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16. Abstract

The current passive signing system for railroad-highway grade crossings is used at both actively and passively controlled crossings. A sign system unique to passively controlled crossings which conveys to the driver his or her responsibility is needed. This research developed two experimental passive signing systems and tested driver comprehension, understanding, and reaction to them under both laboratory and field conditions.

The experimental signs were installed at 90 crossings in three Texas counties, with eight crossings identified as test crossings. A before and after study was conducted at each of the eight test crossings. Quantitative measures of driver speeds on the approaches to these crossings, as well as qualitative measures of driver looking behavior and driver responses to exit surveys, were analyzed.

The results of these analyses indicate that both sign systems performed well in the field. The results suggest a decrease in driver speed on the approach, an increase in driver looking behavior, and a positive driver opinion of the sign system. Driver ability to recall signs seen on the approach to the crossing improved from 39 percent for the before condition to 78 percent for the after condition. The survey also indicated that drivers do not know the meaning of the advance warning sign and are unaware of the action required by the advance warning sign.

The results of the study indicate promise of increased safety at passive railroad-highway grade crosssings. It is recommended that these signs be installed at additional crossings and evaluated over longer periods of time to investigate possible novelty effects that may be occurring.

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ENHANCEMENTS TO PASSIVE WARNING DEVICES

AT RAILROAD-HIGHWAY GRADE CROSSINGS

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IMPLEMENTATION STATEMENT

This study evaluated two experimental signing systems for enhancing passive warning devices at railroad-highway grade crossings. Both experimental systems showed promise for increasing driver awareness and understanding of their responsibilities at grade crossings, and thus, improving safety at railroad-highway grade crossings. There were, however, some novelty effects associated with the new signs; i.e., drivers tended to revert back to their previous behavior as they became familiar with the new signs. Because the experimental signs showed potential for reducing the number of accidents at grade crossings and the novelty effect needs further evaluation, it was recommended that the experimental signs be installed at additional railroad-highway grade crossings in other Texas counties and evaluated over a longer period of time.

To implement either of the experimental signing systems developed as a part of this research at the over 8,000 passive grade crossings in Texas would require approximately $2,400,000 ($300 for two signs per crossing) plus labor for installation and maintenance of the sign systems. At an average cost of $1,000,000 per fatal grade crossing accident, a reduction of three fatalities (approximately five percent of the annual rate) would pay for the new signs. Because the new signs should last for five to seven years, a relatively small improvement can be highly cost effective; however, available funding and resource limitations necessitate reasonably certain safety improvements as a result of installing the new signing systems that have not as yet been verified. Funding limitations and the uncertain safety effectiveness of the new signs also support the recommendation for further evaluation of the experimental signing systems.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions 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 and is NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES. The engineer in charge of this project was Daniel B. Fambro, P.E. No. 47535 (Texas).

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

TABLE OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF TABLES (Cont'd.)

LIST OF FIGURES

LIST OF FIGURES (Cont'd.)

1.0 INTRODUCTION

Railroad-highway grade crossing safety remains a concern even though the Federal Highway Administration reports that fatal, nonfatal injury and combined fatal-plus-nonfatal injury accident rates have declined by 88, 60, and 65 percent, respectively, from 1974 to 1991 (1). Approximately half of the accidents occurred at passively controlled crossings, which account for some 75 percent of all crossings (2). Passive crossing control utilizes signs, pavement markings, and other passive traffic control devices to warn and inform the motorist of the crossing. Active control, in addition to displaying the same passive signs and markings, uses some combination of flashing lights, bells, and gates to warn of the hazardous proximity of a train. Most of the improvement in the accident rates can be attributed to the improvement of approximately 26,000 railroad-highway grade crossings from 1974 to 1991, with many of the projects upgrading passively controlled crossings to actively controlled crossings (1).

Although the accident rate is decreasing at railroad-highway grade crossings, both daily vehicle trip miles and train traffic are growing (3), increasing exposure at grade crossings and, therefore, increasing the potential for accidents at crossings. To ensure that accident rates at crossings do not begin increasing, a sign system for exclusive use at passive railroad-highway grade crossings providing more information to the driver than the current standard passive sign system is needed.

PROBLEM STATEMENT

There are more than 13,000 railroad-highway grade crossings in Texas, with some 9,000 of those grade crossings passively controlled. While approximately 100 to 150 of these crossings are converted to active control each year, the conversion of all eligible passively controlled crossings to actively controlled crossings is limited by the amount of available funds for crossing safety. The Texas Priority Index Formula is applied to each crossing in the state providing a numerical ranking by which crossings are identified and prioritized for upgrading to a higher level of control.

Contrary to the belief of some motorists, not all crossings would benefit by conversion to active control. Crossings with low train volumes, low train speeds, or low traffic volume may not warrant active control. Many passively controlled crossings in rural Texas are spur track crossings used for low speed service operations during harvest season in daylight conditions, and, although not necessarily required, the train crew often conducts traffic control as the train approaches the crossing. Other spur track operations in rural towns and in urban areas are conducted during daylight hours at slow speeds and may not benefit from active control. Some mainline railroad crossings which meet certain volume and speed requirements for both trains and vehicles, display desirable geometric characteristics, and meet sight distance requirements and other considerations, such as a vehicle mix void of hazardous material carriers and school buses, may also benefit by remaining passively controlled. Notwithstanding the development of some type of advanced technology in-vehicle active warning system, it is foreseen that at some point in time, all crossings which would benefit from conversion to active control will have been converted and those crossings remaining would benefit most by a passive control system.

The passive warning system required at public railroad-highway grade crossings by the current *1980 Manual on Uniform Traffic Control Devices* (MUTCD) (4), is specified for use at both passively controlled and actively controlled crossings. The fact that motorists encounter the same passive warning system for both levels of control at crossings can cause confusion. While the full responsibility of detecting and reacting to the presence of a train at a passively controlled crossing rests solely with the motorist, the responsibility of detecting the presence of a train shifts to the active warning device, and the driver only needs to observe the active warning device to know that a train is in hazardous proximity.

Enhancements to current standard traffic control devices now being used at passively controlled crossings would be desirable if the enhancements could be shown to improve safety. The enhancements would be unique to the passively controlled crossing so that the motorist would recognize his/her responsibility when approaching the crossing. At the current average rates of $1.5 million per fatal accident and $11,000 for each nonfatal injury accident used by the Federal Highway Administration in evaluating accident benefits and costs at grade crossings (5), a modest improvement in accident rates would more than justify the economic cost of implementing the enhancements. A passive warning system which would increase positive driver behavior and awareness at the passively controlled crossing is needed.

RESEARCH OBJECTIVE

The objective of this study is to develop passive warning devices which are more effective than the current forms of passive grade crossing traffic control, such as the standard crossbuck sign and the advance warning sign. These devices should be less expensive than active warning devices, but must serve the same basic purpose, which is to prevent or reduce the occurrence of collisions between railroad equipment and highway users. To accomplish this objective, the following tasks were conducted:

1. Review relevant literature;
2. Identify promising devices;
3. Conduct laboratory tests;
4. Conduct field tests; and
5. Develop implementation guidelines.

ORGANIZATION

This report contains five sections, including this introductory section. Sections 2 through 5 discuss background and supporting information, study design and data analysis, results, and study conclusions.

Section 2 presents relevant background and supporting information that explain the importance of the project in reference to other efforts in the area of grade crossing safety. The background information also assures that duplication of effort is avoided. Background and supporting information include information on passive traffic control devices at railroad-highway grade crossings, railroad-highway grade crossing safety, human factors considerations on driver behavior and driver response at railroad-highway grade crossings, and the types of methodologies used to measure driver response in past research.

Section 3 contains the study design for the controlled laboratory tests conducted as a part of this research. The experimental designs, study procedures, and measures of effectiveness are discussed. This section also presents the treatment, analysis, and results of the data collected and also recommendations for testing of passive systems in a field environment.

Section 4 contains the study design for this field study test conducted as a part of this research. The experiment type, site selection criteria, and measures of effectiveness are discussed. The study procedures, sample size goals, and methods of data treatment and analysis are discussed. This section also presents the treatment, analysis, and results of the data collected including quantitative data associated with the measures of speeds on the approaches and qualitative data associated with driver looking behavior observations and driver survey results.

Section 5 presents conclusions and recommendations arising from the research. Suggestions for implementation of the study results and recommendations for further research are also presented.

2.0 BACKGROUND

Background information relevant to this study includes prior studies of railroad-highway grade crossing safety, driver performance measures at railroad-highway grade crossings, traffic control at passively controlled crossings, driver understanding of railroad warning devices, experimental signs at railroad-highway grade crossings, evaluation techniques for current and experimental signing, and the effectiveness of icon signs. Each of the areas identified are discussed in the following sections.

SAFETY AT GRADE CROSSINGS

The railroad-highway intersection is unique in the transportation system in that two different basic modes of transportation compete for the same physical space. With the advent of the railroad expansion in the latter half of the nineteenth century, the need to provide warning of an approaching a train to pedestrians, riders on horseback, and carriage drivers crossing the tracks became evident. Earlier warning systems consisted of a signalman, either on the front of the train or on horseback preceding the train, who warned of the approaching train by waving a flag or red lantern. As motor vehicle traffic started using the crossings, active warning devices such as wig-wags and flashing lights that were activated by the train were developed and implemented at some of the more traveled crossings. The remainder of the crossings were marked by a wide array of signs, holding no particular conformity to standard. It is likely that the railroad crossbuck sign was developed during this time and placed at crossings by the railroad companies.

In 1923, three highway department officials from Indiana, Minnesota, and Wisconsin traveled through several states in an effort to standardize traffic signs (5). Their report to the Mississippi Valley Association of State Highway Departments (MVASHD) set the basis for uniformity of many of the highway signs seen today. In their report, these officials recognized the railroad-highway intersection as being the most dangerous type of intersection. Their recommendation of reserving the round shape for the advance warning sign on highway approaches is still unique to that sign. The only other sign with a round shape found in the *1980 Texas Manual on Uniform Traffic Control Devices* is that of the civil defense evacuation route sign to be used only during emergencies.

Efforts to improve safety at grade crossings in recent years can be found in studies such as the Federal Highway Administration (FHWA) funded study to develop a more effective advance warning sign with red and yellow colors as opposed to the current black on yellow color scheme (6). The study concluded that very large samples would be required to determine a significant reduction in accidents and that the cost of such a study would be prohibitive. This conclusion demonstrates the difficulty of measuring improvement effectiveness by studying accident rates.

MEASURES OF DRIVER PERFORMANCE

According to the *Texas Drivers Handbook* (7), a motorist should always "slow, look, listen, and be prepared to yield the right of way to an approaching train." The actions required by the *Texas Drivers Handbook* can be analyzed by studying driver looking behavior, speed profiles, speed changes, and deceleration rates.

Driver Looking Behavior. Looking behavior is the action by drivers to look for warning signs, identify the location of the crossing, and determine if a train is approaching or is present when the driver approaches a crossing. Measuring driver looking behavior in the field is based on observing discernable driver head movements. Several problems are associated with the measurement of head movements to determine driver looking behavior. First, driver head movement might be difficult to discern during the day and is practically impossible to determine at night. Secondly, drivers may be able to observe the crossing, where a clear view of the crossing is available, without making discernable head movements (8).

The Federal Highway Administration (FHWA), Federal Railroad Administration (FRA), and several states investigated new at-crossing and advance warning signs which resulted in an 8 to 10 percent increase in driver looking behavior (9). In the case of this study, it was inferred that the increase in looking behavior is the result of drivers exhibiting more vigilance at crossings, which would presumably result in more caution and enhanced safety. Another study, however, discarded the use of head movement observations as a measure of effectiveness after driver head movement was found to be nonexistent in the field (10). Still another study surveyed 1,200 drivers and found that approximately 80 percent of drivers relied on past experience and memory to detect the railroad crossing. Drivers familiar with particular crossings were more likely to rely on past experience and their perception of train volume than to look as they should at the grade crossings (8), while drivers who classified themselves as very unfamiliar with a crossing exhibited looking behavior more frequently (10).

Considering crossings with limited sight distance, a study by Lerner et al. (11) of driver looking behavior noted that the number of drivers that look for trains does not increase when quadrant-sight distance is obstructed, a finding that may seem counterintuitive as well as disconcerting from a safety standpoint. This finding has been supported by other reports. Observations at active crossings indicated that fewer drivers look for trains in cases where visibility was more restricted. Included in this sample was a site where visibility was restricted from one approach and unrestricted from the other, allowing a repeated measures analysis. Fewer drivers exhibited head movements indicating a search for trains in the restricted direction than did the same drivers in the unrestricted direction (12).

At passive crossings, similar observations have been made. Multiple studies have found that drivers exhibit approximately equal looking frequencies on both approaches to the crossing even at crossings where the sight distance on one approach is more severely restricted than the sight distance on the opposite approach (13, 14). This finding might suggest that most drivers who do "look for a train" are exhibiting a habitual and cursory examination rather than a conscientious search. Perhaps the most significant factor determining the frequency of looking behavior is the extent of the driver's familiarity with the crossing. Head movements also increase as a function of the number of trains. Looking behaviors are more likely at high volume crossings, a finding related to driver familiarity with the specific crossing in question and, in turn, to driver expectancies about the likelihood of encountering a train.

Speed-Based Measures. Speed profiles, speed changes, and deceleration rates are all speed-based measures of driver performance at grade crossings. Most studies at grade crossings have used these measures of effectiveness as they are more readily obtained in the field than driver looking behavior. The use of speed-based measures, such as the speed profile measure, to indicate detection of warning is rationalized because the more conspicuous the stimuli that provide information to the driver, the earlier he will detect these inputs, and, therefore, the sooner and more gradually he will begin to slow down (11). The use of all speed based measures is limited, however, because railroad warning devices do not require the driver to slow down unless there is a train present. Therefore, no difference in speed measures between the standard and "improved" devices does not necessarily mean the new device is ineffective, and even if the speed does change, the stimulus may not be known. Changes in speed may be due to the warning device, or they may be due to the alignment of roadway, the anticipated roughness of the crossing, prior knowledge of an upcoming crossing, or in response to preceding slower vehicles (15).

A study by Russell et al. (16) arrived at several conclusions pertinent to the use of speed measures based on measurement of spot speeds at eight points on the approach to a gated active crossing before and after improvements to the warning system. Although mean speeds showed useful trends, the authors suggest that they are a relatively weak parameter for testing device effectiveness because means do not isolate the occasional unsafe driver. A better measure, they conclude, is the percent reduction in speed of the fastest vehicles along with observation of individual high speed vehicles. They also found vehicle deceleration to be a weak parameter for determining the effectiveness of new signals, apparently because they did not observe decelerations that could be classified as indicative of emergency stops, and the decelerations that could be considered undesirable were too infrequent to be evaluated statistically.

Another driver performance measure that may be studied is the braking response and perception-brake reaction time (PBRT), a measure related to the speed and deceleration measures discussed above. The true PBRT, however, cannot be measured at crossings with passive warning devices because there is no onset of a signal from which to measure the reaction time. Observations that can be made at passive crossings include measurement of the distance from the crossing or the advance warning sign to the location where brakes are applied, or a comparison of the frequency of brake light activation under different passive warning configurations. As with speed-related measures, however, the braking response may be caused by stimuli other than the warning device (15).

Despite the drawbacks discussed above, driver looking behavior and speed based measurements made in the field can provide useful information about the effectiveness of a sign system when analyzed in conjunction with other measures of effectiveness. Other measures of effectiveness may include driver surveys to determine the level of understanding of elements of a warning system, conspicuity of individual elements and the overall system, and subjective ratings of the devices by drivers.

TRAFFIC CONTROL AT PASSIVELY CONTROLLED CROSSINGS

The current standard for traffic control at passive railroad-highway grade crossings is shown in Figure 1; it consists of the railroad advance warning sign (a round yellow sign with the letters "RR" and an X in black), and the railroad crossing sign, commonly identified as the "crossbuck" (a white X shaped sign with the words "railroad crossing" in black). The advance warning sign is normally located 750 feet (228.5 meters) or more in advance of the crossing in rural areas and 250 feet (76.16 meters) in advance of the crossing in urban areas. The crossbuck is located immediately prior to the tracks, generally a minimum of 12 feet from the nearest tracks when the railroad tracks and roadway intersect at a right angle.

The instructions given in the *Texas Drivers Handbook* (*7*) to "always slow, look, listen, and be prepared to yield the right-of-way (ROW) to an approaching train" seem to support the contingent of professionals who believe that the crossbuck is a yield sign, warning the driver to slow down and look for trains at or approaching the crossing. Other factions claim that the crossbuck only serves to alert the driver to the existence and location of the tracks, and therefore, a YIELD sign is needed to indicate the appropriate driver behavior. The latter practice, however, meets resistance. Opponents of this practice say that the use of a YIELD sign at a rail-highway intersection is inappropriate and not in conformance with the MUTCD, claiming that the sign should only be used to assign the ROW to traffic at the intersection of two or more roadways.

While all guidelines for the use of the YIELD sign imply that the YIELD sign is to be used at the intersection of two or more roadways, there is no specific prohibition to its use at a railroad crossing. Guidelines for the use of traffic control devices at railroad crossings similarly make no mention of the use of a YIELD sign. The MUTCD does, however, recognize the importance of safety at crossings and recommends a variety of solutions to safety problems including the installation of active control, the illumination of railroad crossings, and the erection of crossbuck signs back to back or otherwise displayed with two faces to each approach.

There have been cases where the YIELD sign has been attached to the crossbuck sign; in these situations the responsible agency is informed that the signs are not in conformance with the MUTCD, and the signs have usually been removed. One exception is in rural areas of Michigan where the county has the responsibility for the installation and maintenance of the crossbuck sign. In these cases, the practice of attaching a YIELD sign onto the crossbuck may be in accordance with the local road signing manual.

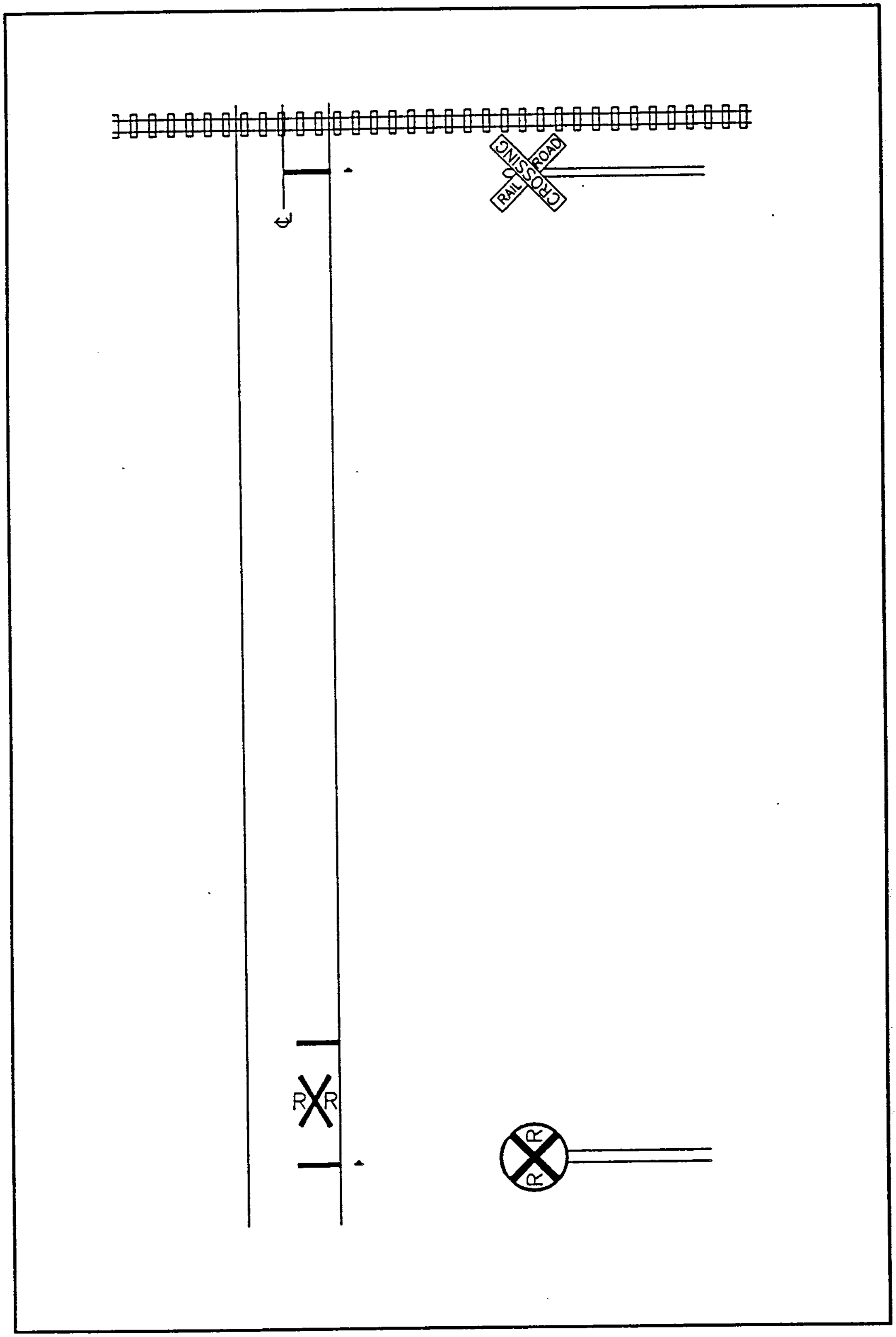


Figure 1. Current Standard for Passive Warning Devices

At locations where an engineering study has indicated that sight distance is restricted, a STOP sign may be installed at the railroad crossing. According to the MUTCD, the STOP sign may be placed either on the same post as the crossbuck (if placement on a separate post would obscure the crossbuck or sight of the train track), or on a separate post. The MUTCD also states that the erection of a STOP sign at a railroad crossing should be considered an interim measure until active control devices can be installed. The Association of American Railroads discourages the placement of the STOP sign on the same post with the crossbuck, based on the fact that the stop and YIELD sign cannot be placed on the same post according to the MUTCD, and the contention that the crossbuck functions as a YIELD sign.

UNDERSTANDING OF RAILROAD WARNING DEVICES

Many studies have been made to assess motorist understanding of the various warning and informational devices shown in the MUTCD. There seems to be a large discrepancy between the studies of motorist understanding of the standard crossbuck and advance warning sign. The discrepancy could be due to the manner in which the various surveys were administered. A clear comprehension of motorist understanding of the current passive sign system is necessary to evaluate the effectiveness of the sign system and any proposed enhancements to the system.

An example of the seemingly large discrepancy of motorist understanding of the current sign system can be seen in three previous studies documented by Mounce, et al. (17) in which respondents gave 97 percent, 76 percent, and 17 percent correct responses to the survey question about the meaning of the standard crossbuck sign. The same report documented a study in which 85 percent correct responses were found to the meaning of the standard advance warning sign. Studies conducted by numerous other researchers have found from 80 percent to near 100 percent respondent understanding of the advance warning sign and the crossbuck.

Other studies have found varying degrees of motorist understanding of the current sign system. One such study indicated that 15 percent of the motorists surveyed believed that all crossings are actively controlled. The study concluded that drivers who performed more safely at passive grade crossings had seen and correctly understood the traffic control devices. Driver lack of awareness of the railroad-highway crossing was also demonstrated by surveys of drivers downstream of the crossing; one percent of the drivers stopped and surveyed indicated that they were not aware of passing through a crossing (10).

Another study, a survey questionnaire of 176 drivers, confirms the lack of motorist understanding of railroad warning devices and the associated traffic regulation. The results indicate that many drivers are uncertain about the meaning of the crossbuck and advance warning signs, and are unsure of their responsibility at passive crossings. Many drivers felt that the train operator should assume some responsibility for safety by slowing down the train (18). The belief that the train operator should take some responsibility to avoid an accident is reiterated in other studies. One survey indicated that only 21.8 percent of the drivers questioned said that there was nothing a train operator could or should do if cars cross in front of the train. The remaining drivers indicated that the train should slow (27.7 percent), the train should stop (17.7 percent), or the operator should flash the train's headlights (17.7 percent) (19).

The large number of drivers who believe a train should slow or stop indicates that many drivers do not have a realistic assessment of a train's ability to compensate for driver error and avoid accidents. When asked about the relative stopping distances of trains and large trucks, 10 percent of the drivers did not know which required a longer stopping distance, and 3 to 7 percent believed that a heavy truck required as much or more distance to stop (11, 20, 21, 22). The ramifications of this lack of knowledge about train stopping distance are multiplied when one considers that drivers are not good judges of their own speed or other vehicles' speed (23, 24). Furthermore, the determination of a train's speed and distance are complicated due to perceptual problems introduced by the "large object" illusion which causes larger objects to appear to be moving slower than smaller objects (24).

Not all studies, however, find the alarming deficiencies discussed above. A study by the American Automobile Association in 1980 found that 97 percent of the 1,700 drivers studied gave the correct meaning for the railroad advance warning sign. This study utilized motion pictures of traffic control devices to represent driving scenes. A multiple choice question was asked about each device and the driver selected the meaning from one of the choices given (25). The conclusion that many drivers do understand current railroad signing is substantiated by another recent study which found that when shown a picture of a standard railroad crossbuck at a passive railroad crossing, 94 percent of the drivers surveyed said that the statement, "Automobiles should slow down and be prepared to yield to approaching trains" was true (26).

The discrepancies in study results may be attributed to differences in study methodologies. Even the same kind of test (field test, lab test, multiple choice written test, true/false written test) may have variant results due to differences in the wording of the questions, or due to differing possible answers in the case of a multiple choice test. For example, one study that examined driver comprehension of railroad warning devices found that the inclusion of details such as distances resulted in fewer correct answers (26).

The fact that study results may vary greatly depending on the inclusion or exclusion of details in the question or possible answers raises the point that most comprehension tests rely on the respondent's verbal and communication skills. In all comprehension tests, the participant must understand the question. Furthermore, the participant must either formulate his own answer, or understand the possible answers in the case of a multiple choice test. Thus, the researcher is challenged to formulate both a study format and specific questions that can be understood by drivers of various ages, driving experiences, and educational and ethnic backgrounds.

Assuming that an acceptable study format can be formulated, some threshold of acceptable driver comprehension must then be determined. Some researchers have proposed that three factors should be considered when evaluating driver understanding: consequence of misunderstanding, type of misunderstanding (degree to which sign is confused with similar signs), and the degree of misunderstanding (as indicated by previous research findings on motorist comprehension) (27, 28, 29). Appropriate techniques for the evaluation of driver comprehension of traffic control devices are discussed in greater detail in a following section.

EXPERIMENTAL SIGNS AT GRADE CROSSINGS

Many studies have been made to evaluate the effects of alternative traffic control devices at railroad-highway grade crossings on safety. Various aspects of some of the studies have been discussed in this chapter. One common theme to be found in these studies is that the current passive system is inadequate. The advance warning sign and crossbuck, while familiar to drivers, do not convey the type of information needed by the drivers. When approaching a crossing, the driver should be able to determine the type of protection, passive or active, present at the crossing.

Several of the studies have evaluated improvements to the advance warning sign and crossbuck such as enlargement and color and shape changes (6, 9, 10). Schoppert and Hoyt evaluated several experimental signs and made extensive recommendations on implementation of the signs in a variety of crossing conditions (30). None of the recommendations from these studies, however, have been adopted for use. A possible concern in adopting the recommendations is the alteration of the current standard signs; motorists are familiar with current signing and exchanging the signs in the field would need to be implemented in a relatively short period of time to minimize driver confusion. A nationwide driver education program would probably have to be conducted during the transition period.

A study conducted by the Texas Transportation Institute developed recommendations for enhancements to passive crossings to improve safety (31). These recommendations included:

1. All sign treatments should be applied to both sides of the roadway.

2. Advance warning signs should be larger and modified to be unique in color combination.

3. A series of two advance warning signs should be incorporated in advance of the crossing. The first would be located at the stopping sight distance from the crossing. In addition to the proposed new advance warning sign, the familiar crossbuck sign would be mounted over the first advance warning sign to attract the attention of more motorists. The second sign would be placed at the braking distance from the crossing. This sign would also inform the driver as to the type of crossing, passive or active, ahead.

4. In situations of limited visibility at the crossing, a third advance warning sign should be implemented conveying the message of limited visibility.

5. A rough textured pavement should be placed in advance of the crossing, preferably at the pavement marking, to further alert the driver of the crossing.

6. The standard crossbuck should be substantially larger.

7. The crossing should be illuminated where feasible.

For several reasons, none of these recommendations were ever adopted for use. First, as mentioned previously, the expected reductions in accidents was never documented. Second, most of the recommendations involve the modification of existing sign standards such as the removal or alteration of the standard crossbuck and advance warning sign. The recommendations were never approved by the National Committee on Uniform Traffic Control Devices (NCUTCD).

Because the signs were never approved by the NCUTCD, operating agencies were reluctant to utilize the proposed improvements in light of liability concerns. Although the state may legislate a standard that is not recommended by the National Committee, in doing so it may increase its potential liability. If an accident were to occur at a crossing that did not display standard traffic control devices, it is likely that a lawsuit would be brought against the responsible agency; and precedent indicates that the responsible agency would consequently pay a large settlement to the injured party. Consequently, any deviation from an approved standard generally is not implemented by either the railroads or a government agency. Thus, modifications to passive devices should be enhancements rather than alternatives to the existing standard, and any enhancements must be in conformance with the general policies set forth by the National Committee.

STOP and YIELD Signs. Regulatory signs such as the STOP sign and YIELD sign have been advocated for use at all passively controlled crossings by some professionals. A study by Mortimer (32) found that 8 percent of all crossings display the STOP sign. Arguments against the STOP sign include creating undue delay, increase in vehicle-to-vehicle rear end collisions, and a development of disrespect by motorists for the STOP sign. The *1980 Texas Manual on Uniform Traffic Control Devices* (4) outlines several requirements which should be met before a STOP sign is erected at a railroad grade crossing. The indiscriminate installation of STOP signs at all passively controlled crossings is not a viable solution due to the arguments made above and to the possibility of limited sight distance down the tracks from the stop bar.

The YIELD sign has been placed at crossings in combination with the crossbuck by at least one agency. The argument made against the YIELD sign by many professionals is that the crossbuck serves the purpose of warning drivers to slow down, look for trains, and be prepared to yield the right-of-way; therefore, the YIELD sign is redundant to the point of causing confusion. While this interpretation of the meaning of the crossbuck may be that intended by professionals, the interpretation by the driving public is the issue that must be addressed. Also, the crossbuck is part of the passive sign system found at active crossings. The interpretation that the crossbuck conveys the YIELD meaning would contradict its use at a location with active warning devices. The measurement of the level of driver comprehension of the advance warning sign and the crossbuck sign is an integral part of this study.

Canadian Crossbuck. The Canadian crossbuck is a traditional "X" design with the colors red and white (Figure 2). No word message in on the crossbuck. The National Committee on Uniform Traffic Control Devices (NCUTCD) stated the following about the Canadian crossbuck:

1. It increases awareness of crossbucks and promotes their importance.

2. It increases target value during the day and night, front and back. It fixes the point of conflict, as a stop sign does at an intersection, with the unique shape desirable for regulatory applications.

3. It is in conformance with previously established color priorities.

4. It brings the U.S. in agreement with Canada and other countries and could motivate other countries (like Mexico) to change.

5. It establishes a purpose for the replacement of crossbucks that have been in place beyond their useful life.

FHWA, however, turned down the recommendation of the committee because the Canadian crossbuck had not been properly tested, replacement costs would be excessive, and the replacement schedule would have to be accomplished over a very short period of time. Except in Canada, the sign is not in use today.

Conrail Crossbuck. The basic design of the Conrail crossbuck is based on the standard crossbuck. The sign, however, has been modified in color, and enhanced by a panel design to capture and reflect the headlights of trains toward the motorist (Figure 3). Its most unique feature is the attachable panels. The triangular, self-triggering, three-dimensional aspect of the device means that light is automatically reflected from the device without the assistance of any other mechanism. Except for limited testing in the Conrail Buckeye Yard in Columbus, Ohio and at sites near Columbus, this device has not been installed at rail-highway grade crossings.

Burlington Northern Railroad/3M sign. The Burlington Northern Railroad and 3M Company have been testing high-grade reflective sheeting for use on passive signs at rail-highway intersections. The materials being tested are said to be of "mirror design" and can capture train headlights and reflect the light in the direction of the approaching motorist. There is no specific information available regarding the testing of this material.

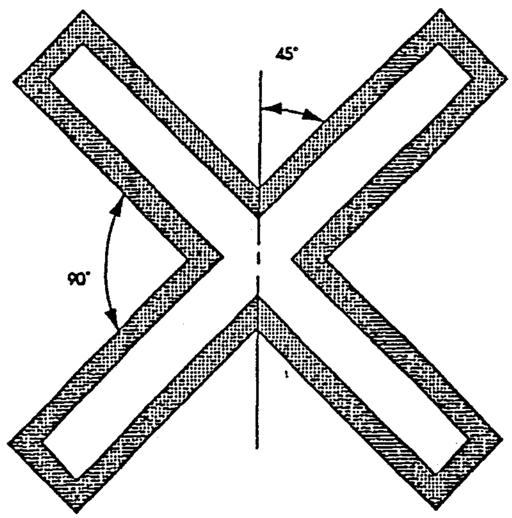


Figure 2. Canadian Crossbuck

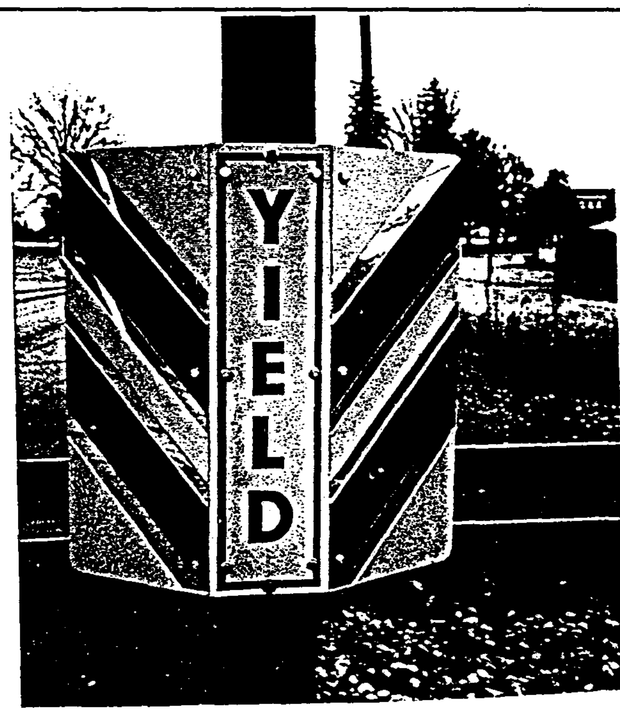


Figure 3. Conrail Crossbuck

EVALUATION TECHNIQUES FOR EXPERIMENTAL SIGNING

There is presently no standard procedure to adequately test the effectiveness of traffic control devices before they are implemented in the field. As suggested by Pietrucha, the lack of a standard methodology to evaluate driver comprehension has resulted in many techniques used to evaluate "comprehension," which apparently means different things to different people. The many tests that measure similar characteristics of the sign, or the response to the sign, go under a variety of names, and many arguments have been advanced as to the validity and importance of each of these techniques. Whereas all techniques are valid to a degree, their relative importance to the design process varies. It can be argued that there are only two measures of real importance in the initial design process: conspicuity and understandability. Conspicuity is how well the sign stands out from the background and how often it is noticed (in order to read and understand a sign, it must first be seen). Understandability is a measure of how well the meaning or intent of the sign is communicated. If the motorist cannot understand a sign, then it if of no use (33).

Dewar reiterates the importance of driver understanding of traffic control devices and acknowledges that whereas field testing may allow the observation of driver behavior, it does not provide reasons for the observed behavior. Dewar claims that one of the most effective techniques for finding out how a driver interprets what a sign means is to simply ask the driver what the sign means (in the case of symbols/icons). A follow-up procedure should then be used to determine why a particular meaning was conveyed to the driver. This procedure can provide valuable information about why a symbol is or is not effective. Another technique suggested is the use of clarity ratings, where subjects are asked to rate the clarity of the meaning of a sign on an ordinal scale. Other aspects that should be considered when evaluating driver comprehension include the speed with which subjects can understand the message (reaction time), and the distance at which messages can be understood. Glance legibility (ability to comprehend the traffic control device when it is seen for only a second) may also be important. Finally, Dewar reiterates the fact that both driver comprehension and the appropriate response are of prime importance (34).

Hulbert recognizes that human factors and driver capabilities need to be considered when developing a standardized testing procedure for traffic control devices. He offers the following points to illustrate the complexities and limitations inherent to commonly used testing procedures for traffic control devices (35):

1. *Stopping drivers downstream.* Drivers may be questioned about recognition and response several hundred yards downstream from the device. The limitation of this method is that the brain's short-term memory erases information quickly in order to go on to the next problem, and the fact that people do not remember the device does not necessarily mean they failed to take it into account before discarding the input. This testing method fails for reasons of validity.

2. *Presentation out of context.* When a traffic control device is displayed out of context, it is not likely that much useful information will be obtained from the viewer. The question then arises as to how far one must go to present the test device in a roadway driving context. Movies and video displays have been used; however, it is still very expensive and time consuming to obtain a large, dispersed, and representative sample of subjects to observe the movies or videos.

3. *Novelty effect.* If drivers are shown a symbol they have never seen before, their response will likely be overly positive, due to the novelty effect. Yet if the symbol is adopted and put in the field in competition with the other aspects of the highway scene, when the novelty wears off there may be no improvement in response.

4. *Nighttime degradation of visual acuity.* Testing only under daytime lighting fails for validity because many people suffer night myopia (the pupil opens as light dims, resulting in a loss of focus). Twenty/twenty (20/20) eyesight during the daylight may degrade to 20/40 or 20/70 at night.

5. *Visual degradation under specular conditions.* Specular glare from mirrored surfaces, such as wet pavement, sign faces, or roadway delineators may suddenly and completely eliminate the message being conveyed.

6. *Singular testing.* Many devices are used in concert with other devices, rather than by themselves. Testing in this case must be done in context with the other dependent devices.

7. *Realistic display.* Presentations of traffic control devices in test conditions usually do not include normal distractions that drivers regularly experience such as other moving vehicles, pedestrians, parking maneuvers, etc.

8. *Restrictive visibility mode.* Testing is usually conducted under clear visibility conditions; however, many traffic control devices are most critically needed under less than clear visibility conditions. Test conditions should recognize the need to replicate critical viewing conditions.

9. *Non-verbal response.* Many test procedures depend on a verbal response, including written or multiple-choice answers. This requires fluency in the testing language, although fluency is not necessarily required to understand and respond correctly to the device under test. More accurate, reliable indications can be obtained from test procedures that require nonverbal responses.

Hulbert's comments demonstrate the limitations implicit in many testing methodologies. Although neither Hulbert nor anyone else has suggested a procedure that is free of such limitations, it is important that the limitations of any testing procedure be recognized and compensated for, when possible.

Many studies use lab tests to evaluate driver comprehension for determining sign effectiveness. Lab tests include written tests that can be done anywhere and tests that can be done in a laboratory setting and do not require a test course or a field site. One lab test previously mentioned had drivers view movies of different scenes and traffic control devices and answer a multiple choice question about the meaning of each device (35). A study format such as this one, utilizing motion pictures, allows dynamic representation of the traffic control device and provides environmental cues that may represent the context of presentation with greater integrity than static photos. It is photographs of traffic control devices, however, that are more often used, generally in conjunction with a multiple choice or true/false questionnaire (e.g. 36, 37). The reliance of these test results on verbal responses, however, may limit their validity, as indicated by Hulbert's comments above.

Although field testing of traffic control devices may be preferable from a validity standpoint, in many cases, financial and liability concerns may preclude the use of field testing. When field testing is not possible, controlled testing may be used as a second best alternative; or, as is the case with this research, controlled testing may be used as a pilot study prior to the implementation of a device at a field location for further testing. The main limitation of controlled testing, however, is the inability to accurately simulate field conditions, including everything from the road itself to environmental features such as other vehicles and pedestrians that demand division of the driver's attention.

