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16. Abstract

This report summarizes four research reports completed as part of a study focusing on improving safety at highway-railroad grade crossings. 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. The reports included in this summary are identified below.

- Enhanced Traffic Control Devices and Railroad Operations for Highway-Railroad Grade Crossings: First-Year Activities. Report FHWA/TX-98/1469-1.
- Enhanced Traffic Control Devices and Railroad Operations for Highway-Railroad Grade Crossings: Second-Year Activities. Report FHWA/TX-98/1469-2.
- Enhanced Traffic Control Devices and Railroad Operations for Highway-Railroad Grade Crossings: Third-Year Activities. Report FHWA/TX-98/1469-3.
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ENHANCED TRAFFIC CONTROL DEVICES AND RAILROAD OPERATIONS FOR HIGHWAY-RAILROAD GRADE CROSSINGS

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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 or the Federal Highway Administration. 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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IMPLEMENTATION RECOMMENDATIONS

Based on the results of this research, the authors propose the following recommendations for TxDOT's consideration.

1. Two enhancements to passive warning devices show promise for improving safety at highway-railroad grade crossings. These devices (a "YIELD TO TRAIN" sign and vehicle-activated strobe) should be installed at additional grade crossings and further evaluated.

2. If the additional testing is successful, TxDOT may adopt the "YIELD TO TRAIN" sign and vehicle-activated strobe as two of its standard traffic control devices at passive grade crossings programmed for upgrading to active control. These *interim* devices would be removed when the active warning devices are installed.

3. TxDOT should distribute the public safety education materials to Texas citizens of all ages. Specifically, they should distribute relevant sections to TxDOT Public Information officers, Operation Lifesaver, the Texas Railroad Commission, the Texas Education Agency, and the Texas Department of Public Safety.

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 much greater than in any other state; Illinois ranks second with 10,364 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 tracks 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. 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 to direct the attention of the motorist, 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 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 that two different modes of transportation compete for the same physical space. This attribute, and the entirely different operating characteristics of motor vehicles and trains, lead to the safety problem at highway-railroad grade crossings. Trains can neither stop quickly nor 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 motorist 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 grade crossing. Alternatively, the driver may detect the train but decide erroneously that adequate time is available to clear the crossing before the train arrives. There are many reasons that drivers fail to detect the train or make faulty decisions. If a driver is only familiar with active grade crossings, he or she may not understand his or her responsibilities at passive crossings. Conversely, if a driver is only familiar with low volume crossings, he or she may not pay adequate attention at high volume crossings.

Another source of confusion to drivers 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 driver's decision-making task. National statistics show that more than 50 percent of all collisions between motor vehicles and trains occur at active crossings, which should have substantially fewer crashes. One explanation is that the types of warning device technologies used and the warning time they provide might contribute to the frequency of crashes at these crossings; however, higher train and traffic volumes at active crossings are more likely contributors. The point should be made that many more collisions, injuries, and fatalities would have occurred if active warning devices had not been installed at these crossings. Methods for improving communication between advanced warning signs and drivers are needed to reduce driver confusion, maximize driver expectancy, and improve the 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. Proposed traffic control 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 low implementation cost versus alternative measures. To accomplish this 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 report documenting the research findings and recommendations.

1.3 ORGANIZATION

This report summarizes the research activities completed as part of this study. It is divided into five sections - *Introduction, Driver and Safety Studies, Enhancements to Passive Warning Devices, Public Information,* and *Implementation.*

Driver and Safety Studies summarize results from a survey of drivers' comprehension of traffic control devices at highway-railroad grade crossings, a study of in-vehicle observations of driver behavior at highway-railroad grade crossings, and an analysis of vehicle-train crashes and contributing factors contributing at highway-railroad grade crossing.

Passive Warning Devices summarize results from a field evaluation of "YIELD TO TRAINS" and "LOOK FOR TRAINS" signs and the development and evaluation of the vehicle-activated strobe enhancement for the railroad advance warning sign. *Public Information* summarizes a highway-railroad grade crossing safety document, a series of two-page chapters describing important facts related to highway-railroad grade crossings. The final section focuses on implementation of the research results.

2.0 DRIVER AND SAFETY STUDIES

2.1 INTRODUCTION

This section presents a summary of the driver understanding survey, a review of the driver behavior study, and an analysis of car-train crashes at highway-railroad grade crossings.

2.2 DRIVER UNDERSTANDING

The current system of visual communication fails to differentiate between passive and active 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. When approaching a crossing, the driver is unaware if the crossing is active or passive until the crossing is within view. The determination is made near the crossing when the observance of a flashing light signal leads to the assumption that the crossing is active. The distinction between crossing types is more difficult at night and during periods when meteorological conditions make the crossing less conspicuous. This lack of advance 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 problem. Collisions between trains and vehicles usually result in fatalities.

Over the past 20 years, more than two billion dollars have been allocated for the improvement of highway-railroad grade crossings. Many passive crossings have been upgraded with active protection which has decreased the number of collisions at grade crossings each year; however, grade crossings crashes, injuries, and fatalities are still a major concern. To continue improving safety at highway-railroad grade crossings, driver comprehension and attitudes concerning traffic control devices require investigation.

2.2.1 Objective

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

2.2.2 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. Researchers were careful to provide clarifications to questions raised by participating drivers, rather than interpretation of survey questions. Assuring that the research team had a consistent interpretation of traffic control devices at highway-railroad grade crossings also reduced interview bias.

Researchers gave each participant a notebook containing several photographs of traffic control devices at highway-railroad grade crossings to each driver. The objective was to present the traffic control devices in the most realistic setting possible. Researchers also provided each participant an answer sheet to record his or her responses to the survey questions.

The research team's goal was to distribute the survey to a large, diverse sample that was representative of the Texas driving population. To accomplish this objective, they chose 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 the them to survey diverse crowds of both rural and urban populations.

The survey was available in either English or Spanish. Researchers informed participating drivers that the survey was created for a research project on highway-railroad grade crossings sponsored by the Texas Transportation Institute and Texas Department of Transportation. The 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.

2.2.3 Hypotheses

The research team reviewed several studies on grade crossing crashes and driver behavior as part of the literature review for this task. After reviewing this literature, the research team developed six hypotheses concerning driver comprehension of traffic control devices at railroad-highway grade crossings.

