5.38	34.48	5.31	36.34	6.02
Crossing	13.26	6.96	21.26	5.82	20.53	8.11	17.28	7.14

Looking Behavior	Prestudy		Poststudy I		Poststudy II		Poststudy III	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
None	1	8.3	9	16.1	9	23.7	4	8.3
Left Only	0	0.0	11	19.6	0	0.0	0	0.0
Right Only	2	16.6	5	8.9	3	7.9	8	16.7
Both	9	75.0	31	55.4	26	68.4	36	75.0
Totals	12	100.0	56	100.0	38	100.0	48	100.0

APPENDIX I

ENHANCED TRAFFIC CONTROL DEVICES: PARTICIPANT DEMOGRAPHIC DATA

1. What is your age?

☐	18-24	26.9%
☐	25-34	19.2%
☐	35-44	15.4%
☐	45-59	11.5%
☐	Over 59	26.9%

2. How many years of driving experience do you have?

☐	Less than 1 year	0%
☐	Between 1 and 5 years	11.5%
☐	More than 5 years	88.5%

3. What is your gender?

☐	Male	65.4%
☐	Female	34.6%

4. What is your ethnic background?

☐	African-American (black)	0%
☐	Anglo (white)	84.6%
☐	Asian	0%
☐	Hispanic	15.4%
☐	Other (please specify) ____________	

5. Have you completed a driver's education course in the past year?

☐	Yes	11.5%
☐	No	88.5%

6. What is the highest level of school you have completed?

☐	Less than high school	
☐	High school graduate (or equivalent)	11.5%
☐	Trade school graduate	
☐	Some college	30.8%
☐	College graduate	15.4%
☐	Advanced degree	42.3%

7. Is your occupation transportation-related?

☐	Yes	50%
☐	No	50%

8. Do you find it difficult to drive at night for extended periods of time?

☐	Yes	30.8%
☐	No	69.2%