EFFECTIVENESS OF ICON SIGNS

The use of icon signing has become a common practice as world travel increases and communication with people of various native languages becomes increasingly important. The possibility that sign effectiveness may be enhanced by the use of icon (symbol) signs rather than text signs has been investigated in several studies.

One study compared the response of young subjects to text traffic signs with their response to icon traffic signs. All signs indicated either a left or right turn. The results found that both verbal and manual response speeds were greater for icon signs (38). A similar study confirms this finding, indicating that the verbal reaction speed of young subjects was faster for icon signs than for text signs for both normal and degraded viewing conditions. The advantage of icon signs was particularly pronounced in degraded viewing conditions (39).

Not all research, however, indicates that icon signs are always better. One study found that although icon signs were recalled correctly more often than text signs when the presentation was brief (1/18 sec), icon signs were not superior to text signs when participants were given an extended viewing duration (1/3 sec) (40). Although the findings of all these studies are informative, the findings are limited because none of the samples studied included older or elderly drivers.

One study that included older persons in a comparison of icon and text signs found that the responses of both young and old subjects were faster if their task was to match an icon to its corresponding text version than when their task was to match text to its corresponding icon (41). Another study found that the verbal responses of young subjects to both icon and text signs were equally fast, whereas elderly subjects responded more quickly to text signs (42).

There are questions, however, as to the value of verbal response time measures in sign research because oral response is not part of the driving task. When driving, a sign is initially small and indistinct, becoming larger and increasingly visible as the driver approaches and can finally discern the sign content. The distance at which the driver can discern the sign content determines the time available for the driver to react appropriately to the sign's message. Thus, it is argued that an assessment of the sign's visibility distance provides a more direct and appropriate index of the relative utility of text and icon signs. Based on this theory, a study that used visibility distance to compare sign legibility found that icon signs could be seen at about twice the distance of their text versions (43). This finding was reiterated in another study that confirmed that icon signs were visible at much greater distances than text signs for the three age groups studied. The advantage of icon signing was even more pronounced under dusk conditions (44). These studies suggest that icon signs afford a distinct advantage over text signs, provided that the icon signs are correctly interpreted.

3.0 LABORATORY TESTS

This section focuses on the following: a summary of the Texas Panel of Experts Workshop held in Austin, focus group interviews conducted to obtain driver input into the design and evaluation of warning devices for passive railroad-highway grade crossings, the controlled laboratory tests and testing procedures used for this research, and the results and conclusions generated from this study.

EXPERT PANEL WORKSHOP

At the start of the study, it was determined that a panel of Texas experts should be convened to discuss grade crossing issues and how the problem of safety at passive crossings might best be approached. Representatives of federal and state agencies, city governments, engineering consulting firms, equipment suppliers, and the railroad industry comprised the panel's membership. The intent of the panel's suggestions and recommendations was to serve as a guide for future study tasks, including the development and testing of new or improved passive traffic control devices.

To fulfill this task, a workshop was held in Austin, Texas on June 6, 1991. The workshop was sponsored by the Texas Department of Transportation and TTI. Over twenty grade crossing experts from across the state attended this Texas Panel of Experts Workshop. During the morning session, researchers from TTI made presentations on the history of grade crossing traffic control devices, contemporary problems and issues in the area of grade crossing safety, and current research of potential solutions at several institutions across the country. The afternoon session provided an opportunity for the attendees to discuss grade crossing issues and brainstorm for possible solutions or approaches to the problem in a small group setting.

This section documents the proceedings of the Texas Panel of Experts Workshop held in Austin. A list of criteria for evaluating passive traffic control devices, which served as the starting point for the group discussions, is presented and the workshop's conclusions and recommendations are briefly summarized. Listed in Appendix A are the workshop participants and a detailed account of each group's discussions.

Criteria for Evaluation of Improvements. Before the workshop participants divided into groups for the afternoon session, a list of six criteria by which passive grade crossings improvements are evaluated was presented. These criteria were as follows:

1. The device should alert highway users to the presence of the tracks and their location.

2. The device should indicate to motorists that they must look for trains as they approach the crossing.

3. The device should inform the driver that he/she must yield the right-of-way to trains when the possibility of a conflict exists.

4. The device should function the same way during day and night conditions.

5. The device should be consistent with standard or existing traffic control devices to avoid confusing motorists.

6. The device should provide the same or similar results as would the installation of active crossing protection, but at considerably less expense.

Workshop Findings. There was a consensus among the workshop participants on three basic issues. First, it was agreed that a need exists to provide more information and instructions for motorists at passive railroad grade crossings. Drivers should be informed of potentially hazardous conditions which may exist at the crossing such as sight distance limitations. They should be told to look for trains and yield the right-of-way to trains. Several recommendations were made for solving this problem including the use of standard STOP or YIELD signs, symbolic warning signs, and supplemental plates with instructions for drivers.

A second conclusion was that new or enhanced passive traffic control devices should be fully compatible with the standard traffic control devices used currently. Furthermore, these devices should complement existing signing. It was recommended that symbolic signs be researched in response to concerns about language-related interpretation.

The final conclusion was that the existing railroad grade crossing database should be updated and expanded. The participants felt that this would improve the engineer's ability to identify those crossings which merit improvement, and to specify what types of improvements are necessary.

FOCUS GROUP INTERVIEWS

Building on the recommendations from the expert panel workshop, a series of group in-depth interviews (focus groups) were conducted to obtain driver input into the design and evaluation of warning devices for passive railroad-highway grade crossings. This section summarizes the activities and analysis of the first group session. The value of driver participation in the design and evaluation process is two-fold. First, because they are the ultimate "consumers" or users of any new or modified warning devices, it was important for the research staff to be cognizant of the range of drivers' interpretations of prospective devices before they are tested on a broad scale. Second, ordinary drivers, without special expertise or interest in highway devices, may bring fresh perspective and insight to design alternatives that researches and others with "expert" opinions may not otherwise recognize.

It is important to recognize both the limitations and benefits of the information generated through the use of focus groups. Such groups provide qualitative as opposed to quantitative information. By their nature, they do not offer a means for assessing, in a statistical sense, the degree to which drivers understand or misunderstand specific warning devices; nor do such groups take the place of empirical efforts aimed at establishing either the short or long term influence of particular devices on driver behavior at crossings. Focus groups do, however, provide a means for investigating, to an extent unattainable with driver surveys or observational studies, driver reactions to potential warning devices.

The specific objectives of the focus group process were to:

1. Assess drivers' interpretations/understanding of existing passive crossing warning devices, specifically the Railroad Advance Warning Sign (W10-1) and the Railroad Crossing (Crossbuck) Sign (R15-1).

2. Assess driver's interpretation of and reactions to several modifications and alternatives to current passive crossing signing.

3. Elicit drivers' perspectives on both the general types of information they believe would be useful to incorporate into passive crossing warning device systems and any specific ideas or concepts for implementing new warning devices.

Sample and Procedures. The panel convened was comprised of seven licensed drivers: five females and two males, all Caucasian, ranging from 20 to 44 years old. As evidenced by Table 1, the participants are above population averages with respect to educational attainment and span a fairly broad range in terms of extent of driving. While representing somewhat diverse occupations, the group was weighted rather heavily toward student and professional occupations to the exclusion of business, trade or laborer classifications.

Following panel and moderator introductions, the general topic of highway signs, but not specifically railroad crossing signs, was introduced, emphasizing the interest in obtaining driver reactions to some specific signs and in facilitating discussion about the types of information the participants believed would help them in the driving task. A brief written exercise was then pursued in which panelists were requested to write down their initial impressions of three signs, shown sequentially, that they might encounter on a rural two-lane roadway. The three signs comprise the sign system proposed for implementation at a Midland passive crossing. In addition

Table 1. Focus Group Participants

Age	Gender	Occupation	Miles driven per Year (thousands)
20	F	Undergraduate Student	5-10
26	F	Revenue Officer	15-20
29	M	Graduate Student	10-15
39	M	Graduate Student	<5
41	F	Library Assistant	5-10
43	F	Artist	15-20
44	F	Educational Diagnostician	<5

to black and white printed representations, participants viewed appropriately colored photographic slide renditions of each sign. For each sign, the group members were asked to write down, without group discussion:

1. What, if anything, they thought they **would** do when they saw the sign;
2. Anything else, or anything different, they believed they **should** do; and
3. What, specifically, they thought each sign meant.

The written exercise served as a springboard for the group discussion that followed. In an effort to avoid directing participants' responses, most specific focus issues were raised by the group participants rather than by the moderator. This group was sufficiently verbal; most issues of interest were raised spontaneously by the group with little need for direction from the moderator. During the course of the session, numerous suggestions were made by participants that echoed very closely many of the suggestions and even specific design concepts generated by project personnel and by members of the "expert" panel convened earlier in the project.

Responses to First Advance Warning. (Figure 4) The first sign to which panelists were exposed was a combination of the current railroad advance warning sign (W10-1) with a standard advisory speed plate (W13-1). Panelists were directed to assume that they were travelling at or slightly above a posted speed limit of 45 mph (72 kph) on a two-lane rural roadway when they saw the sign.

All respondents agreed that the sign indicated that they would encounter a railroad crossing somewhere in the near distance. However, a considerable range of opinion was offered with regard to how far ahead the tracks would be; estimates ranged from about 100 feet (30 meters) to several hundred yards. Several participants suggested that their actual response to the sign would be dependent largely on site specific aspects of the roadway environment in which they saw the sign and their familiarity with the area. There was general agreement that if they were familiar with the area and/or had an unimpeded view up and down the tracks (and did not see a train), they would likely continue at their current speed and cross the tracks. On the other hand, if they were not familiar with the area and/or could not clearly see the tracks, several participants suggested that they would likely check their speed and slow down, though not necessarily to the recommended 15 mph (24.25 kph). At least one respondent suggested that he would slow down, perhaps even to the advised speed. His reason for slowing had little to do with any perceived potential hazard associated with encountering a train. Rather the advisory speed plate suggested to him that the tracks might be rough and could damage his vehicle if crossed at his original speed. One panelist, self-described as a "conservative" driver, stated that she would likely stop or at least slow greatly at the tracks in response to this single sign.

Responses to Second Advance Warning. (Figure 5) The second sign to which the panel was exposed consisted of two panels. The top panel was very similar to the W11 Series of advance crossing signs. "Train crossing" was symbolized by a graphic representation of a train with arrows pointing left and right. The lower panel comprised a supplementary panel with the legend "LOOK FOR TRAINS." The printed version of the sign and the photographic slide differed somewhat in the specific train icon used. While both icons are stylized silhouettes of "old-fashioned" locomotives, the projected image was somewhat more complex.

The sign evoked a variety of responses both in terms of what the participants believed they would do in response to it and what they thought was the sign's intended meaning. Generally, most panelists agreed that the sign was intended to suggest that there was a railroad track ahead and that they should look both ways for trains. The specific train symbols used, however, elicited widely divergent degrees of respect for the potential hazard implied by the sign. Several participants immediately suggested the similarity between this sign and other advance crossing signs (e.g., "... it's like the deer crossing signs, or playground signs"). Recognition of this similarity, however, in some cases seemed to diminish the seriousness with which the sign was taken. To wit, one respondents' statements that, like "deer crossing" or "fallen rock" signs, he would not do anything in response to the sign. This same panelist suggested that the symbols used were too toy-like, suggesting that they referred to a miniature train such as might be found at an amusement park or zoo. Alternatively, he thought it might refer to the presence of a train station, access to which was available from either side of the roadway. In this regard, he likened seeing the train symbol to seeing a sign with an airplane symbol: (see sign I-5 in the I series of General Information signs) "When I see an airplane on a sign, I don't watch out for planes, I look for the airport."

This viewpoint is contrasted with other opinions offered that the train symbol would evoke a general heightening of awareness, that "...there must be a train somewhere around here so I'd better be careful." One respondent spontaneously suggested that this sign, especially with the LOOK FOR TRAINS message, meant that the railroad tracks ahead did not have any active signals or gates. Significantly, this was noted before any mention was made by the moderator

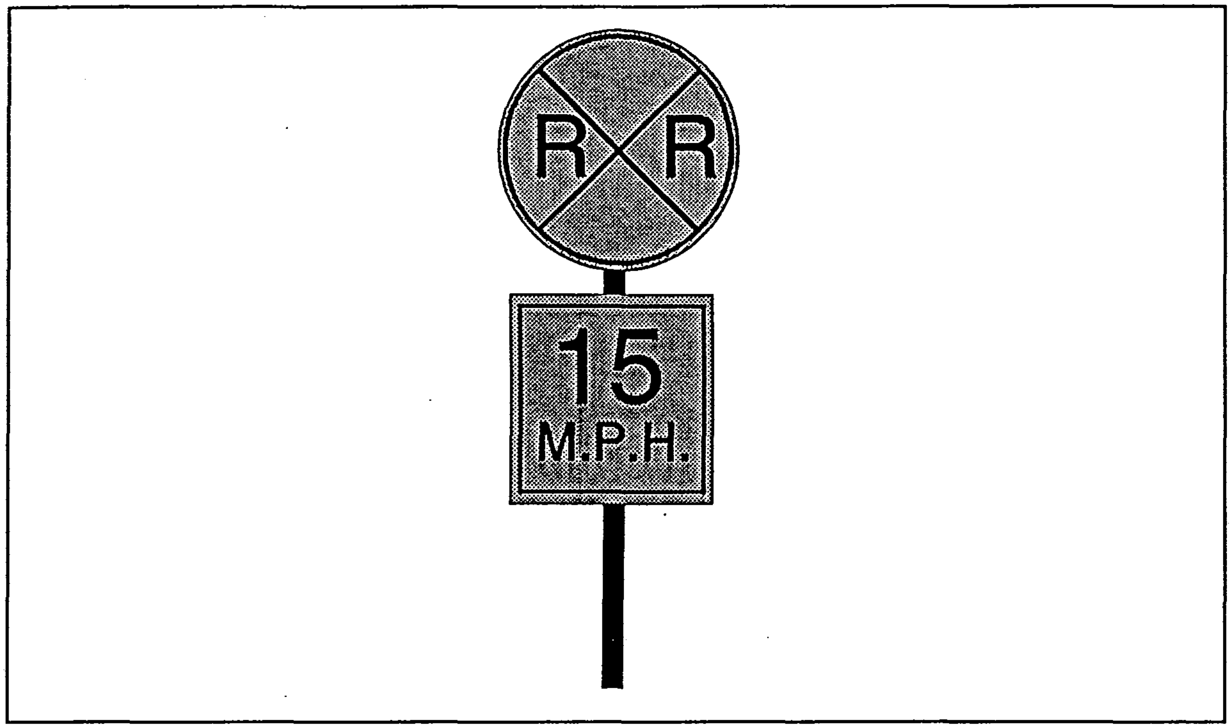


Figure 4. First Advance Warning Sign

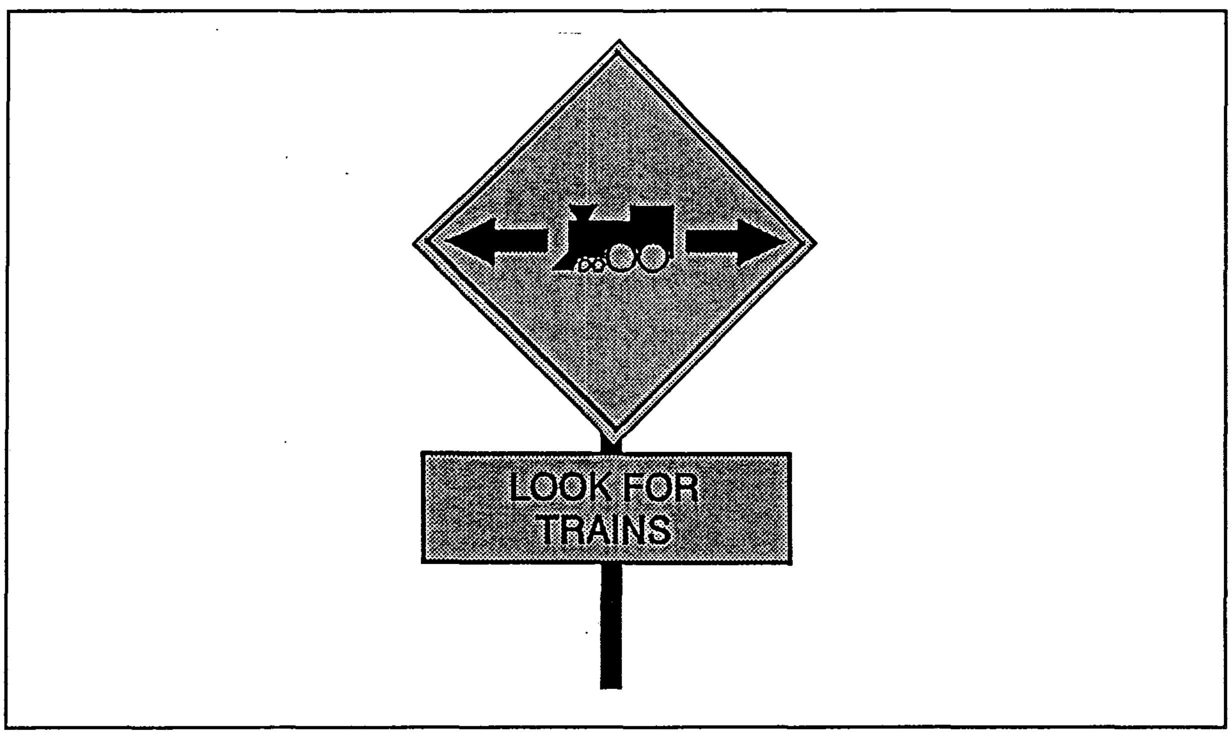


Figure 5. Second Advance Warning Sign

of the distinction between passive and active railroad crossings! With some contradiction, this same respondent suggested that he thought the verbal message was redundant. He suggested that the presence of a "speed sign" would be more effective and, expressed his belief that, in general, speed limit signs were more attended to than most other signs.

Given the opinion of several panel members that the train symbols they viewed might not be taken seriously, the group was asked for suggestions regarding alternative symbols. Some support was expressed for a pictograph depicting a more modern locomotive. Additional probing led to a general group consensus that such symbols, while possibly more realistic, would be neither as universally nor as quickly recognized as a more stereotypical train image, especially at relatively long viewing distances. To further simulate this discussion, the group was shown several examples of signs with symbolic representations of railroad tracks crossing a roadway. The specific icons displayed were unanimously rejected by the group as being less immediately understandable than nearly any train symbol. In addition to a train being easier to recognize than a track, one participant noted that the hazard of interest is a train, not the track.

Responses to At-Crossing Sign. (Figure 6) The third sign presented to the panelists was a standard R15-1 crossbuck, below which was mounted a conventional R1-2 YIELD sign. Immediately below the YIELD sign was a supplementary panel with the inscription TO TRAINS.

Overall, this composite sign was well received by most group members. The primary negative comments about it were that it is too "busy," providing too much information. The TO TRAINS panel was viewed by some to be redundant. While not all panelists shared this opinion, however, most did agree that elimination of the bottom panel would make the sign less complex. The combination of the crossbuck with the YIELD sign appeared appealing to several participants primarily because of the high perceived familiarity of drivers with YIELD signs ("...you're used to seeing YIELD; you know what you're supposed to do."). In general, panelists interpreted the sign to mean that they should slow down, search for an on-coming train, and give any approaching train the right-of-way. There was some suggestion that the sign was believed to indicate that vehicle should stop before proceeding across the tracks.

Responses to Canadian Crossbuck. (Figure 7) While discussing the proposed at-crossing sign, a panelist suggested that the addition of color, specifically red, to the crossbuck would be more attention-getting. This provided an opportunity to show the group a representation of the Canadian crossbuck. This sign is geometrically consistent with the standard crossbuck; however, each arm of the cross has a red outline and no message is displayed.

The red on white of the Canadian crossbuck was generally applauded as being more attention-getting, conspicuous, and generally more striking than the R15-1 crossbuck. The absence of a verbal message on the sign, however, was clearly disconcerting to several of the participants. Without some message, (either the standard RAILROAD CROSSING, or LOOK FOR TRAINS, etc.) these drivers viewed the crossbuck as incomplete.

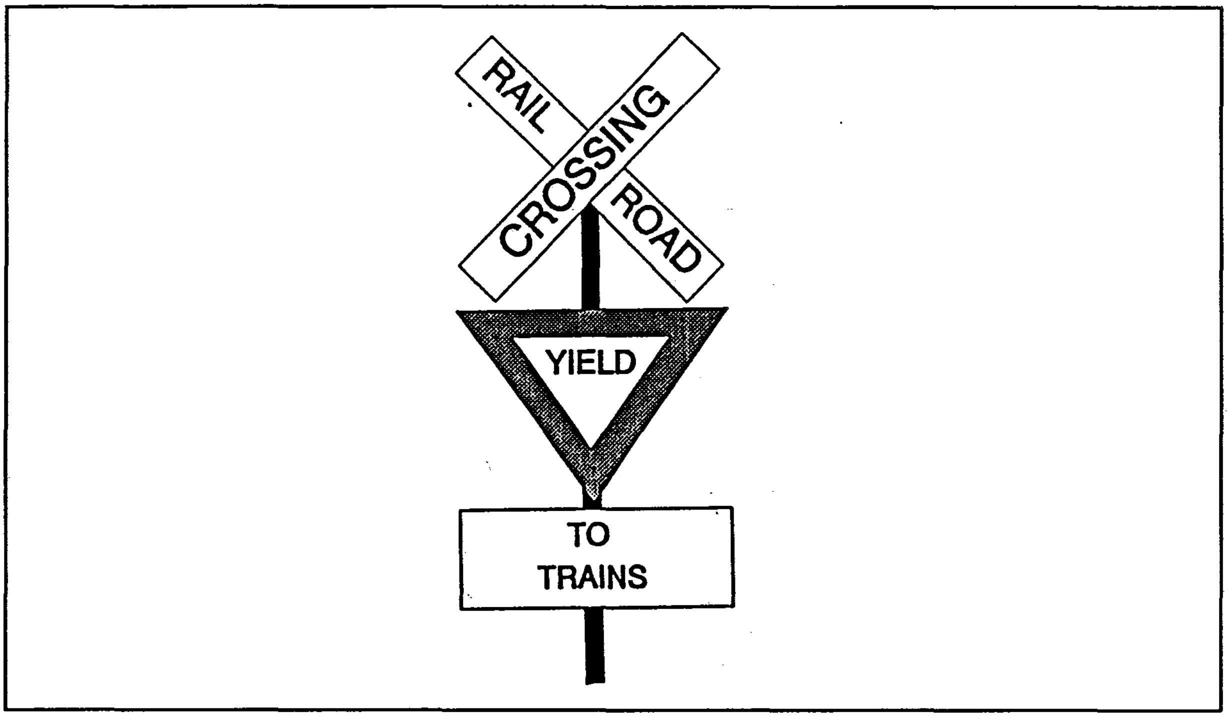


Figure 6. At-Crossing Sign

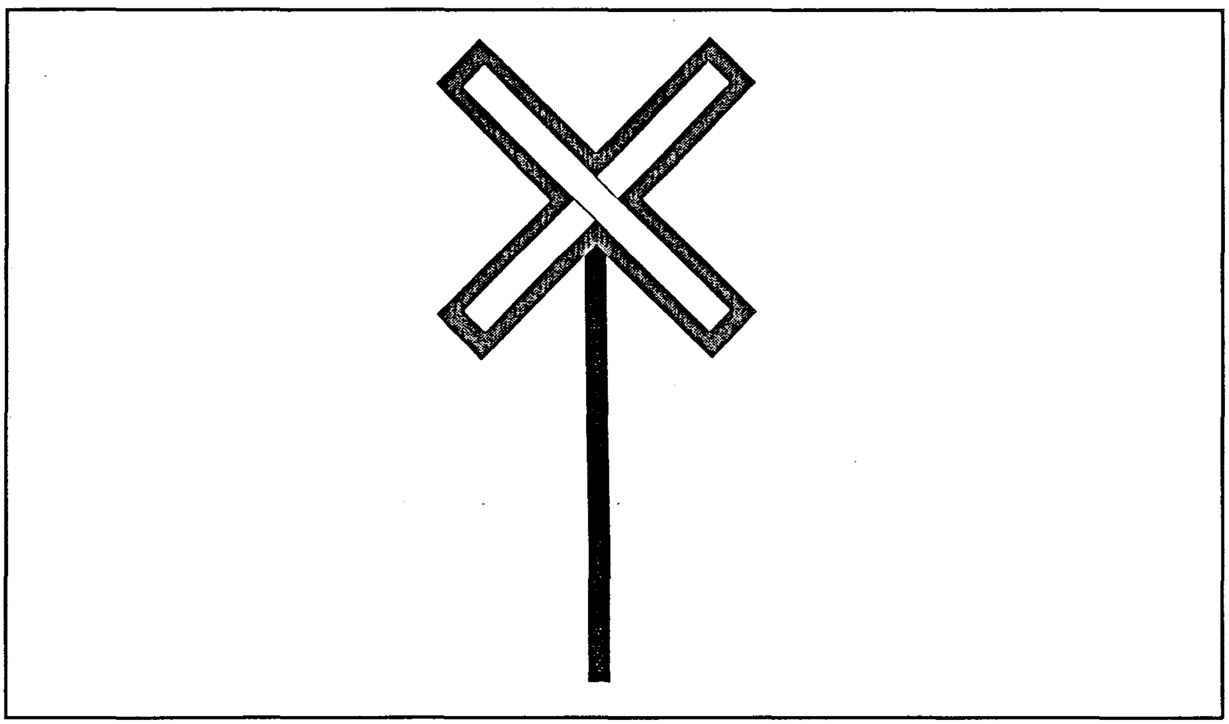


Figure 7. Canadian Crossbuck

Responses to R15-1 Crossbuck and W10-1 Advance Signs. The R15-1 crossbuck was suggested by several group members to be the only "real" railroad crossing sign. Its function was seen primarily as an indicator of the physical location of the tracks. While prompting some general notions that caution needed to be exercised when the crossbuck was seen, it did not appear to illicit any specific driver behavior. At least one panelist suggested that the crossbuck was the "old" railroad crossing sign and that the W10-1 advance warning sign was the "new" sign. The physical location of the crossbuck relative to the actual track crossing appeared, among this group, to be much more specific and obvious than the relationship between the tracks and the advance sign. The crossbuck seemed to indicate quite clearly "the track is here," whereas the advance sign appeared more likely to evoke the idea that "there are tracks somewhere around here, but I don't have a very good idea how far ahead they might be." One panelist suggested the crossbuck be made more conspicuous by mounting it on a highly reflective square background panel, thereby greatly increasing the overall reflective area of the sign.

Responses to R1-1 STOP Sign. The possibility of using STOP signs at passive crossings was raised, without prompting, by the panelists. Initially, the use of STOP signs was viewed favorably by most of the group. Several participants suggested that a STOP sign would both reduce the likelihood of accidents in which vehicles run into trains that are already occupying the crossing and increase the probability that drivers would both look and listen for on-coming trains. Upon further probing, the overall enthusiasm for STOP signs was tempered by the idea that, although the STOP sign inherently carries more weight of authority than many other signs (e.g. YIELD), drivers who were familiar with the area would eventually ignore the sign.

Responses to W3-2a YIELD AHEAD Sign and Modified YIELD AHEAD. Discussion of the pros and cons of STOP and YIELD sign use at passive crossings led to the issue of the use of advance YIELD signs. Panelists thought that some form of advance notice that there was a yield situation ahead would be beneficial, and further suggested that an indication of the reason (i.e. railroad crossing) would be useful. The panel was then shown a slide of the sign depicted in Figure 5. This sign is identical to the W3-2a YIELD AHEAD with the addition of a small version of the W10-1 railroad advance warning. Conceptually, this sign had some advocates among the group. Its execution, however, was generally deemed somewhat confusing. It appeared to several participants to be saying too much. Several suggestions were advanced which would use the standard YIELD (R1-2) or YIELD AHEAD (W3-2a) signs in combination with a separate panel showing a train symbol.

In addition to the responses to specific signs and sign concepts discussed in the preceding sections, the panel proposed several other means for warning drivers about upcoming passive grade crossings. The inclusion of some kind of tactile signal to the driver was raised by different group members and generated substantial interest among all participants. Ideas ranged from the addition of subtle changes in roadway texture to "get the driver's attention," to more substantial cues provided by speed bumps, rumble strips, pavement markers and "dips" or depressions in the road prior to the crossing. Considerable enthusiasm was expressed for the inclusion of some kind of flashing beacon, both red and yellow lights were advocated, at the crossing. Flashing lights were seen as more attention-getting than reflective signs. One suggestion was for a large lens face incorporating a train silhouette. General area lighting was recommended to enhance the visibility of the crossing at night.

The group raised and addressed the issue that signs and other warning techniques would likely lose effectiveness after relatively short periods of exposure. Drivers who regularly used a particular roadway were especially thought to be likely to ignore most devices eventually. General consensus was reached by the group that some methods of conveying information to drivers would be more resistant to this "habituation" than others. The aforementioned "rough roads" and "flashing lights" were thought to have longer term effects on driver behavior than the usual reflective signing approaches. One panelist suggested that novelty was important, and recommended some kind of "changeable sign."

Focus Group Findings. As suggested previously, caution must be exercised in drawing conclusions from information generated from a single group that cannot be considered a random or representative sample of Texas drivers. Nonetheless, the group did provide additional insight into the railroad crossing issue from the driver's perspective that is useful. Analysis of the group responses indicated that at least some portion of the driver population believe or will behave in such a way that:

1. Site specific characteristic of at-grade crossings are likely to have a strong influence on the credence drivers place in warning devices. At least some drivers believe that their behavior at crossings is predicated in large part on how well they can see up and down the tracks. This, in turn, they believe will determine the extent to which they conform with warning signs.

2. Certain signs may evoke the intended driver behavior for reasons unrelated to the intended message. Thus, for example, advisory speed signs may tend to slow some drivers down because of anticipated conditions that may be unrelated to the actual conditions. (They may slow down because they assume the tracks are rough, not because they may need to reduce their speed in order to provide adequate stopping distance.)

3. In designing symbolic images, care must be taken to avoid trivializing the symbol and thereby potentially reducing the seriousness with which the intended message is taken. At the same time, the symbols selected need to be easily recognized.

4. The effectiveness of warning devices decreases as a function of driver familiarity with the specific roadway condition.

5. Understanding the intent/meaning of a device is not the same as assuring that a driver will behave in accordance with the device. Several panelists noted differences between what they would do upon seeing certain signs and what they should do to be in compliance intended with the meaning of the sign.

CONTROLLED LABORATORY TESTS

Based on the recommendations of the expert panel and the focus group, three candidate signing systems were selected for controlled laboratory testing. To meet this objective, both qualitative and quantitative aspects of driver behavior were evaluated. This study measured driver response to the passive warning alternatives, including both driver comprehension and driver preference. This study also attempted to quantify driver response to the warning devices by comparing driver measures of performance for the various sign systems.

Study Design. The study design includes the sign systems tested, the measures of performance used, the study procedure followed, the physical layout of the test site, the requirements for the sample size and demographics, and the analysis procedure that was utilized.

Sign Systems Tested. The sign systems that were evaluated are shown in Figures 8, 9, 10, and 11. Figure 8 is referred to as sign system A, the current signing standard at railroad grade crossings; Figures 9, 10, and 11 are referred to as sign systems B, C, and D, respectively. Sign system A, the current standard, consists of a railroad advance warning sign 750 feet (229 meters) from the crossing, and a railroad crossbuck immediately before the railroad tracks. Sign systems B, C, and D are the sign systems proposed for implementation.

Sign system B, a proposed alternative, consists of the railroad advance warning sign, and a modified Canadian crossbuck (rather than the standard crossbuck). The modified Canadian crossbuck is a white X shaped sign with a red border offset from the edge one-half inch (the modification of the Canadian crossbuck is the one-half inch offset of the red border from the edge; the modified Canadian crossbuck will be referred to as the Canadian crossbuck in this document). Note that sign system B is identical to sign system A, except that sign system B replaces the standard crossbuck with the Canadian crossbuck.

Sign system C, a proposed alternative, consists of four signs: two advance warning signs and two signs located at the railroad crossing. Advance warning signs include the standard railroad advance warning sign, and a diamond shaped yellow sign that has a symbol of a train in black, and a LOOK FOR TRAINS advisory plate. The latter sign is referred to as the train symbol sign in this document. The train symbol sign is located after the advance warning sign, but prior to the railroad crossing. The two signs located at the crossing include the Canadian crossbuck, and a standard YIELD sign with a TO TRAINS advisory plate.

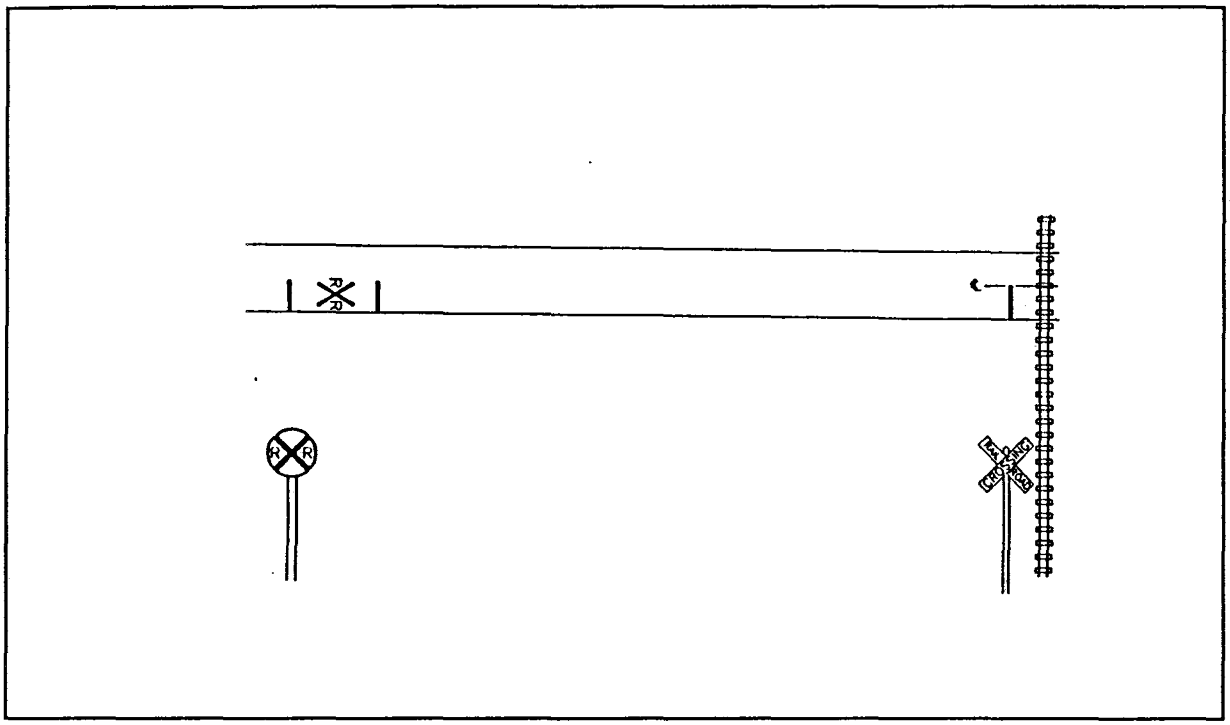


Figure 8. Sign System A (Existing Standard)

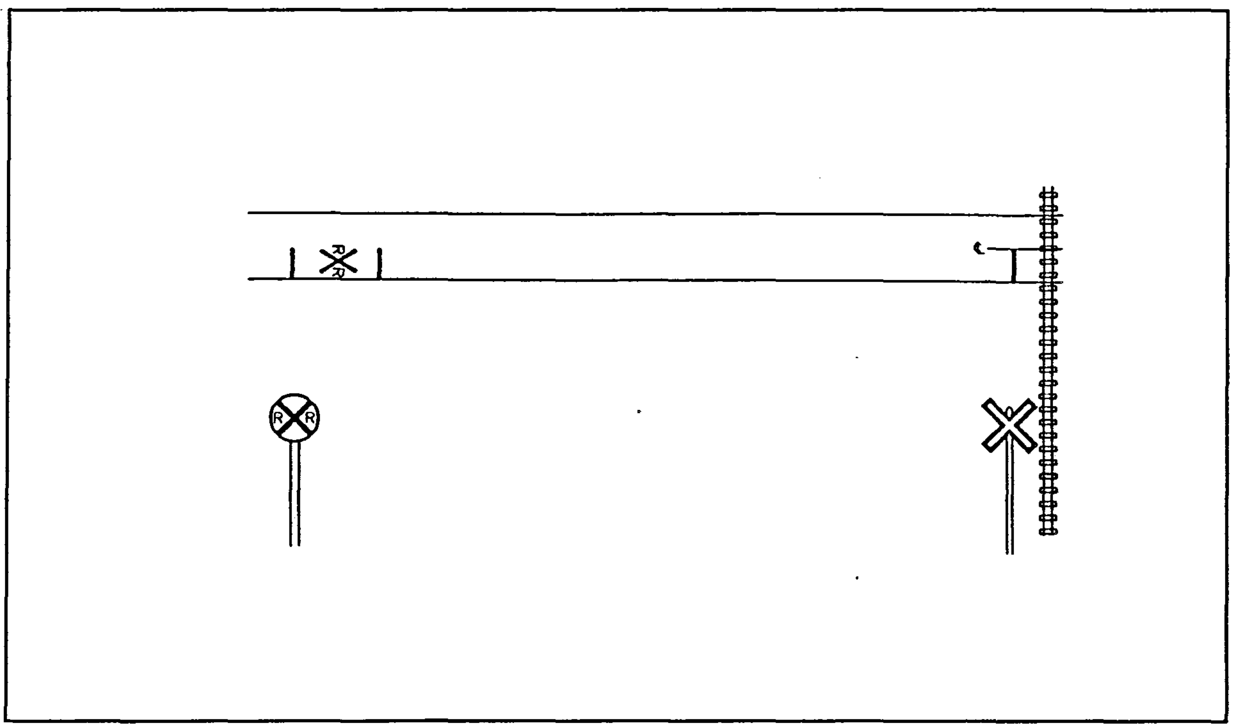


Figure 9. Sign System B (Proposed for Implementation)

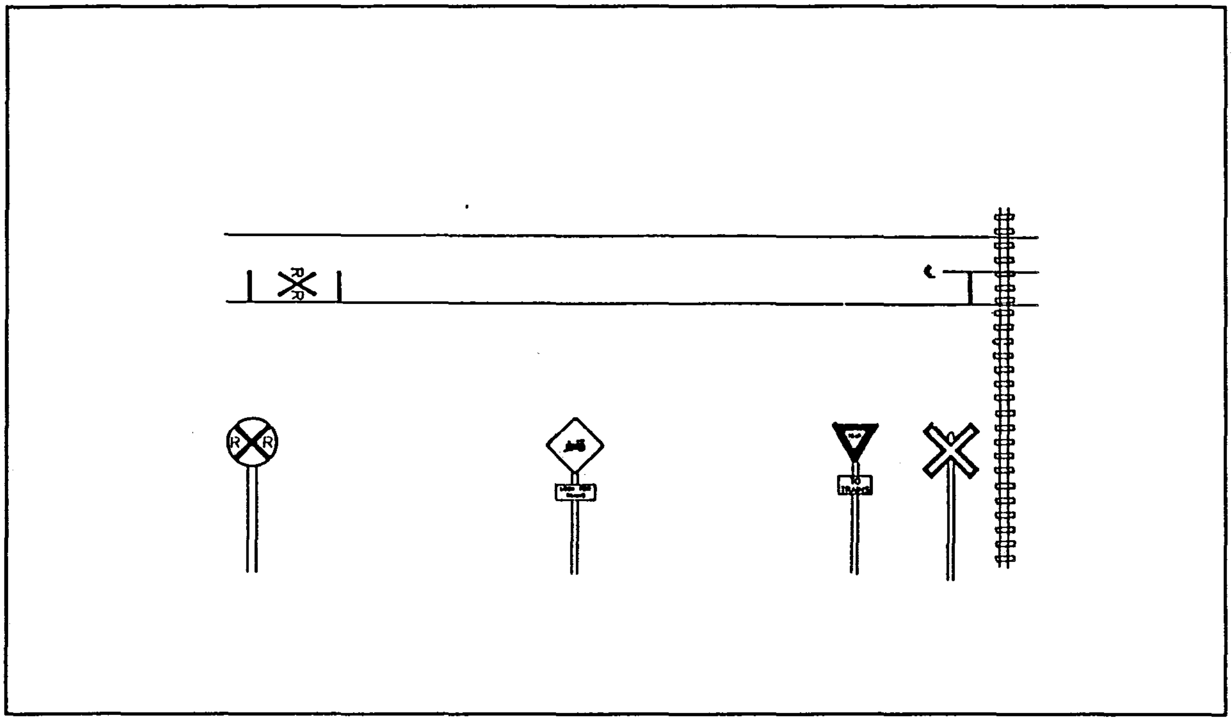


Figure 10. Sign System C (Proposed for Implementation)

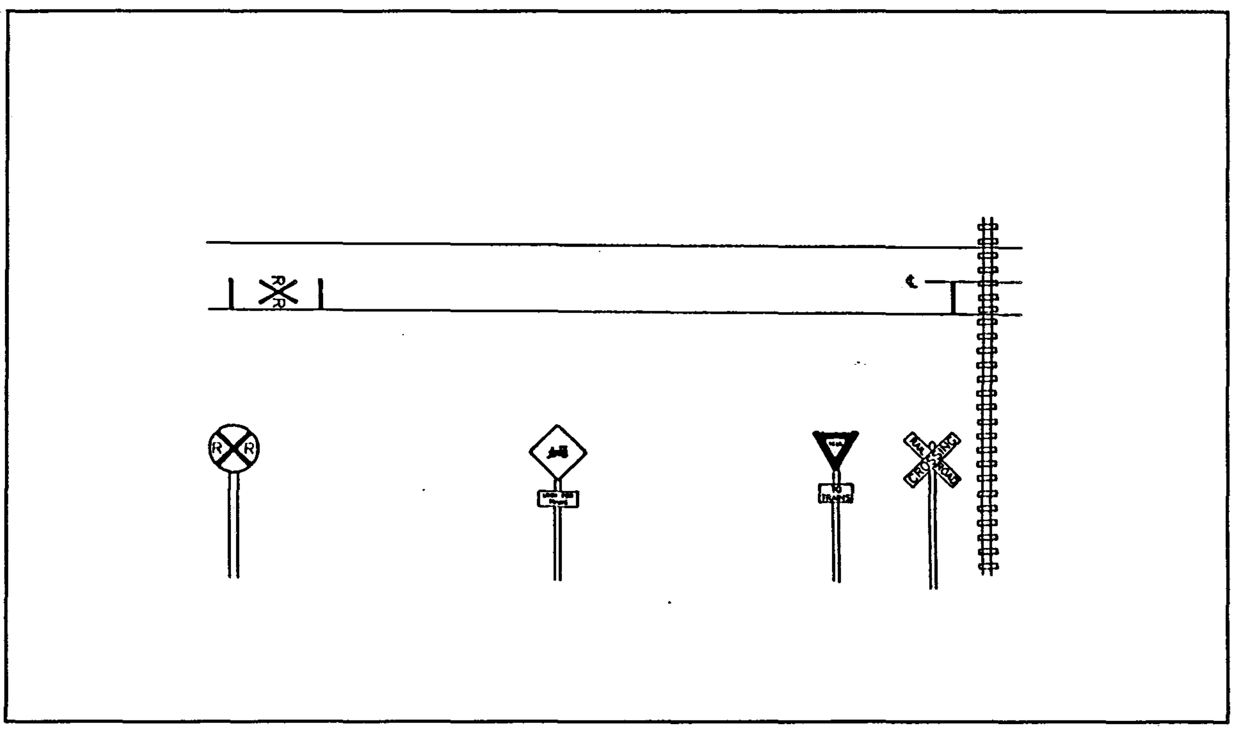


Figure 11. Sign System D (Proposed for Implementation)

Sign system D, the final alternative proposed, consists of four signs: two advance warning signs and two signs located at the railroad crossing. Advance warning signs include the standard railroad advance warning sign and the train symbol sign. The two signs located at the crossing include the standard crossbuck and a standard YIELD sign with a TO TRAINS advisory plate. Note that sign system D is identical to sign system C, except that sign system D uses the standard crossbuck while sign system C uses the Canadian crossbuck.