The research team developed four hypotheses to identify the effects of experience on drivers' comprehension of traffic control devices at highway-railroad grade crossings. First, the research team hypothesized that young drivers would not exhibit as high a comprehension of the traffic control devices as older drivers who participated in the survey. To test this hypothesis, the research team compared the responses from drivers with less than five years experience to the responses from drivers with more than five years experience.

Second, the research team hypothesized that drivers who had taken a defensive driving or driver's 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 research team compared the responses of those who had taken a driving course to responses from drivers who had not taken such a course.

Third, the research team expected drivers who live in urban areas to be more familiar with active warning devices and drivers who live in small cities and rural areas to be more familiar with passive warning devices. To test this hypothesis, the research team compared the responses of those living in large cities to the responses of those living in small cities or rural areas.

Fourth, the research team expected drivers familiar with grade crossings to display a better understanding of traffic control devices at railroad-highway grade crossings. To test this hypothesis, the research team compared the responses from those who cross tracks more than once a day to the responses of those who cross tracks less than once a day.

The research team also developed two hypotheses to identify the effects of demographic factors on driver comprehension of traffic control devices at highway-railroad grade crossings. First, female drivers were expected to show a higher level of comprehension since they are involved in fewer collisions at highway-railroad grade crossings. To test this hypothesis, the research team compared the responses from female drivers to the responses from male drivers.

Second, Caucasian and Hispanic male drivers were expected to show a lower level of comprehension since they are involved in more collisions at highway-railroad grade crossings. To test this hypothesis, the research team compared the responses of drivers from different ethnic backgrounds.

2.2.4 Findings

The driver comprehension survey suggested a lack of understanding of the requirements and responsibilities at passive and active grade crossings. For both types of crossings, most of the drivers said that the correct action was to stop at the crossing and look and listen for trains. 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 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 advance warning sign, and 50 percent of the drivers did not know that the sign is used at both active and passive crossings. Drivers also expressed a lack of understanding related to the crossbuck. Only 71 percent of the drivers correctly identified the location of the crossbuck; however, only 34 percent of the drivers knew that it is used for both active and passive crossings.

Other research results suggest that compared with other states, Texas drivers are involved in a higher proportion of crashes in which the causal factor was listed as "drove around the gates." Twelve percent of the participating drivers said that driving around the gates at active crossings was acceptable if they could not see a train, and 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 often disregard them.

Most of the participating drivers said that they remembered some instructions about grade crossings from either a driver's education or defensive driving class, Operation Lifesaver, or other educational campaign. In addition, 53 comments suggested more public education would improve safety at grade crossings. Interestingly, hypothesis testing did not show any difference in responses between drivers who had taken a driver's education or defensive driving course in the past year and drivers who had not taken such a course. This result suggests that these courses should incorporate more material on traffic control devices at highway-railroad grade crossings.

Twenty-one drivers suggested that lights and gates should be present at every 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 the crossings are too rough and should be 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 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. Crossing frequency also affected driver comprehension. Driving environment, gender, or ethnic background did not affect driver comprehension of traffic control devices and driver requirements at grade crossings.

2.3 DRIVER BEHAVIOR

Highway-railroad safety research activities have focused on improving the engineering, education, and enforcement issues surrounding the grade crossing scenario. Focus group studies, questionnaires, field observations, and crash records reflect a weak appreciation for the highway-railroad grade crossing as an intersection between two distinctly different modes of transportation. Driver behavior at highway-railroad grade crossings shows the perceived risk that the driver acknowledges.

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

2.3.1 Objective

The objective of this task was to evaluate driver behavior at highway-railroad grade crossings through in-vehicle observations.

2.3.2 Methodology

The research team established the criteria for assessing safe driving behavior at highway-railroad grade crossings as looking behavior and deceleration on the approach to the crossing. This study involved a unique method of observing these performance measures. Rather than observing the behavior of random drivers as they approached a particular crossing, a researcher accompanied a driver in his or her vehicle as they traveled along a predetermined test course. Before beginning, drivers were instructed to drive as he or she would normally drive on an open roadway. The driver was also informed that the research team had not arranged or prepared situations that he or she might encounter during the study. No indication was given that the researcher would be observing driver behavior at grade crossings. The researcher engaged the driver in casual conversation while guiding them along the test course.

This methodology offered many advantages. The researcher could observe the behavior of the same driver at a variety of crossing scenarios. While riding in the vehicle, the researcher could observe the driver's motives for initiating looking , braking, and deceleration. Observing looking behavior and deceleration from outside the vehicle requires researchers to speculate whether a desire to assess potential track activity motivated these actions. In-vehicle observation allows the researcher to differentiate behaviors directed toward activity along the track from those directed elsewhere.

At the conclusion of the driving portion of the study, the researcher administered a questionnaire to better understand any misconceptions regarding 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 crossings.

The research team established a test course that 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 crossing within the cities of Bryan and College Station, Texas. Crossings along the test course included those with a variety of traffic control devices, warning equipment, approach angles, sight obstructions, grade profiles, approach speed limits, and traffic control devices.

2.3.3 Findings

The in-vehicle researcher observed differences in looking behavior and deceleration at the active and passive crossings along the test course. Drivers initiated more looking behavior at the passive crossings except at the industrial spur track crossing. The observation of different driving behavior at active and passive crossings suggests that drivers detect differences, either subconsciously or unconsciously, in the degree of warning at the crossing.

Many drivers were motivated to decelerate by the crossing roughness rather than looking for trains as they approached the crossings. Understandably, drivers may not need to initiate looking behavior in both directions to achieve safe passage at active crossings, nor are they 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 woman slowed almost to the point of stopping without looking in either direction on the approach to an active crossing. One cannot conclude that her behavior was risky for that assumption implies that she stopped on the tracks without regards to the potential for train activity. She may have subconsciously thought that the no trains were approaching because the active warning devices were not activated, and thus chose to reduce her speed and focus her attention on negotiating the crossing to avoid damaging her vehicle.

In summary, 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 highway-railroad grade crossings, most drivers did not actually do 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.

2.3.4 Recommendations

Observations of "good" or desirable looking behavior does not necessarily mean that drivers will avoid collisions at highway-railroad grade crossings. Many drivers who initiated looking behavior in both directions did so within the hazard zone, which is within 4.6 meters of the railroad tracks. Looking within this region may not allow enough time to avoid a 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 do when approaching a highway-railroad grade crossing.

- **Look** for approaching trains;
- **Look** for activity along a second track;
- **Look** for/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.

This list specifically targets certain tasks for the driver to initiate when approaching a highway-railroad grade crossing. This approach should improve driver expectancy of potential hazards at either passive or active grade crossings. Drivers' 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 result in a more desirable driving behavior.

The in-vehicle observations within this study were all performed during daylight conditions. Nighttime observations of driver behavior at highway-railroad grade crossings may yield further insight into the misconceptions drivers have regarding grade crossing scenarios. For example, many drivers assume that most crossings used by trains have warning devices to alert drivers of approaching trains. This misconception is especially dangerous at night because the flashing light signal at active crossings are difficult to see due to the black backplates that are used. The backplates are black to improve the conspicuity of the flashing lights during daylight conditions.

2.4 GRADE CROSSING CRASH ANALYSIS

A highway-railroad grade crossing is a unique intersection in that two different modes of transportation (trains and vehicles) use the same physical space. Many factors can contribute to collisions between trains and vehicles at these crossings. Crashes involving trains and vehicles are a significant safety problem in Texas.

Intuitively, crash experience at highway-railroad grade crossings is an indication of relative hazards. Studying crash histories at highway-railroad grade crossings can help researchers understand what factors are prevalent and what possible treatments may be. The study of traffic crashes is different from that of other traffic stream parameters. Researchers cannot observe crashes as they occur because they occur infrequently and at unpredictable times and locations. Thus, they must study crash data through secondary sources such as motorists and police crash reports.

Two basic approaches can be used in a crash analysis: the statistical approach and the case study approach. The statistical approach involves analyzing large samples of crash data for common trends. In the case study approach, a smaller sample of crossings is chosen and an in-depth analysis of each crash is conducted. This research used a combination of the statistical approach using statewide crash data and a "quasi" case study using information from crash narratives to identify primary and secondary factors for the same crashes.

2.4.1 Objective

The primary objective of this task was to perform a analysis of train-involved crashes in Texas. To have a large enough database to study, all train-involved crashes for 1992, 1993, and 1994 were analyzed. Table 1 provides a summary of the total number of train-involved crashes for the three-year study period.

2.4.2 Methodology

The research team studied all crashes involving a train (or other vehicles on the rails) and a motor vehicle (i.e., train-involved) in Texas during the years 1992, 1993, and 1994. More than 1,300 train-involved crashes occurred in these years. This total represents all train-involved collisions since the Federal Railroad Administration (FRA) requires that any collision between on-track equipment and automobile, bus, truck, motorcycle, bicycle, farm vehicle, or pedestrian at a railroad crossing be documented.

The research team obtained crash data from a variety of sources, including the LANSER database, FRA database, crash narrative (ST-3) forms, GO software, and the Texas Department of Transportation inventory files. The research team identified factors contributing to train-involved crashes in two ways. The first involved obtaining the coded number for contributing factors from the ST-3 crash narratives. The second involved determining the primary contributing factors using a case study review of each individual crash narrative.

Table 1. Crashes Selected for Statewide Study

Year	Number of Crashes	Injuries	Fatal
1992	415	196	36
1993	436	203	53
1994	477	199	45
TOTAL	**1328**	**598**	**134**

2.4.3 Findings

This section summarizes the findings from the statewide analysis of train-involved crashes. Findings are divided into railroad factors, environmental factors, roadway factors, and driver/passenger factors.

Railroad Factors. More than 30 percent of Texas train-involved crashes and 20 percent of U.S. train-involved crashes occurred at crossings with automatic gates. A statistical comparison revealed that the proportion of train-involved crashes at crossings with automatic gates in Texas is significantly higher than the proportion of train-involved crashes at crossings with automatic gates nationwide. This finding suggests that Texas motorists are more likely to drive around lowered gate barriers and be involved in train-involved crashes.

Crossings with passive warning systems have more fatalities than crossings with active warning systems. Crossings with passive warning systems also account for more than 70 percent of crashes with multiple fatalities. These findings and the severity index comparison suggest that compared to active crossings, crashes are more severe at passive crossings.

Motion Sensitive and Audio Frequency Overlay circuits experience a higher proportion of train-involved crashes than the proportion of crossings with this type of active warning system. One explanation for these findings is that these circuits provide variable warning times that adversely affect driver behavior and the subsequent crash history. Conventional and constant warning time track circuits perform well in terms of the average crash severity (i.e., the severity index values are lower than the baseline value for all crashes). One reason for the good performance of the conventional track circuits may be that because they tend to be located at crossings with uniform train speeds, they provide constant warning times, which provides benefits in terms of driver behavior and subsequent crash history.

Compared with motor vehicle crashes, train-involved crashes have significantly greater proportions of serious and fatal injuries. This finding suggests that crashes at highway-railroad grade crossings are more severe than other types of crashes.

Environmental Factors. The proportion of train-involved crashes in rural areas is significantly greater than the proportion of vehicle-involved crashes in rural areas (approximately 65 percent of the train-involved crashes occurred in areas with populations of 25,000 or less compared with 36 percent of all crashes statewide). This finding supports the contention that train-involved crashes in Texas are a major problem in rural areas.

The average severity for daytime train-involved crashes was greater than the average severity for nighttime train-involved crashes. This finding was surprising but can be explained by the greater amount of automobile and railroad traffic during the day. The highest frequency for both total and fatal crashes occurred between 3:00 and 6:00 p.m. The proportion of train-involved crashes late at night (i.e., 9 p.m. to 6 a.m.) are significantly greater than the proportion of vehicle-involved crashes in the same time period.

Roadway Factors. The proportion of train-involved crashes on county and farm-to-market roads are significantly greater than the proportion of vehicle-involved crashes on the same roads. This finding is consistent with the premise that train-involved crashes are a major problem in rural areas. The analysis also revealed that a significantly greater proportion of large trucks and towed trailers are involved in train-involved crashes where intersection proximity is the primary contributing factor.

The analysis of parallel roadway crashes showed that significantly greater proportions of crashes occurred at crossings protected by cantilever signals as well as at crossings on city streets. The greater proportion crashes at crossings with cantilever signals is not surprising as motorists may have difficulty detecting this type of signal after making a turn onto the intersecting roadway. The greater proportion of crashes at crossings on city streets also is expected as more there are nearby intersections in urban areas than in rural areas.

Driver/Passenger Factors. Inexperienced drivers (16 to 24 years of age) are involved in significantly greater proportions of train-involved crashes where tried to beat train (especially males 16 to 20) or impaired driver (especially males 21 to 24) were the primary contributing factors. These findings suggest that inexperienced drivers (especially males) are willing to take risks at highway-railroad grade crossings.