Measures of Performance. Measures of performance that were observed include driver looking behavior and vehicle speed. Driver looking behavior was observed prior to a YIELD sign at a mock intersection, and prior to the mock railroad crossing. It was assumed that observable driver head movement to the left or right was indicative of driver looking behavior. Vehicle speeds were observed to determine both absolute and relative vehicle speeds. Vehicle speeds were measured using a vehicle-installed distance measuring instrument (DMI). The absolute speed evaluated was the vehicle speed at the crossbuck. A relative speed was used to account for individual differences in driver behavior. The relative speed measure used was a comparison of the vehicle speed at the crossbuck with the vehicle speed at a YIELD sign at a mock intersection. This comparison was made based on the fact that drivers are legally required to yield to a train.

Although the comparison between a YIELD sign at an intersection and a crossbuck at a railroad crossing with a crossbuck is not perfect, there is some justification. Although vehicles can alter their path or speed to accommodate another driver's error and a train is unable to do so, the probability of encountering another car at a roadway intersection is much higher than the probability of encountering a train at a railroad crossing. The inference validating a comparison between a YIELD sign and a crossbuck is that the factor of vehicle accommodation (possible at a roadway intersection) is offset by the factor of train expectancy (generally low at railroad crossings).

In order to examine driver comprehension of the alternative passive warning devices in this manner, the assumption was made that a driver recognizes and understands what to do at a YIELD sign. Furthermore, in the controlled environment of this study, drivers recognized that they were not likely to encounter either another vehicle at the YIELD sign, or a train at the crossing, and presumably behaved as they knew they should, or with the same degree of apathy. The use of this comparison allowed some compensation for individual driver behavior: a driver who was likely to be conservative at a YIELD sign was likely to be conservative at a crossbuck, and a driver who was likely to be careless at a YIELD sign was likely to be careless at a crossbuck. By comparing an individual's behavior at one location with the same individual's behavior at another location (paired comparison), variability in individual driving behavior was accounted for to some extent.

Study Procedure. Sixty licensed drivers who agreed to participate in the study met the test administrators at Texas A&M Riverside Campus where the controlled testing took place on a course set up on an old runway. Prior to beginning the actual testing, drivers were able to practice driving a Texas Transportation Institute car until they were familiar with the car's controls and comfortable driving the vehicle. The subject was then instructed to drive through the course, following all signs and any directions given by the test administrator in the car with her/him. The subject was told that although no other vehicles were expected to be out on the course, she/he should stay on the marked route and behave as she/he would if she/he were driving on a public road. The subjects were requested not to drive in any unusual, unsafe, or illegal manner.

Each subject was randomly assigned to one of four groups. There were 15 subjects in each group. Table 2 shows the order in which each group saw the sign systems. Note that each group saw a different sign system first, and that the signs were seen in a different order. The order was varied to account for any learning effect that might occur during the experiment. On the first trial run, the vehicle speed was measured at four locations:

1. At the YIELD AHEAD advance warning sign;
2. At the YIELD sign;
3. At the railroad advance warning sign; and
4. At the railroad crossbuck.

The vehicle speed at the railroad crossbuck was measured and analyzed to determine if the sign system seen had an effect on the absolute speed at the railroad crossing. The subject's speed at the YIELD sign was recorded and compared to the subject's speed recorded at the railroad crossbuck. This comparison of speeds allowed a quantitative evaluation of driver behavior as a response to the various warning sign systems. The speeds at the YIELD AHEAD advance warning sign and at the railroad advance warning sign were observed so that this information would be available for other types of studies.

Table 2. Order of Sign System Presentation

	Group 1	Group 2	Group 3	Group 4
Trial Run 1	A	B	C	D
Trial Run 2	B	C	D	A
Trial Run 3	C	D	A	B
Trial Run 4	D	A	B	C

On the first trial run the subject's looking behavior was observed prior to the YIELD sign; and prior to the railroad crossbuck. The looking behavior prior to the YIELD sign was observed so that this information would be available for other studies; however, this data was not analyzed in this research. The driver looking behavior at the crossbuck was analyzed to determine if the sign system seen had any effect on the incidence of looking behavior. All data was collected during the day, when it was not raining. Data was not collected at night or during inclement weather because it was desirable to minimize the number of independent variables.

After the first run, the subject was asked a series of questions. Questionnaire responses were verbally determined; the questions were read to the participant, and her/his answers were recorded by the test administrator. First, the subject was asked to describe all of the railroad warning signs that he/she had seen on the course. Second, the subject was shown photos of the signs that were on the course and was asked questions to determine his/her understanding of the signs. The subject was asked what she/he thought each sign meant, and what, if any, action he/she would take when he saw the sign. This series of questions provided a qualitative evaluation of driver comprehension. The instructions that the drivers were given and specific questions that were asked are shown in Appendix B.

The purpose of the study was then explained to the subject. Each participant then completed the remaining three trial runs, and was asked a few more questions to determine comprehension of the signs not seen in the first trial. After all four sign systems were seen, the subject was asked to rank the sign systems in terms of their relative effectiveness. Effectiveness was defined for each subject as follows, "an effective sign system should be noticeable, should indicate to the driver that there is a railroad crossing ahead, should warn the driver of the potential danger at the crossing, and should prompt the driver to approach the crossing with caution." Diagrams of each sign system, and photos of each sign were available to assist the subject in her/his recollection of each sign system. The subject rankings provided a basis for the qualitative evaluation of driver preference.

Each subject was then asked for comments about the signs and for any comments and suggestions concerning improvements to passive railroad crossings. Some of these comments and suggestions are shown in Appendix B.

Physical Layout of Test Site. A diagram of the test course is shown in Figure 12. Note that the course consists of two straight lengths of roadway, each approximately 1180 feet (359 meters) long, also note that each straightaway is followed by a horizontal curve to the right. This configuration was chosen because it fit in the area available for use and because it provided two similar vehicle paths that would presumably minimize differences in speed (at the YIELD sign and crossbuck) due to different geometries, alignment, or sight distances. It was desirable to minimize differences between the YIELD sign at the mock intersection and the crossbuck at the mock railroad crossing to make the relative speed measure more meaningful.

Note that, as shown in Figure 12, the YIELD AHEAD advance warning sign is 100 feet (30 meters) from the start of the course and 750 feet (228 meters) from the intersection; similarly the railroad advance warning sign is 100 feet (30 meters) from the beginning of the straightaway and 750 feet (228 meters) from the railroad crossing. A horizontal curve begins approximately 330 feet (100 meters) after the YIELD sign; similarly, a horizontal curve begins approximately 330 feet (100 meters) after the railroad crossbuck.

The railroad advance warning sign was located a distance of 750 feet (228 meters) from the railroad crossing and 9 feet (2.75 meters) from the edge of the roadway). The 750 feet (228 meters) is the distance specified in the MUTCD as the approximate distance recommended for rural railroad crossings; this distance also represents standard TxDOT practice. The YIELD AHEAD advance warning sign also was located 750 (228 meters) feet from the intersection and 9 feet (2.75 meters) from the edge of the roadway so that the advance warning would be the same distance from the possible hazard for both situations. The 750 feet (228 meters) distance chosen for the YIELD AHEAD advance warning sign is within the specifications stated in the MUTCD.

The crossbuck was located 10 feet (3 meters) from the railroad tracks and 12 feet (3.65 meters) from the edge of the roadway. Similarly, the YIELD sign at the intersection was located 10 feet (3 meters) from the intersection and 9 feet (2.75 meters) from the edge of the roadway. Although the MUTCD recommends that the crossbuck be placed a minimum of 12 feet (3.65 meters) from the railroad tracks, this distance was not used because the addition of the YIELD sign with the TO TRAINS advisory plate at the railroad crossing necessitated moving the crossbuck closer to the tracks so that both signs could clearly be seen, and so that both signs were within a reasonable vicinity of the tracks.

For sign systems C and D, the train symbol sign with the LOOK FOR TRAINS advisory plate was located 375 feet (114 meters) from the railroad crossing (9 feet (2.75 meters) from the edge of the roadway). This distance is one half of the distance between the advance warning sign and the railroad crossing. In these sign series, the signs were placed at equal intervals to allow the driver to read them all without forcing her/him to select which roadside environmental factors (in this case signs) she/he would pay attention to.

For sign systems C and D, a YIELD sign with a TO TRAINS advisory plate was located 18 feet (5.5 meters) from the railroad tracks and 6 feet (1.83 meters) from the edge of the roadway. This location places the YIELD sign immediately prior to the railroad crossbuck, but adequately separates it from the crossbuck to allow a clear view of both signs. Note that all signs are placed 9 feet (2.75 meters) from the marked lane, except the crossbuck and the YIELD sign with the TO TRAINS advisory plate. The MUTCD specifies normal lateral clearance in rural areas as 6 feet (1.83 meters) from the edge of the highway shoulder or 12 feet (3.65 meters) from the edge of the traveled way. The environment on the course, however, was very different than the environment on a public rural road (there were no shoulders adjacent to the roadway marked on the course, and the paved area extended well beyond the marked lanes). When the signs were placed 12 feet (3.65 meters) from the roadway, they seemed so far away from the lane that it almost looked as if they were not part of the course. For this reason, the signs were moved in to a lateral clearance of 9 feet (2.75 meters). The crossbuck was located 12 feet (3.65 meters) from the edge of the roadway, however, and the YIELD sign with the TO TRAINS advisory plate was located 6 feet (1.83 meters) from the edge of the roadway. These exceptions were made so that both signs could be clearly seen.

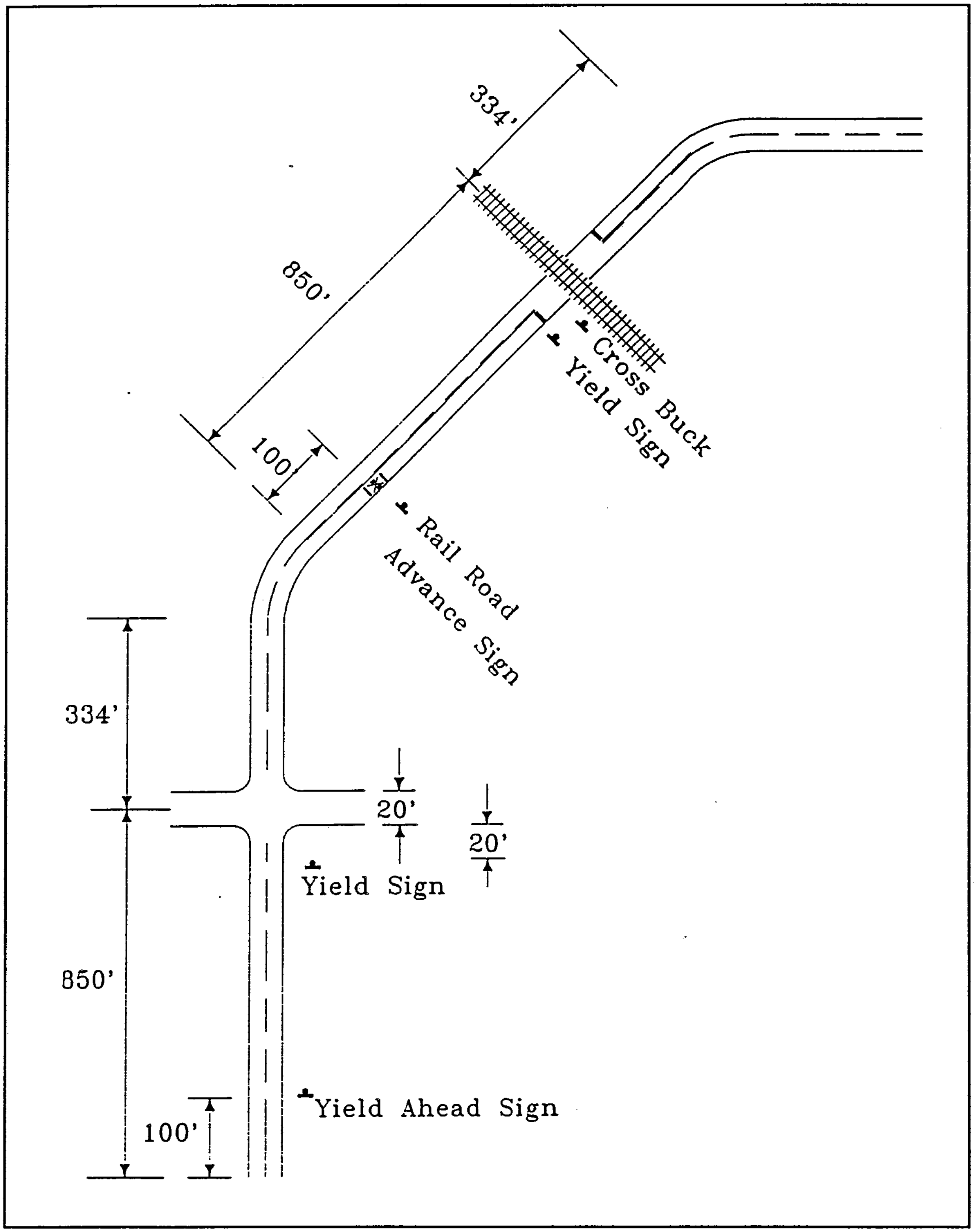


Figure 12. Test Course Layout

Advance warning pavement markings were located as specified in the MUTCD. They consisted of an X, the letters RR, a no passing marking (solid yellow centerline), and transverse lines above and below the X. The pavement markings were located approximately 10 feet (3 meters) after the advance warning sign. The symbols and letters were elongated to allow for the low angle at which they were viewed. All markings were reflectorized white traffic paint. A stop bar, 2 feet wide (0.6 meters) was painted 18 feet (5.5 meters) from the railroad crossing.

The course was set up so that the driver could not see the end of the course until the railroad "tracks" had been crossed; this was done so that the driver would not realize that the only traffic control devices on the course were the YIELD AHEAD advance warning sign, the YIELD sign, and the passive railroad warning signs. Railroad tracks were simulated by painting them on the ground (black paint). The driver completed the entire course on the first run, but completed only the last portion of the course (the second straightaway, the part of the course that had the passive railroad warning signs) for trials 2, 3, and 4.

All of the signs used in the study were standard size, with standard text. All signs were engineering grade, except for the Canadian crossbuck, which was diamond grade (the Canadian crossbuck used had been fabricated during the previous phase of testing). The current standard for all signs in the state of Texas is high intensity grade; the exception is that the standard for signs with a white background is engineering grade because the high intensity white sheeting causes too much glare. Although the sheeting used for the signs was neither the state standard (except for the crossbuck), nor entirely consistent, there is no reason to believe that this fact negatively affected the study results. All data was collected during the daytime when it was not raining (good visibility conditions); additionally, the signs were new and clean. The real advantages of the higher grade sheeting are demonstrated during nighttime or other times (such as during bad weather) when visibility is limited. Furthermore, a critical component of this study was the evaluation of driver comprehension. There is no reason to believe that the evaluation of driver comprehension was compromised by the lack of standardization of the sign sheeting.

Requirements for Sample Size and Demographics. Although it was desirable that the sample used in this study represent the general Texas driver population considering age, gender, education level, and ethnic background, a very large sample size would have been necessary to represent every combination of the above factors. Both fiscal and time constraints precluded a controlled study with such a large sample size. Effort was made, however, to use a sample of 60 drivers that was diverse and provided some representation of every segment of the Texas driver population. Each participant in the study was requested to provide demographic information, including age, gender, English literacy, and education level. This information is provided in Appendix C.

Analysis Procedure. Analysis addressed both quantitative and qualitative issues. The information that was analyzed included speed data, head movement data, driver responses to questions about specific signs, and driver rankings of the sign systems.

Speed Data. Both the absolute speed at the crossbuck and the speed at the crossbuck relative to the speed at the YIELD sign were analyzed for the first trial for each subject. For analysis of the relative speed, the difference in speed at the crossbuck and the YIELD sign was determined using matched pairs. Each driver provided data for one matched pair (from the first trial), resulting in one matched pair difference in speed. To some extent the use of matched pairs eliminated differences due to individual driver tendencies, because a conservative driver would presumably drive slower at both the YIELD sign and the crossbuck. The use of the difference in speed resulted in quantification of a relative rather than absolute measure of speed at the crossbuck.

Single factor analysis of variance was used to test for equality of means for both the absolute and relative speed data sets. The research hypothesis was that the sign system seen would have an effect on driver speed. The null hypothesis tested was that the mean speed at the crossbuck, or the mean of the matched pair differences in speed, would be the same for each sign system. The treatment variable was the sign system seen, and the response variable was either the speed at the crossbuck (absolute speed) or the matched pair difference in speed (relative speed). A significance level of 5 percent was used.

Driver Looking Behavior. Driver head movement after the advance warning sign but prior to the railroad crossbuck was recorded on the first trial for each sign system. Observable driver head movements to the left or to the right in this zone (after the advance warning sign but before the YIELD sign or crossbuck) were considered indicative of driver looking behavior.

The number of drivers exhibiting looking behavior was tabulated for each sign system prior to the railroad crossbuck. The research hypothesis tested was that the sign system seen would have an effect on the frequency of driver looking behavior. The chi-square test was used to test the null hypothesis that the sign system seen by the driver did not have an effect on driver looking behavior. A significance level of 5 percent was used.

Questionnaire Responses. Driver responses to questions about each sign were tabulated with respect to driver recollection and driver understanding. Driver recollection was determined by asking the driver to describe all railroad warning signs that she/he just saw (on trial 1 only). Driver understanding was determined by the driver's response when asked the meaning of a sign and the action required by the sign when shown a color photo of the sign in question. The photos of each sign showed the signs in their "natural environment." For example, the photo of the crossbuck showed the crossbuck in the context of its usual surroundings, including the edge of the roadway and the nearby railroad tracks. The presentation of the signs in context may have improved the level of comprehension by providing environmental cues.

When determining driver comprehension, all subject responses were classified into one of the following categories: enhanced correct, correct, incorrect noncritical, or incorrect critical. An enhanced correct answer not only correctly described the sign's meaning and any action required, but also provided additional insight about the use or meaning of the sign. A correct answer correctly described both the sign's meaning and any action required. An incorrect noncritical answer did not correctly describe the sign's meaning and the action required, but the misunderstanding would not result in any critical consequences. An incorrect critical answer did not correctly describe the sign's meaning and the action required, and it is possible the consequences of this misunderstanding would result in a critical situation.

The level of comprehension was tabulated for each sign. The research hypothesis tested was that the level of comprehension would vary depending on the sign. The null hypothesis tested was that the level of comprehension would be the same for all signs. The chi-square test was used to test the null hypothesis. A significance level of 5 percent was used.

Rankings. Drivers were asked to rank the sign systems based on effectiveness. Each driver was read the following definition of effectiveness: "an effective sign system should be noticeable, should indicate to the driver that there is a railroad crossing ahead, should warn the driver of the potential danger at the crossing, and should prompt the driver to approach the crossing with caution." The subjects were then asked to rank each sign system, keeping in mind this definition of effectiveness. The sign system considered most effective was ranked as one, the sign system considered least effective was ranked as four.

The rankings for the four sign systems were evaluated based on the average rank for each system. The sign system with the lowest rank was considered the most effective according to the drivers included in this study. The Friedman test was used to determine if there was a significant difference in the sign system preferences. The research hypothesis was that there was a significant difference in preference for at least two sign systems. A significance level of 5 percent was used.

RESULTS OF LABORATORY STUDY

This section presents the results of the controlled laboratory testing procedures. It includes information regarding sample demographics, driver speed, driver looking behavior, questionnaire responses, ranking of signing systems, and driver comments.

Sample Demographics. The results of any study are dependent on the sample used for evaluation and analysis. It was desirable that the sample used in this study represent the general Texas driver population considering age, gender, education level and ethnic background.

The age distributions of the Texas driver population, and of the participants in this study are shown in Table 3. Note that the percent of study participants in each age group closely approximates the percent of Texas drivers in each age group. Table 4 gives more detailed information about the participants used in the study. Table 4 indicates the gender and ages of all participants in each group; although the demographic characteristics of each group with respect to gender and age are not identical, the composition of the groups is very similar.

Examining other demographic characteristics, the sample used is probably less representative of the Texas driver population. Considering ethnicity, 82 percent of the subjects were white, 8 percent were Hispanic, 2 percent were African-American, and 8 percent were none of the above. It is likely that the sample used does not exactly represent Hispanic and African-American segments of the Texas driver population.

Considering the language used by the participants, 95 percent spoke English in the home, none spoke Spanish in the home, and 5 percent spoke neither English nor Spanish in the home. Furthermore, all 60 of the participants (100 percent) were able to read English. The fact that all study participants were English literate, and the fact that none of the participants spoke Spanish in the home indicates that perhaps the sample used does not exactly represent the segment of the Texas driver population who do not speak or read English. However, these factors should not bias the results of the laboratory study.

Finally, it is important to mention that the educational level of the participants was very high. Ninety-two percent of the participants had attended at least some college (12 percent had graduate degrees, 52 percent had college degrees, and 28 percent had taken some college classes). Only 8 percent had not been to college at all, and only 1 participant had not graduated from high school. Considering these numbers, it is safe to assume that the educational level of the sample does not reflect the educational level of the Texas driver population.

Table 3. Age Distribution of Texas Drivers and Study Participants

	Texas Driver	Study Participants	
Age	Population[1]	Number	Percent[2]
< 25	21.7 %	13	21.7
25 - 54	53.8 %	31	51.7
55 +	24.5 %	16	26.7

[1]Obtained from the Texas State Data Center, Department of Rural Sociology, Texas A&M University
[2]In all of the tables in this document the sum of the percent values may not equal 100 due to rounding

Table 4. Age and Gender Distribution of Study Participants

Group	Gender	< 25	25 - 54	55 +
1	Male	1	5	1
	Female	1	4	3
2	Male	2	3	2
	Female	1	5	2
3	Male	2	5	2
	Female	1	3	2
4	Male	3	3	1
	Female	2	3	3

In summary, it appears that the sample used approximates the Texas driver population with respect to driver age and gender. The sample used in this study, however, probably does not adequately represent the Texas driver population with respect to ethnicity, English literacy, and education. Complete demographic data about the sample used can be found in Appendix C.

Driver Speed. Speed data was analyzed to determine if the sign system seen had any effect on driver speed at the crossbuck. Speed values were observed at four locations: at the YIELD advance warning sign, at the YIELD sign, at the railroad advance warning sign, and at the crossbuck. The range of speed values at each location, and the mean speed at each location are shown in Table 5. Note the wide range of speeds at each location; speed varied greatly from driver to driver. Also note that the driver speeds are lower at the railroad advance warning sign than at the YIELD advance warning sign. It is likely that speeds were lower at the railroad advance warning sign because this sign was immediately after a horizontal curve, which caused drivers to slow down. Examining the speeds observed at the railroad crossbuck, drivers apparently never regained the speeds they had earlier displayed.

Also note that not only did some drivers stop at the YIELD sign and railroad crossbuck, but that some drivers (10 percent) stopped at the railroad advance warning sign. One might conclude that the drivers came to a stop at the advance warning sign because they thought that the sign identified the location of the railroad tracks. Driver responses to questions used to determine comprehension indicate, however, that of those who stopped at the advance warning sign, two-thirds could correctly identify the meaning of the sign. This fact illustrates the limitations of the analysis of any study results. No study can adequately represent the many responses of the participants under a variety of circumstances, and no study can always explain the reasons for driver behavior. All of the speed data can be found in Appendix D.

Table 5. Speed Values

	Intersection		Railroad	
	YIELD Advance Warning Sign	YIELD Sign	Railroad Advance Warning Sign	Railroad Crossbuck
High Speed	46	44	37	38
Low Speed	15	0	0	0
Mean Speed	32.8	26.9	22.9	18.1

Analysis of Speed Data. The speed at the crossbuck was measured for each driver on the first trial (an absolute speed measure). These values are shown in Table 6. The difference in speed between the crossbuck and the YIELD sign was determined using matched pairs (a relative speed measure). Each subject provided data for one matched pair, resulting in one matched pair difference in speed. The matched pair difference in speed values for each sign system are shown in Table 7. Each value represents the driver speed at the YIELD sign minus the driver speed at the railroad crossbuck; all positive values indicate that the speed was higher at the YIELD sign than at the railroad crossbuck. Negative values indicate that the speed at the crossbuck was higher than the speed at the YIELD sign.

Examining the speed values in Table 6, it is interesting to note the number of people that stopped in each group. One driver who saw sign system A stopped at the crossbuck, 5 drivers who saw sign system B stopped, 2 drivers who saw sign system C stopped, and 4 drivers who saw sign system D stopped. It may be that drivers were more likely to stop for an unfamiliar sign (the most drivers stopped for the Canadian crossbuck in sign system B) or unfamiliar group of signs (sign systems C and D); it may be that drivers were more likely to stop based on the effectiveness of the sign system; or, it may be that the tendency to stop was merely affected by individual driver characteristics.

This last possibility is substantiated by looking at other speed characteristics of the drivers who stopped at the railroad crossbuck. Examining speeds at the railroad advance warning sign as well as at the crossbuck, all of the drivers who stopped at the advance warning sign also stopped at the railroad crossbuck. None of the drivers who saw sign system A stopped at the advance warning sign, 2 drivers who saw sign system B stopped at the advance warning sign, 1 driver who saw sign system C stopped at the advance warning sign, and 3 drivers who saw sign system D stopped at the advance warning sign. Considering behavior at both the advance warning sign and at the railroad crossbuck, twice as many people stopped at the crossbuck as stopped at the advance warning sign in all groups. This ratio of 2-to-1 approximates the stopping behavior in each group, as well, indicating that the variance in behavior may be due to sampling differences among the four groups, rather than a result of the sign system seen.

Single factor analysis of variance was used to test for equality of means for both the absolute and relative speed at the crossbuck. The mean and sample standard deviation values are shown in the last two rows of Tables 6 and 7, for the mean speed and mean of the matched pair difference, respectively. The summary of results of the single factor analysis of variance are shown in the ANOVA tables, Table 8 and Table 9, for the speed values and matched pair speed differences, respectively.

Table 6. Speed Values at the Crossbuck

Driver	Sign System A	Sign System B	Sign System C	Sign System D
1	16	0	9	22
2	38	17	29	7
3	10	27	0	0
4	36	0	32	33
5	27	35	16	22
6	35	0	24	0
7	38	20	25	20
8	22	30	25	0
9	37	24	0	25
10	6	34	30	5
11	22	35	14	10
12	27	0	17	17
13	0	5	5	27
14	10	28	20	0
15	20	0	15	35
Mean	22.9	17.0	17.4	14.9
s	12.6	14.6	10.4	12.5

Table 7. Matched Pair Differences in Speed

Driver	Sign System A	Sign System B	Sign System C	Sign System D
1	19	16	8	9
2	-3	3	12	15
3	11	1	0	35
4	-21	33	3	1
5	11	-2	12	15
6	0	38	11	0
7	6	10	10	6
8	10	0	5	10
9	0	-4	33	16
10	20	-2	2	0
11	-1	2	4	-10
12	0	27	5	-3
13	35	13	19	5
14	0	-3	10	42
15	5	25	5	0
Mean	6.1	10.5	9.3	9.4
s	12.7	14.2	8.2	13.9

Table 8. ANOVA Table for Speed Values at Crossbuck

Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Explained by Treatment	3	532.6	177.5	
Error or Unexplained	56	8886.3	158.7	1.1
Total	59	9418.9		

Table 9. ANOVA Table for Difference in Speed Values

Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Explained by Treatment	3	157	52.3	
Error or Unexplained	56	8752	156.3	0.33
Total	59	8908		

As can be seen in Tables 8 and 9, the calculated value of F for the absolute speed values and matched pair differences is 1.1 and 0.33, respectively. The computed F values of 1.1 (absolute speed at crossbuck) and 0.33 (matched pair difference in speed) did not fall in the rejection region ($F > 2.78$) for either the absolute speed values or the matched pair difference in speed values. Therefore the null hypothesis was not rejected in either case, and there was not sufficient evidence to indicate that the sign system seen had any measurable effect on either the absolute driver speed at the railroad crossbuck or the driver speed at the crossbuck relative to the driver speed at the YIELD sign.

To summarize, the results of this study indicate that there is no evidence that the sign system seen by the drivers who participated in this controlled field study had an effect on the driver speed at the crossbuck. Although there is no way to determine if these results can be extrapolated to other conditions (such as the conditions on a public road), there is no compelling reason why similar results would not occur on a public road if the proposed sign systems were implemented. Although there is no evidence to indicate that implementation of the proposed sign systems would cause drivers to proceed with greater caution (to slow down for grade crossings), neither do these results suggest that the current safety level would be compromised by the implementation of any of these sign systems when considering driver speed at the railroad crossing only.

Driver Looking Behavior. Driver head movements prior to the railroad crossbuck, but after the railroad advance warning sign, also were observed. It was assumed that driver head movement was indicative of looking behavior. The number of drivers exhibiting looking behavior at the crossbuck on the first trial for sign system A through D was 67, 87, 100, and 93 percent, respectively.

The chi-square test statistic was used to determine if driver looking behavior was dependent on the sign system. Calculations can be found in Appendix E. The research hypothesis tested was that the sign system would have an effect on driver looking behavior. Based on the calculated value $X^2 = 8.08$, and three degrees of freedom, the probability value was determined to be 0.046. Because 0.046 is less than 0.05, the alpha value chosen, the null hypothesis is rejected at a significance level of 5 percent.

Based on the chi-square calculations for driver looking behavior, there is evidence that the sign system seen may have had an effect on driver looking behavior, at a significance level of 95 percent. Examining the percent of drivers exhibiting looking behavior for each sign system, it appears that sign system A resulted in significantly less looking behavior at the railroad crossing.

The fact that more drivers exhibited looking behavior at the crossbuck for sign systems B, C and D may be due to sign system effectiveness, or it may be due to the novelty effect because sign system A was the only sign system that was familiar to the drivers. Considering sign system effectiveness, note that the percent of drivers exhibiting looking behavior for sign systems C and D was high, 100 percent and 93 percent, respectively. Both of these sign systems included the train symbol sign with the LOOK FOR TRAINS plate.

While the difference in looking behavior for the various sign systems may be due to the novelty effect or to the sign system effectiveness, the difference in looking behavior may also be due to sampling differences among the four groups. Table 10 shows the looking behavior for each group at both the railroad crossbuck and at the YIELD sign at the mock intersection. Examining the values in Table 10, it can be seen that group 1, the group that exhibited significantly less looking behavior at the crossbuck when seeing sign system A, also exhibited less looking behavior at the YIELD sign than any of the other groups. Because the YIELD sign and the advance warning for the YIELD sign were constant for all the groups, it appears that some difference in looking behavior may be due to differing driver characteristics in the four groups.

Table 10. Looking Behavior at Crossbuck and at YIELD Sign

Group (Sign System)	1 (A)	2 (B)	3 (C)	4 (D)
Crossbuck	67 %	87 %	100 %	93 %
YIELD Sign	53 %	73 %	73 %	67 %
Difference	14 %	14 %	27 %	26 %

Consider, also, the difference in looking behavior at the YIELD sign at the mock intersection and at the railroad crossbuck. Note a fourteen percent increase in driver looking behavior at the crossbuck as compared to the YIELD sign for sign systems A and B; note that there was a 26 to 27 percent increase in driver looking behavior at the crossbuck as compared to the YIELD sign for sign systems C and D. Recall that sign systems C and D included the train symbol sign with the LOOK FOR TRAINS advisory plate. The large increase in driver looking behavior at the crossbuck as compared to the YIELD sign for these two sign systems may be attributable to the effectiveness of the inclusion of the train symbol sign with the LOOK FOR TRAINS advisory plate in sign systems C and D.

While the chi-square test of independence indicated that the looking behavior was not identical for all four sign systems, it is impossible to know what factor caused the looking behavior to differ. Furthermore, when considering the driver looking behavior observed during this study it is very important to consider the environmental conditions under which the study was conducted. The study was held on a course that was laid out on an old runway. Although the "roadway" painted on the concrete was a standard 2-lane road, on either side of the road the concrete extended beyond the edge of the marked lane approximately 15 feet on one side and 40 feet on the other side. The concrete runway had fields on both sides. In this environment, it was clear that there were no true railroad tracks, and that there would be no train. Any head movement was either habitual, cursory, purely for the benefit of the test administrator, or to look at the scenery on either side of the road.

Questionnaire Responses. Driver responses to questions about each sign were tabulated with respect to recollection and driver understanding. Drivers were asked to recall signs seen from the first trial only, but were asked questions to determine comprehension for all of the signs in the four sign systems. Driver recollection and driver comprehension are addressed in the following two sections.

Driver Recollection. Driver recollection was determined by asking the subject to describe all the railroad warning signs that she/he had seen on trial run 1. The driver was asked to recall the signs immediately after she/he had completed trial run 1. The percentage of subjects in each group who were able to recollect the signs is shown in Table 11. Because subjects were only asked to recall the signs seen on the first trial run, most of the signs do not have values for all groups. The average for all the groups is shown in the last row of Table 11.

As can be seen in Table 11, all of the signs were remembered by at least two-thirds of the subjects. Consider first the advance warning signs. The standard advance warning sign was recalled by 75 percent of the subjects. Surprisingly, the train symbol sign was recollected by the smallest percentage of respondents; only 67 percent of the subjects who saw the train symbol sign on the first trial could then recall and describe it. Perhaps the train symbol sign was more difficult to recall and describe because it was unfamiliar to the subjects, and because it was always shown in sign systems that had four signs. The multiple signs may have competed for the driver's attention and memory, resulting in fewer drivers being able to recall the train symbol sign.

Now consider the warning signs located at the crossing; the recollection level for all four of these signs is higher than for either of the advance warning signs. It is possible that the signs located at the crossing were more easily recalled because they were the last signs seen.

Examining the results of a crossbuck seen by itself, more subjects were able to recall the standard crossbuck (87 percent) than the Canadian crossbuck (80 percent). As with the advance warning signs, the familiar sign was more often recalled than the sign that had not been seen before.

The best remembered signs, according to the results in Table 11, were the YIELD sign in combination with either the standard or Canadian crossbuck (87 percent and 93 percent, respectively). It is possible that more drivers were able to recall these sign combinations because both of the signs either were familiar or had familiar elements, and yet were presented in a slightly different context which may have had a novelty effect.

Although it is interesting to know which sign is best remembered, and important characteristics like visibility and conspicuity may be related to driver recollection, perhaps it is driver comprehension of the sign that is of greater importance to both the motoring public and to engineering professionals.

Driver Comprehension. Driver comprehension of the railroad warning signs was determined by showing the subject a photo of the sign (or signs, in the case of the YIELD sign in conjunction with either the standard or Canadian crossbuck) and asking her\him what she\he thought the sign meant and what, if any, action should be taken. The subjects were asked about a sign only after they had seen the sign on a trial run, immediately after the first trial run that the sign was in. The photo that the driver was shown pictured the sign in context, adjacent to the roadway and adjacent to the railroad tracks, if applicable.

Table 11. Percentage of Subjects Able to Recall Specific Signs

	Advance	Warning	At	the	Crossing	
Group	Advance Warning	Train Symbol	Cross-buck	Canadian Cross-buck	YIELD w/ Cross-buck	YIELD w/ Canadian Cross-buck
1	87	-	87	-	-	-
2	73	-	-	80	-	-
3	73	73	-	-	-	93
4	67	60	-	-	87	-
Ave	75	67	87	80	87	93

Driver responses were originally classified as either enhanced correct, correct, incorrect noncritical, or incorrect critical. Because there were very few responses classified as enhanced correct, and because there is no difference between enhanced correct and correct from either an operational standpoint or from a safety standpoint, the enhanced correct answers were categorized with the correct answers.

The results of the evaluation of driver comprehension of the railroad warning signs tested are shown in Table 12. Results are expressed as both the number of driver responses in each category (correct, incorrect noncritical, incorrect critical), and the percentage of driver responses in each category for each sign. Percent values are indicated in parenthesis. When examining the results, it is important to note the distinction between incorrect noncritical and incorrect critical; this distinction is a very significant one.

A response that is incorrect noncritical indicates that while the subject does not understand completely the meaning and/or action required by a sign, the consequences of her/his misunderstanding are not likely to result in serious ramifications such as a car-train accident. A response that is classified as incorrect critical indicates a gross lack of understanding that may result in serious consequences, including a car-train accident. Thus the distinction between incorrect noncritical and incorrect critical has serious implications, and may be more important than the distinction between correct and incorrect noncritical. A driver whose response was incorrect noncritical might display the same driving characteristics as a driver who correctly interprets a sign; her/his reasons for doing so, however, might be very different. The distinctions between the various response classifications, and their implications on safety, should be kept in mind when examining the level of driver comprehension for the various signs.

Table 12. Driver Comprehension of Sign Meaning and Required Action

	Advance Warning		At the Crossing			
Response	Advance Warning	Train Symbol	Cross-buck	Canadian Cross-buck	YIELD w/ Cross-buck	YIELD w/ Canadian Cross-buck
Correct	54 (90.0)[1]	54 (90.0)	51 (85.0)	27 (45.0)	56 (93.3)	53 (88.3)
Incorrect Non-critical	5 (8.3)	6 (10.0)	6 (10.0)	26 (43.3)	4 (6.7)	6 (10.0)
Incorrect Critical	1 (1.7)	0 (0)	3 (5.0)	7 (11.7)	0 (0)	1 (1.7)
Total	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)	60 (100)

[1]Numbers in parenthesis denote corresponding percentage

Consider first the driver comprehension of the advance warning signs. The railroad advance warning sign was correctly interpreted by 90 percent of the subjects. Examining the incorrect responses, 8.3 percent of all responses were considered incorrect noncritical and 1.7 percent incorrect critical. The 1.7 percent of responses that were critical represents the one person who thought that the advance warning sign indicated that there was a railroad with flashing red lights.

Driver comprehension of the train symbol sign with the LOOK FOR TRAINS plate was relatively high with 90 percent of the subjects correctly interpreting this sign, the same proportion of subjects who understand the standard railroad advance warning sign. Moreover, the remaining 10 percent of responses were all categorized as incorrect noncritical. There were no responses that were considered incorrect critical. The large number of correct responses for the train symbol sign is not surprising. Although the sign was unfamiliar, the subject merely had to read the text printed on the advisory plate to answer the question adequately. (LOOK FOR TRAINS defines both the meaning and action required.) Although multiple subjects indicated that they felt this sign would be helpful to drivers who do not read English, there was no data in this study to substantiate this hypothesis.

Consider next the level of comprehension for the signs located at the railroad crossing. The standard crossbuck was correctly interpreted by 85 percent of the drivers. Examining the incorrect interpretations of the crossbuck, two-thirds were noncritical (10 percent of all responses), and one-third were critical (5 percent of all responses). Only the Canadian crossbuck had more incorrect critical responses.

The Canadian crossbuck was the sign that had the lowest level of driver comprehension. Less than half (45 percent) of the subjects interpreted the sign correctly. Approximately 43 percent of all responses were considered incorrect noncritical, and 11.7 percent of all responses were considered incorrect critical. There were more incorrect critical responses for the Canadian crossbuck than for any other sign evaluated. In fact, there were more incorrect critical responses for the Canadian crossbuck than for all of the other signs combined. The large number of incorrect critical responses indicates that it would be advisable to educate the public before the implementation of the Canadian crossbuck.

When considering the YIELD sign in conjunction with the standard crossbuck, 93.3 percent of the subjects knew the meaning of these two signs and understood the action that was necessary. Although 6.7 percent of the subjects could not correctly identify the meaning and action required by this pair of signs, this lack of understanding was determined not critical. This combination of signs is the only sign system located at the railroad crossing that had zero responses classified as incorrect critical.

The YIELD sign and the Canadian crossbuck were correctly interpreted by 88.3 percent of the subjects. Considering the incorrect responses, 10 percent of all responses were deemed noncritical and 1.7 percent were considered incorrect critical. The only warning device located at the crossing that had fewer incorrect critical responses was the YIELD sign in conjunction with the standard crossbuck. The high percentage of correct responses to the YIELD sign in combination with either the standard or Canadian crossbuck is not surprising, because although the grouping of the two signs together was unfamiliar, the subject merely had to read the text printed on the signs to answer the question adequately. (The YIELD sign with the TO TRAINS plate dictates both the meaning and action required.) All of the subjects in this sample were able to read English. This capability undoubtedly had an effect on the ability to interpret this pair of signs.

The chi-square test statistic was used to determine if driver comprehension was dependent on the sign seen; calculations can be found in Appendix F. The research hypothesis was that the level of driver comprehension would vary, depending on the sign. Based on the calculated value, $X^2 = 70.66$, and ten degrees of freedom, the null hypothesis was rejected at a significance level of 5 percent. The results of this analysis indicate, therefore, that the level of driver comprehension did vary depending on the sign in question.

Because the comprehension level of the Canadian crossbuck was much lower than the comprehension level of the other signs, the chi-square test of independence was applied again to determine if comprehension of all of the signs except the Canadian crossbuck was dependent or independent; calculations can be found in Appendix F. Using this reduced sample (the advance warning sign, the standard crossbuck, the train symbol sign with advisory plate, the YIELD sign with advisory plate and standard crossbuck, and the YIELD sign with advisory plate and Canadian crossbuck), the chi-square value was calculated to be 6.84. With eight degrees of freedom and a significance level of 5 percent, the chi-square value was 15.51 and the null hypothesis was not rejected. This analysis indicates that for the reduced sample (Canadian crossbuck excluded) there is no evidence to indicate that driver comprehension was different for any of the signs tested.

The results of both of these analyses imply that driver comprehension is the same for all of the railroad signs studied except for the Canadian crossbuck. The only sign that was not well understood was the Canadian crossbuck. It is suggested that an educational campaign be conducted prior to the implementation of the Canadian crossbuck by itself. With respect to driver comprehension it appears that there would be no negative consequences if either sign system C or D were implemented (advance warning sign, train symbol sign with LOOK FOR TRAINS advisory plate, and YIELD sign with TO TRAINS advisory plate and either the Canadian or standard crossbuck), because both of these sign systems incorporate elements that are understood at least as well as the current standard. Specific comments about the signs and sign systems can be found in Appendix B.

Ranking of Signing Systems. Each subject was asked to rank the four sign systems in terms of effectiveness. Diagrams of each sign system and photos of the signs were available to aid subjects in their decision. An effective sign system was defined for each driver: "an effective sign system should be noticeable, should indicate to the driver that there is a railroad crossing ahead, should warn the driver of the potential danger at the crossing, and should prompt the driver to approach the crossing with caution."

A rank of one was considered the most effective; a rank of four the least effective. The average rank of each of the four sign systems for each group is shown in Table 13. Note that sign system D was ranked as the most effective (the lowest average value) not only in the averaging

Table 13. Average Sign Rank According to Driver Preference

Group	Sign System A	Sign System B	Sign System C	Sign System D
1	2.8	3.1	2.3	1.9
2	3.0	3.4	2.1	1.5
3	2.9	3.6	2.1	1.4
4	3.1	3.5	2.0	1.4
Average	2.9	3.4	2.1	1.6

all of the data, but also for the average of each group. In fact, the ranking order was the same for all four of the groups and consequently for the overall average.

Although the ranking of averages for each sign system was consistent over all four groups, there was a wide range of individual preferences. In fact, each sign system was ranked at every position by someone. Sign system D, ranked first on average, was ranked first by 65 percent of the participants and was ranked first or second by 87 percent of the participants. Sign system B, ranked last on the average, was in fact ranked last (fourth) by 61 percent of the drivers and was ranked third or fourth by 83 percent of the drivers.

To summarize the information found in Table 13 and reiterate the signs in each system, the sign systems were ranked as follows (1 is considered the most effective):

1. *Sign system D* - advance warning sign, train symbol sign with LOOK FOR TRAINS advisory plate, YIELD sign with TO TRAINS advisory plate, and standard crossbuck.

2. *Sign system C* - advance warning sign, train symbol sign with LOOK FOR TRAINS advisory plate, YIELD sign with TO TRAINS advisory plate, and Canadian crossbuck.

3. *Sign system A* - advance warning sign and standard crossbuck (the current standard).

4. *Sign system B* - advance warning sign and Canadian crossbuck.

Note that sign systems that included signs that gave explicit directions to the driver were preferred to those that did not.

The Friedman test was used to determine the statistical significance of the rankings of driver preference. Complete data for driver rankings of preference can be found in Appendix G. The null hypothesis tested was that there was an equal preference for all sign systems. The research hypothesis was that there was a significant difference in preference for at least two sign systems. The critical value for 3 degrees of freedom and a significance level of 0.05 was 7.81. The calculated Friedman test statistic was 73.7; thus the null hypothesis was rejected and there was a significant difference in preferences for at least two sign systems.

Pairwise multiple comparisons based on rank sums were used to determine which sign system rankings were statistically different; calculations can be found in Appendix G. Based on a significance level of 0.05, the results of this analysis indicate that sign system A and B are significantly different from sign systems C and D; sign system A is not significantly different from sign system B; and sign system C is not significantly different from sign system D. These results indicate that with respect to driver preference, it does not matter whether the sign system incorporates either the Canadian or standard crossbuck.

Summarizing the results of driver preferences as indicated by sign system rankings, both sign systems C and D (the advance warning sign, the train symbol sign, the YIELD sign and the Canadian or standard crossbuck) were considered more effective than the current standard, sign system A. Furthermore, although sign system B (the advance warning sign and the Canadian crossbuck) was ranked less effective than the current standard (sign system A), the difference was not considered statistically significant.

Driver Comments. Throughout the duration of the study, subject participants expressed valuable opinions and comments that cannot be easily quantified or compiled. For example, while some drivers expressed the feeling that sign systems C and D represented "overkill" with respect to the number of signs, other drivers vocalized the sentiment "the more signs the better". The implementation of an acceptable and effective passive railroad warning device is clearly a situation where, to fall back on a wise old adage, "you can't please all of the people all of the time." Keeping this philosophy in mind, it is edifying to reiterate some of the comments that drivers expressed.

Some drivers noted that the standard crossbuck was difficult to see. It was difficult to discern the white of the standard crossbuck from background of the sky. The Canadian crossbuck was more easily seen, both because it had a better grade background (higher reflectivity), and because it had a red border which made it stand out from its background. In fact, some drivers mentioned that the red and white colors of the Canadian crossbuck indicated that they should stop or yield.

As mentioned before, some drivers felt that there were too many signs in sign systems C and D. One driver expressed the sentiment that all of the signs distracted attention from the driving task. When asked to rank sign systems, many drivers said that they thought they could improve on the four systems they were to choose from. The proposed improvements include:

1. Using a crossbuck that is a combination of the standard crossbuck and the Canadian crossbuck, for example, the standard crossbuck with a red border.

2. Using a better grade background for the standard crossbuck so that it is more reflective.

3. Eliminating sign "overkill" in sign systems C and D by using either the train symbol sign with the LOOK FOR TRAINS advisory plate or the YIELD sign with the TO TRAINS advisory plate, but not both.

4. Eliminating some of the "clutter" in sign systems C and D by putting the YIELD sign and the TO TRAINS plate on the same sign post that the crossbuck is on.

Other comments and suggestions made by study participants can be found in Appendix C.

SUMMARY

The completion of the controlled testing of the proposed passive warning devices was an important step in the development of more effective warning devices to enhance safety at railroad crossings. The evaluation process encompassed both quantitative and qualitative areas of analysis. Based on the findings of these studies, the conclusions are as follows:

1. There was no evidence that the sign system seen had any effect on either the absolute or relative driver speed at the crossbuck.

2. There was less looking behavior exhibited by drivers who saw the existing standard than by drivers who saw any of the three proposed sign systems. It is not clear if the difference in the frequency of looking behavior was due to the sign system seen or to sampling differences between the groups.

3. Rankings based on driver evaluation of sign system effectiveness indicate that two of the proposed sign systems were preferred to the existing standard. Systems that included signs that gave explicit directions to the driver were preferred to those that did not. The sign systems were ranked as follows (from most to least effective):

   a. *Sign system D* - advance warning sign, train symbol sign with LOOK FOR TRAINS advisory plate, YIELD sign with TO TRAINS advisory plate, and standard crossbuck.

   b. *Sign system C* - advance warning sign, train symbol sign with LOOK FOR TRAINS advisory plate, YIELD sign with TO TRAINS advisory plate, and Canadian crossbuck.

c. *Sign system A* - advance warning sign and standard crossbuck (the current standard).

d. *Sign system B* - advance warning sign and Canadian crossbuck.

4. Most drivers understood all of the signs except the Canadian crossbuck, according to driver responses to questions used to determine driver comprehension.

Based on the findings of the laboratory testing, the following recommendations were formulated:

1. Field testing should be conducted to further evaluate the effectiveness of sign system C or D or a variation of these sign systems.

2. Due to the large number of drivers who did not correctly identify the meaning of the Canadian crossbuck, an educational campaign should be conducted prior to implementation of a sign system that incorporates the Canadian crossbuck at actual crossings.

3. Based on comments of participants, other alternatives should be considered for implementation. Alternatives recommended for further study include:

   a. Using either the train symbol sign with the LOOK FOR TRAINS advisory plate, or the YIELD sign with the TO TRAINS advisory plate, but not both in sign systems C and D.

   b. Placement of the YIELD sign and the TO TRAINS plate on the same sign post as the crossbuck for sign systems C and D.

   c. Using a crossbuck that is a combination of the standard crossbuck and the Canadian crossbuck, for example, the standard crossbuck with a red border.

   d. Using a better grade background for the standard crossbuck so that it is more reflective.

4. Additional controlled or field testing of the proposed signs should be conducted using subjects that have one or more of the following characteristics:

   a. Limited education (high school or less).

   b. Minority ethnicity (Hispanic or African American).

   c. Language other than English as the native tongue (spoken in the home).

   d. Cannot read English.

4.0 FIELD TESTS

The experimental design used for the field study is described in this section. The study was designed to examine driver response to the current standard passive warning system and driver response to two experimental warning systems. A comparison of the responses to the current standard sign system and responses to the two experimental sign systems provides both qualitative and quantitative support for the objective of this research. The study design includes a description of the sign systems tested, type of experiment, measures of effectiveness, survey questionnaire design, study procedures, sample size goals, and data analysis.

PASSIVE SIGN SYSTEMS TESTED

Current Sign System. The current standard sign system required by the *1980 Texas Manual on Uniform Traffic Control Devices* (1980 TMUTCD) (4) at passively controlled railroad-highway grade crossings is shown in Figure 1. For rural areas, in which most of the test crossings of this research are located, the advance warning sign is shown as typically located 750 feet (229 meters) in advance of the crossing. In urban areas, the advance warning sign is placed according to approach speed and available sight distance. Field measurements made at the test sites, however, show that the actual placement of the advance warning sign to be from a minimum found at one rural crossing of 246 feet (75 meters) to 740 feet (225 meters) found at another. The *1988 National Manual on Uniform Traffic Control Devices* (1988 NMUTCD) (45) specifies the placement of the advance warning sign in both rural and urban areas based on approach speed. It must be noted, however, that in many of the cases where the advance warning sign was found to be placed closer to the crossing than specified by the 1980 TMUTCD, geometric features such as intersections close to the crossing and lower operating speeds on county roads probably contributed to the decision of the sign placement. Those advance warning signs which were placed closer to the crossing, notwithstanding the specifications for rural placement in the 1980 TMUTCD, were found to be acceptable in terms of approach speed, and, therefore, they were left in place for testing purposes.

Another aspect of the current sign system shown in Figure 1 (page 9) is the placement of the advance pavement marking. According to the 1980 TMUTCD, the advance pavement marking should be placed at a distance from the crossing dependent on the approach speed. The 1988 NMUTCD, however, states that the pavement marking should be placed at the same distance from the crossing as the advance warning sign, dependant on approach speed and available sight distance. It is anticipated that the next edition of the TMUTCD will adopt the recommendations of the 1988 NMUTCD on the placement of the pavement marking. The 1988 NMUTCD states that the pavement marking shall be placed on all paved approaches to actively controlled crossings and at all other crossings where the approach speed is 40 miles per hour (64 kilometers per hour) or greater.

Advance pavement markings were present on all approaches for the test crossings in this research. At three of the crossings, however, the advance pavement markings were at the same distance from the crossing as the advance warning sign, whereas, the remainder of the crossings displayed the advance pavement marking between the advance warning sign and the crossing. Since the placement of the markings would remain constant at each site, the study did not attempt to control for the variance in the placement of pavement markings between sites.

YIELD TO TRAINS Sign System. One of the two experimental sign systems to be tested is shown in Figure 13. The system incorporates a standard YIELD sign (TMUTCD R1-2) with a supplementary message plate mounted below which states "TO TRAINS." The YIELD TO TRAINS sign is placed within the current sign system and is located at the crossing near the crossbuck. The YIELD TO TRAINS sign clearly differentiates itself from a YIELD sign found at highway intersections due to the supplementary message plate. Therefore, the argument that the effectiveness of the YIELD sign seen at highway to highway intersections will be diminished is unsubstantiated.

The YIELD TO TRAINS sign, however, must be applied discriminately at crossings due to requirements in the 1980 TMUTCD concerning the placement of STOP signs at crossings. According to the 1980 TMUTCD, in addition to certain vehicle volume and train volume requirements, if a vehicle must slow to 10 miles per hour (16.1 kilometers per hour) or less in order to safely detect and react to the hazardous presence of a train due to sight distance restrictions, a STOP sign or higher order of control should be considered. A YIELD TO TRAINS sign at these crossings would be inappropriate.

LOOK FOR TRAINS Sign System. The other experimental sign system to be tested is shown in Figure 14: a 36 inch (0.91 meter) yellow high intensity backed diamond warning sign with a black train locomotive symbol supplemented by a yellow high intensity backed message plate which states "LOOK FOR TRAINS." The LOOK FOR TRAINS sign is also placed in the current standard passive warning system. The LOOK FOR TRAINS sign is placed opposite the advance pavement marking at the beginning of the pavement marking. At locations where the advance pavement marking is placed at same distance from the crossing as the advance warning sign, the LOOK FOR TRAINS is placed at the distance shown in the 1980 TMUTCD for placement of the advance pavement marking plus 50 feet (15 meters), where 50 feet (15 meters) is the length of the pavement marking. No other considerations for sight distance than that for placement of the advance pavement marking is required.

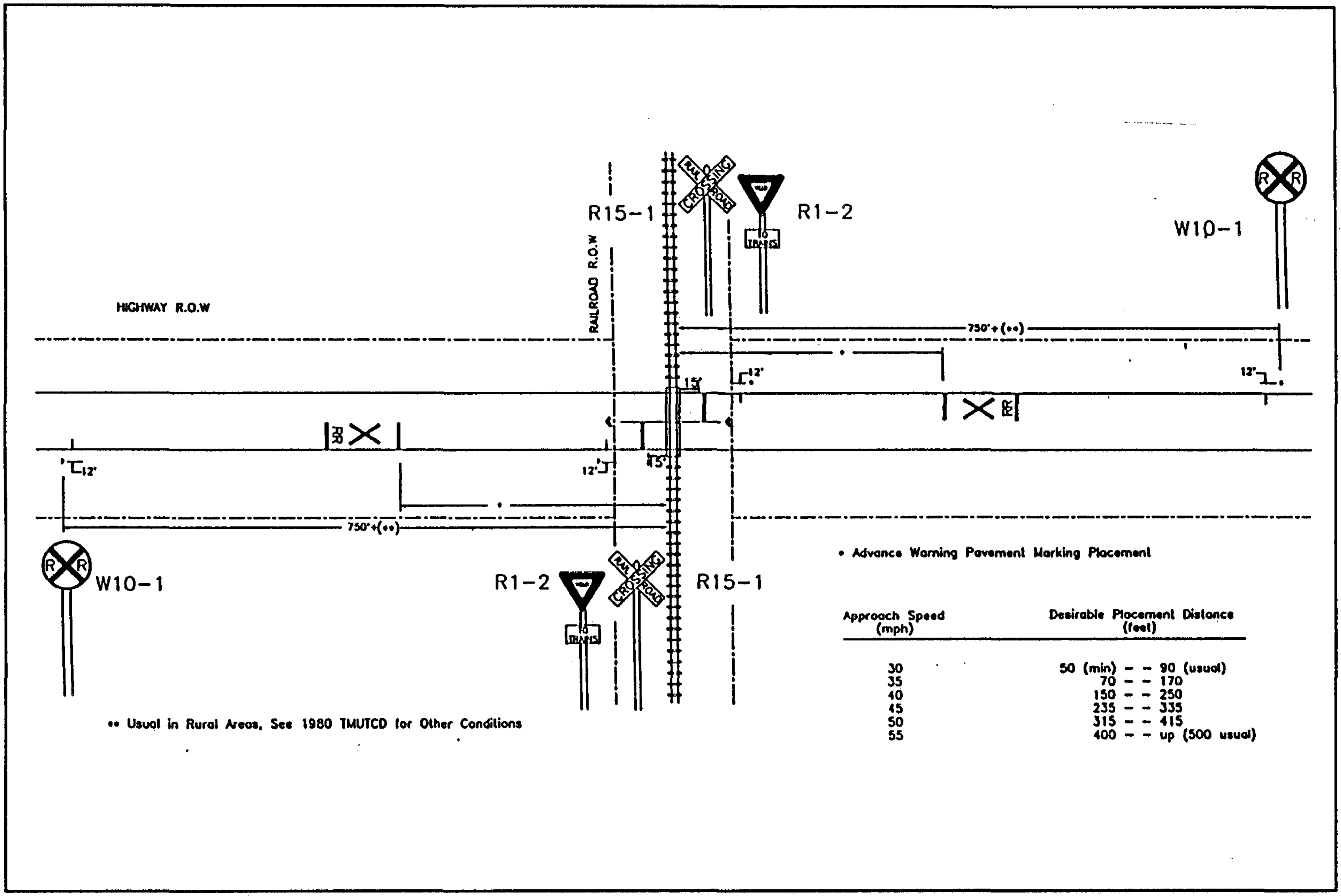
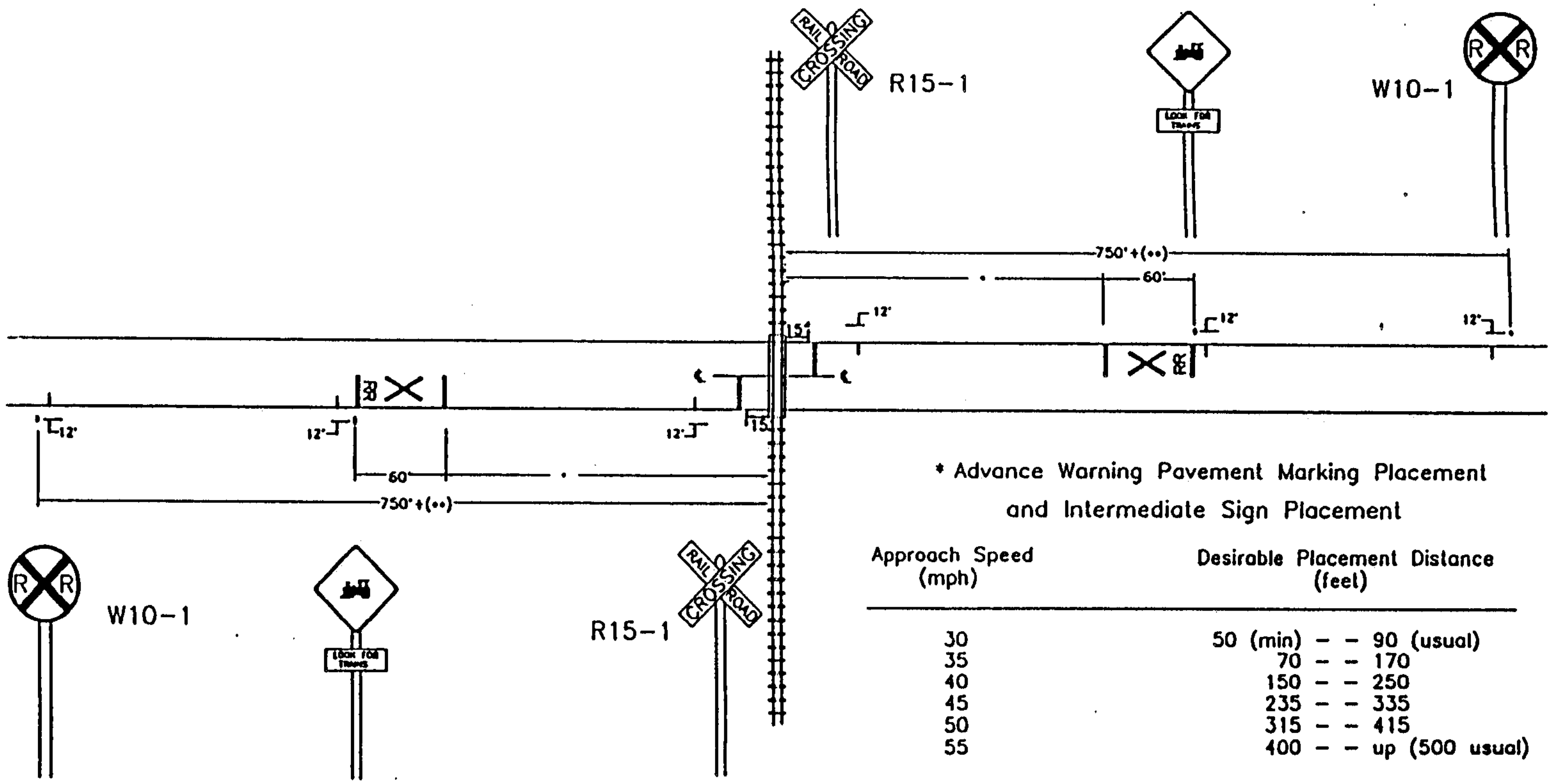


Figure 13. Experimental Sign System with YIELD TO TRAINS Sign



* Advance Warning Pavement Marking Placement and Intermediate Sign Placement

Approach Speed (mph)	Desirable Placement Distance (feet)
30	50 (min) - - 90 (usual)
35	70 - - 170
40	150 - - 250
45	235 - - 335
50	315 - - 415
55	400 - - up (500 usual)

** Usual in Rural Areas, See 1980 TMUTCD For Other Conditions

Figure 14. Experimental Sign System with LOOK FOR TRAINS Sign

STUDY ELEMENTS

Type of Experiment. The experimental design used for this study is a longitudinal or before and after study as opposed to a cross-sectional study. In the cross-sectional approach to evaluating traffic control devices, response to other stimuli other than the experimental variable is difficult to control. The researcher is looking for differences in response due to the experimental variable, in this case the introduction of the YIELD TO TRAINS sign or the LOOK FOR TRAINS sign. A cross-sectional study design for this research would require finding two crossings with essentially the same features. Each railroad-highway grade crossing is, however, by its very nature a unique situation. Therefore, differing driver responses at crossings with the same features cannot necessarily be explained by the experimental variable.

In the longitudinal design, however, the test crossing selected serves as the site to measure both the response to the before condition and to the after, or experimental, condition. A disadvantage of the longitudinal study in evaluating traffic control devices is that conditions can change between the time that the before condition response is measured and the time that the after condition response is measured. For example, traffic volumes can increase or decrease making driver response different. The difference in the angle of the sun between the winter and summer seasons can make drivers react differently between situations. Changes in vegetation growth can affect driver looking behavior at a railroad highway grade crossing. Although it is assumed in this study that all differences in response between the before and after conditions are due to the experimental variable, some differences in response are recognized to occur due to the conditions listed above.

Measures of Effectiveness. In evaluating safety at grade crossings, the ultimate measure of effectiveness of any improvement to grade crossing safety is the reduction in accident rates. The expected accident rate at any one passive crossing, however, is very small for a given year in Texas. The low accident expectancy makes a short-term (less than one year) study, based on accident analysis alone, impossible to conduct with sustainable conclusions. Surrogate measures of effectiveness were identified and measured in the field to evaluate the potential safety impact of the two experimental sign systems relative to the current standard sign system.

The research hypothesis for this study was that the installation of the experimental system at passive railroad-highway grade crossings will increase safety through a reduction in accident rates. Accident rates are not, however, a viable measure for short term evaluations at a limited number of test crossings. Improvements in driver behavior at grade crossings after the installation of the experimental systems are indicative of an increase in safety effectiveness at the crossings. Thus, three surrogate measures of effectiveness were identified for the field studies: vehicle speed, driver looking behavior, and driver response to questionnaire survey.

These measures of effectiveness discussed in the following paragraphs are only three of many driver reactions at crossings. Although an improvement in these three measurements of driver reactions may not be shown, a safety benefit from the installations of the experimental sign systems may exist in improvement of behavior not measured. A finding of negative results such as a significant increase in speed on the approach, decreased looking behavior, or a significant number of negative driver opinions to the experimental signs would be cause for rejecting the research hypothesis.

The following observations were analyzed in order to evaluate the effectiveness of the experimental sign systems:

1. Motorist understanding of the current advance warning sign and crossbuck sign;

2. The extent of the ability of the experimental sign systems to modify driver behavior at passive crossings; and

3. The opinion of motorists of the experimental sign systems relative to the standard sign system.

Spot speed measurements, driver looking behavior observations, and a driver exit survey were conducted. All three measurements were observed simultaneously at each of the test crossings, although the measures were not linked by individual vehicle.

Speed Measurements. Spot speeds were observed at three locations on the approach to each test site;

1. The advance warning sign;
2. The beginning of the advance pavement marking; and
3. The crossbuck.

If the advance pavement marking was located at the advance warning sign on the approach, the second spot speed was observed at the point where the pavement marking would be located under the 1980 TMUTCD guidelines.

Spot speeds were used to determine relative speed differentials between the control and experimental condition. Mean speeds and variances were found for each spot speed location on the approach.

Driver Looking Behavior. It is inferred that drivers who look for trains at railroad-highway grade crossings operate in a safer manner than do those drivers who do not look. The purpose of observing driver looking behavior is to determine if any change in looking can be discerned with the experimental sign system in place. Drivers were observed on the approach to the crossing and discernable head movements within 150 feet (45.7 meters) of the crossing were recorded. Four types of head movements were observed and recorded under the assumption that head movements were indicative of looking behavior: no discernable head movement, head movement left only, head movement right only, and head movement both directions.

Driver Exit Survey. Drivers were stopped downstream of the crossing and asked to participate in a survey. To stay clear of the driver's view, the survey point was located at a sufficient distance downstream of the crossing. Questions asked of the drivers were related to demographics, driver understanding of the advance warning sign, and driver opinion of the experimental system.

Survey Instrument Design. The objective of the survey was to determine the current level of driver understanding of the advance warning sign and crossbuck, determine the percentage of drivers who recalled seeing railroad crossing warning signs, and solicit driver opinion of the experimental sign system. The survey instrument can be found in Appendix H. The design of the survey questions were recognized as an important part of the study.

The questionnaire was designed to minimize driver delay since each driver was stopped involuntarily. The first part of the questionnaire addressed demographic statistics including state residency, age, years of driving experience, language spoken in the home, and frequency of crossing. Ideally, demographic questions such as family income and educational level would be more helpful in stratifying the data; however, asking such personal questions might put the driver in a defensive posture for the remainder of the survey.

The remaining questions were designed as open ended questions so as no to lead the driver to the correct response (such as a multiple choice list). The disadvantage in developing open ended questions, however, was the difficulty in coding the responses for data analysis (46). The drivers were asked to recall and describe any signs or markings that they had seen to warn them of the crossing that was just crossed. These answers were recorded on the questionnaire form.

The next portion of the survey was designed to measure the current level of driver understanding of the advance warning sign and the crossbuck sign. In each case, the driver was shown a picture of the sign in question and asked what the sign meant to him/her. If the driver did not indicate what action he/she thought was required by the sign, that question was asked. Also, if the driver did not indicate that the advance warning sign meant "railroad crossing ahead" or that the crossbuck was located near the tracks at the crossing, the question of relative location was asked. In the analysis of driver responses, if the driver responded to the question dealing with the meaning of the advanced warning sign as "railroad crossing," the next two questions required more complete answers.

After the experimental system was in place, the last part of the survey was included. The definition of what is considered to be an effective sign system was explained to the driver. The driver was then asked if he/she felt that the addition of the experimental sign made the system more effective for safety at the crossing. Driver responses were coded as strongly agree, somewhat agree, no opinion, somewhat disagree, and strongly disagree.

Sample Size Goals. A sufficiently large sample to conduct statistical tests was required for each measure of effectiveness at each test site. For this study, a goal of 100 speed observations, or the number of speed observations which could be observed in one day, was set. A sample size goal was set for the number of driver looking behavior observations to be equal to the goal for speed observations. Driver looking behavior observations could be made at the same frequency as spot speeds.

The number of driver surveys to be conducted was set to be a minimum of 30 at each crossing, or the number that could be conducted in one day. The goal for surveys was set at approximately one-third that for speed and looking behavior to account for drivers who did not want to participate or for drivers who were instructed to bypass the survey station due to excessive queue formation. In most cases, the number of surveys that could be conducted was higher than 30 due to a higher than expected driver participation rate.

FIELD STUDY

Site Selection. Three counties in Texas were chosen for test site locations. A total of eight crossings were identified for test crossings: Two crossings in Grimes County and three crossings in each of Coleman and San Patricio Counties. Grimes, Coleman, Nacogdoches and San Patricio Counties are shown in Figure 15 in their respective locations throughout the State. Experimental sign systems tested in the respective counties were also installed at several other crossings in the vicinity of the test crossings.

Site selection criteria included train volume, train speed limit, vehicular volume, vehicular speeds, crossing roughness, approach surfaces, geometric configuration at the crossings and on the approaches, and sight distance. Several candidate crossings were identified from the railroad crossing database maintained by the Texas Department of Transportation. Visits to each candidate crossing were then made to determine the crossings which exhibited the best conditions for test crossings.

Desirable Characteristics. It would be desirable for the test crossings to be identical in character in order to evaluate effects of the experimental systems between the sites. As mentioned earlier, each railroad-highway grade crossing is unique in character. Thus, when evaluating potential crossings for inclusion in the study, several characteristics were considered. The test crossings in this study were selected on the basis of displaying as many of the following characteristics as possible:

1. Train volume of at least 2 trains per day were desired. A crossing at which drivers would not expect to see a train, such as a spur track serving a seasonal operator, may not produce the speed and looking behavior characteristics desirable for this study.

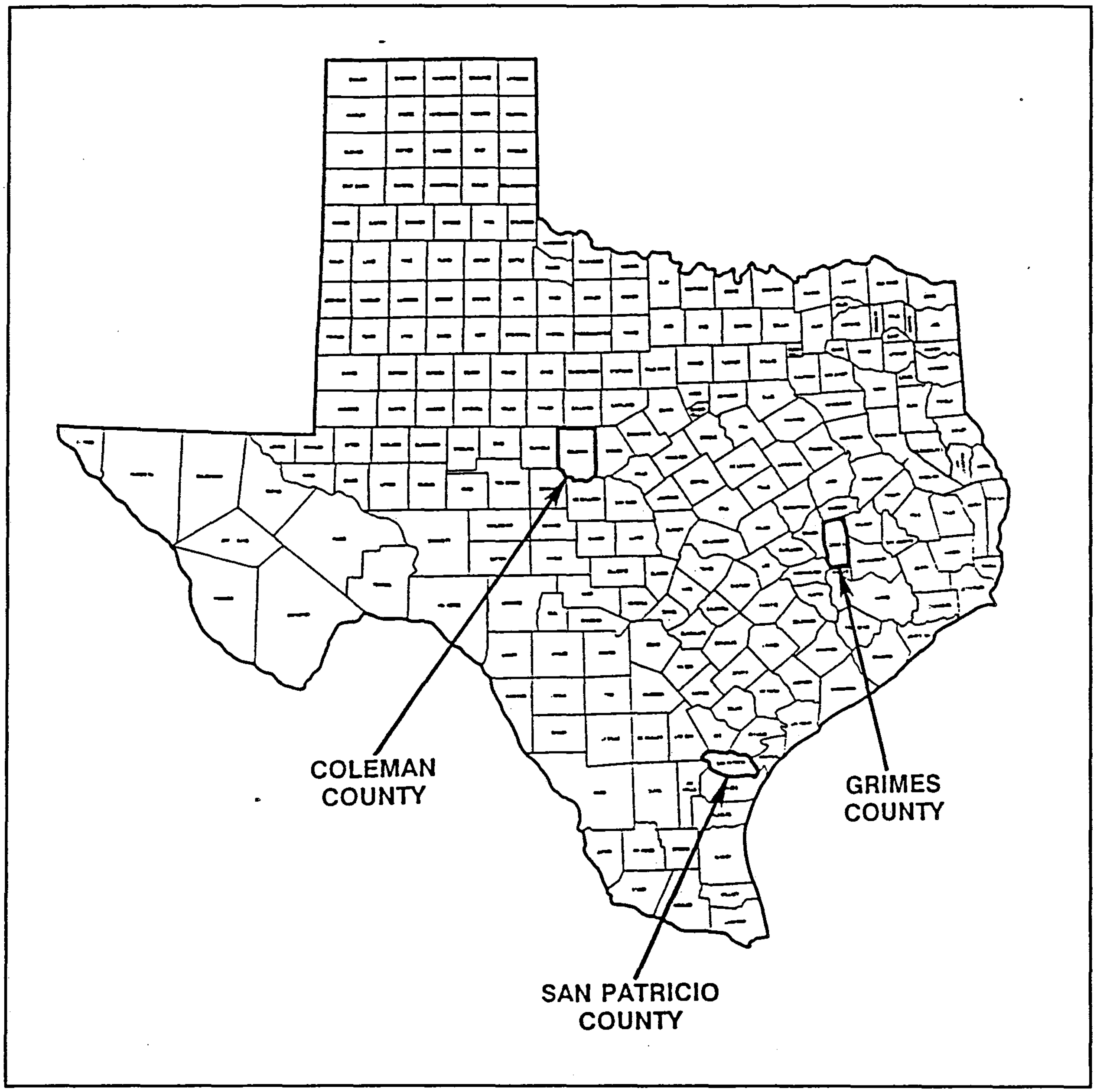


Figure 15. Texas Counties Selected for Study Sites

2. Train speeds of at least 30 miles per hour (48.3 kph) were desired. A driver approaching a crossing at which slow train speeds are expected may not exhibit speed reductions conducive to this study. Drivers may reduce speed between the intermediate point of speed observations and the crossbuck only.

3. Vehicular volumes of 300-2000 average vehicles per day, or average daily traffic (ADT) were desired. Volumes less than 300 ADT would produce a sample too small for statistical evaluation. Volumes in excess of 2000 ADT might pose traffic control problems for the survey team.

4. Vehicular speeds higher than 30 miles per hour (48.3 kph) on the approach were desired. A percentage reduction in speed on high speed approach would be more reliable than the same percentage reduction on a low speed approach. The speed detection equipment used reported speeds in whole numbers. Also, the speed detection equipment used in this study would not detect speeds under 11 miles per hour (17.71 kph).

5. A smooth crossing surface was desired. Drivers tend to slow down at crossings in response to a rough crossing. This variable may be one of the more significant in the speed portion of the study in that drivers already slowing due to crossing roughness may not reduce further in response to the experimental system.

6. Paved approach surfaces were desired in that unpaved surfaces encourage slower driving already. Also, since pavement markings are a desirable feature between the test sites, paved approaches are necessary.

7. Crossings void of geometric features such as intersections in close proximity to the crossing, excessive vertical grades on the approach or excessive horizontal curvature on the approach were desired. These features are undesirable in that driver speed at the crossing could be influenced.

8. Crossings with and without sight distance restrictions were desired. Sight distance was a critical factor in the placement of the YIELD TO TRAINS Sign. Candidate crossings for a YIELD TO TRAINS were required to meet minimum sight distance requirements, below which a higher level of control such as a STOP sign or active control would be appropriate. Restricted sight distance, however, would not affect the placement of the intermediate LOOK FOR TRAINS warning sign. Sight distance restrictions on the approach would be conducive to this study in order for

drivers to make necessary head movements to look for trains close to the crossing.

Although all of the desirable characteristics discussed above could not be found at any of the candidate crossings, an attempt was made to select crossings which displayed the most desirable characteristics. General information on the test crossings and the communities in which they are located are discussed in the following subsections. Detailed descriptions of each crossing can be found in Appendix I.