The proportion of elderly drivers (55 and older) in train-involved crashes is significantly greater than the proportion of elderly drivers in vehicle-involved crashes. These findings indicate that elderly drivers are having problems at highway-railroad grade crossings. A related finding is that the proportion of elderly drivers in train-involved crashes at night is higher than the proportion of elderly drivers in vehicle-involved crashes at night. These findings suggest that elderly drivers may have an even bigger problems detecting and reacting to trains at night.

The proportion of White and Hispanic males in train-involved crashes is significantly greater than proportion of White and Hispanic males in vehicle-involved crashes. One explanation is that males exhibit more aggressive and risky behavior and are involved in a greater proportion of crashes at highway-railway grade crossings. In addition more White and Hispanic males live in rural areas and have access to a motor vehicle.

2.4.4 Recommendations

The research team suggested a number of recommendations for potential safety improvements and public education strategies. Because a significantly greater proportion of Texas train-involved crashes (30 percent) occur at crossings with automatic gates than the national average (20 percent), enforcement efforts should be increased to help deter motorists from driving around lowered gates. Both police presence and automated techniques (i.e., video surveillance) could be used to provide enforcement.

It appears that train-involved crashes in Texas are a bigger safety problem in rural areas. Public education efforts should concentrate efforts on rural and small towns where there are large numbers of highway-railroad grade crossings. Crashes at grade crossings with flashing light signals and nearby highway intersections may be reduced if additional signal displays are oriented parallel to the roadway so the drivers can receive the information regarding the presence of a train before attempting a turn across the tracks.

Because a large number of train-involved crashes occur in dark, unlighted conditions, the Texas Department of Transportation should work with the railroad companies to have railcars and locomotives equipped with reflective paint, tape, or buttons. This improvement may help reduce the frequency of nighttime crashes for motorists (especially the elderly who were involved in a higher proportion of crashes at night) who run into the side of a train already occupying the crossing. Another possible improvement that may reduce the frequency of train-involved crashes at night is the illumination of more highway-railroad grade crossings.

3.0 ENHANCEMENTS TO PASSIVE WARNING DEVICES

3.1 INTRODUCTION

This section presents the results of studies evaluating experimental passive sign systems, the development of enhanced traffic control devices, and the field study of the vehicle-activated strobe light system.

3.2 EXPERIMENTAL PASSIVE SIGN SYSTEMS

Where the paths of any two vehicles meet, steps must be taken to reduce 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 size and speed of the vehicles involved. While crash rates have been on the decline, the potential for crashes at highway-railroad grade crossings has been increasing due to higher train and automobile volumes. Thus, new methods to enhance the safety of these locations are being sought.

3.2.1 Objective

The objective of this task was to evaluate the effects that enhancements to the standard traffic control devices at passively controlled highway-railroad grade crossings have on safety at the crossing.

3.2.2 Sign Systems

The first experimental sign system tested consisted of a standard size "YIELD" sign with a supplementary message plate containing the words "TO TRAINS." This sign was located at the crossing near the crossbuck. The "YIELD TO TRAINS" sign is shown in Figure 1. While there has been a considerable argument against the use of YIELD signs at highway-railroad grade crossings, the addition of the "TO TRAINS" sign clearly distinguishes the experimental sign from the standard "YIELD" sign. Thus, the experimental sign should not effect the effectiveness of the standard "YIELD" sign at other locations.

The second experimental sign system consists of a diamond-shaped warning sign with yellow high-intensity sheeting and a black train locomotive symbol. The sign assembly also contains a supplementary message sign that reads "LOOK FOR TRAINS" on a yellow background. This experimental sign is shown in Figure 2. The "LOOK FOR TRAINS" sign is placed on the approach to the crossing between the advance warning sign and the crossbuck. At most of the test sites, the sign was placed next to the beginning of the advance pavement marking. At those sites where the pavement marking and advance warning sign are at the same distance, the "LOOK FOR TRAINS" sign was placed 15 meters beyond the advance pavement marking location specified in the *1980 Texas Manual on Uniform Traffic Control Devices.*

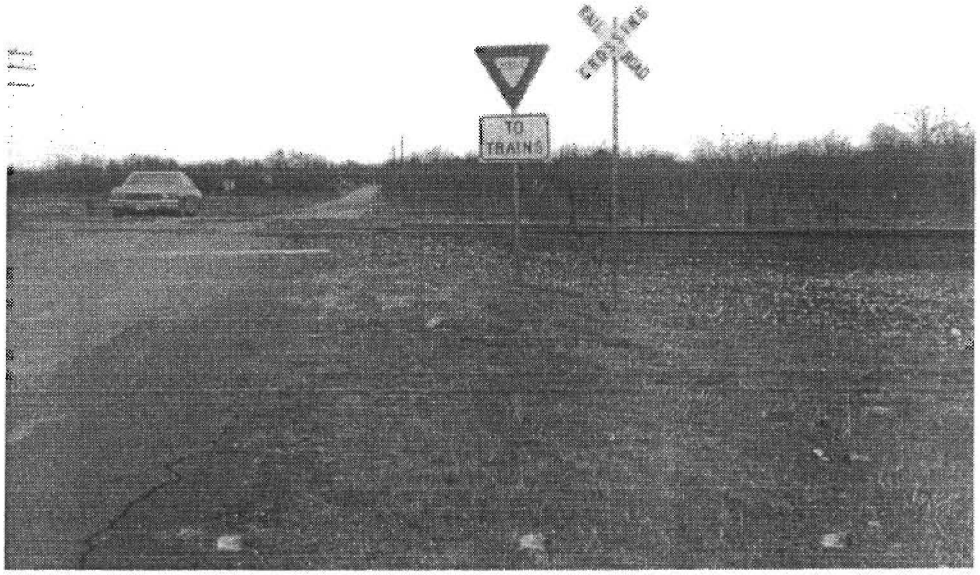


Figure 1. "YIELD TO TRAINS" Sign System.

Figure 2. "LOOK FOR TRAINS" Sign System.

3.2.3 Methodology

The methodology for this study focused on the measurement of those behaviors that are indicative of safe driving behavior at highway-railroad grade crossings. The results provide a comparison between the response due to the standard sign system and that due to the two experimental sign systems. The experimental design for this study used a *before* and *after* methodology. This type of study compares data taken at a particular study area at different times. This differs from a cross-sectional study that compares an experimental crossing to a control crossing at the same point in time.