Grimes County. Grimes County is located in southeast Texas about fifty miles northwest of Houston. The county is rural in nature and supports approximately 18,828 residents through agriculture, ranching and small manufacturing (47). The county seat is located in Navasota, which is the largest city in Grimes County. One mainline railroad runs through the northeast corner of the county. Another mainline railroad runs from the south portion of the county through Navasota and then north. Two mainline railroads run from the southeast corner of the county west to Navasota exiting the county in the northwest corner of the county. The two test crossings in Grimes County used for this research were located on one or both of the latter described mainlines. The Grimes County Road 304 crossing is located in southeast Grimes on one mainline track. The other crossing, Courtney Road, is located south of Navasota and involves two mainline tracks. The YIELD TO TRAINS experimental system was also placed at three other crossings.

Coleman County. Coleman County is located in mid-west Texas approximately 200 miles east-south-east of Dallas. The county is rural in nature and supports about 9,700 residents. Most of the residents reside in the city of Coleman, which also serves as the county seat (48). The community supports itself through ranching, agriculture, oil and gas, and small manufacturing. One mainline railroad runs from the northwest portion of the county to the southeast corner of the county. One shortline railroad breaks from the mainline south of the city of Coleman and runs in a southwesterly direction through the county. The experimental system incorporating the YIELD TO TRAINS sign was placed at three test crossings. The test crossings are located on Vale Street in the city of Coleman, FM 2131 south of the city of Coleman and Parker Street in the city of Santa Anna.

San Patricio County. San Patricio County is located in south Texas bordering on Nueces County to the north. The county is suburban to Corpus Christi in some respects, with most of the land area devoted to agriculture. Refining, coastal industry, and agriculture support a population of about 38,700 (47). The county seat is located in Sinton, which is a crossroads for two mainline railroads. One mainline railroad runs from the southwest portion of the county northeast through Sinton. Another mainline runs from the coastal area of Ingleside and Gregory northwest through Sinton. One other mainline railroad runs from the coastal area west through Odem and Mathis. The test crossings in this county were located in Ingleside on Avenue A, Odem on Baylor Street, and north of Mathis on Hidden Acres Road.

A summary of the test site descriptions can be found in Table 14. While no test crossing satisfied all criteria of the preferred test site, the test sites chosen were those of the candidate crossings that best fit the criteria. Results of the analysis of the measures of effectiveness observations and the driver exit survey are presented in the next section.

Study Procedures. Each test site was visited at least twice: once to make observations in the control condition and a second time to make observations in the experimental condition. Some sites were visited more than twice when low traffic volumes or adverse weather conditions were encountered.

Law enforcement officials, both local and state, were notified in advance of the arrival of the data collection team. The first step when arriving at the test site was to complete a Data Collection Sheet-General form. Data relating to geometric characteristics, traffic control, site layout, and number and type of signs in the vicinity of the crossing were recorded. Data collection team members were then assigned to specific duties involving either speed observations, driver looking behavior observations, or survey administration.

Speed Data. Team members assigned to spot speed observation duty were positioned in a location where speeds could be accurately observed with the radar speed gun. The location of the observer could be downstream or upstream of the spot speed location, depending on the subjective judgement of the team leader as to the best location to collect the data. The spot speed observer was instructed to record the type of vehicle and speed on a data collection form. Only vehicles which were unaffected by other traffic or trains, in the judgement of the observer, were to be observed and recorded.

Driver Looking Behavior Data. The driver looking behavior observer was stationed near the crossing in a position which afforded the best view of drivers as they travelled the last 150 feet (45 meters) of the approach. The observer was instructed to record only those drivers that the observer could see in the last 150 feet (45.72 meters). Head movements of right only, left only, both left and right, or no head movement were recorded. The observer was also instructed not to "guess" as to what the driver did. If the driver could not be seen, or the vehicle was missed, the driver was to record that data also. Although the number of observations which were able to be made was high, several reasons for not being able to observe the driver were recognized:

1. Many vehicles have tinted windows which makes observations of driver head movements difficult.
2. Observations on cloudy, overcast or otherwise dimmed daylight days were difficult.
3. High approach speeds could make driver looking behavior observations difficult.

Table 14. Description Summary of Field Study Sites

Physical Description	Crossing Location and D.O.T. Number							
	County Road 304	Courtney Road	Parker Street	Vale Street	FM 2131	Baylor Street	Avenue A	Hidden Acres
	24310M	24298II	21210X	21239V	21387P	436030Y	742696N	435600F
Number of Traffic Lanes	2	2	2	2	2	2	2	2
Horizontal Alignment	Sight Curve - NB	Straight - NB Straight - SB	Straight - SB	Straight - NB Straight - SB	Straight - NB Straight - SB	Straight - SB	Straight - NB	Straight - EB Straight - WB
Vertical Alignment	Level - SB	Level - NB Level - SB	Level - SB	Level - NB Level - SB	Level - NB Level - SB	level - SB	Level - NB	Upgrade - EB Upgrade - WB
Street Intersection in Vicinity	Y	N	Y	Y	N	Y	N	Y
Sight Distance Obstruction	None	None	1 Quadrant - SB	1 Quadrant - NB 1 Quadrant - SB	None - NB 1 Quadrant - SB	1 Quadrant - SB	2 Quadrants - NB	2 Quadrants - EB
Average Daily Traffic	490	280	230	370	210	2310	2360	720
Number of Tracks	1	2	1	1	1	1	1	1
Thru Train Volume	7	8	16	49	2	2	2	4
Train Speed Limit	49	49	30	55	30	20	20	49
Number of Accidents (Last Five Years)	0	3	0	0	0	2	6	4

The driver exit survey was administered at a location downstream of the test crossing so as not to influence driver behavior at the crossing. At least two team members were present to conduct the survey. The primary responsibility of one member was to administer the survey questions to drivers, while the primary responsibility of the other team member was to provide traffic control and to provide backup survey administration if traffic volumes were low and one vehicle had queued behind the first stopped vehicle.

Traffic control was achieved through the use of a portable advance warning sign indicating a driver survey ahead. A portable STOP sign with a supplementary message plate stating "DRIVER SURVEY" was used at the survey location. The signs used and the team member assigned to traffic control proved to be effective in providing safety at the survey site and in stopping drivers to ask for their participation in the study.

Data Analysis. Quantitative measures of spot speeds on the approach, driver looking behavior on the approach, and driver responses to the questionnaire were analyzed by statistical treatment. A significance level of 0.05 was used in all statistical tests. Treatment of each measure of effectiveness is discussed separately below.

Speed Data. Spot speeds were measured at three locations on the approach to the test crossing. The mean speed and standard deviation were calculated for each sample and plotted on a distance-speed diagram. The distance-speed diagrams are presented in Section 5. Linear regression was used to model the trends in mean speeds for both the before and after mean speeds. The explanatory variable in both the before and after models was either the current standard system or the experimental system. The response variable was speed in both cases. Linear regression analysis and Statistical Analysis Software (SAS) were used to test the research hypotheses.

Driver Looking Behavior Data. Head movement was considered indicative of driver looking behavior and was observed in the last 150 feet (45.72 meters) of the approach to the crossing. Driver looking behavior observations were grouped into three categories for analysis: no head movement, head movement left or right, or head movement left and right. The number of observations for each category was tabulated for the before and after condition. A chi-squared test of independence was performed using SAS to test the research hypothesis.

Survey Responses. Demographic data collected in the survey administration were used to stratify the responses given to questions about sign meaning and sign recollection. The responses were tabulated and examined for obvious differences between responses. The responses to sign meaning questions were tabulated for each site. Responses to sign recollection were tabulated across all test sites.

Driver opinions of the effectiveness of the experimental sign system in relation to the current sign system were tabulated by county and by sign. A chi-square test was performed to determine if drivers preferred one of the experimental sign systems over the other.

STUDY RESULTS

Results regarding sample demographics, number of data collected, speed observations, driver looking behavior observations and results from the driver survey are presented in this section.

Sample Demographics. The results of the demographic questions asked in the survey are shown in Table 15. Although not all vehicles which were observed for speeds and driver looking behavior on the approach were stopped for the driver survey, the sample taken for the driver survey is considered representative of all vehicles which crossed the test crossings. The demographic data may not necessarily represent the distribution found throughout the state of Texas. The counties selected for the study, however, were chosen for their diverse locations throughout the state.

The age distribution of the respondents appears to be nearly the same for the different age categories. The lower percentage for the under-twenty-years-of-age category was expected due to only four years that category compared to fifteen years or more in the other categories. The comparisons of gender categories, although not evenly split, can be seen to be reasonably close to an even distribution.

A question was asked of the survey respondents to determine what language was spoken in the home. Most responded that the language spoken in the home was English, with 12.3 percent responding that either Spanish and English or Spanish only was spoken in the home. Although not shown in Table 15, one respondent indicated that a language other than English or Spanish was spoken in the home. This question was asked to examine if any differences in survey responses to questions concerning the understandability of the signs could be due to language-based differences.

There were two questions concerning driving experience. Responses to the question regarding the number of years holding a driver license showed a balance between the age categories. Responses to the question regarding familiarity of a crossings showed that many of the drivers were familiar with the crossings at the test sites (passed more than once a week). This result appears to indicate a diverse range of experience in drivers who are mostly familiar with the test crossings. Drivers familiar with a crossing may not notice the warning devices in place; rather, they may rely on their previous experiences at the crossings for cues of when and where to slow down and look for trains.

Number of Data Collected. Shown in Table 16 is the number of data collected for each measure of effectiveness stratified by county and by the time at which the data was collected, before or after the experimental sign was placed in the system. The number of data collected at certain test sites was below the sample goals cited in the previous section. The ramifications of shortfalls will be discussed for the particular test site where this occurred and was significant.

Table 15. Summary of Demographic Data

County	AGE				GENDER		FREQUENCY OF CROSSINGS				LANGUAGE IN HOME		YEARS-HOLDING DRIVER'S LICENSE		
	<20	20-35	36-50	>50	Male	Female	Once a week	Once a month	Once a year	First time to cross	English	Spanish	0-14	15-29	>29
Grimes	3 (3.2)[1]	35 (38.0)	33 (35.9)	21 (22.8)	60 (61.9)	37 (38.1)	76 (80.0)	13 (13.7)	5 (5.3)	1 (1.1)	94 (100)	0 (0.0)	23 (25.3)	40 (44.0)	28 (30.8)
Coleman	14 (6.8)	57 (27.8)	73 (35.6)	61 (21.8)	127 (62.6)	76 (37.4)	189 (92.2)	10 (4.9)	2 (1.0)	4 (2.0)	183 (90.1)	20 (9.9)	54 (26.3)	76 (37.1)	75 (36.6)
San Patricio	22 (6.9)	100 (31.5)	103 (32.4)	93 (29.3)	161 (50.0)	161 (50.0)	297 (92.2)	13 (4.0)	9 (2.8)	3 (0.9)	245 (82.5)	53 (17.8)	101 (31.9)	105 (33.1)	111 (35.0)
Total	39 (6.3)	192 (31.2)	209 (34.0)	175 (28.3)	348 (56.0)	274 (44.0)	562 (90.0)	36 (5.8)	16 (2.6)	8 (1.3)	522 (87.5)	73 (12.3)	178 (29.0)	221 (36.1)	214 (34.9)

[1] Numbers in parenthesis indicate percentage

Table 16. Summary of Observations Made

	Grimes County		Coleman County		San Patricio County		Total	
	Before	After	Before	After	Before	After	Before	After
Number of crossings signed with experimental system	0	5	0	47	0	38	0	90
Number of crossings where observations were made (test crossings)	2	2	3	3	3	3	8	8
Number of speed observations	179	179	198	223	221	292	598	694
Number of driver looking behavior observations	174	163	201	227	497	254	872	644
Number of surveys conducted	36	61	103	102	207	115	346	278

The number of crossings at which the experimental sign systems were installed is greater than the number of test crossings, as can be seen in Table 16. An additional number of crossings in the vicinity of the test crossings displaying the experimental sign system was expected to reduce the effect of novelty at the test sites. Drivers familiar with seeing the experimental signs at most of the passively controlled crossings in the vicinity may be less affected by the novelty of seeing the experimental system at the test crossing.

Driver Speed. Spot speed observations were made at the advance warning sign, the advance pavement marking and the crossbuck at each test crossing to determine if the experimental sign system had any effect on speeds on the approach. The speeds were observed. The differential in mean speeds for the locations were then analyzed to determine if a difference was observed in the condition of before and after the experimental sign was placed in the system. A reduction in the approach speed differentials in the after condition observations over the before observations might indicate a positive driver reaction to the experimental sign system. A reduction in speeds on the approach might also indicate safer behavior on the crossing approach where the difference between a train-vehicle collision and a safe outcome can be measured in fractions of a second.

In collecting the speed data, the radar speed gun used would not indicate speeds of less than ten miles per hour. In those cases where the speeds were less than 10 miles per hour at the observation point but greater than zero, a low end value of five miles per hour was used. In the cases where the driver stopped, zero was recorded.

The speed profile for each test crossing as constructed using the three mean speed points on each test approach can be seen in Appendix J. The approach speed for the before and after condition were each modeled by linear regression. A significance level of five percent was used for each test. SAS software was used to test the research hypotheses. The results of the SAS analysis for each test crossing can be found in Appendix K. A summary of the results of the statistical tests for speeds can be seen in Table 17.

As can be seen in Table 17, two of the six test sites evaluated for speeds at crossings where the YIELD TO TRAINS experimental sign was installed showed a significant decrease in speeds on the approach. One of the two sites evaluated for speeds where the LOOK FOR TRAINS was installed also showed a significant decrease in speeds on the approach.

The Vale Street crossing was not evaluated by the regression method due to a difference in the locations on the approach where before and after speeds were observed, and to a very small sample size obtained for the before observations. As can be seen in Figure 16, however, an overall decrease in speeds on both approaches is apparent, although the decreases may not be statistically significant.

Table 17. Summary of Speed Data Analysis

Test Site	H_o: $\beta_3 = 0$		H_o: $\beta_1 = 0$	
	Probability	Reject H_o	Probability	Reject H_o
CR 304	0.660	No	0.278	No
Courtney NB	0.351	No	0.710	No
Courtney SB	0.707	No	0.659	No
Parker	0.519	No	<0.001	Yes
Vale NB	*			
Vale SB	*			
FM 2131 NB	0.115	No	0.810	No
FM 2131 SB	0.562	No	<0.001	Yes
Baylor	0.088	No	<0.001	Yes
Avenue A	0.738	No	0.324	No
Hidden Acres EB	* *			
Hidden Acres WB	* *			

* Not evaluated by regression method due to small sample size.
* * Not evaluated by regression method due to questionable field data.

The Hidden Acres Road crossing also was not evaluated statistically due to questionable collection of the after condition speed observations. As can be seen in Figure 17, the before observations show the expected decrease in speeds from the advance warning sign to the crossing. The after observations, however, show an increase in speeds from the advance warning sign to the advance pavement marking and then a decrease in speeds to the crossbuck. One possible explanation was the position of the analyst when observing the speeds. It appears that the observer may have been positioned near the advance warning sign, which would cause an excessive angle to the vehicle from the radar speed gun, and thus an erroneous registered speed.

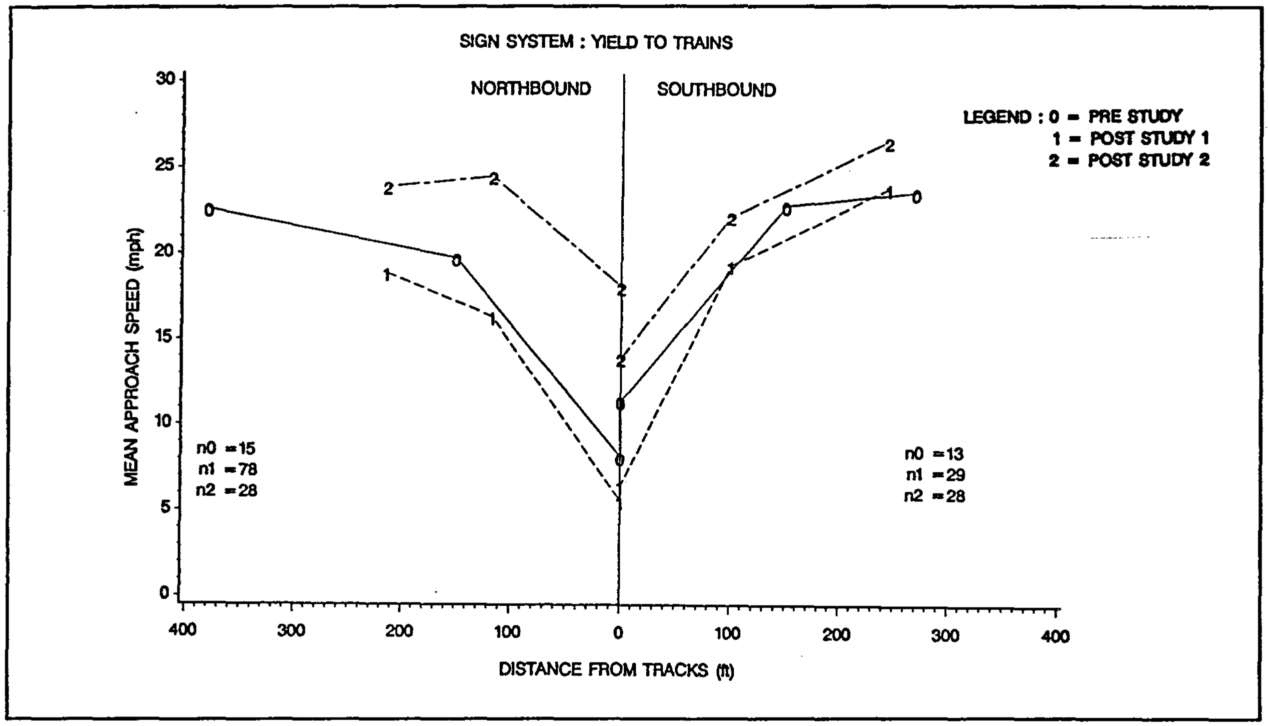


Figure 16. Mean Speeds for Vale Street

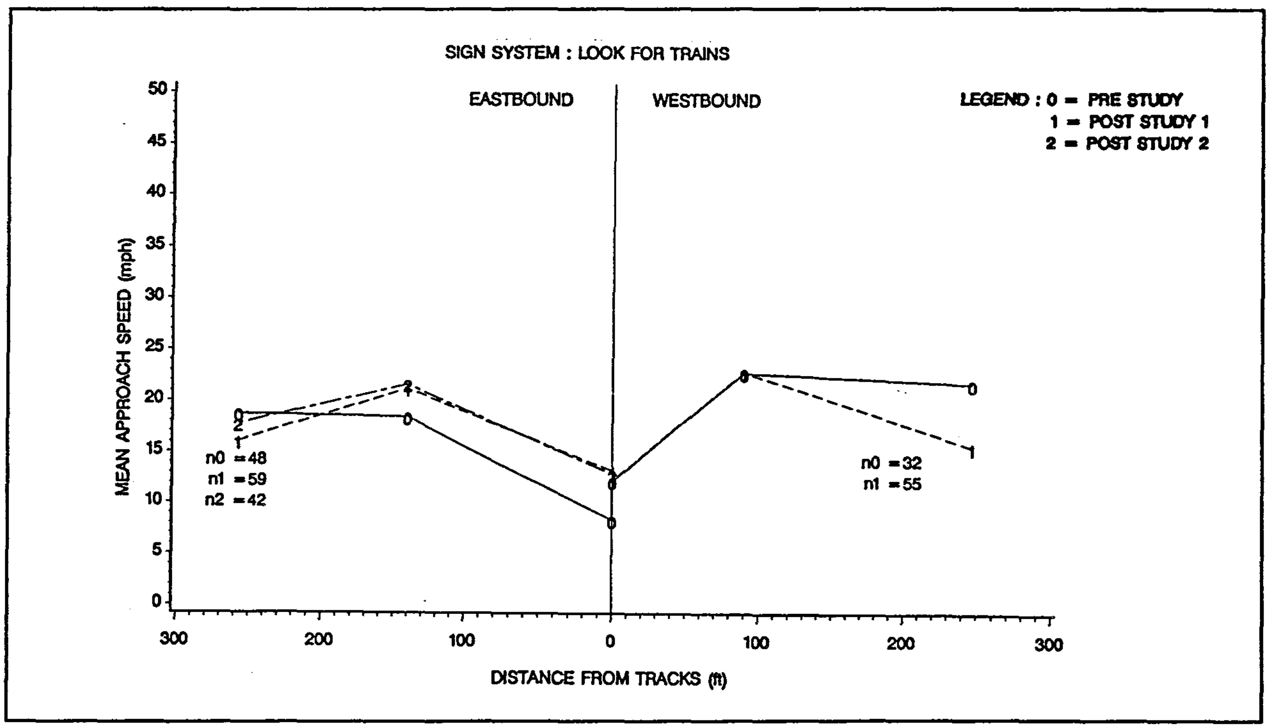


Figure 17. Mean Speeds for Hidden Acres Road

To summarize the results of the speed-based measure of effectiveness, three of the eight sites evaluated statistically showed a significant decrease in speeds on the approach. Equally important, there was not a significant increase in speeds on the approaches to any of the test sites evaluated. These findings suggest that a statewide implementation of one the of experimental systems would not cause a significant increase in speeds on the approach to a railroad-highway grade crossing and would show a significant decrease in speeds on the approach to some crossings.

Driver Looking Behavior. Driver looking behavior was also observed on the approach to the test crossings within 150 feet (45 meters) of the crossbuck. Driver head movements were observed within 150 feet (45 meters) of the crossing and recorded. Driver head movement is considered indicative of driver looking behavior. Observations made were no head movement discerned, head movement right only, head movement left only, and head movement left and right. The tabulations of the observations can be found in Appendix K.

The percentage of the total for each category of the before and after conditions are represented graphically for each test crossing and can be found in Appendix K. A regression line was fitted to the three points for the before and after condition, resulting in one line for the before condition and one line for each of the after conditions. An increase in slope of the after condition regression line over the before regression line indicates an overall increase in driver looking behavior. As can be seen from the graphs for all twelve approaches, all but one showed an increase in the slope of the after line as compared to the before line, although most of the increases were found not to be significant.

The frequency of head movements before the experimental sign was installed in the system and the frequency of head movements after the experimental sign was installed were compared using a chi-square test of independence. The null hypothesis was tested at a level of significance of 0.05.

In several of the tests, the number of observations for no looking or the number of observations for looking left or right was less than five. In the evaluation of these test sites, the categories of no head movement and head movement left or right were combined. The category of head movement both ways was not combined with any other category in any of the tests.

SAS was again used to perform the statistical tests. The output from the SAS runs can be found in Appendix L. The results of the chi-square tests for each test crossing approach can be found in Table 18.

For the test approaches at which the YIELD TO TRAINS sign was placed for the after condition, a significant increase in driver looking behavior was found in three of the eight sites. For the test approaches at which the LOOK FOR TRAINS sign is installed, a significant increase in looking behavior was observed at one of the four approaches. No significant decrease in looking behavior was observed at any of the test approaches.

Table 18. Summary of Looking Behavior Data Analysis at Individual Sites

TEST SITE	SAMPLE SIZE	PROBABILITY	SIGNIFICANT INCREASE IN LOOKING BEHAVIOR
YIELD TO TRAIN Sign System			
County Road 304	142	0.401	NO
Courtney Road NB	83	0.041	YES
Courtney Road SB	112	0.226	NO
Parker Street	103	0.332	NO
Vale Street NB	93	0.339	NO
Vale Street SB	50	0.339	NO
FM 2131 NB	92	<0.001	YES
FM 2131 SB	90	<0.001	YES
LOOK FOR TRAIN Sign System			
Baylor Street	256	0.776	NO
Avenue A	317	<0.001	YES
Hidden Acres Road EB	70	0.113	NO
Hidden Acres Road WB	108	0.726	NO

The driver looking behavior observations for each experimental system and for both of the experimental systems were combined and tested statistically under the same null hypothesis as the individual approaches. Again, the SAS output can be found in Appendix F. The results of the statistical tests can be seen in Table 19.

The very low p-values (<0.001) shown in Table 19 indicate a strong relationship between the increase in looking behavior and the sign system in place. The combining of test site observations and the results of statistical tests must be approached with caution. The strong relationship in increased looking behavior shown between the control condition and the experimental condition at one or two individual test sites with relatively high sample sizes can greatly influence the outcome of the statistical tests for the combined observations. For this reason, no conclusions will be drawn from the combined observations.

Driver Survey. Drivers were stopped downstream of the test crossings and asked to participate in a questionnaire survey. Those drivers who did not want to participate were allowed to proceed. The results of the driver survey were reduced and tabulated in spreadsheet form. The resulting database can be found in Appendix M. The results of the driver survey are discussed in the following subsections and cover the areas of driver recollection of warning devices at the crossing, driver understanding of the advance warning sign and the crossbuck, driver opinions on the effectiveness of the experimental sign system, and any relevant comments to the study that drivers may have volunteered during the survey.

Recollection of Warning Devices. After demographic questions were asked, the driver was asked if he/she could recall seeing any warning devices such as signs or markings to warn of the crossing. When asked in the survey conducted before the experimental system was in place, the responses were grouped into two categories: did not recall seeing any signs or markings and recalled and correctly described at least one sign or the advance pavement marking. The results of this question for the before condition can be found in Table 20.

In the survey conducted after the experimental systems were installed, the drivers were again asked if they could recall seeing any warning devices to warn of the crossing on the approach. The responses were categorized as:

1. Did not recall seeing any warning device.
2. Recalled and correctly described a standard warning device only.
3. Recalled and correctly described seeing the experimental sign only.
4. Recalled seeing and correctly described at least one standard sign or the advance pavement marking and the experimental sign.

The results are shown in Table 21.

The percentage of drivers who were not able to recall any devices and the percentage of drivers who recalled seeing the experimental sign only (62.2 percent) was about the same as the number of drivers who did not recall seeing any devices in the before survey (61.0 percent). The percentage of drivers who recalled seeing either at least one standard device or at least one standard device and the experimental sign in the after survey approximates the percentage of drivers able to recall at least one standard device in the before survey. These results suggest that driver awareness of warning devices is increased due to the introduction of the experimental sign to the system. While the novelty of the experimental sign may have had an effect on these data, the results indicate some improvement in driver awareness of warning devices on the approach.

Driver Understanding of Standard Signs. Questions were asked to determine the level of driver understanding of the current signs. The absence of driver understanding of standard signs in the passive warning system may indicate a need for an additional sign to inform drivers of their responsibilities at crossings.

Pictures of the advance warning sign and the crossbuck sign were shown to drivers who were then asked what the sign meant to them. If the correct answer was given, the next two questions were skipped. The two questions that followed if an incomplete answer was given concerned any action that was required by the particular sign and where on the approach the driver might expect to see the signs.

Table 19. Summary of Looking Behavior Data Analysis at Combined Sites

SYSTEM	SAMPLE SIZE	PROBABILITY	SIGNIFICANT INCREASE IN LOOKING BEHAVIOR
YIELD TO TRAINS	765	<0.001	YES
LOOK FOR TRAINS	751	<0.001	YES
COMBINED	1516	<0.001	YES

Table 20. Results of Recollection Question from the Before Surveys.

	Grimes	Coleman	San Patricio	Total
Did not recall seeing any signs	N/A	N/A	64 (61.0)[1]	64 (61.0)
Recalled seeing at least one sign or pavement markings	N/A	N/A	41 (39.0)	41 (39.0)

[1] Numbers in parenthesis indicate percentage

Table 21. Results of Recollection Question from the After Surveys.

	Grimes	Coleman	San Patricio	Total
Did not recall seeing any signs	9 (14.7)[1]	20 (19.6)	32 (27.8)	61 (21.9)
Recalled seeing at least one standard sign or pavement marking	5 (8.2)	9 (8.8)	18 (15.7)	32 (11.5)
Recalled seeing experimental sign only	30 (49.2)	34 (33.3)	48 (41.7)	112 (40.3)
Recalled seeing experimental sign <u>and</u> at least one standard sign or pavement marking	17 (27.9)	39 (38.2)	17 (14.8)	73 (26.3)

[1] Numbers in parenthesis indicate percentage.

The results of these questions were stratified by the demographic data obtained and are shown in Table 22. The results show a surprising absence of understanding of what the advance warning sign means. The correct answer to the meaning of the advance warning sign is: "railroad crossing ahead, slow down, look and listen for trains, and be prepared to yield the right of way to a train." The most common answer to the question was that the advance warning sign means "railroad crossing." When the question of the meaning of the sign was followed by the question of the location of the sign, the percentage of correct responses increased from 19.9 percent to 51.2 percent. This is to say that 51.2 percent of the drivers surveyed recognized that the advance warning sign means "railroad crossing" and that the sign is located somewhere before the crossing on the approach.

The railroad crossbuck sign was understood to mean "railroad crossing" and to "slow down and look for trains" by 81 percent of the drivers. Only 60 percent of the drivers, however, were able to correctly identify the location of the crossbuck as being near the crossing. Many of the incorrect responses to the question of the location of the two signs were of the order that the crossbuck sign would be seen in urban areas and the advance warning sign would be seen in rural areas, or vice versa. Another common incorrect response was that the crossbuck sign was an obsolete sign and/or was used at crossings with little or no train traffic. The advance warning sign was incorrectly recognized as being a "new" sign used at dangerous crossings.

The results of the questions designed to test driver understanding of the current warning signs seen at railroad-highway grade crossings indicate a deficient understanding of these signs by drivers. These results suggest that a sign which would more effectively inform the driver of his/her responsibility at the crossing may improve safety at the crossing.

Driver Opinion of Experimental Systems. In the survey conducted after the experimental sign systems were in place, a question was asked to gauge drivers opinions on the effectiveness of the experimental systems in terms of safety at the crossing. An effective sign system at a railroad-highway grade crossing was described to drivers as one which is noticeable, indicates to the driver that a railroad crossing is ahead, warns the driver of the potential danger at the crossing, and prompts the driver to approach the crossing with caution. The driver was then asked if the addition of the experimental sign, in his/her opinion, provides for a safer crossing. The driver responses were categorized as strongly agree, somewhat agree, no opinion, somewhat disagree, and strongly disagree.

A wide majority of drivers surveyed at all of the test crossings indicated that they felt the signs would improve safety at the crossings. The question of whether drivers preferred one of the two systems over the other was then considered. To examine this question, the percentage of driver responses were plotted against each response category and is shown in Figure 18. Responses by county can be found in Appendix L. A chi-square test for independence was then conducted to determine if a significant difference in the two distributions of responses exists.

Table 22. Driver Understanding of Standard Signs

Treatment	AGE				GENDER		FREQUENCY OF CROSSINGS				LANGUAGE IN HOME		YEARS HOLDING DRIVERS LICENSE			ACROSS ALL STRATA
	<20	20-35	36-50	>50	Male	Female	Once a week	Once a month	Once a year	First time to cross	English	Spanish	0-14	15-29	>29	
AWS Meaning	25.0	23.5	18.7	22.6	18.1	21.2	21.3	30.8	21.7	14.3	21.3	23.2	21.5	20.1	18.1	19.9
AWS Position	69.2	57.1	58.9	55.1	58.0	56.1	58.4	54.6	42.9	57.1	59.4	53.7	56.5	62.8	62.8	60.6
Crossbuck Meaning	87.5	77.5	76.3	80.2	80.7	80.0	79.9	71.8	56.5	78.6	78.9	78.7	79.7	78.0	78.9	81.0
Crossbuck Position	69.2	58.6	59.9	57.7	58.2	55.9	59.7	60.6	57.1	50.0	61.4	54.6	59.8	56.1	59.1	60.0

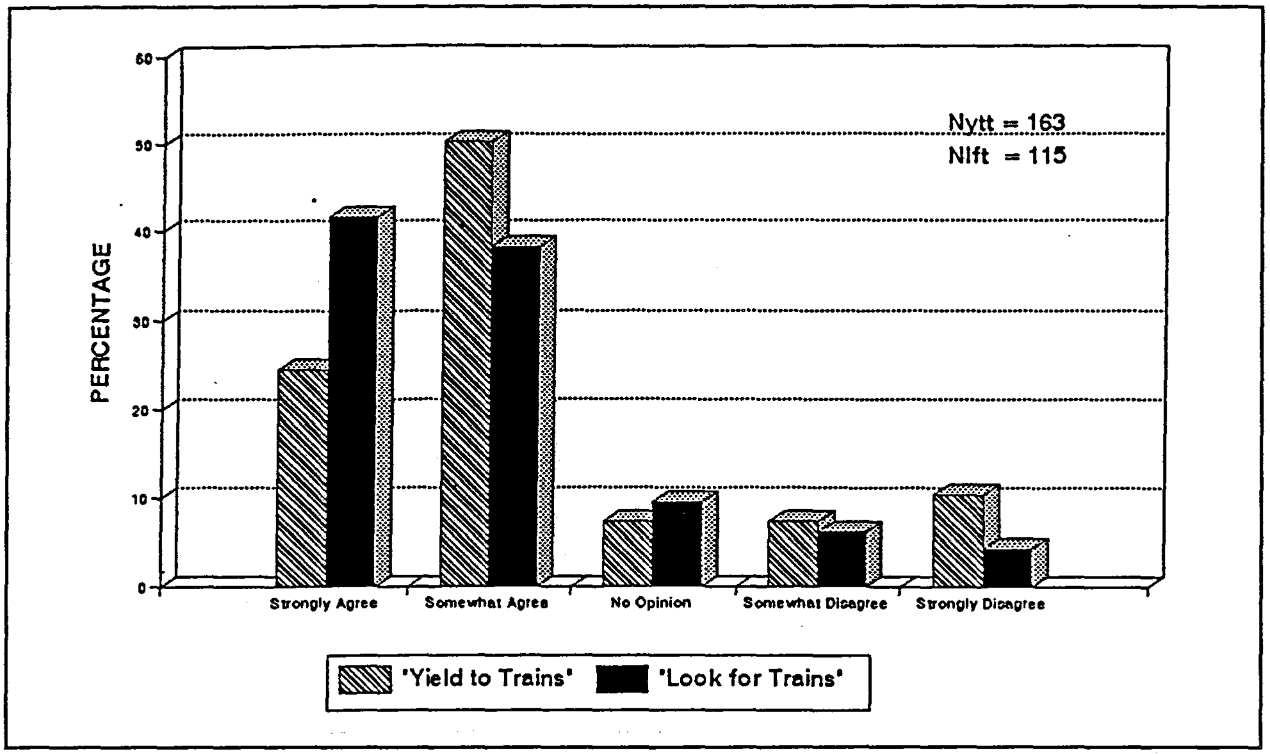


Figure 18. Results of Driver Opinion

The results of the SAS output for the chi-square test can be found in Appendix L. The results of the chi-square test indicate that the addition of either of the experimental signs to the current standard passive sign system will provide for a safer crossing in the opinion of the drivers surveyed, and that there was no preference of either sign between the independent samples. A matched pair test in which drivers see both experimental sign systems may have indicated a preference of one of the experimental signs over the other.

Driver Comments. During the course of the survey, it became obvious that many drivers are concerned with safety at railroad-highway grade crossings and offered unsolicited comments at various points in the survey. A listing of selected driver comments can be found in Appendix N. Some of these comments will be discussed here.

Many drivers expressed the need for improved safety devices at railroad grade crossings and were pleased to see that research was being conducted in this area. Others, although quite fewer in number, felt that research was a waste of time and that "if folks don't know to look and stop for a train, then they get what they deserve." Many drivers indicated that active signals should be installed at all crossings and could not understand why crossings in the city warrant active control while the crossing they traverse several times a day do not.

Several drivers recognized sight distance restrictions through comments such as "brush needs to cleared" and "building in the way." A few drivers at specific crossings also complained that trains would often speed through the crossing with no lights or horn.

Comments from three respondents at the Vale Street crossing indicated a surprising and serious misunderstanding of control devices. A railroad control signal is located approximately 750 feet west of the Vale Street crossing. The three drivers indicated that they look at the railroad signal when approaching the crossing. If the signal is green, they proceed through the crossing. If the signal is red, they responded that they look several more times for a train before they cross. The only other crossing from which railroad signals were visible in this study was Parker Street. None of the respondents, however, made comments about the signals at this crossing. There is concern that more drivers may look to railroad signals for information as the comments made to researchers from this study were unsolicited.

Other comments were made specific to the experimental signs. Many drivers indicated that the color or the shape of the sign caught their attention. Although all surveys were conducted during the day, several drivers commented that the signs were very effective at night. While some of the standard signs in the study were backed with engineering grade sheeting, all of the experimental signs in the study were constructed with high-intensity grade backing.

Some drivers commented that the LOOK FOR TRAINS sign with its icon symbol, may be helpful to those who either do not read or for whom English is a second language. Several comments were made that the YIELD TO TRAINS sign was confusing the first time it was seen, but that the meaning became clear during subsequent crossings. Two respondents indicated that they believed that the YIELD TO TRAINS signs meant that two trains might be encountered at the crossing. One respondent did not connect the supplementary TO TRAINS plate with the YIELD sign, indicating that he thought that the TO TRAINS message was somehow directing the driver to a train station.

Based on the varied comments from drivers, it is clear that some portion of the driving public will misinterpret any sign, no matter how clear the message is to most other drivers. None of the comments or responses to the survey, however, indicate a critical misunderstanding of either of the two experimental signs.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The research documented in this report evaluated two experimental sign systems for use at railroad-highway grade crossings under both laboratory and field conditions. Three measures of effectiveness were identified as surrogate to the accident rate, which will be the ultimate measure of effectiveness for any safety improvement. The findings of the field studies discussed in the previous chapter lead to the following conclusions:

1. In regards to approach speeds and driver looking behavior, there is no evidence to suggest that the implementation of either of the sign systems tested will cause a significant increase in approach speeds at a crossing. Nor is there evidence to suggest that the implementation of either sign system will decrease driver looking behavior in the vicinity of the crossing. The data do suggest, however, that with either of the experimental sign systems, speeds may be reduced on some approaches and looking behavior may increase at some crossings. The data also suggest that the new signs may have a novelty effect and their effectiveness may diminish over time.

2. In regards to driver awareness and understanding, the findings suggest that the implementation of either of the experimental systems will increase driver awareness of the crossing due to an increase in recognition of warning signs on the approach. The data indicate a deficiency in driver understanding of the current standard advance warning sign leading to a conclusion that a sign added to the current which reinforces the message of what is expected of a driver approaching a crossing is needed. The experimental signing systems contain such a message, and their meaning was understood by almost all drivers.

3. In regards to driver preference, the results of the driver opinion portion of the survey suggest that a majority of drivers feel that the addition of the experimental sign will improve safety at the crossing. No preference of the two sign systems could be established from the opinion results.

Based on the results and findings from the laboratory and field studies, the following recommendations were made:

1. Because the experimental signs appear to improve driver behavior and increase driver awareness and understanding, they should be installed at passive crossings in additional counties. Further field evaluations should also be conducted on the experimental sign systems already in place. These further studies should

concentrate on determining whether the findings of this research might have been due to the novelty effect of the experimental signs.

2. A survey to further study driver comprehension of the experimental sign would also be of benefit to determine which sign system, if either, would be the most effective in the field. If the results of these further studies show no detrimental effects due to the sign systems, then one of the two sign systems should be recommended for statewide implementation at all passively controlled railroad-highway grade crossings.

3. The results of this study suggest several areas of additional research at passive crossings that should be considered. Areas such as the effect of sight distance restrictions on driver behavior at passive crossings, and the effect of devices such as railroad wayside signals that might confuse drivers at passive crossings should be examined.

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APPENDIX A

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GROUP I PROCEEDINGS

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The issue of what devices are appropriate for a given set of conditions at passive grade crossings was discussed. It was recommended that at passive-control locations, the current railroad crossing advance warning sign (W10-1) be replaced with a STOP AHEAD (W3-1a) or YIELD AHEAD (W3-2a) advance warning sign (see Figures B-1 and B-2). The choice of sign should correspond to the type of control used at the crossing, which in turn should be a function of train frequency and highway volume (see Table A-1).