Since there was a period of time between each study, crossing conditions could have changed which might cause a difference in driver behavior that was not attributable to the experimental sign system. Such changes include changes in vegetation, traffic volumes, or the angle of the sun. As none of these changes were observed, the research team assumed that any changes in driver behavior were due to the experimental signing systems.

The research team observed driver looking to determine if the enhanced warning devices affected the looking behavior of drivers at the highway-railroad grade crossings. It is implied that an increase in driver looking behavior will result in increased safety. The number of drivers who looked to the left, right, or both, and the number of drivers who looked in neither direction within 45 meters of the crossing were recorded. The in-vehicle observer made spot speed measurements at the standard advance warning sign, the beginning of the advance R X R pavement marking, and at the crossing itself as vehicles approached the crossing.

The research team calculated that the mean difference in speeds to determine if speeds increased or decreased on the approach to the crossing. They also calculated the mean and variance of the speeds at the three locations. During the initial post-study, drivers were stopped downstream from the 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.

The experimental sign systems were installed at passive grade crossings in four Texas counties. The "YIELD TO TRAINS" sign system was installed at two crossings in Grimes County and three crossings in Coleman County. The "LOOK FOR TRAINS" sign system was installed at three crossings in San Patricio County and three crossings in Nacogdoches County. Vandalism of the Nacogdoches signs prohibited after data collection in that county.

3.2.4 Hypothesis

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 and by inference, create a safer driving environment. With respect to the measures of effectiveness, the research hypothesis is that driver looking behavior and mean speed reduction will increase after the experimental signs are installed.

3.2.5 Findings

The research team measured approach speeds and looking behavior to determine the effectiveness of the two sign systems. The results suggested that both sign systems decreased approach speeds and increased reductions in speed at the crossing; however, the subsequent results suggest that over time, approach speeds will increases and reductions in speed will decrease. At some locations, looking behavior increased significantly after the "YIELD TO TRAINS" sign system was installed. No evidence suggested that this sign system would cause a 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 significant increases in looking behavior. The latter sign system did not have as great an impact on approach speeds and produced no improvement in looking behavior.

3.3 DEVELOPMENT OF ENHANCED TRAFFIC CONTROL DEVICES

When approaching a railroad crossing, drivers must be aware of the crossing's presence. Providing advance warning signs or markings can enhance awareness of the crossing and the need to look for a train. The critical point for drivers occurs when approaching a 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 that if a train is observed, he or she has enough time to bring the vehicle to a safe stop. Consequently, it is important that drivers be made aware of the highway-railroad grade crossing through conspicuous advance warning signs on the approach to the crossing.

The visibility of signs in the traffic environment and the resulting communication with the motorist is dependent upon detection, identification, and legibility. Adequate visibility and detection of the sign are 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 advance warning signs, that are important parts of a safe and efficient transportation network.

An enhancement that will make the advance warning sign at passive railroad crossings more conspicuous to passing drivers is needed. A TxDOT engineer proposed the use of a supplemental strobe light on the advance warning sign at highway-railroad grade crossings. To make the sign more conspicuous, 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 before field implementation of the experimental sign system.

3.3.1 Objective

The objective of this task was to find out if adding a strobe light to the advance warning sign at a passive railroad crossing would cause adverse driver reactions such as hard braking or erratic steering maneuvers.

3.3.2 Methodology

The research team evaluated the enhanced sign system in a closed driving course at the Texas A&M University Riverside Campus. Vehicles were detected by a motion sensor that activated a strobe light. The strobe light was placed on top of the railroad advanced warning (W10-1) sign and began flashing when the vehicle was at a point where the advance warning sign was in the driver's cone of clear vision. In addition to the vehicle-activated strobe light system, the test course also included a W10-1 sign without enhancements and a W10-1 sign with a steady flashing yellow beacon.

Each driver drove the course in the same vehicle with an in-vehicle observer that recorded head movements, steering reactions, and braking reactions to the sign systems. The research team also conducted several focus group meetings to determine driver opinions of the experimental signing system and whether the enhanced sign system was more conspicuous than the standard signing system, or an 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 sign system and the two supplemental devices, the study procedures, and the data analysis procedures.

The study design for this research consisted of three parts: a driver study, a driver questionnaire, and a focus group meeting. Data collection was conducted over a period of five nights, with one focus group meeting each night. Each night represented a different group of drivers, with the first night representing a pilot study. The drivers in the first focus group had experience in transportation-related issues, including expertise in traffic control devices, geometric design, human factor issues, and railroad research. Driver comments 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 unknowns related to the strobe light. The third and fourth focus groups represented drivers under the age of 25 and Hispanic drivers over the age of 18, respectively. The fifth and final focus group represented drivers over the age of 55. The research team tried to insure equal representation of both males and females, drivers who feel uncomfortable driving at night, and those who experience trouble driving after dark.

The course had two entry points to allow for different orders of presentation of the signs. Besides the three 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 drivers to watch for these distractor signs and read each number aloud when they saw it. The purpose of this exercise was to keep the drivers busy by dividing their attention as often happens under normal driving conditions.

The in-vehicle observer gave each driver the same instructions before entering the driving course. The observer also 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 until all of the drivers had completed the driving study and answered the questions on their questionnaire.

As mentioned previously, each driver completed a questionnaire immediately after they returned from the driving course. The intention of the questionnaire was to help the driver remember what they thought or felt as they observed each sign. Additionally, the in-vehicle observer marked the questionnaires with each drivers' identification numbers so their responses could be compared with their reactions on the driving course. Completion of the questionnaire was also done so that all drivers had a chance to record their opinions without being influenced by what other members of the group thought of the different advance warning signs. The research team used the questionnaires to answer questions not discussed and serve as a written record of the driver opinions.

After each driver had completed the driving course and their questionnaire, the focus group leader facilitated a discussion. The discussion focused on several topics 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 also varied.

3.3.3 Findings

The measures of performance used to evaluate the device included driver head movement, braking reaction, and steering reaction. None of the three sign systems, including the vehicle-activated strobe light, resulted in any adverse driver reaction. The strobe light and flashing beacon 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 flashing beacon to the strobe light. Additionally, the strobe light was preferred to the standard sign. Both the strobe light and the flashing beacon were said to have better attention gaining qualities than the standard sign and that made drivers exercise greater caution near them. While some drivers simply did not like the strobe light, only three drivers said it startled them. Most of the startling effect was due to the novelty of the strobe light 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 any adverse driver reactions such as sudden braking or head movements, rapid deceleration, 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 flashing beacon and strobe light. The braking behavior showed drivers exhibiting caution and preparing for whatever conditions lie ahead.

Test drivers preferred the advance warning sign with the flashing beacon to grab the drivers attention and alert them that a passive highway-railroad grade crossing was ahead. Driver ranking of the effectiveness of the three sign systems showed that drivers preferred the enhanced systems to the standard sign. All drivers understood the meaning of the standard 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 flashing beacon than with the strobe light.

3.3.4 Recommendations

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

3.4 EVALUATION OF THE VEHICLE-ACTIVATED STROBE LIGHT

The vehicle-activated strobe light was intended for use at passive railroad crossings with the purpose of gaining and directing the driver's attention to the W10-1 sign and increasing driver awareness of the presence of a highway-railroad grade crossing. As discussed in the previous section, focus group comments concerning the vehicle-activated strobe light were generally positive. The research team observed no adverse driver reactions when drivers encountered the strobe light as part of the closed-course driving study. Because of the positive reaction, they recommended additional investigation of the vehicle-activated strobe light.

One concern raised in the focus group meetings was how drivers would interpret the meaning of the vehicle-activated strobe light. Some focus group participants thought that the strobe light to mean a train was present at the crossing. Thus, if the strobe light was not flashing, a driver could safely assume that no train was present and pass through the grade crossing with little caution. Since the strobe light was designed to be an attention-getting device and was not intended to be correlated with the presence of a train at the crossing, this interpretation created a potential safety problem.

To overcome this problem, the research team decided to add a supplemental sign, placed directly below the W10-1 sign, that stated, "LOOK FOR TRAIN AT CROSSING." This supplemental sign provided the driver a written message consistent with the desired action at the crossing and reduced the potential for misunderstanding the meaning of the flashing strobe light. TxDOT granted permission to undertake a field evaluation of the vehicle-activated strobe light system at a passive grade crossing near Temple, Texas. The sign system placed in the field is shown in Figure 3.

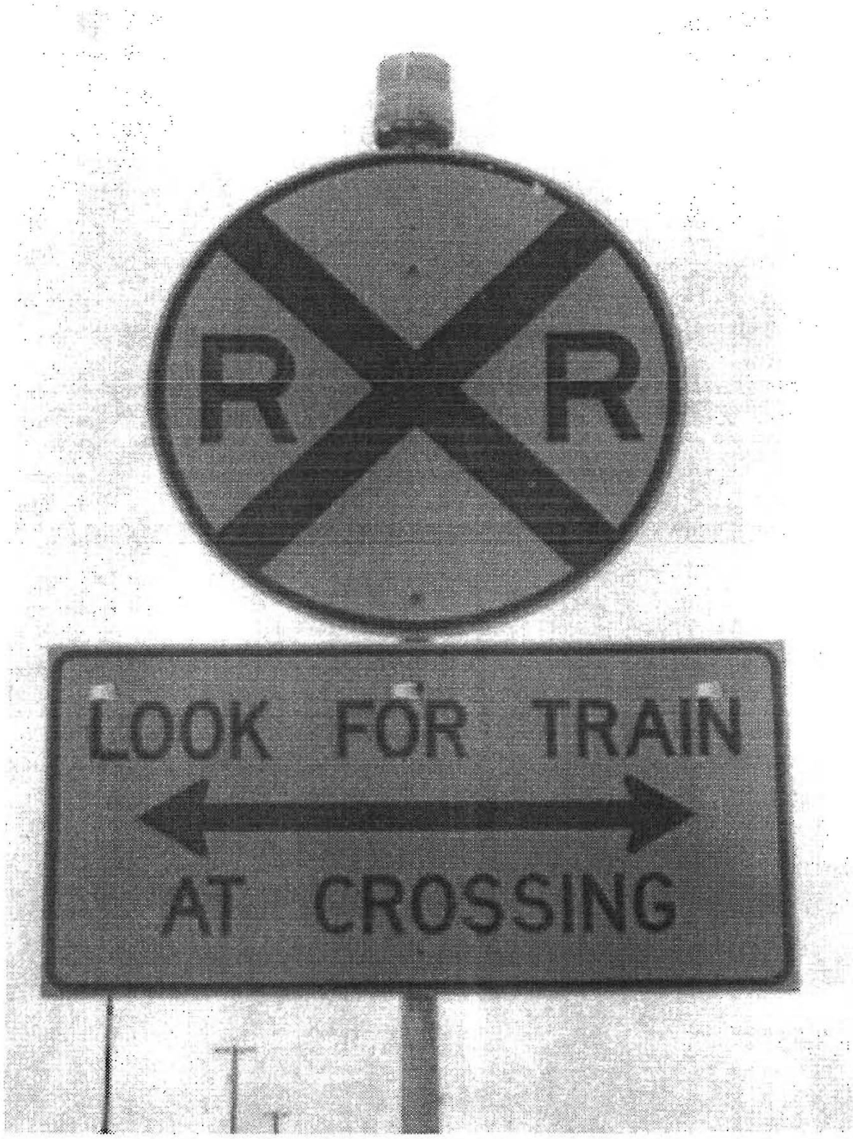


Figure 3. Vehicle-Activated Strobe Light System.

3.4.1 Objective

The objective of this task was to determine the effectiveness of the vehicle-activated strobe light and supplemental sign as enhancements to the W10-1 sign at passive grade crossings.

3.4.2 Methodology

The research team developed three study methods for evaluating the effectiveness of the enhanced sign system. First, a spot speed study was designed using a *before* and *after* methodology to determine if the implementation of the enhanced sign system led to a more cautious approach to the railroad crossing. Second, a driver survey was developed to measure driver awareness of the flashing strobe light and supplemental sign and to collect drivers' opinions of the enhanced sign system. Third, a driver observation study was developed and conducted during night driving conditions to evaluate drivers' reaction to the strobe light and the associated driving patterns between the vehicle-activated strobe light and the highway-railroad grade crossing.

3.4.3 Results

The results of this research suggest that the enhanced sign system is an effective traffic control device and can improve roadway safety at passive highway-railroad grade crossings. Average speeds on both approaches to the grade crossing were lower after the installation of the vehicle-activated strobe light. This reduction in average speeds was especially true at night as lower average speeds were observed at all data collection locations. A four mile-per-hour speed reduction between *before* and *after* study conditions was observed 100 meters west of the crossing. It is difficult to predict how much of the speed reduction is directly attributable to the vehicle-activated strobe light; however, it is safe to conclude that the enhanced sign system had a positive contribution in reducing speeds on the approaches to the grade crossing.