Table A-1: Recommendations for Passive Control at Rail-Highway Crossings

HIGHWAY VOLUME	TRAIN FREQUENCY					
	LOW		MODERATE		HIGH	
	GOOD SIGHT DIST.	POOR SIGHT DIST.	GOOD SIGHT DIST.	POOR SIGHT DIST.	GOOD SIGHT DIST.	POOR SIGHT DIST.
LOW	yield	yield	yield	****	stop	****
MODERATE	yield	yield	****	****	****	****
HIGH	yield	****	****	****	****	****

**** - Denotes beyond the scope of passive control evaluation

In addition to the warning sign, a supplemental plate should be mounted on the same signpost directly beneath the primary sign. The plate should be rectangular in shape, with the longer dimension placed horizontally. It should display an antique-style locomotive (steam engine) in the center with horizontal arrows directed away from the locomotive at either end. This design is intended to create driver head movement along a horizontal plane. Such motion will encourage the driver to scan the highway and its surroundings for railroad tracks and approaching

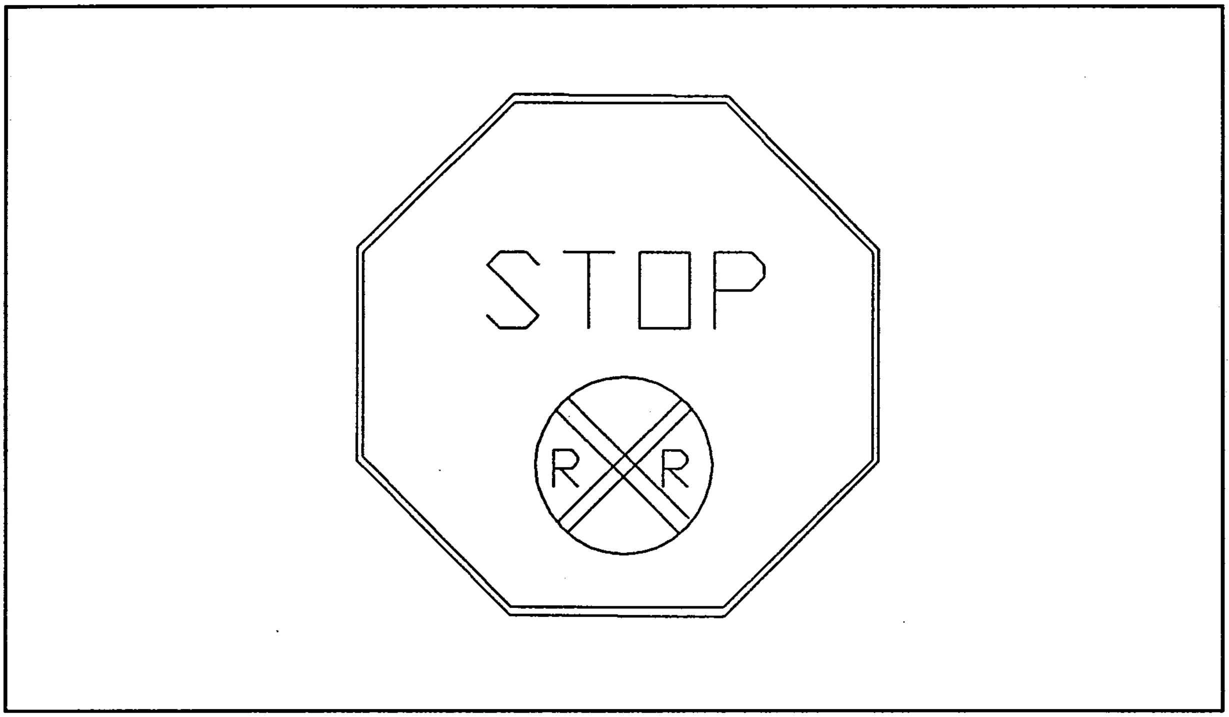

Figure A-1: Advance Warning Sign at Stop-Controlled Crossing

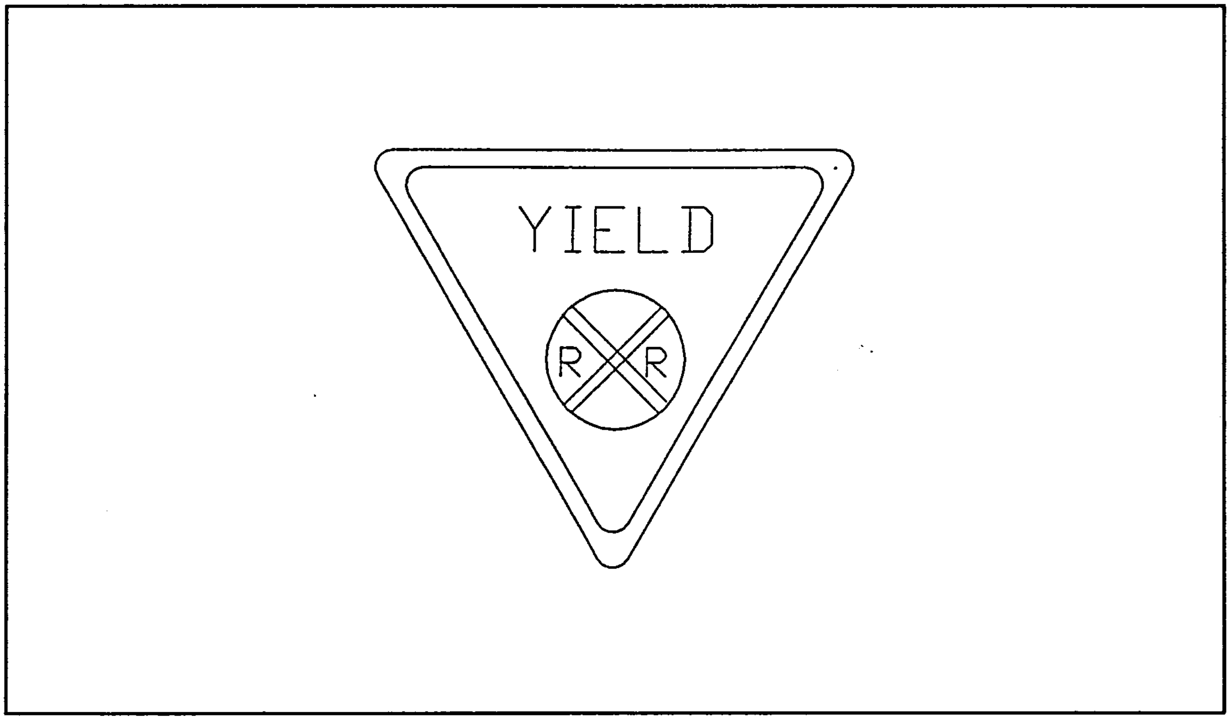

Figure A-2: Advance Warning Sign at Yield-Controlled Crossing

trains. Use of an older-style locomotive pictograph was recommended over one of a modern locomotive for purposes of legibility and recognition. A modern locomotive symbol was thought to have poor legibility, and it was expected that many drivers would not understand its meaning.

Problems with the standard railroad crossbuck were addressed. This sign has repeatedly been shown to serve effectively as an identifying factor at railroad crossings, but it does not command proper respect from drivers, nor does it effectively convey its intended meaning, which is to yield. It was recommended that the standard crossbuck be replaced with a modified stop sign (Figure B-3) or a modified yield sign (Figure B-4), depending upon roadway characteristics, traffic volume, and train frequency (Table 1). The modification should involve inclusion of the circular "RXR" symbol (as on the W10-1 advance warning sign) below the sign's text. This would inform motorists of the reason for the stop or yield sign. Use of these signs should occur in conjunction with the stop ahead or yield ahead signs mentioned previously, as appropriate.

It was recommended that rumble strips be utilized at low-volume off-system roadways where passive protection is employed. These strips should consist of grooved asphalt or textured concrete surface areas and be located just prior to the pavement markings which are used in advance of the grade crossing. The strips should extend across the full width of the roadway to prevent motorists from encroaching upon or occupying the opposing lane of traffic in order to avoid them. The intent of the rumble strips would be to alert the inattentive motorist to the presence of some important roadway feature (the crossing) through stimulation of the tactile senses.

The problem of dormant railroad grade crossings was discussed. It was agreed that at crossings where train operations have been terminated, all signs and markings should be removed, in addition to the tracks. In the past, the railroads have been reluctant to relinquish their right-of-way at such locations due to the possibility of renewed operations over the line. In North Carolina, agreements between the railroads and highway department have allowed inoperative tracks to be paved over, with the stipulation that the crossing will be restored should service over the line be reinstated. It was concluded that this type of cooperative effort between the railroads and state transportation agencies should be encouraged.

The special problems presented by nighttime operations at grade crossings were addressed. It was recommended that reflective sheeting be used on the back of all signs at the crossing, as is now required. This reflective material will create a flickering effect at night when it is illuminated by the automobile's headlights and as a train passes. Illumination of passive crossings was also advised to aid in detection of the crossing and of trains. To further improve train visibility during both day and night operations, it was suggested that strobe lights or reflectors be placed on the sides of locomotives.

Figure A-3: Stop Control Signing at Crossing

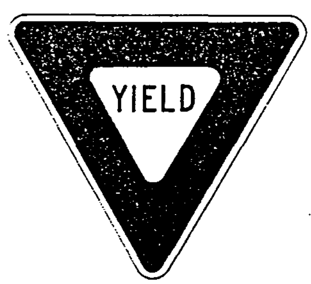

Figure A-4: Yield Control Signing at Crossing

GROUP II PROCEEDINGS

Members:	Neil Rowan (leader)	Rick Bartoskewitz (recorder)
	Wesley Pair	Jerry Masters
	Luis Ybanez	Mike Calhoun

Initially, the elements which should comprise an effective passive grade crossing warning system (auditory, tactile, and visual stimuli) were discussed. It was suggested that the problem of driver awareness and distraction on the approach to the crossing could be solved by means of auditory and tactile stimuli, such as those produced by raised pavement markers, small speed bumps, rumble strips, and surface texturing. Implementation of these devices would necessitate some education process to inform drivers of why they are present. Furthermore, such devices should be consistently applied at all passive grade crossings, and perhaps active crossings as well. The drawbacks to these devices are high maintenance and replacement costs.

Current applications of the standard railroad crossbuck sign were addressed. It was noted that a problem with this sign is that it is expected to do too much. Furthermore, its interpretation tends to vary between active and passive crossings. At a passive crossing, the crossbuck locates the point of the hazard and tells drivers to look for trains. At active crossings, activation of the flashing signals tells drivers to look for trains or that a train is present. The crossbuck essentially acts to locate the crossing in this case. If the flashing signals are not activated, it is implied that the driver is not required to look for trains, which tends to diminish driver respect for the crossbuck. This situation is especially confusing for drivers who have no prior knowledge of whether the crossing they are encountering has an active warning system or simply passive warning devices.

One suggestion was that different versions of the crossbuck should be used depending upon the method of crossing protection. At active crossings, no changes should be made and the standard railroad crossbuck sign should remain in use. It was noted that this point has been emphasized by the American railroads, which believe that active devices should be left alone at this time and that research should concentrate specifically on passive crossings. The device used at passive crossings should be unique and should convey to drivers their responsibilities on the approach to and at the crossing. Use of the Canadian crossbuck sign was recommended. It was also suggested that a unique advance warning sign should be developed for use in conjunction with the Canadian crossbuck, such as a word or symbolic sign with the message "LOOK FOR TRAINS".

The advantages of the Canadian crossbuck were discussed. This sign may be considered a suitable replacement for the standard crossbuck at passive crossings for several reasons:

1. The shape of the sign is similar to the shape of the standard crossbuck, which is already instilled in the minds of motorists;

2. The Canadian crossbuck has greater target value than the standard crossbuck sign;

3. The red and white colors of the Canadian crossbuck are already used on stop and yield signs; and

4. The Canadian crossbuck does not incorporate a word message, so language-related problems are not a concern.

The next topic was the need to indicate to drivers that the trains travel faster than they appear. It was suggested that train speed should be a warrant for placing stop signs at crossings. For example, all crossings where trains travel in excess of 60 mph could have stop sign control. Another suggestion was that stop signs might be appropriate at urban and rural locations where severe sight restrictions due to buildings, foliage, curves, or other factors exist.

Several problems with using stop signs were discussed. The public's attitude towards stop signs might limit their effectiveness at grade crossings. It was stated that the public believes stop signs to be a positive assignment of right-of-way when a conflict exists between multiple traffic movements. As a result, many drivers fail to stop at a stop sign if they do not perceive that a stop is necessary. This is in contrast to the older view that a complete stop is required at each and every stop sign encountered. The implication for stop sign usage at grade crossings is that many drivers will slow to what they believe is a safe speed, perhaps 10-15 mph, to ascertain if it is safe to proceed when they encounter a stop sign at a grade crossing.

Some additional problems with the stop sign which were mentioned included:

1. Train operations may not be sufficient to warrant stopping all vehicular traffic at the crossing;

2. Requiring all vehicular traffic to stop is likely to create congestion on high-volume roadways; and

3. Over-application of stop signs tends to diminish driver respect for these signs in all stop situations, not just at grade crossings.

It was suggested that stop sign use should be reserved for locations with high speed trains or accident-prone crossings. In regard to stop signs, it was concluded that warrants should be developed for stop signs to be placed at grade crossings. Engineering studies would be required to define locations which meet any established warrants.

Some of the experimental devices currently under study were briefly discussed. The experimental reflective devices which rely upon the locomotive as a source of light appear to be of limited use. Such devices may not operate effectively until the train is very close to the crossing, by which time it may be too late to alert the driver to the train's presence so that the vehicle may be safely stopped. The presence of curves on the railroad track and dissipation of the locomotive headlamp in foggy or rainy weather might further reduce the effectiveness of some of these reflective devices.

It was proposed that once drivers stop at the crossing and recognize that tracks are present, they will realize their responsibility to be aware of the potential presence of a train. Highway-highway intersections were presented as an analogy to this. At such locations, intersection signs are not used at the point of the intersection to locate it or control traffic movements through it, although advance warning signs may be used to signify that an intersection is ahead. At the actual point of the hazard, a regulatory sign, such as a stop or yield sign, is used. If a rail-highway intersection were treated as if it were a highway-highway intersection, stop or yield signs could be used in place of the crossbuck. Signs with messages such as "STOP AHEAD" or "YIELD AHEAD" placed in advance of the grade crossing would act as the advance warning, just as they do in advance of highway-highway intersections. Such treatment of railroad grade crossings would eliminate the need for unique passive grade crossing signs and devices and would provide for consistency and uniformity on the highway system.

Another topic of discussion was data availability and the existing grade crossing databases. An engineering study procedure for passive grade crossing data collection should be developed. The required data, such as sight distance and highway geometrics, must first be identified. A file system for decision-making should be developed to act as a supplement to the existing priority index computation and to signify any problems which are not indicated by the priority index formula.

Sight distance at grade crossings was also addressed. Several concerns or questions which are relevant to this issue were raised:

1. Definition of sight distance requirements at railroad-highway grade crossings;

2. Degree of sight distance obstruction and how this is determined; and

3. Contribution of sight distance to the accident problem and whether this contribution is statistically significant.

Photogrammetry was mentioned as a possible method of collecting sight distance data. It was also stated that removal of sight distance obstructions can be a problem, as the railroads and highway departments can only clear their respective properties. Neither have the legal authority to clear obstructions from private property.

GROUP III PROCEEDINGS

Members:	Robert Wunderlich (leader)	Carol Tan (recorder)
	Ken Willis	Ken Rouse
	Cathy Wood	Cissy Taylor

The adequacy of the standard crossbuck was evaluated. This sign, as it is now used, indicates the presence of the railroad tracks, but not the presence of a train (or trains). The general consensus of the group was that the crossbuck does not convey to drivers that they are supposed to look for and yield to trains. It was suggested that too much may be expected of existing passive devices, that in a sense they are asked to do more than they can.

Several suggestions were made regarding future use of the crossbuck. The crossbuck shape should be retained because motorists are familiar with it and generally understand that it indicates the presence of a railroad track (or tracks). Use of the color red to enhance the crossbuck would probably improve conspicuity but was not believed to significantly aid in the conveyance of meaning. Use of a border on the crossbuck was also listed as an improved design.

To indicate that the driver must yield, it was suggested that a yield sign be used in conjunction with the crossbuck. Another suggestion was that a supplemental plate with a train symbol be used under the yield sign, and that the crossbuck be deleted from this configuration.

Advance warning signs for grade crossings were addressed. It was agreed that these signs act to indicate the presence of the tracks, but their major shortcoming is that they do not indicate the presence or absence of flashing signals, nor do they indicate the distance to the tracks. Some suggestions for improving advance warning signs included:

1. Retain the W10-1 sign as the standard advance warning sign at all crossings;

2. Use a flashing signal symbol with a slash to indicate that the crossing does not have active protection;

3. Incorporate a yield sign and arrow into the advance warning sign;

4. Incorporate a red crossbuck and arrow into the advance warning sign;

5. Add a supplemental plate with a locomotive or train symbol to the advance warning sign mast;

6. Add a supplemental plate with the word message "LOOK" to the advance warning sign mast; and

7. Use a design similar to the European triangle in place of the advance warning or yield sign.

A recommendation that various pavement markings be used to delineate the crossing was discussed. They should have the following characteristics:

1. Raised;

2. Wider than standard;

3. Extend across full width of roadway;

4. Enhance edge lines;

5. Use a distinctive symbol or color; and

6. Use more closely-spaced center stripes on the approach.

Application of rumble strips on the approach to the crossing should be researched. It was felt that these devices could be an effective improvement if used in conjunction with signing. Two drawbacks to this approach were noted. These included maintenance of the pavement markings, and the fact that the markings would probably not adequately address the problem of driver familiarity.

The potential value of illumination in improving nighttime operation of the crossing was discussed. It was agreed that nighttime illumination would enable a driver to see a train which was already occupying the crossing, but it would not necessarily aid in the detection of approaching trains unless the illumination extended some distance in either way along the tracks. Train-activated lights would be beneficial at locations with limited sight distance. It was also believed that illumination would be a significant improvement at crossings with high nighttime train traffic or an unusually high amount of nighttime accidents. It was stated that any markings or symbols on these nighttime devices should be consistent with those on other crossing-related protective devices.

Many agreed that the driver should be informed of the distance to the crossing, particularly at locations where the view of the crossing is restricted. Such information could be incorporated into the advance warning sign. This approach would probably be of little value in an urban setting where the driver would be unlikely to have sufficient time to react to this information.

The use of stop signs at grade crossings was the final topic discussed. It was felt that stop sign use is warranted in certain situations, such as where sight distance is limited. In these cases, the stop sign should be used in conjunction with standard railroad signing. At crossings which are candidates for active control, stop signs should only be used as interim devices during construction of the active system.

APPENDIX B

SUBJECT INSTRUCTIONS, DATA COLLECTION SHEET, AND QUESTIONNAIRE

Subject Instructions

Prior to Trial Run 1:

1. Driver must read and sign consent form.

2. Allow the driver to drive the TTI car until the driver is familiar with the car's controls, and comfortable driving the vehicle.

3. Instructions to the driver: Please drive through the course, following all signs. No other vehicles are expected to be out on the course, however, please stay on the marked route and behave as you normally would if this course were a public road. You will be asked some questions; please ask for clarification if a question or request is not understood. You will not be asked to drive in an unusual, unsafe or illegal manner. If we believe you are threatening the safety of yourself or others, we will ask you to discontinue your participation in this study.

Data Collection Sheet

Subject Number_______

Date:____________________

Driver Age: (< 25) (25 - 54) (> = 55)

Gender: (M) (F)

Ethnic background: (White) (Hispanic) (Black) (Other)

Language primarily spoken in your home: ________________________________

Can you read English? (yes) (no)

Education level: (< h.s.) (h.s. diploma) (some college)
(college grad) (grad degree)

Do you currently have a valid Texas driver's license (must have a valid license in some state): (yes) (no)

Average number of miles driven a year (in thousands of miles):
(<10) (10-19) (20-29) (30-39) (40-49) (>50)

Group: 1 2 3 4

During Trial Run 1:

Location	Speed (mph)	Head Movement
Yield warning sign	________	
Yield sign	________	N Y
RR warning sign	________	
Crossbuck	________	N Y

Questionnaire

Subject Number_______

After Trial Run 1:

Do you remember the railroad warning signs that you saw (if so, please explain: what did they look like, where were they, list all the ones you can remember)?

description ______________________________
location ______________________________

description ______________________________
location ______________________________

description ______________________________
location ______________________________

description ______________________________
location ______________________________

Inform driver that now he will be shown some photos of signs that were on the course, and will be asked a few questions about them.

After Trial Run 1: Group 1 (sign system A, existing standard)

1. *Circular advance RR warning sign.* This is a photo of the sign that was on the course.
   What do you think this sign means? ______________________________
   What, if any, action should you take when you see this sign? ____________________

2. *Crossbuck.* This is a photo of the sign that was on the course.
   What do you think this sign means? ______________________________
   What, if any, action should you take when you see this sign? ____________________

After Trial Run 1 and Questions: Debriefing
(The purpose of the study is explained to the driver.)

The purpose of this study is to evaluate warning signs for passive railroad crossings. As you have probably noticed, there are some railroad crossings that have flashing lights or gates that are activated by an approaching train. These flashing lights and gates are called active warning devices, because by these actions they actively tell the driver that there is a train at or near the crossing. While it would be nice to put flashing red lights at all railroad crossings to warn drivers when a train is near, this is not possible because it would be too expensive.

At railroad crossings that do not have lights or gates, the DRIVER must determine if it is safe to cross; this is the kind of crossing that we are studying. When there are no lights or gates at a crossing, it is important that the driver knows that he must look out for a train. The only way we can warn drivers about this situation is to warn them with signs alongside the roadway. That is why we are studying these signs. We want to find out which ones are best understood by drivers like you.

You have seen one set of signs that could be used at a railroad crossing. Now I'd like you to drive through and look at three more sets of signs. I will then ask you a few questions, like I did before. After you have seen all four of the sign systems, I'll ask you to rank the systems based on effectiveness.

While you drive through and look at each set of signs, please consider if the sign is easy to see, if the sign is easy to read, and if you can understand what the sign is telling you to do. Don't be too concerned about remembering the details of each sign system, I'll show you a layout of each one to refresh your memory when you need to compare them.

Questionnaire (continued)

Subject Number_______

Trial Runs 2, 3, and 4: Show a photo to driver and ask questions about each of the following signs after the sign has been seen in a run, until all signs have been evaluated.

Group 1

1. *Train symbol warning sign with advisory "LOOK FOR TRAINS" plate.* This is a photo of the sign that was on the course.
   - What do you think this sign means? ______________________
   - What, if any, action should you take when you see this sign? ______________
2. *Yield sign with advisory "TO TRAINS" plate and modified Canadian crossbuck.* This is a photo of signs that were on the course.
   - What do you think these signs mean? ______________________
   - What, if any, action should you take when you see these signs? ______________
3. *Modified Canadian crossbuck.* This is a photo of a sign that was on the course.
   - What do you think this sign means? ______________________
   - What, if any, action should you take when you see this sign? ______________
4. *Yield sign with advisory "TO TRAINS" plate and crossbuck.* This is a photo of signs that were on the course.
   - What do you think these signs mean? ______________________
   - What, if any, action should you take when you see these signs? ______________

Ranking Procedure

Subject Number_______

After All Trial Runs

Now you have seen four sign systems to warn drivers about a passive railroad crossing. Here are diagrams that show each system (indicate which diagram corresponds to the sign system they saw on each trial run), and here are photos of each sign.

The purpose of these sign systems is to warn the driver that there is a railroad crossing ahead, and that he must approach the crossing with caution. An effective sign system should be noticeable, should indicate to the driver that there is a railroad crossing ahead, should warn the driver of the potential danger at the crossing, and should prompt the driver to approach the crossing with caution.

Keeping in mind the definition of an effective sign system, please rank these four sign systems, rank the system you most prefer as one, and the system you least prefer as four.

Rank	System
1	_____
2	_____
3	_____
4	_____

I am also interested to hear any comments you have about the signs you have seen today, the sign systems you ranked, and any other comments and suggestions for improvements to passive railroad crossings. ____________________________________

____

____

APPENDIX C

SUBJECT COMMENTS ABOUT SIGN SYSTEMS AND SIGNS

Comments about sign systems C and D:
confusing, too many signs
more signs the better
look cluttered, too many signs
the yield sign is confusing at train tracks
yield sign and crossbuck need to be spaced farther apart
overkill on signs
redundant but definitely show the right-of-way
"yield to trains" was more effective the second time through

Comments about the train symbol sign:
the symbol is good for people who are illiterate
liked the train symbol
would be stolen a lot because it is cute
silly sign, makes you laugh when you see it
means that there are tracks ahead, be aware because there are not any lights
effective
use larger symbol for the train, possibly
catches your attention

Comments about the Canadian crossbuck:
if used, people must be taught what it means
more effective
don't like it
hard to see
the shape means railroad, but it's not clear
means nothing
kind of confusing, never seen it before
never seen it, not sure what to do

Comments about the standard crossbuck:
understand the standard, it is better with the writing on it
difficult to see
has no meaning, but look more for railroad tracks
hard to read

Miscellaneous comments:
the colors black and yellow get your attention
the sign system used should depend on the kind of road you are on
all countries should standardize
combination crossbuck would be good, with both red border and words
color is important in getting your attention

APPENDIX D

DEMOGRAPHIC INFORMATION

Key

Age: 1 = (< 25)
2 = (25-54)
3 = (55+)

Ethnic: W = White
H = Hispanic
A = African-American
O = Other

Language (spoken in the home): E = English
S = Spanish
O = Other

Education: <H = less than high school diploma
HS = high school diploma
SC = some college
CG = college graduate
GD = graduate degree

Miles driven: 0 = < 10,000
1 = 10 - 19,000
2 = 20 - 29,000
3 = 30 - 39,000
4 = 40 - 49,000
5 = 50,000 +

Table D-1. Demographic Information

Subject	Group	Age	Gender	Ethnic	Language	Read E	Education	Licence	Miles
1	1	1	F	W	E	Y	CG	TX	1
2	4	1	M	W	E	Y	CG	OTHER	1
3	3	1	M	W	E	Y	GD	TX	0
4	2	2	M	W	E	Y	CG	TX	1
5	1	2	F	W	E	Y	CG	TX	1
6	4	2	M	W	E	Y	CG	TX	1
7	3	2	F	W	E	Y	SC	TX	0
8	2	3	M	H	E	Y	CG	TX	2
9	1	3	F	H	E	Y	SC	TX	0
10	4	2	M	O	E	Y	SC	TX	2
11	3	2	M	W	E	Y	CG	TX	1
12	2	2	M	W	E	Y	CG	TX	2
13	1	2	F	H	E	Y	SC	TX	1
14	4	1	M	W	E	Y	CG	TX	1
15	3	2	M	W	E	Y	CG	TX	0
16	2	2	F	W	E	Y	HS	TX	1
17	1	2	F	W	E	Y	CG	TX	1
18	4	1	M	W	E	Y	SC	TX	1
19	3	2	F	W	E	Y	GD	TX	5
20	2	1	F	W	E	Y	CG	TX	0

Table D-1. Demographic Information (continued)

Subject	Group	Age	Gender	Ethnic	Language	Read E	Education	Licence	Miles
21	1	2	M	W	E	Y	CG	TX	1
22	4	2	F	W	E	Y	GD	TX	0
23	3	3	M	W	E	Y	<H	TX	0
24	2	3	F	W	E	Y	HS	TX	0
25	1	2	M	W	E	Y	CG	TX	2
26	4	2	M	O	E	Y	CG	TX	0
27	3	1	M	O	O	Y	CG	TX	1
28	2	1	M	O	O	Y	CG	TX	0
29	1	1	M	O	O	Y	CG	TX	0
30	4	1	F	W	E	Y	CG	TX	0
31	3	2	M	H	E	Y	CG	TX	1
32	2	3	F	W	E	Y	CG	TX	1
33	1	3	F	W	E	Y	SC	TX	1
34	4	3	F	W	E	Y	GD	TX	1
35	3	3	F	W	E	Y	HS	TX	1
36	2	3	M	W	E	Y	SC	TX	1
37	1	3	M	W	E	Y	SC	TX	1
38	3	1	F	W	E	Y	SC	TX	0
39	4	3	M	W	E	Y	CG	TX	1
40	3	2	F	W	E	Y	CG	TX	1

Table D-1. Demographic Information (continued)

Subject	Group	Age	Gender	Ethnic	Language	Read E	Education	Licence	Miles
41	2	2	F	W	E	Y	SC	TX	1
42	1	2	F	W	E	Y	CG	TX	1
43	4	1	F	H	E	Y	SC	TX	1
44	1	2	M	W	E	Y	GD	TX	1
45	4	2	F	W	E	Y	SC	TX	1
46	3	3	F	W	E	Y	SC	TX	0
47	3	3	M	W	E	Y	GD	TX	2
48	4	2	F	W	E	Y	CG	TX	2
49	2	2	F	B	E	Y	SC	TX	1
50	2	2	F	W	E	Y	CG	TX	0
51	4	3	F	W	E	Y	SC	TX	0
52	2	2	M	W	E	Y	GD	TX	0
53	1	2	M	W	E	Y	CG	TX	1
54	1	2	M	W	E	Y	SC	TX	5
55	3	2	M	W	E	Y	CG	TX	1
56	2	1	M	W	E	Y	SC	TX	2
57	1	3	F	W	E	Y	CG	TX	0
58	4	3	F	W	E	Y	HS	TX	1
59	3	2	M	W	E	Y	CG	TX	1
60	2	2	F	W	E	Y	CG	TX	0

APPENDIX E

SPEED DATA

Table E-1. Speed Values Observed for Group 1

Subject	Yield Advance Warning	Yield	Railroad Advance Warning	Crossbuck
1	34	35	24	16
2	39	35	35	38
3	30	21	25	10
4	15	15	29	36
5	44	38	25	27
6	46	35	33	35
7	45	44	33	38
8	30	32	23	22
9	31	37	35	37
10	36	26	6	6
11	31	21	22	22
12	27	27	30	27
13	35	35	25	0
14	40	10	15	10
15	40	25	25	20

Table E-2. Speed Values Observed for Group 2

Subject	Yield Advance Warning	Yield	Railroad Advance Warning	Crossbuck
1	37	16	0	0
2	27	20	18	17
3	28	28	24	27
4	35	33	21	0
5	36	33	29	35
6	35	38	0	0
7	28	30	20	20
8	18	30	31	30
9	20	20	20	24
10	34	32	33	34
11	32	37	27	35
12	32	27	30	0
13	28	18	3	5
14	43	25	28	28
15	30	25	16	0

Table E-3. Speed Values Observed for Group 3

Subject	Yield Advance Warning	Yield	Railroad Advance Warning	Crossbuck
1	22	17	25	9
2	38	41	32	29
3	35	0	0	0
4	35	35	33	32
5	34	28	24	16
6	35	35	32	24
7	33	35	28	25
8	36	30	35	25
9	38	33	14	0
10	40	32	32	30
11	31	18	25	14
12	23	22	15	17
13	27	24	20	5
14	35	30	20	20
15	30	20	25	15

Table E-4. Speed Values Observed for Group 4

Subject	Yield Advance Warning	Yield	Railroad Advance Warning	Crossbuck
1	35	31	26	22
2	35	22	22	7
3	39	35	25	0
4	41	34	33	33
5	36	37	30	22
6	29	0	0	0
7	20	26	28	20
8	35	10	0	0
9	41	41	37	25
10	29	5	28	5
11	25	0	25	10
12	21	14	20	17
13	32	32	27	27
14	40	42	0	0
15	30	35	25	35

APPENDIX F

CALCULATIONS FOR CHI-SQUARE TEST OF INDEPENDENCE FOR HEAD MOVEMENT DATA

Table F-1. Chi-Square Calculations for Driver Looking Behavior

(i,j)	Actual Frequency f_{ij}	Expected Frequency f_{ij}^*	$f_{ij} - f_{ij}^*$	$(f_{ij} - f_{ij}^*)$^2	$(f_{ij} - f_{ij}^*)$^2 / f_{ij}^*
(1,1)	10	13	-3	9	0.69
(1,2)	13	13	0	0	0.00
(1,3)	15	13	2	4	0.31
(1,4)	14	13	1	1	0.08
(2,1)	5	2	3	9	4.50
(2,2)	2	2	0	0	0.00
(2,3)	0	2	-2	4	2.00
(2,4)	1	2	-1	1	0.50
sum	60	60	0	0	
				chi-square	8.077

Table F-2. Chi-Square Calculations for Driver Comprehension of Signs

(i,j)	Actual f_{ij}	Expected f_{ij}^*	$f_{ij} - f_{ij}^*$	$(f_{ij} - f_{ij}^*)$^2	$(f_{ij} - f_{ij}^*)$^2 / f_{ij}^*
(1,1)	54	49.17	4.83	23.36	0.48
(1,2)	51	49.17	1.83	3.36	0.07
(1,3)	27	49.17	-22.17	491.36	9.99
(1,4)	54	49.17	4.83	23.36	0.48
(1,5)	56	49.17	6.83	46.69	0.95
(1,6)	53	49.17	3.83	14.69	0.30
(2,1)	5	8.83	-3.83	14.69	1.66
(2,2)	6	8.83	-2.83	8.03	0.91
(2,3)	26	8.83	17.17	294.69	33.36
(2,4)	6	8.83	-2.83	8.03	0.91
(2,5)	4	8.83	-4.83	23.36	2.64
(2,6)	6	8.83	-2.83	8.03	0.91
(3,1)	1	2.00	-1.00	1.00	0.50
(3,2)	3	2.00	1.00	1.00	0.50
(3,3)	7	2.00	5.00	25.00	12.50
(3,4)	0	2.00	-2.00	4.00	2.00
(3,5)	0	2.00	-2.00	4.00	2.00
(3,6)	1	2.00	-1.00	1.00	0.50
sum	360	360	0.00	0.00	
				chi-square	70.66

Table F-3. Chi-Square Calculations for Driver Comprehension of All Signs Except Canadian Crossbuck

(i,j)	Actual f_{ij}	Expected f_{ij}^*	$f_{ij} - f_{ij}^*$	$(f_{ij} - f_{ij}^*)$^2	$(f_{ij} - f_{ij}^*)$^2 / f_{ij}^*
(1,1)	54	53.6	0.40	0.16	0.00
(1,2)	51	53.6	-2.60	6.76	0.13
(1,4)	56	53.6	0.40	0.16	0.00
(1,5)	53	53.6	2.40	5.76	0.11
(1,6)	53	53.6	-0.60	0.36	0.01
(2,1)	5	5.40	-0.40	0.16	0.03
(2,2)	6	5.40	0.60	0.36	0.07
(2,4)	6	5.40	0.60	0.36	0.07
(2,5)	4	5.40	-1.40	1.96	0.36
(2,6)	6	5.40	0.60	0.36	0.07
(3,1)	1	1.00	0.00	0.00	0.00
(3,2)	3	1.00	2.00	4.00	4.00
(3,4)	0	1.00	-1.00	1.00	1.00
(3,5)	0	1.00	-1.00	1.00	1.00
(3,6)	1	1.00	0.00	0.00	0.00
sum	300	300	0.00	0.00	
				chi-square	6.84

APPENDIX G

CALCULATIONS FOR FRIEDMAN TEST AND PAIRWISE MULTIPLE COMPARISONS

Table G-1. Rankings of Driver Preference

Subject	Sign System			
	A	B	C	D
1	3	4	2	1
2	2	3	4	1
3	3	4	2	1
4	4	3	1	2
5	3	4	2	1
6	3	1	4	2
7	4	3	1	2
8	3	4	2	1
9	3	1	2	4
10	4	3	1	2
11	1	2	4	3
12	3	2	1	4
13	2	4	3	1
14	3	4	2	1
15	1	4	3	2
16	4	2	3	1
17	3	4	2	1
18	4	3	1	2
19	4	3	1	2
20	3	4	2	1
21	3	4	2	1
22	3	4	2	1
23	1	2	4	3
24	4	3	2	1
25	1	2	3	4
26	3	4	2	1
27	3	4	1	2
28	3	4	2	1
29	3	4	2	1
30	3	4	2	1

Table G-1. Rankings of Driver Preference (continued)

Subject	Sign System			
	A	B	C	D
31	4	3	1	2
32	3	4	2	1
33	3	4	2	1
34	3	4	2	1
35	1	2	4	3
36	1	4	3	2
37	3	4	2	1
38	3	4	2	1
39	3	4	2	1
40	3	4	2	1
41	4	3	2	1
42	4	2	1	3
43	3	4	2	1
44	2	4	3	1
45	3	4	2	1
46	3	4	2	1
47	3	4	1	2
48	3	4	2	1
49	4	3	2	1
50	3	4	2	1
51	3	4	2	1
52	4	3	2	1
53	2	1	3	4
54	3	4	2	1
55	4	3	1	2
56	3	4	2	1
57	3	4	2	1
58	2	4	3	1
59	4	3	1	2
60	2	4	3	1

Table G-2. Sum of Rankings for Each Sign System

Sign System	A	B	C	D
Total	176	204	127	93

Table G-3. Pairwise Multiple Comparisons

Pair	Absolute Value of Difference	Significantly Different[1]
A - B	28	NO
A - C	49	YES
A - D	83	YES
B - C	77	YES
B - D	111	YES
C - D	34	NO

[1]The pair is considered statistically different at a significance level of 5 percent if the absolute value of the difference of the sum of the rankings is greater than or equal to 38.2.

APPENDIX H

FIELD DATA FORMS

Data Collection Sheet - General

Name of Recorder - ____________________________
Date - ______
Location - ____________________________
Roadway Surface Type on Approaches - __________
Weather - ____________________________
Posted Speed Limit (if any) - _________

General Direction of Traffic Survey Taken (N,S,E or W) _

In Direction Survey taken is there: RXR Pavement Marking? __
An AWS? __ if Yes, Distance from Crossing (ft) __
A Crossbuck? __ if Yes, is there a single or double blade? _______
if single blade, is it double sided? _______

In the opposite direction approach is there: RXR Pavement Marking? __
An AWS? __ if Yes Distance from Crossing (ft) __
A Crossbuck? __ if Yes is there a single or double blade? _______
if single blade, is it double sided? _______

If any signs above are other than reflective sheeting (Engineer Grade), note sign and type of backing (painted, High-Intensity, etc.):

List any other devices applicable to the crossing (stop sign, yeild sign, etc.) which may be present and describe it's location relative to the crossing:

Other relative comments:

<u>Team Members and Assignments:</u>

Surveyor #1 -

Surveyor #2 -

Looking Behavior Observer -

Speed Detector at X-Buck -

Speed Detector at AWS -

DRIVER SURVEY COLLECTION SHEET
Before Study

Surveyor - ____________________ . . . . Data Collection Sheet # ______
Location - ____________________
Date - ____________ Time - ________

Do you live in Texas? M or F

How many years have you had a drivers license?

What is the language spoken in your home?

Which age group are you in? _ <20 _ 20-35 _ 36-50 _ >50

How often do you drive across this railroad crossing?
___ once a week or more (# of Times = ___per___)
___ once a month
___ once a year
___ first time to cross

(Show picture of AWS)
What does this sign mean to you?

(if not answered by the previous question, ask:) What action do you think is required of you by these signs?

Where, in relation to the crossing, would you expect to see this sign?

(Show picture of Crossbuck)
What does this sign mean to you?

(if not answered by the previous question, ask:) What action do you think is required of you by this sign?

Where, in relation to the crossing, would you expect to see this sign?

DRIVER SURVEY COLLECTION SHEET

Surveyor - ________________
County - ________________
Date - ________________

Data Collection Sheet # ____
Location - ________________
Time - ________________

M or F (Circle One)

Live in Texas? Y or N (Circle One)

Primary language spoken in home? E S O (English, Spanish, Other)

Age Group? <20 20-35 36-50 >50

Frequency of Crossing?

__ once a week or more (# of times __ per ___)
__ once a month
__ once a year
__ first time to cross

Years to have Driver's License? _____

Do you remember seeing any type of warning such as traffic signs, pavement markings, and/or traffic signals) indicating the railroad crossing that you just crossed?
Y or N

(If yes) Can you describe the warning devices that you saw?

Did you participate in a similar study last August?
Y or N

(If No, show picture of AWS); What does this sign mean to you?

(If not answered in previous question, ask:) What action do you think is required of you by these signs?

Where, in relation to the crossing, would you expect to see these signs?

(Show picture of crossbuck) What does this sign mean to you?

(If not answered in previous question, ask:) What action do you think is required of you by these signs?

Where, in relation to the crossing, would you expect to see these signs?