Drivers responded favorably to the addition of the vehicle-activated strobe. The number of drivers who recalled the supplemental sign was encouraging, especially the number of drivers who could recite the exact wording of this unfamiliar sign. Further, by simply adding the flashing strobe light and supplemental sign to the existing W10-1 sign, some drivers thought these enhancements meant that transportation officials considered this location a dangerous grade crossing. These same drivers said that they approached the crossing with more caution than in the past. None of the drivers surveyed said that they correlated strobe light to the presence of a train at the crossing. The research team did not observe any erratic maneuvers at the onset of the strobe light.

The final two driver surveys conducted, just before complete darkness set in, resulted in drivers claiming that they did not observe the flashing strobe light but did observe the supplemental sign. Since the purpose of the flashing strobe light is to draw the driver's attention to the warning sign(s), not to the strobe light itself, it would appear that the enhanced sign system performed perfectly in these two instances.

Based on the findings described above, the vehicle-activated strobe signing system increased driver awareness of the passive highway-railroad grade crossing. Further, the enhanced sign system caused drivers to approach the passive grade crossing with additional caution. The research team observed a reduction in average speed on both approaches to the highway-railroad grade crossing after the installation of the enhanced sign system. The vehicle-activated strobe light was effective in directing drivers' attention to the railroad advanced warning (W10-1) and supplemental signs. The enhanced sign system did not cause any adverse driver reaction.

3.4.4 Recommendations

The results of this study suggest that the vehicle-activated strobe light signing system can be an effective traffic control device at passive highway-railroad grade crossings and one that is worthy of additional investigation and implementation. All of the results of this investigation were positive, and the enhanced sign system shows promise for improving safety at passive grade crossings. The research team recommends that the enhanced sign system be applied to rural passive grade crossings, specifically those slated for future improvements. It is feasible that this enhanced sign system could be applied to between 50 and 100 passive grade crossing throughout the state of Texas each year.

4.0 PUBLIC EDUCATION

4.1 INTRODUCTION

This section presents a summary of the public educational material developed as part of this research.

4.2 RAILROAD CROSSING PUBLIC EDUCATION

An important finding from the expert panel, focus group, and driver comprehension studies was that drivers generally expressed a lack of understanding of requirements and responsibilities at passive and active highway-railroad grade crossings. Similar findings have been documented in the literature. To overcome the problem with substandard levels of driver understanding, a document containing important highway-railroad grade crossing facts was created.

4.2.1 Objective

The objective of this research was to develop a simple and concise document highlighting important facts concerning highway-railroad grade crossings. This document was created in two-page sections, with each section written on a different subject or for a different audience. The document was created to be subdivided if only a subset of the sections are needed.

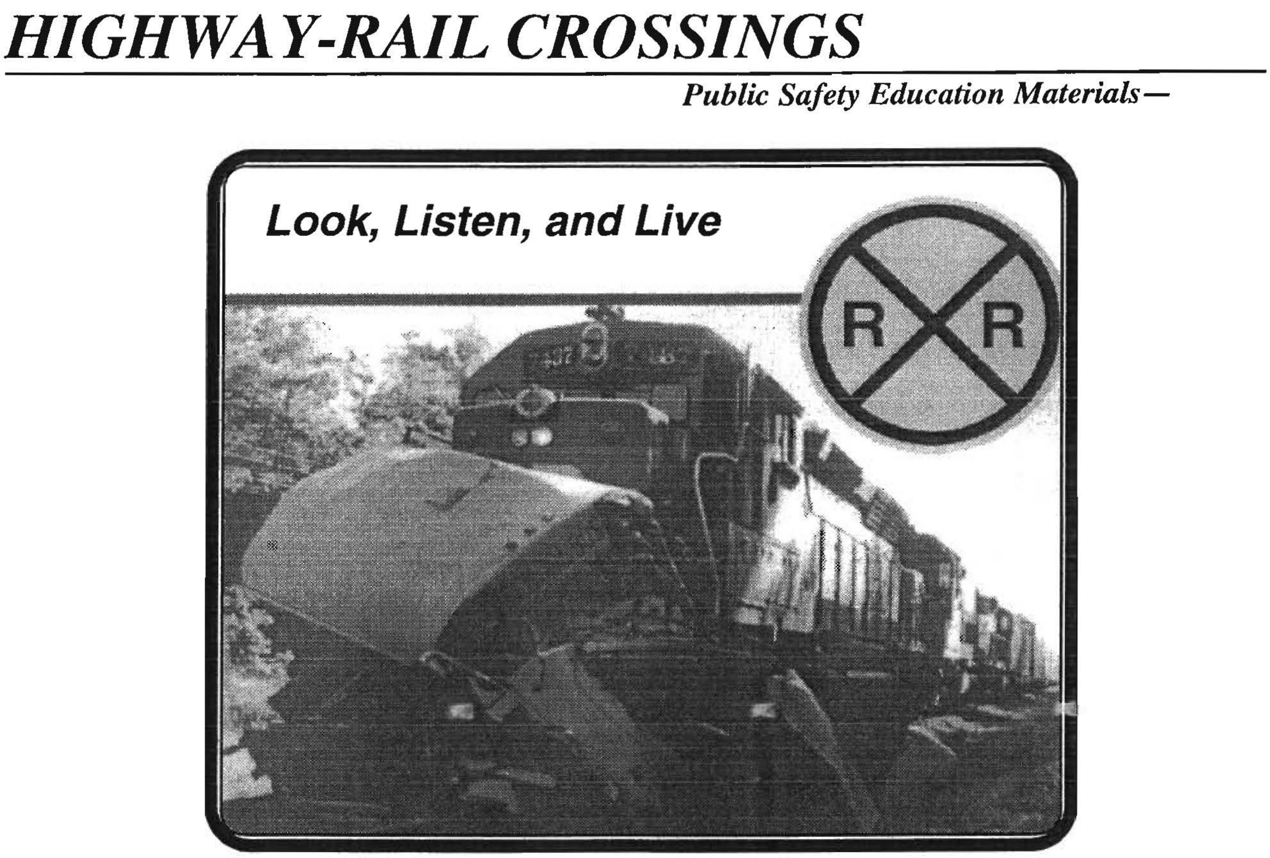
4.2.2 Methodology

The literature, TxDOT materials, research study results, and experience and creativity of the research team was aggregated to develop the educational document. As mentioned, the research team developed the document in two-page sections to provide for different audiences and to allow the document to be divided as necessary. The document was written to cover a wide array of topics and be adaptable to any audience.