The purpose of this study is to determine if additional signs at passive highway-railroad grade crossings will improve safety. Passive highway-railroad grade crossings are those which do not have flashing lights or flashing lights and gates to warn of an approach or presence of a train. The current sign system consists of the round, yellow advance warning sign located at a distance before the crossing to give adequate advance warning of the approaching crossing and the white X crossbuck with the words "Railroad Crossing" located at the tracks which serves to mark the location of the crossing and to inform the driver to yield the right of way to trains. (Show pictures of AWS and Crossbuck to driver).

The purpose of a sign system at a highway-railroad grade crossing is to warn the driver of a railroad crossing ahead, and that the crossing must approached with caution. An effective sign system should be noticeable, should indicate to the driver that there is a railroad crossing ahead, should warn the driver of the potential danger at the crossing and should prompt the driver to approach the crossing with caution.

We are trying to determine if a "YIELD TO TRAINS" (or LOOK FOR TRAINS) sign at the crossing will improve safety at the crossing (Show Picture). Keeping the definition of an effective sign system in mind, in your opinion, do you think that the addition of the YIELD TO TRAINS (or LOOK FOR TRAINS) sign at the crossing will provide for a safer crossing?

Y or N

**** COMMENTS ****

APPENDIX I

TEST SITE DESCRIPTIONS

Grimes County Road 304
USDOT No. (24310M)

The Grimes County Road 304 crossing is located in the southeast portion of the county. Through train volume is seven trains per day and the train speed limit is 49 miles per hour (78.9 kilometers per hour). Vehicular volume is estimated at 490 ADT. There is no posted speed limit on the road. The crossing is constructed of timber planking and is in good, relatively smooth condition. Both approaches are paved and display advance pavement markings. The approach grades are essentially level with a gentle horizontal curve on the south approach and a severe horizontal curve approximately 75 feet (22.8 meters) before the crossing on the north approach. An intersection is also located approximately 150 feet (45.6 meters) from the crossing on the north approach. Sight distance meets minimum requirements on both approaches.

Figure I-1. Grimes County Road 304 Crossing

Courtney Road
(USDOT No. 2498H)

The Courtney Road crossing is located south of the City of Navasota. The crossing consists of two mainline tracks, each track belonging to a different railroad company. The tracks are approximately 150 feet (45.6 meters) apart. Through train volume is eight trains per day on the heaviest used track with a train speed limit of 49 miles per hour (78.9 kilometers per hour). Vehicular volume is estimated to be 280 ADT. There is no posted speed limit. Both crossings are constructed of timber planking and are in a relatively rough condition. Both approaches are paved and display advance pavement markings. The approach grades are level with about a two foot rise in the last 50 feet (15.2 meters) to the crossing. Courtney Road has no horizontal curvature for at least one mile on either side of the crossing. Also, there are no intersections which would cause conflict with driver speed on the approaches. Sight distance meets minimum requirements on both approaches.

Figure I-2. Courtney Road Crossing

Parker Street
(USDOT No. 21210X)

The Parker Street crossing is located on the east side of the City of Santa Anna, which is in the southeast quadrant of Coleman County. Through train volume is sixteen trains per day, with a train speed limit of 30 miles per hour (48.3 kilometers per hour). Vehicular traffic is estimated to be 230 ADT. There is no posted speed limit on the road. The crossing is constructed of timber planking and was rebuilt within the last year providing a smooth crossing. The north approach is paved and is in good condition. The south approach, however, is unpaved. The advance pavement marking is displayed on the north approach. The approaches are level with no horizontal curves on the north approach and reversing horizontal curves on the south approach. There is an intersection with a principal arterial highway approximately 500 feet (152 meters) before the crossing on the north approach. There are two unpaved intersection roadways within 100 feet (30.4 meters) of the crossing on the south approach. A structure is located in the northwest quadrant.

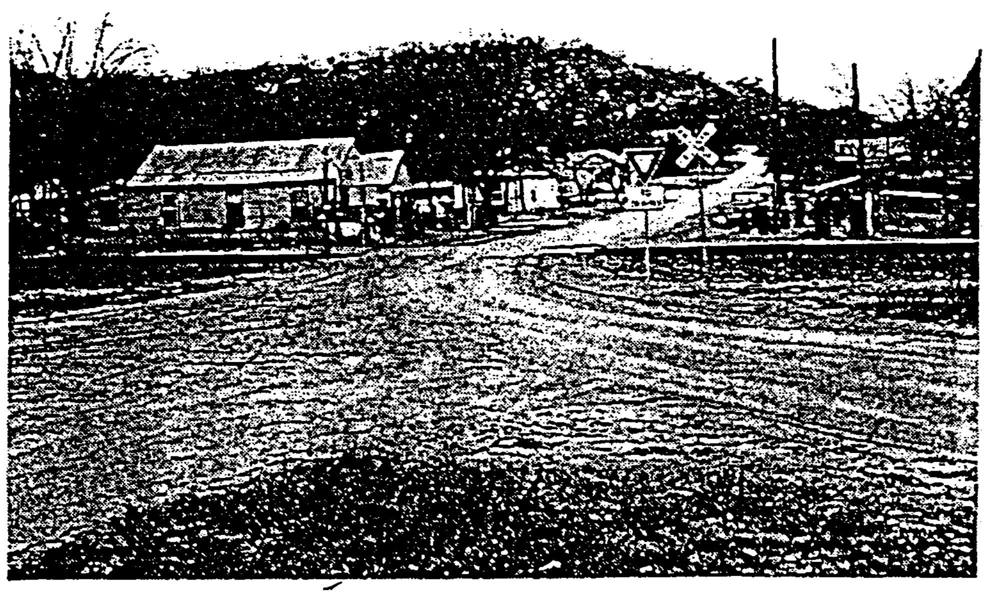

Figure I-3. Parker Street Crossing

Vale Street
(USDOT No. 21239V)

The Vale Street crossing is located in the City of Coleman, just north of the central business district. Small businesses and residences are located in the vicinity of the crossing. Through train volume is 16 trains per day with a train speed limit of 55 miles per hour (88.6 kilometers per hour). Vehicular volume is estimated to be 370 ADT. No speed limit is posted on the street. There are two tracks at the crossing; one mainline track and one out of service side track. The crossings were constructed of timber planking and overlaid with asphaltic concrete pavement. The crossings are relatively rough in rideability. The approach grades are level with no horizontal curves. There is about a two feet (0.6 meter) rise to the crossing, however, for approximately 100 feet (30.4 meters) on either side. A tee intersection is located approximately 75 feet (22.8 meters) north of the crossing with a portion of the north bound traffic turning onto the intersection road. The northeast quadrant of the approach contains encroaching vegetation. A structure is located in the southwest quadrant.

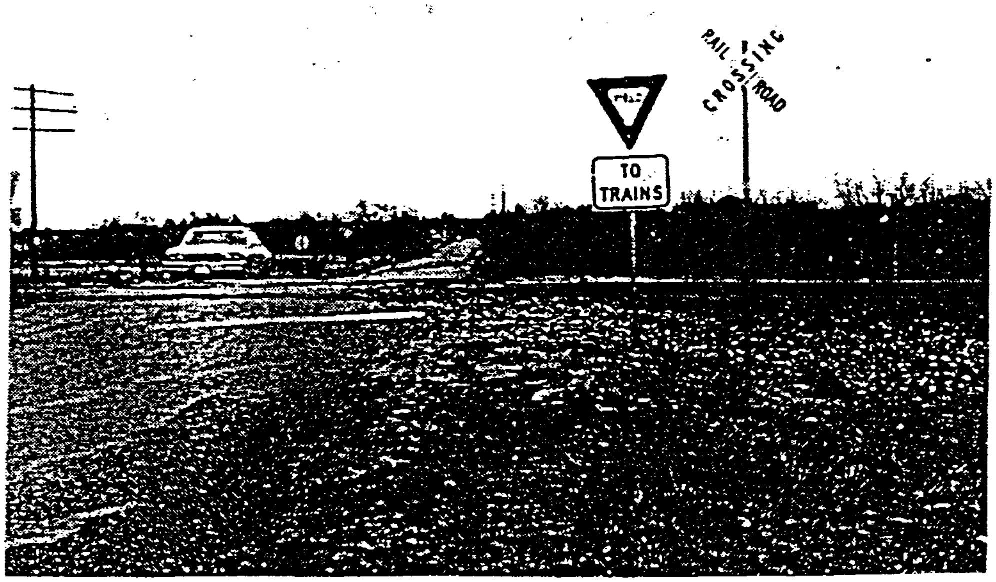

Figure I-4. Vale Street Crossing

FM 2131
(USDOT No. 21387P)

FM 2131 is the only on-system roadway used as a test site in this study. Most other candidate on-system grade crossings have been converted to active control. This crossing is also the only high speed crossing of the study. The FM 2131 crossing is located approximately three miles (4.8 kilometers) south of the City of Coleman. Through trains total two trains per day with a speed limit of 30 miles per hour (48.3 kilometer per hour). Vehicular volume is estimated at 210 ADT. A posted speed limit is present on the highway of 55 miles per hour (88.6 kilometers per hour). The crossing is constructed of timber planking. Both approaches are paved and display the advance pavement marking. A downslop of approximately two percent in the north to south direction is constant for the north approach and continues on the south approach for approximately 600 feet (182.4 meters) when a low point is encountered. A north to south upgrade is then present of about two percent. There are no horizontal curves of influence on either approach. Vegetation is located in the northwest quadrant.

Figure I-5. FM 2131 Crossing

Baylor Street
(USDOT No. 436030Y)

The Baylor Street crossing is located in the City of Odem in the south part of San Patricio County. Baylor Street is a local collector serving a neighborhood south of the Odem central business district. Through train volume is two trains per day and the train speed limit is 20 miles per hour (32.2 kilometers per hour). Vehicular volume is estimated to be 2,310 ADT. The posted speed limit on Baylor Street is 30 miles per hour (48.6 kilometers per hour). The crossing is constructed of timber planking, overlaid with asphaltic concrete pavement. The crossing is in good condition and relatively smooth. Both of the approaches are paved and display pavement markings. The approach grades are level with no horizontal curves. A retail supermarket is set back from Baylor Street by about 200 feet (60.8 meters) in the northeast quadrant. U.S. 77 intersects Baylor Street approximately 500 feet (152 meters) north of the crossing. A structure is located on north approach in the northeast quadrant.

Figure I-6. Baylor Street Crossing

Avenue A
(USDOT No. 742696N)

The Avenue A crossing is located east of the central business district of Ingleside. Avenue A serves a local neighborhood and has the highest traffic volume of the eight test crossings. Through train volume is two trains per day. The train speed limit is 20 miles per hour (32.2 kilometers per hour). Vehicular volume is estimated to be 2,360 and a speed limit of 30 miles per hour (48.6 kilometers per hour) is posted. The crossing is constructed of timber planking and is overlaid with asphaltic concrete pavement. The crossing is smooth and is in good condition. Both approaches are paved and display the advance pavement markings. The approach grades are level and there are no horizontal curves on Avenue A. An intersection with SH 361 is located approximately 600 feet (182.4 meters) north of the crossing. Several intersections south of the crossing serve the residential area. Sight distance is limited in all four quadrants of the crossing. This crossing is scheduled for conversion to active control in the coming year.

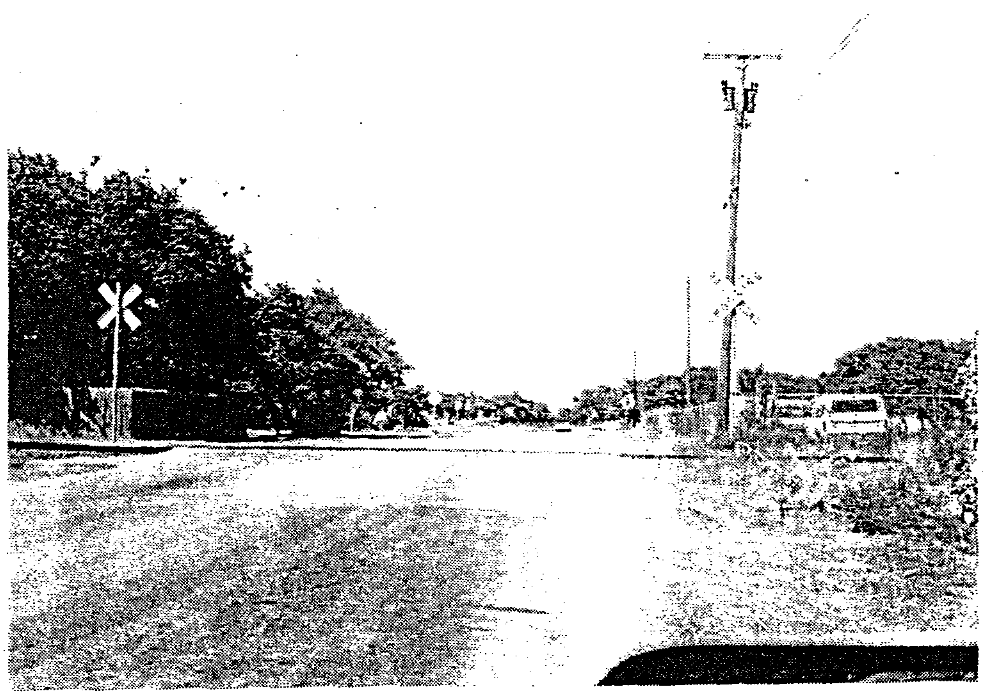

Figure I-7. Avenue A Crossing

Hidden Acres Road
(USDOT No. 435600F)

The Hidden Acres Road crossing is located approximately two miles (3.2 kilometers) northwest of Mathis. Hidden Acres Road serves as access to the Hidden Acres subdivision. Through train volume is four trains per day. The train speed limit is 49 miles per hour (78.9 kilometers per hour). Vehicular volume is 720 ADT. There is no speed limit posted on the roadway. The crossing is constructed of timber planking and is in a rough condition. Both approaches are paved and display the advance pavement marking. The approach grades are an approximate five percent grade on the east approach and an approximate four percent grade on the west approach. The crossing is approximately seven to eight feet (2.1 to 2.4 meter) above the level sections of the approaches. Approaching traffic on the opposite approach cannot be seen until the driver reaches the crossing. An intersection with a county arterial road is located about 700 feet (221.8 meter) east of the crossing. Sight distance is affected on both the east and west approaches by embankment from an adjoining caliche pit and brush.

Figure I-8. Hidden Acres Road Crossing

APPENDIX J

SPEED GRAPHS AND SUMMARIES

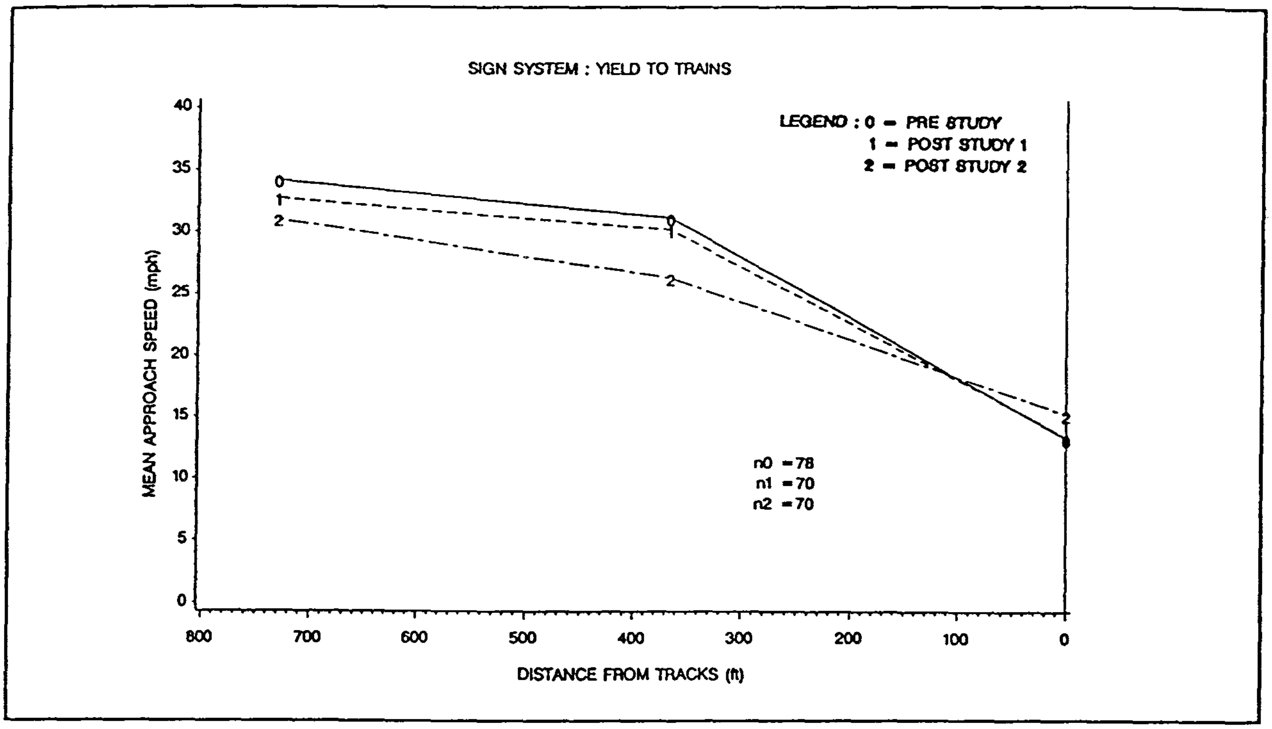

Figure J-1. Mean Speeds Graph for Grimes County Road 304

Table J-1. Mean Speeds Summary for Grimes County Road 304

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
730	34.2	7.6	32.7	6.1	31.0	5.7
370	31.2	6.5	30.2	6.6	26.3	6.1
0	13.3	4.2	13.4	7.1	15.2	5.2

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

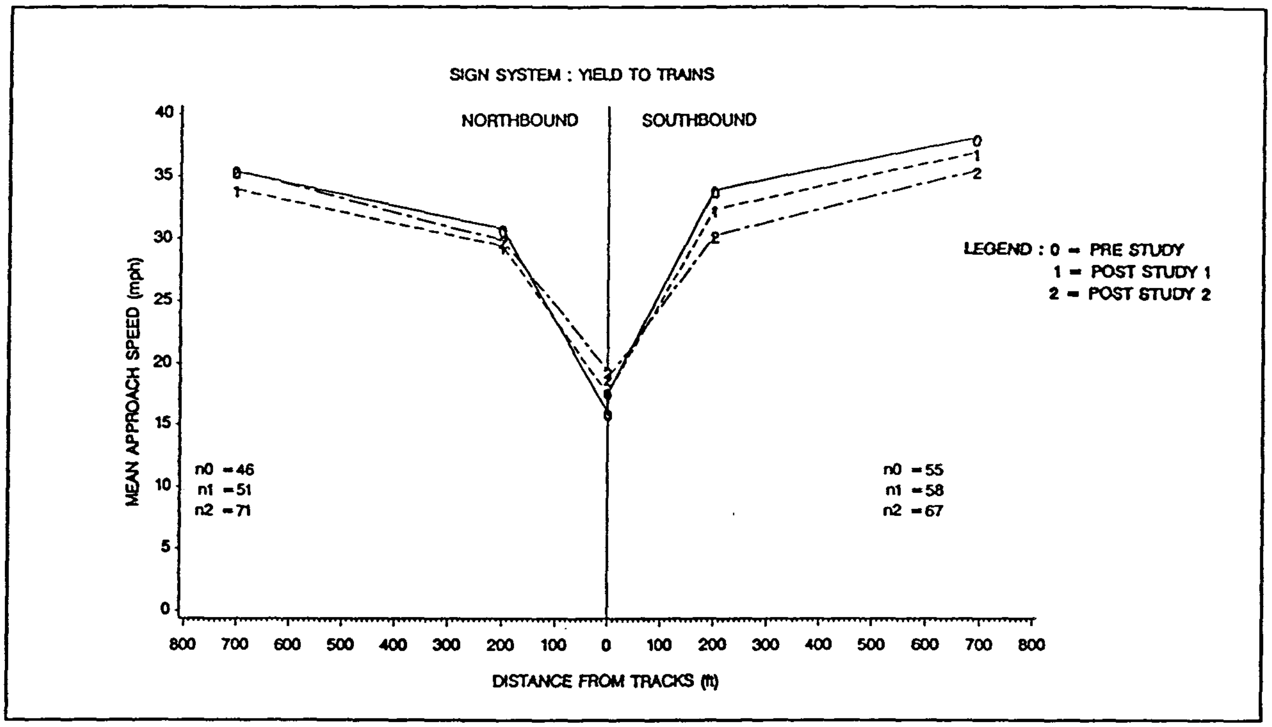

Figure J-2. Mean Speeds Graph for Courtney Road

Table J-2. Mean Speeds Summary for Courtney Road Northbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
700	35.4	9.7	33.9	7.9	35.5	6.8
200	30.8	9.9	29.4	7.9	29.9	7.0
0	16.0	8.1	17.5	6.2	19.4	5.7

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

Table J-3. Mean Speeds Summary for Courtney Road Southbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
700	38.0	7.8	36.8	8.0	35.4	7.7
200	33.9	7.1	32.3	7.2	30.2	7.6
0	17.7	7.6	17.6	5.1	18.8	5.1

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

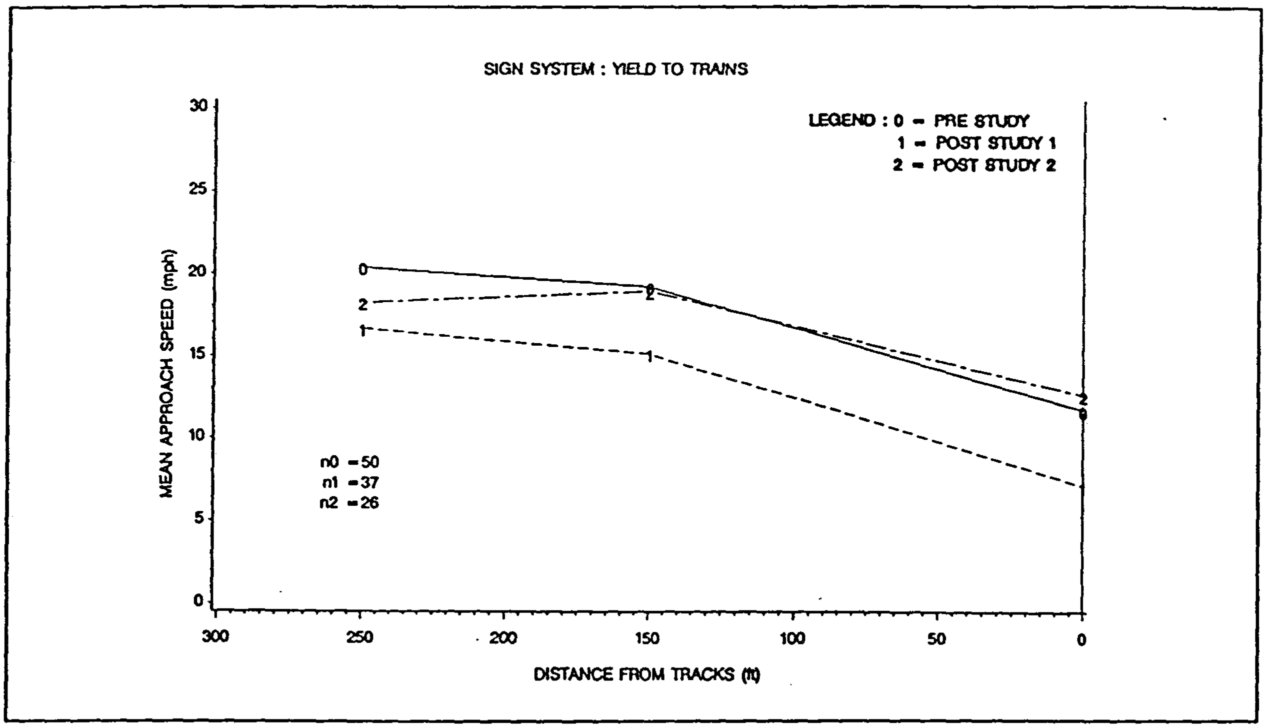

Figure J-3. Mean Speeds Graph for Parker Street

Table J-4. Mean Speeds Summary for Parker Street Southbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
250	20.4	4.5	16.6	4.0	18.2	4.8
150	19.2	4.2	15.1	4.8	18.9	4.8
0	11.7	4.0	7.1	3.9	12.6	3.3

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

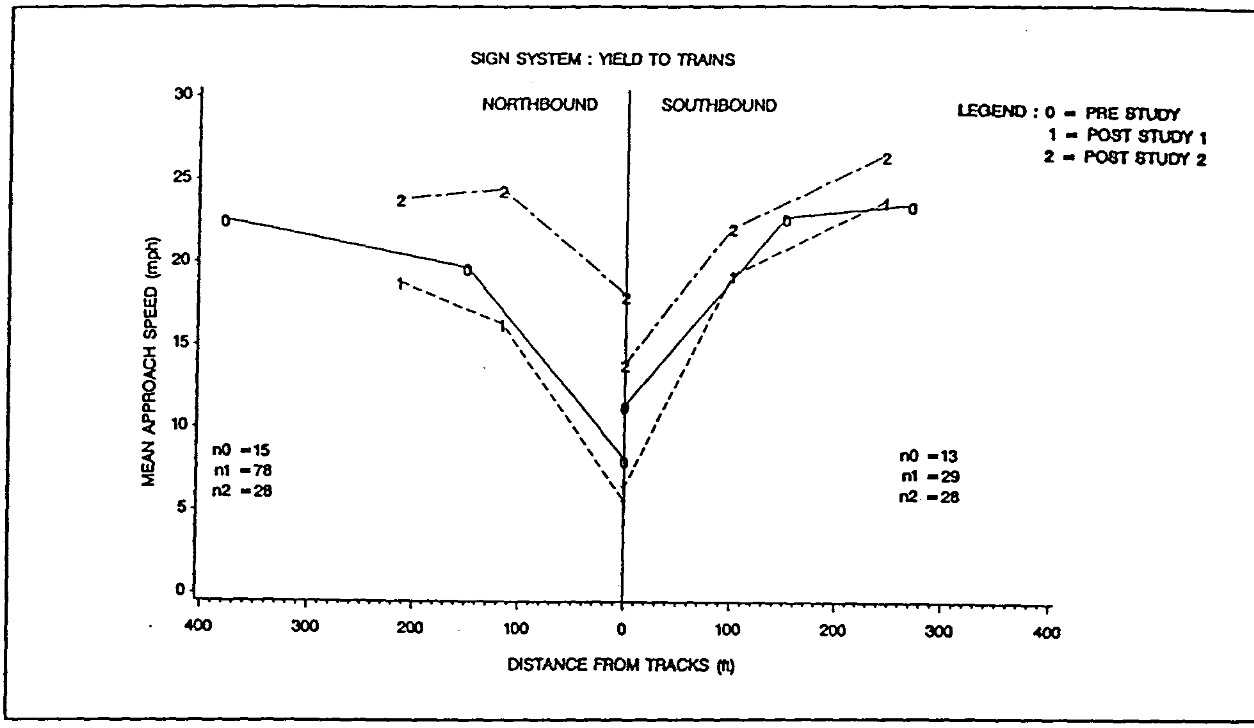

Figure J-4. Mean Speeds Graph for Vale Street

Table J-5. Mean Speeds Summary for Vale Street Northbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
380/215/215	22.6	9.5	18.9	4.6	23.9	5.6
150/120/120	19.7	7.5	16.3	3.9	24.5	6.2
0	8.1	8.2	5.6	2.6	18.1	5.1

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

Table J-6. Mean Speeds Summary for Vale Street Southbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
270/245/245	23.6	4.5	23.9	4.4	26.6	5.3
150/100/100	22.8	6.1	19.3	4.2	22.2	4.6
0	11.4	8.2	6.4	4.9	14.0	5.0

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

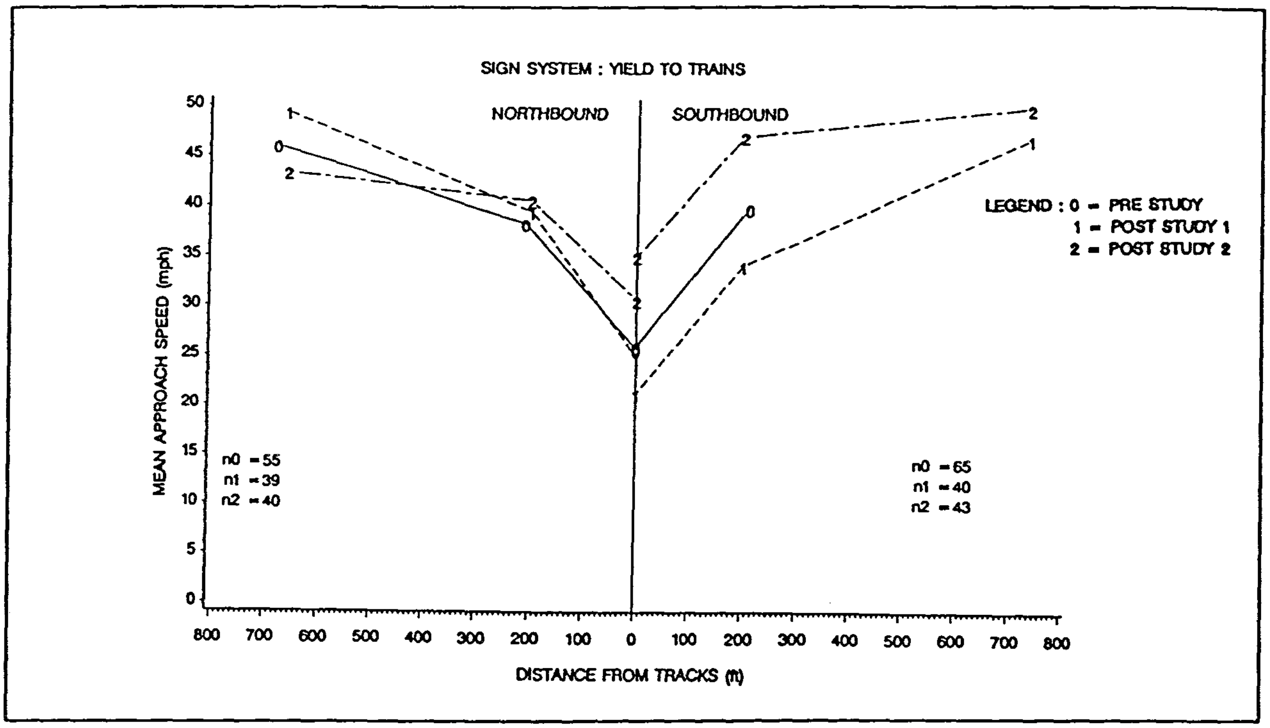

Figure J-5. Mean Speeds Graph for FM 2131

Table J-7. Mean Speeds Summary for FM 2131 Northbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
680/660/660	46.0	6.6	49.3	7.8	43.3	8.8
210/200/200	38.3	7.6	39.5	8.7	40.6	8.0
0	25.8	11.3	24.9	12.6	30.7	11.5

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

Table J-8. Mean Speeds Summary for FM 2131 Southbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
740	50.4	8.2	47.0	7.6	50.0	8.3
210/200/200	39.9	7.5	34.2	7.9	47.1	8.8
0	26.1	11.8	21.3	9.8	35.1	13.3

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

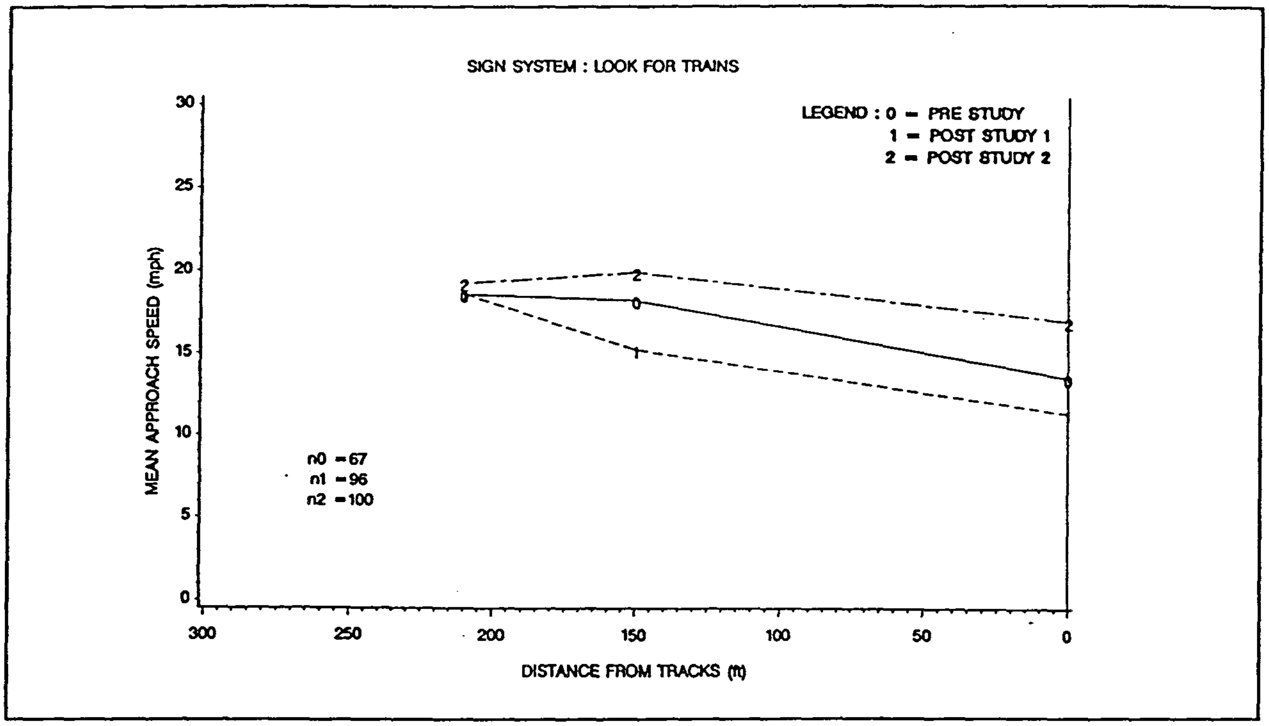

Figure J-6. Mean Speeds Graph for Baylor Street

Table J-9. Mean Speeds Summary for Baylor Street Eastbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
210	18.6	3.3	18.6	3.9	19.3	4.2
150	18.2	3.7	15.2	3.5	19.9	4.0
0	13.5	5.4	11.3	4.6	16.9	4.5

Note: 1 ft = 0.3049 m, 1 mph = 1.61 kph;

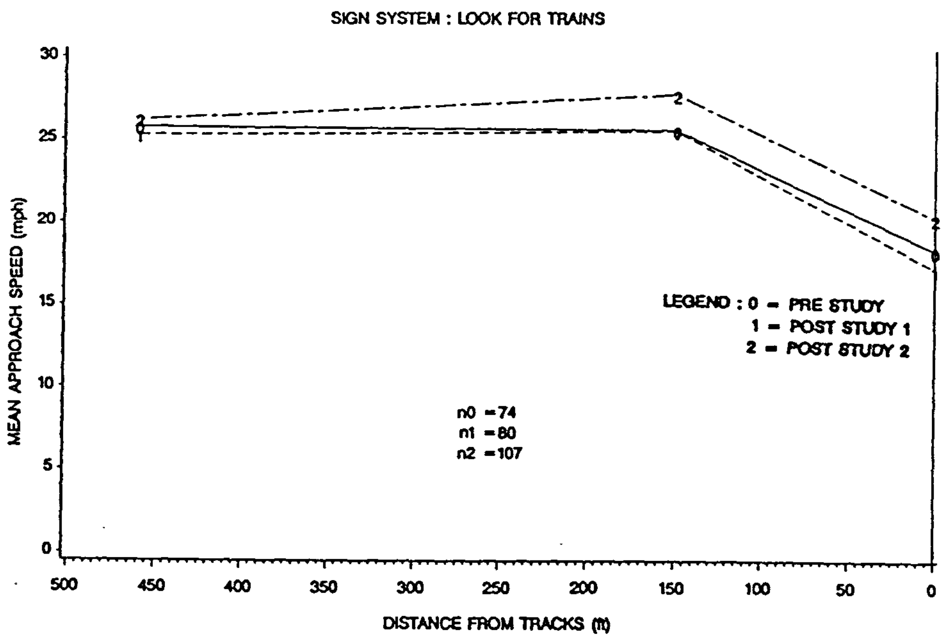

Figure J-7. Mean Speeds Graph for Avenue A

Table J-10. Mean Speeds Summary for Avenue A Southbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
460	25.8	4.9	25.3	4.0	26.2	3.5
150	25.6	4.7	25.5	4.3	27.8	4.3
0	18.3	6.4	17.2	6.5	20.3	6.6

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

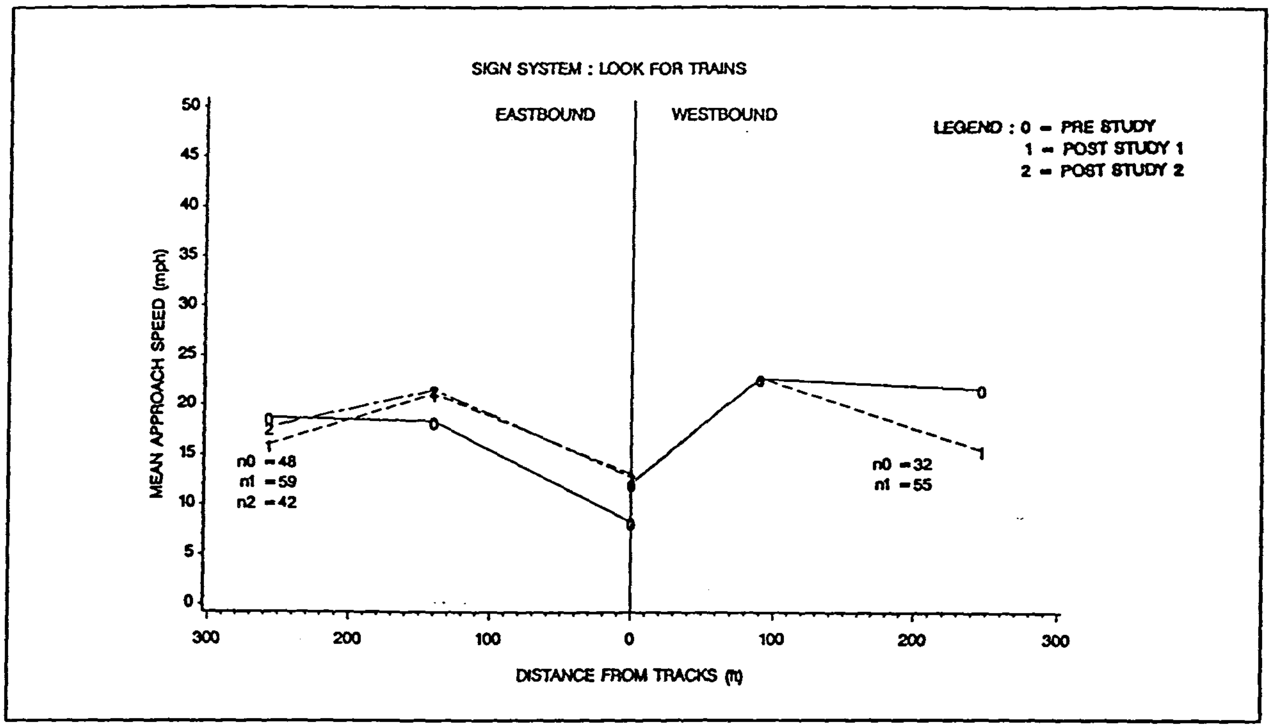

Figure J-8. Mean Speeds Graph for Hidden Acres Road

Table J-11. Mean Speeds Summary for Hidden Acres Road Eastbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
260	18.6	2.9	16.0	3.3	17.7	3.5
140	18.4	4.4	21.1	3.3	21.5	3.3
0	8.3	4.3	13.2	3.3	12.8	5.1

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

Table J-12. Mean Speeds Summary for Hidden Acres Road Westbound

DISTANCE FROM CROSSBUCK (feet)	PRE STUDY		POST STUDY 1		POST STUDY 2	
	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION	MEAN SPEED (mph)	STANDARD DEVIATION
250	21.7	3.7	15.6	2.9	—	—
90	22.8	4.1	22.8	4.0	—	—
0	12.1	6.4	12.2	3.8	—	—