4.2.3 Results

The result of this work was a user friendly document that can be distributed throughout the state of Texas. The cover of this document is shown in Figure 5. The document contained the following sections:

1. COMMON MYTHS - Get the Facts
2. COMMON QUESTIONS - Why are things the way they are?
3. RAIL TRANSPORTATION - Role of the Railroad in the Transportation System
4. STATS AND FACTS - Hard Facts about Grade Crossing Crash Statistics
5. MOTOR VEHICLE LAWS - Laws Pertaining to Railroad Grade Crossing Situations
6. OPERATING PRACTICES - Railroad Operating Practices Defined
7. DRIVER RESPONSIBILITIES - Your Responsibilities as a Driver



HIGHWAY-RAIL CROSSINGS

Public Safety Education Materials—

Look, Listen, and Live

Figure 5. Public Education Document.

8. DRIVER BEHAVIOR ISSUES - Understanding the Human Factors Involved
9. MAINTENANCE - Division of Responsibilities for Maintenance Activities
10. ACTIVE WARNING DEVICES - What They Mean and How They Work
11. CONSOLIDATION & CLOSURE - Crossing Consolidation and Closure Procedures
12. POLITICIANS & OFFICIALS - Role of Authorities in Grade Crossing Safety
13. PEDESTRIANS & TRESPASSERS - Pedestrian and Trespasser Responsibilities
14. SCHOOL BUS OPERATIONS - Safe Transportation of Precious Cargo
15. HAZARDOUS MATERIALS - Safe Transportation of Hazardous Materials
16. EMERGENCY VEHICLES - Safe Routing of Emergency Vehicles
17. THE YOUNGER YEARS - Safety Education for Kindergarten and Elementary
18. GENERATION "NEXT" - Safety Education for Teens and Preteens
19. FREE AT LAST - Safety Education for Young Drivers
20. ADULTS WITH SENIORITY - Safety Education for Older Drivers
21. OPERATION LIFESAVER - Grade Crossing Safety Program
22. RESOURCE LIST - Contacts for Reporting Grade Crossing Concerns

Readers of the document will gain a better understanding of the appropriate actions at or near highway-railroad grade crossings.

5.0 IMPLEMENTATION

5.1 INTRODUCTION

This implementation section is the compilation of recommendations from the several tasks completed as part of the enhanced traffic control devices and railroad operations at highway-railroad grade crossings study. Two enhancements to passive warning devices show promise and are recommended for further implementation. These enhancements are the experimental "YIELD TO TRAIN" sign and vehicle-activated strobe light.

The research team recommends the experimental signing system and the vehicle-activated strobe light systems be installed as interim devices. The interim period will include the time between the identification or programming of a passive highway-railroad grade crossing for upgrade to an active crossing and the time of installation of the active crossing devices. One benefit to applying these enhancements for a short time period is it reduces the potential *novelty* effect commonly associated with the application of new signing systems.

This section presents additional information regarding implementation of these devices. The public safety education material is also discussed.

5.2 EXPERIMENTAL SIGNING SYSTEM

The research team developed two sign systems as part of the experimental signing system study. The first signing system was a "YIELD TO TRAINS" sign system. The second sign system was a "LOOK FOR TRAINS" sign system. Both experimental systems showed promise for increasing driver awareness and understanding of their responsibilities at grade crossings, and thus, improving safety at highway-railroad grade crossings. All things considered, the "YIELD TO TRAINS" sign system was judged the better of the two systems.

The implementation of the "YIELD TO TRAINS" sign system is estimated at $300 per approach plus labor for installation and maintenance. As mentioned, the research team recommends that these signs be placed as an interim measure between the identification of a passive crossing for improvement until the time the active warning devices are installed. It is estimated that between 50 and 100 locations throughout the state of Texas may be eligible for the sign system each year. Installing the sign system at between 50 and 100 locations per year would result in a cost of between $15,000 and $30,000, not including labor and maintenance. TxDOT personnel can complete maintenance. The signs will be reusable and can be applied at more than one location.

5.3 VEHICLE-ACTIVATED STROBE LIGHT

A second study included the field implementation of a vehicle-activated strobe light along with the "Look For Trains At Crossing" supplemental sign at a passive highway-railroad grade crossing in Temple, Texas. The vehicle-activated strobe light was intended for use at passive highway-railroad grade crossings with the purpose of gaining the driver's attention and directing their attention to the W10-1 sign. The results of this investigation were positive, and the vehicle-activated strobe light shows promise for improving safety at passive grade crossings.

The vehicle-activated strobe sign system costs are estimated at approximately $5,000 per approach, excluding labor and maintenance costs, which includes the strobe light, loop detector and amplifier, single shot relay, solar charged 12-volt battery or similar power source, and associated wire. PVC pipe to encase the loop detector wire will be required when installing this device on gravel roadways. The strobe light can be operated on commercial power if available, eliminating the need for the solar charged battery.

All of the components mentioned, with exception of the buried wire, PVC pipe, and in-pavement loop detector, can be reused at a new location when improvements are made to the passive crossings with the vehicle-activated strobe light signing system. It is feasible that this enhancement could be applied to between 50 and 100 passive grade crossing throughout the state of Texas each year, resulting in a total cost of between $250,000 and $500,000, excluding labor and maintenance costs. TxDOT personnel can complete maintenance of the vehicle-activated strobe. Unlike static signs, the electrical nature of the vehicle-activated strobe will require a more frequent maintenance schedule.

5.4 PUBLIC EDUCATION

This study included the development of a *Railroad Crossing Safety* document for use as a public education tool. This document highlights important facts regarding highway-railroad grade crossings and includes 22 individual sections. The 22 sections can be applied collectively or used as individual documents. The implementation of the *Railroad Crossing Safety* document should include public distribution to Texas citizens of all ages. Public Information Officers within each district office can serve as the distribution point in each district of the state. The document should be distributed to Operation Lifesaver, the Railroad Commission, TxDOT Public Information, the Texas Education Agency, the Department of Public Safety, and other related agencies that have contact with drivers in Texas. An Internet web site containing this information can also be developed.