Note: 1 ft = 0.3049 m , 1 mph = 1.61 kph ;

APPENDIX K

DRIVER LOOKING BEHAVIOR GRAPHS AND SUMMARIES

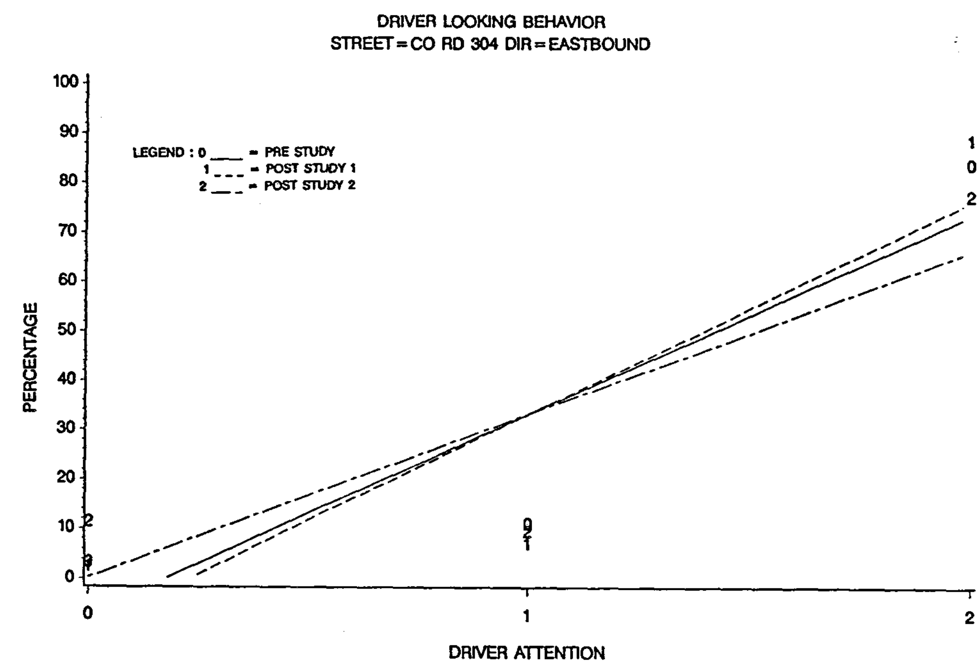

Figure K-1. Driver Looking Behavior for Grimes County Road 304

Table K-1. Summary of Looking Behavior for Grimes County Road 304

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	3	3.9	2	3.1	7	11.8
Looks Left Only	0	0.0	0	0.0	0	0.0
Looks Right Only	9	11.7	5	7.7	6	10.2
Looks Both Left and Right	65	84.4	58	89.2	46	78.0
TOTAL OBSERVATIONS	77	100.0	65	100.0	59	100.0

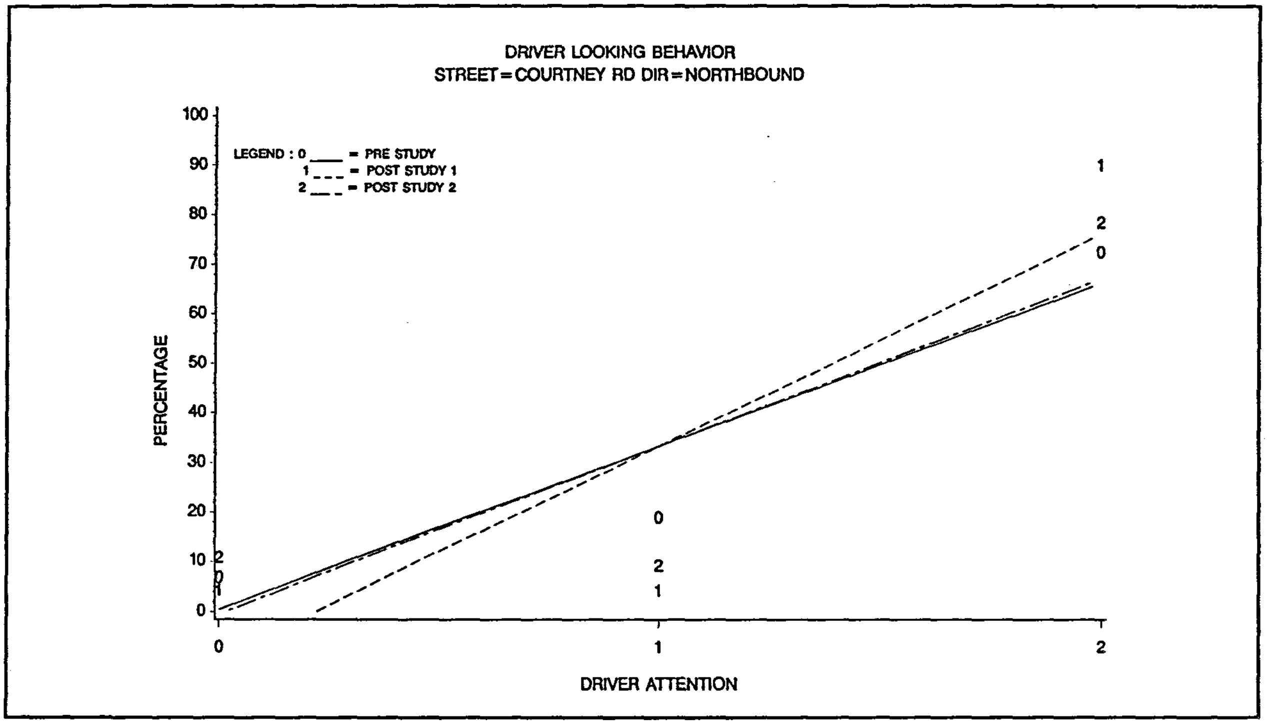

Figure K-2. Driver Looking Behavior for Courtney Road Northbound

Table K-2. Summary of Looking Behavior for Courtney Road Northbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	3	7.3	2	4.8	7	11.3
Looks Left Only	1	2.4	1	2.4	4	6.5
Looks Right Only	7	17.1	1	2.4	2	3.2
Looks Both Left and Right	30	73.2	38	90.5	49	79.0
TOTAL OBSERVATIONS	41	100.0	42	100.0	62	100.0

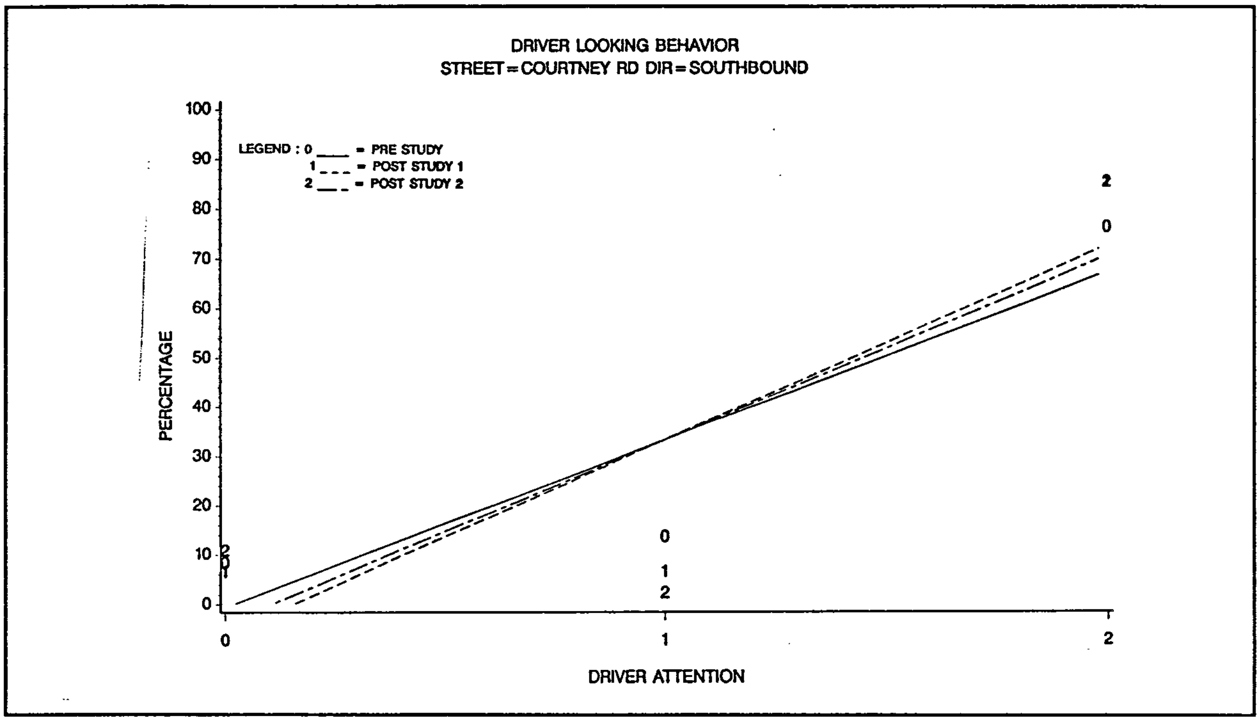

Figure K-3. Driver Looking Behavior for Courtney Road Southbound

Table K-3. Summary of Looking Behavior for Courtney Road Southbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	5	8.9	4	7.1	4	11.4
Looks Left Only	3	5.4	3	5.4	0	0.0
Looks Right Only	5	8.9	1	1.8	1	2.9
Looks Both Left and Right	43	76.8	48	85.7	30	85.7
TOTAL OBSERVATIONS	56	100.0	56	100.0	35	100.0

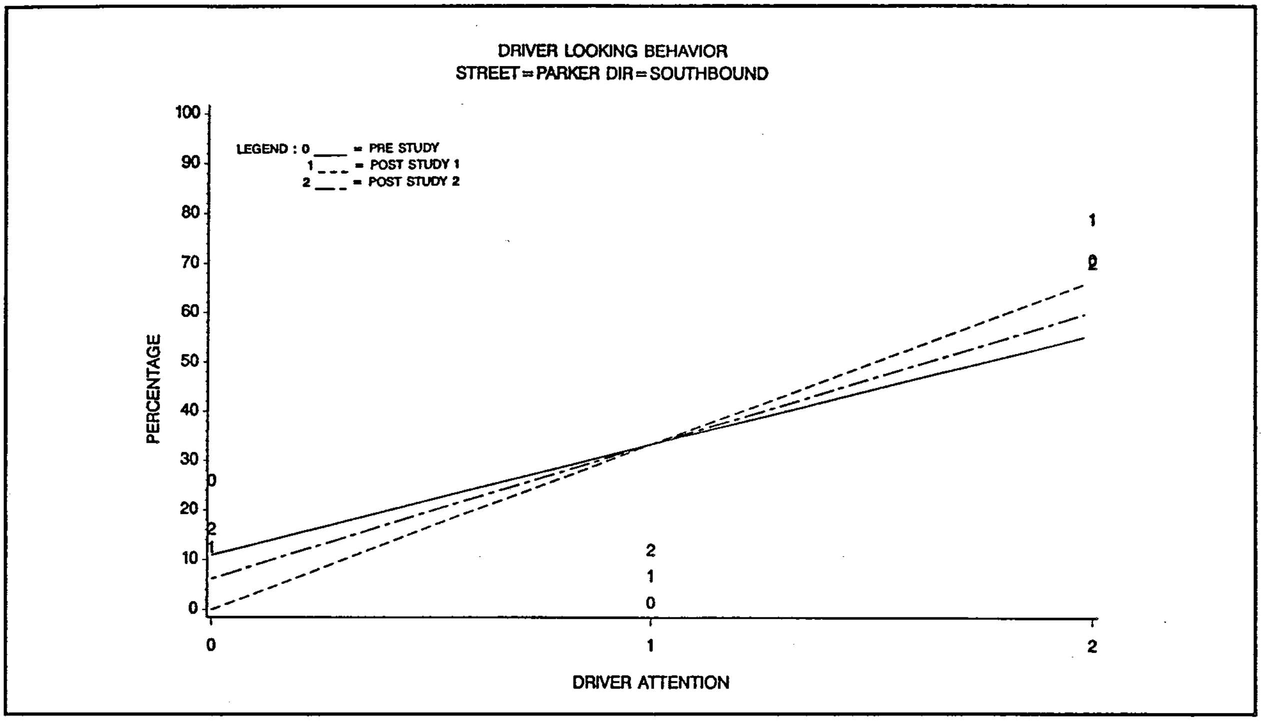

Figure K-4. Driver Looking Behavior for Parker Street

Table K-4. Summary of Looking Behavior for Parker Street

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	13	26.5	7	13.0	4	16.7
Looks Left Only	0	0.0	1	1.9	0	0.0
Looks Right Only	1	2.0	3	5.6	3	12.5
Looks Both Left and Right	35	71.4	43	79.6	17	70.8
TOTAL OBSERVATIONS	49	100.0	54	100.0	24	100.0

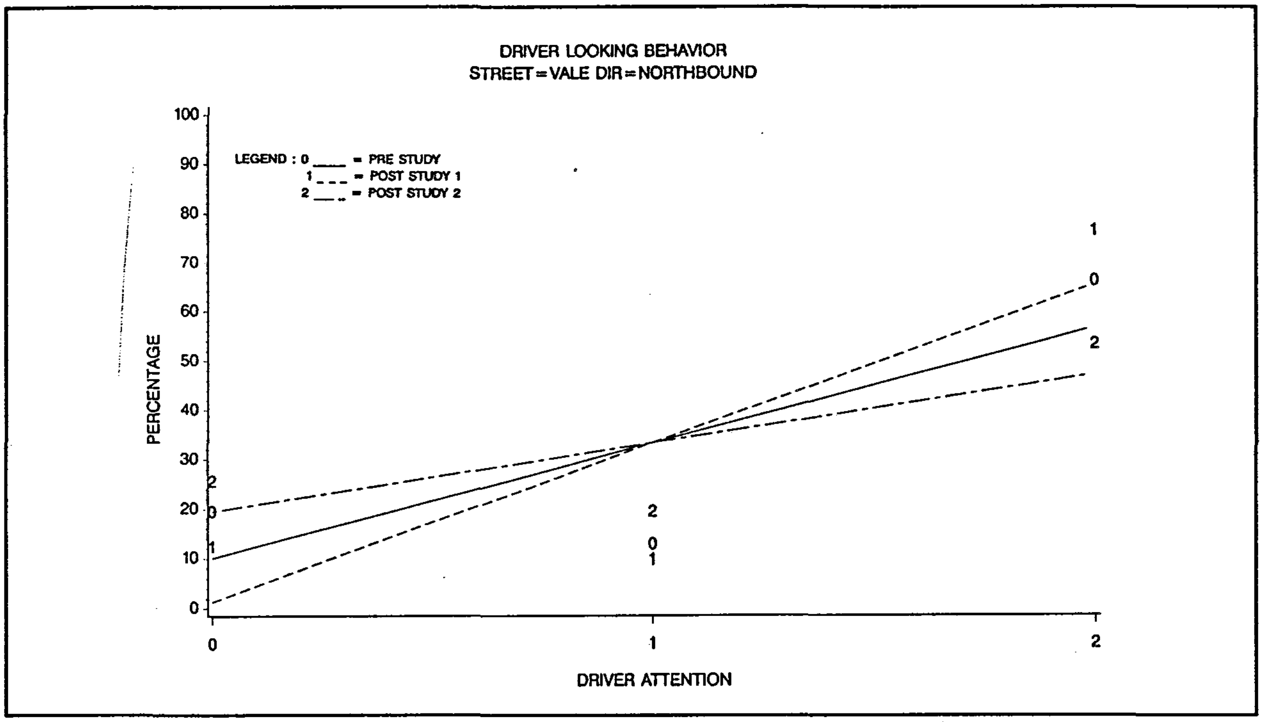

Figure K-5. Driver Looking Behavior for Vale Street Northbound

Table K-5. Summary of Looking Behavior for Vale Street Northbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	3	20.0	10	12.8	17	26.2
Looks Left Only	0	0.0	4	5.1	4	6.2
Looks Right Only	2	13.3	4	5.1	9	13.8
Looks Both Left and Right	10	66.7	60	76.9	35	53.8
TOTAL OBSERVATIONS	15	100.0	78	100.0	65	100.0

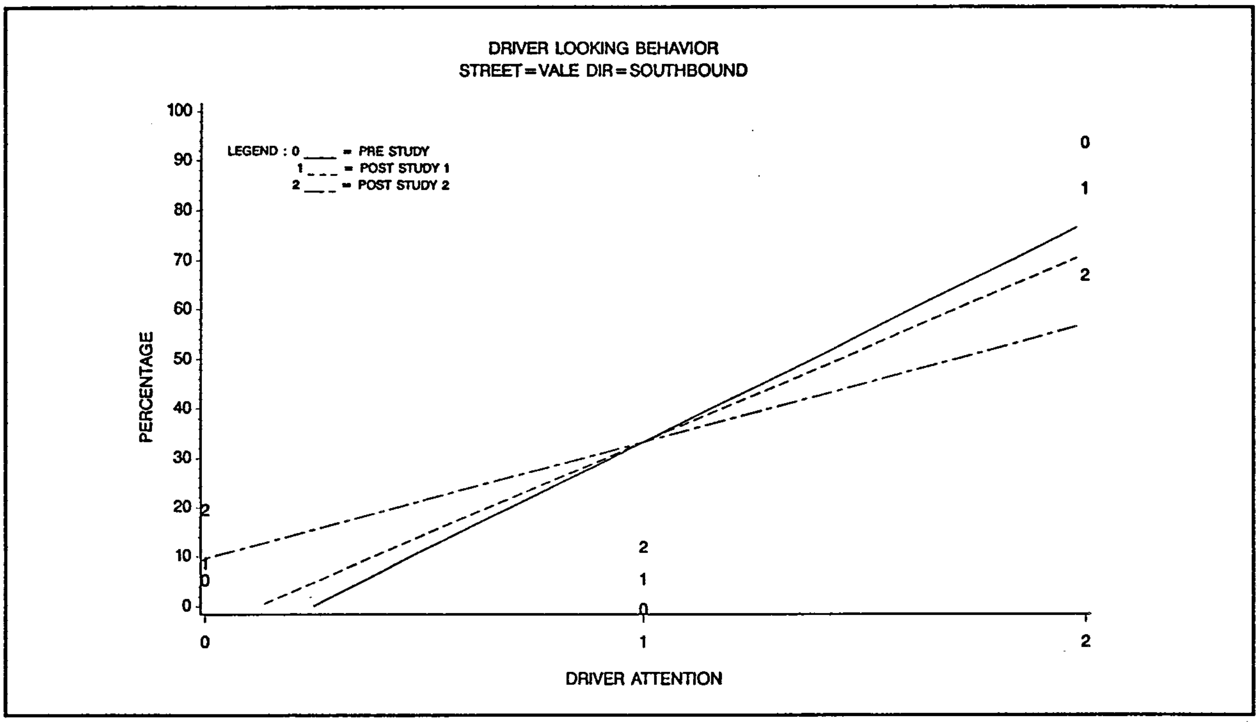

Figure K-6. Driver Looking Behavior for Vale Street Southbound

Table K-6. Summary of Looking Behavior for Vale Street Southbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	1	5.9	3	9.1	8	20.0
Looks Left Only	0	0.0	2	6.1	3	7.5
Looks Right Only	0	0.0	0	0.0	2	5.0
Looks Both Left and Right	16	94.1	28	84.8	27	67.5
TOTAL OBSERVATIONS	17	100.0	33	100.0	40	100.0

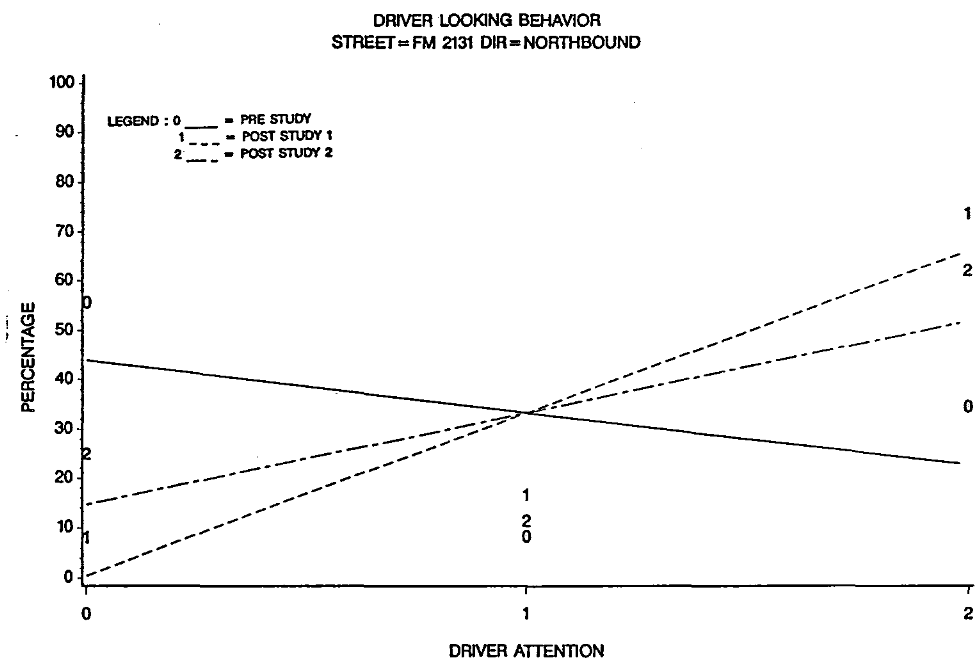

Figure K-7. Driver Looking Behavior for FM 2131 Northbound

Table K-7. Summary of Looking Behavior for FM 2131 Northbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	32	56.1	3	8.6	15	25.4
Looks Left Only	2	3.5	3	8.6	5	8.5
Looks Right Only	3	5.3	3	8.6	2	3.4
Looks Both Left and Right	20	35.1	26	74.3	37	62.7
TOTAL OBSERVATIONS	57	100.0	35	100.0	59	100.0

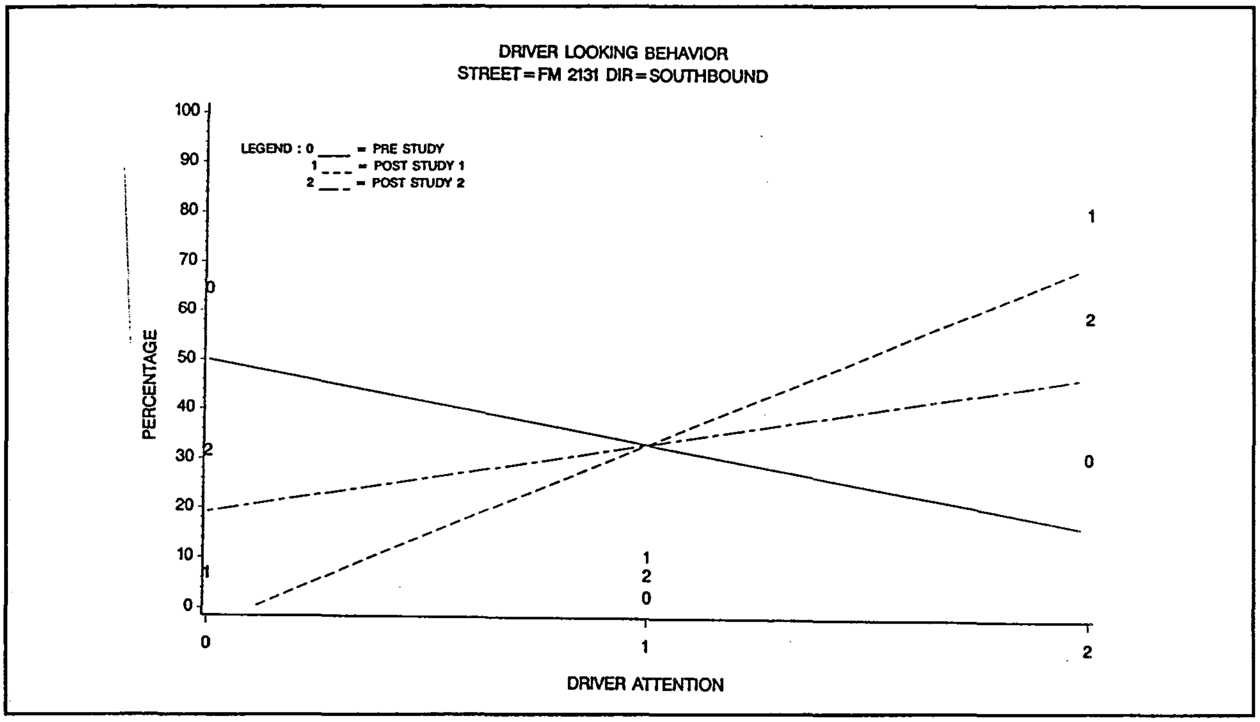

Figure K-8. Driver Looking Behavior for FM 2131 Southbound

Table K-8. Summary of Looking Behavior for FM 2131 Southbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	41	65.1	2	7.4	17	32.1
Looks Left Only	1	1.6	0	0.0	1	1.9
Looks Right Only	1	1.6	3	11.1	3	5.7
Looks Both Left and Right	20	31.7	22	81.5	32	60.4
TOTAL OBSERVATIONS	63	100.0	27	100.0	53	100.0

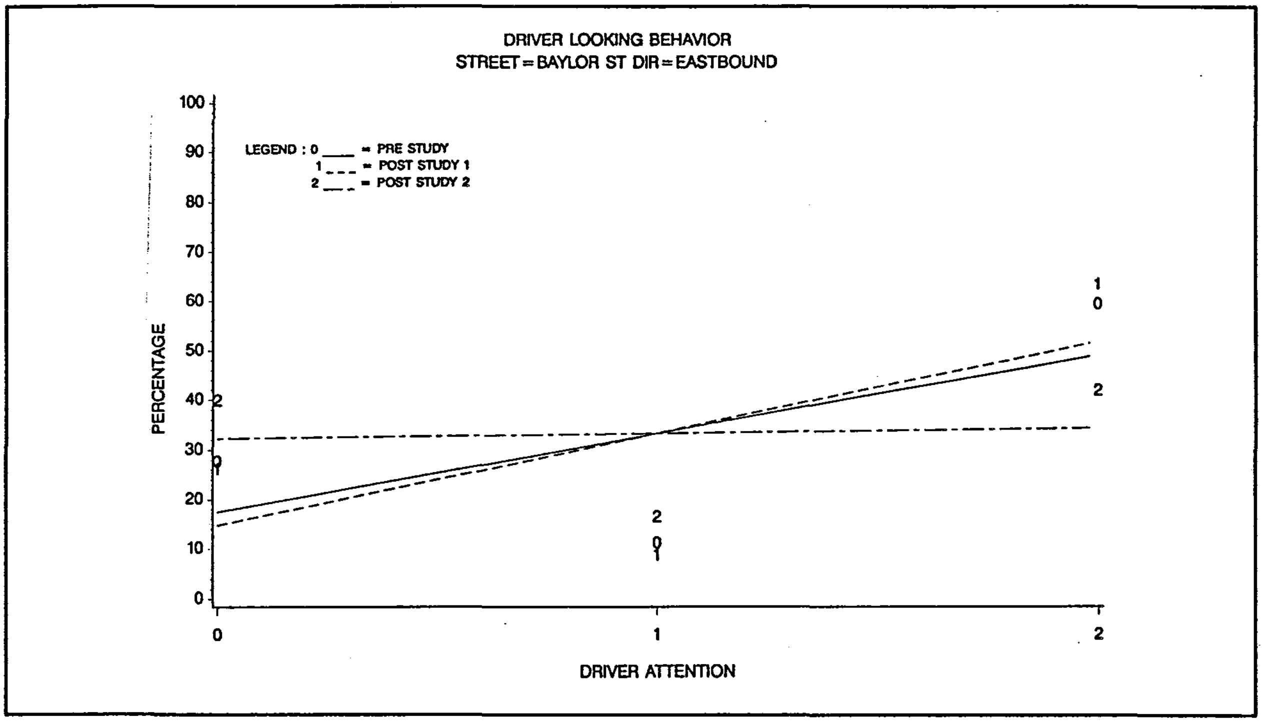

Figure K-9. Driver Looking Behavior for Baylor Street

Table K-9. Summary of Looking Behavior for Baylor Street

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	48	28.2	23	26.7	38	40.4
Looks Left Only	11	6.5	1	1.2	9	9.6
Looks Right Only	9	5.3	7	8.1	7	7.4
Looks Both Left and Right	102	60.0	55	64.0	40	42.6
TOTAL OBSERVATIONS	170	100.0	86	100.0	94	100.0

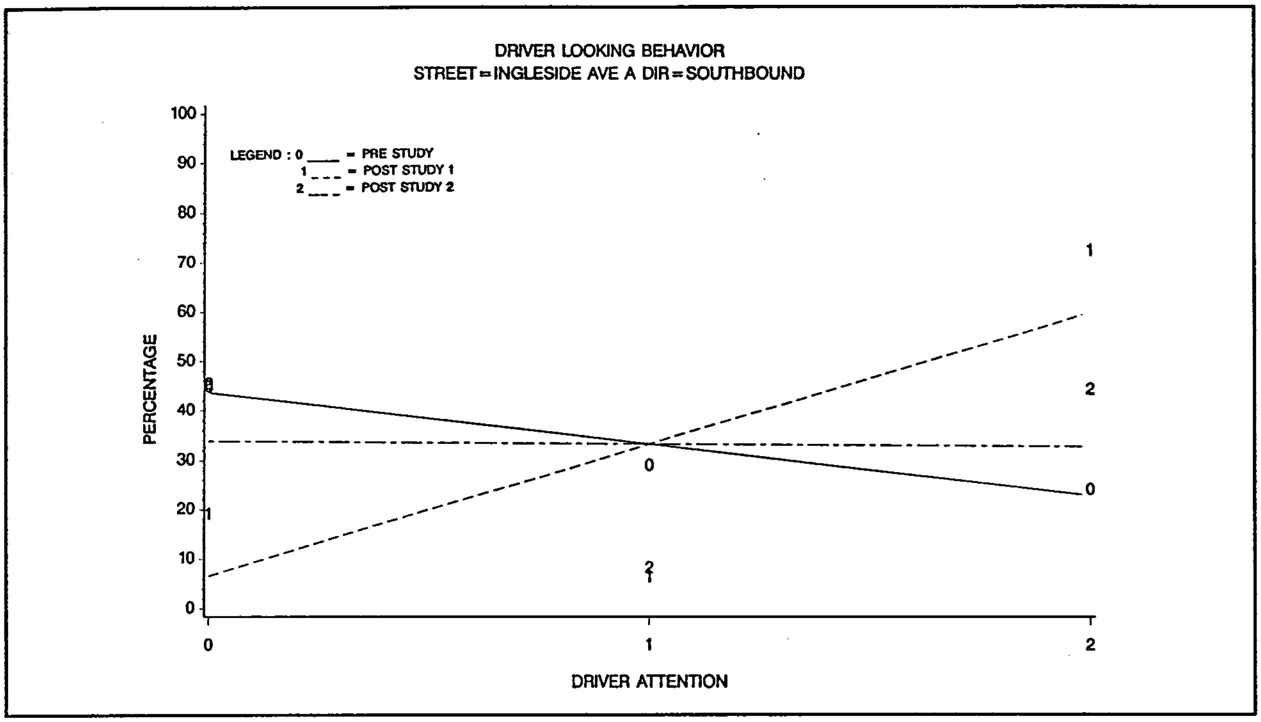

Figure K-10. Driver Looking Behavior for Avenue A

Table K-10. Summary of Looking Behavior for Avenue A

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	112	45.5	14	19.7	47	46.1
Looks Left Only	25	10.2	0	0.0	3	2.9
Looks Right Only	48	19.5	5	7.0	6	5.9
Looks Both Left and Right	61	24.8	52	73.2	46	45.1
TOTAL OBSERVATIONS	246	100.0	71	100.0	102	100.0

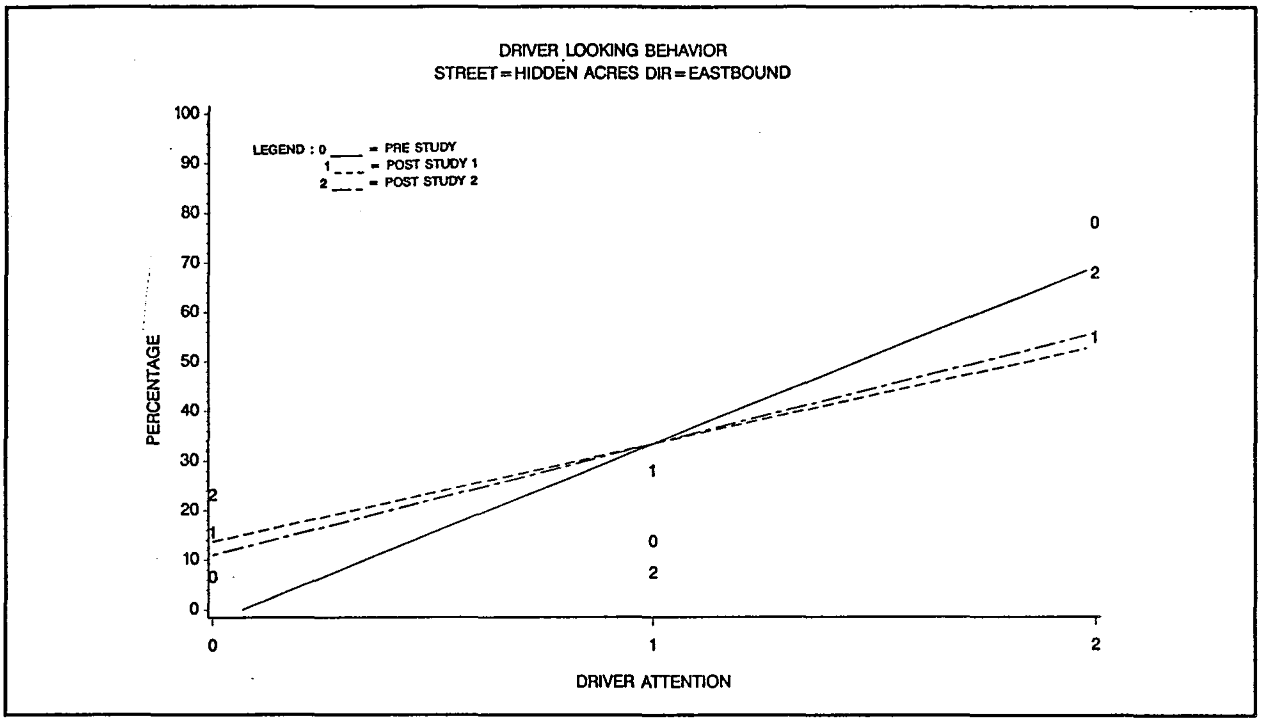

Figure K-11. Driver Looking Behavior for Hidden Acres Road Eastbound

Table K-11. Summary of Looking Behavior for Hidden Acres Road Eastbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	1	7.1	9	16.1	9	23.7
Looks Left Only	0	0.0	11	19.6	0	0.0
Looks Right Only	2	14.3	5	8.9	3	7.9
Looks Both Left and Right	11	78.6	31	55.4	26	68.4
TOTAL OBSERVATIONS	14	100.0	56	100.0	38	100.0

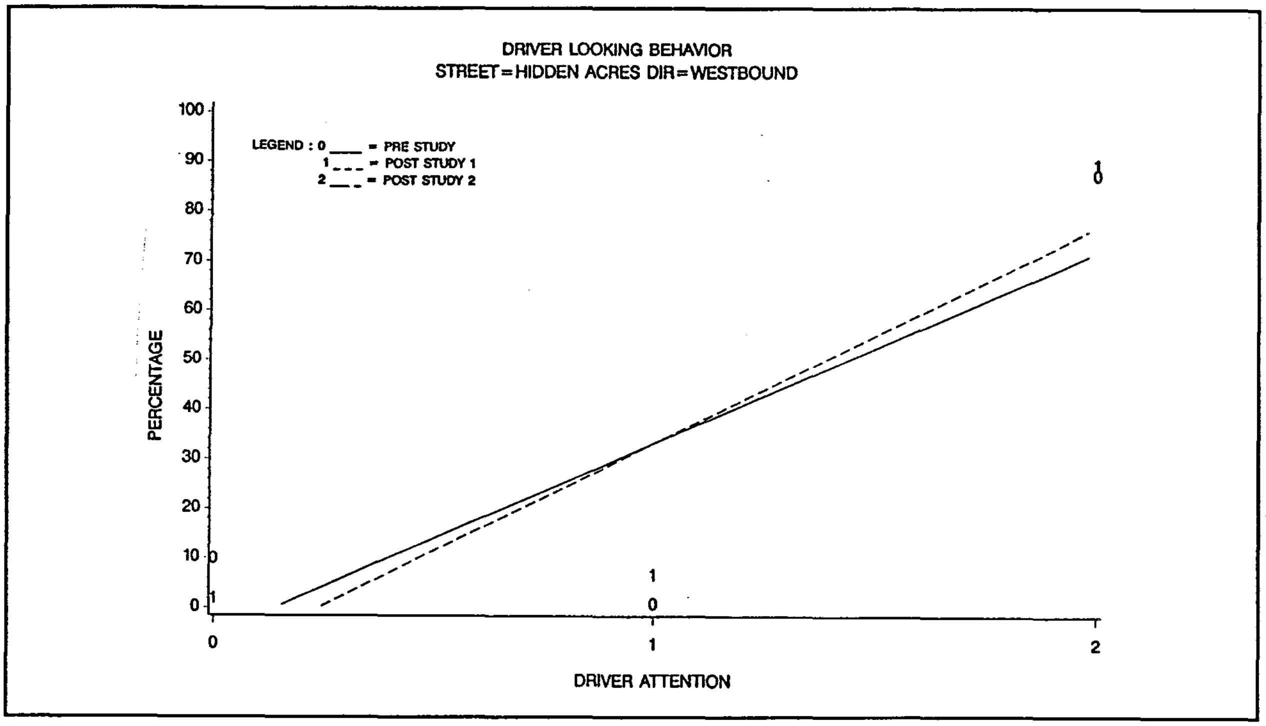

Figure K-12. Driver Looking Behavior for Hidden Acres Road Westbound

Table K-12. Summary of Looking Behavior for Hidden Acres Road Westbound

LOOKING BEHAVIOR	PRE STUDY		POST STUDY 1		POST STUDY 2	
	Number	Percent	Number	Percent	Number	Percent
No Looking	7	10.4	1	2.4	---	---
Looks Left Only	1	1.5	1	2.4	---	---
Looks Right Only	0	0.0	2	4.9	---	---
Looks Both Left and Right	59	88.1	37	90.2	---	---
TOTAL OBSERVATIONS	67	100.0	41	100.0	---	---

Table K-13. Summary of Observations: YIELD TO TRAINS System

CATEGORY	Grimes County			Coleman County			Total		
	Pre Study	Post Study 1	Post Study 2	Pre Study	Post Study 1	Post Study 2	Pre Study	Post Study 1	Post Study 2
Number of Crossings Signed with Experimental System	0	5	5	0	47	47	0	52	52
Number of Test Crossings	2	2	2	3	3	3	5	5	5
Number of Speed Observations	179	179	207	198	223	165	377	402	372
Number of Driver Looking Behavior Observations	174	163	156	201	227	241	375	390	397
Number of Driver Exit Surveys	36	61	0	103	102	0	139	163	0

Table K-14. Summary of Observations: LOOK FOR TRAINS System

CATEGORY	San Patricio County			Nacogdoches County			Total		
	Pre Study	Post Study 1	Post Study 2	Pre Study	Post Study 1	Post Study 2	Pre Study	Post Study 1	Post Study 2
Number of Crossings Signed with Experimental System	0	38	38	0	---	17	0	55	55
Number of Test Crossings	3	3	3	3	---	2[1]	6	3	5
Number of Speed Observations	221	290	249	188	---	180[2]	409	290	429
Number of Driver Looking Behavior Observations	497	254	234	274	---	162[3]	771	254	396
Number of Driver Exit Surveys	207	115	0	120	57[4]	0	327	172	0

Footnotes

1 The experimental signs were not placed or were stolen at one of the designated study sites (CR 525 @ FM 2863); therefore, no additional data could be collected at this location.

2 These speed observations were performed at the Fredonia Street study site approximately six weeks following installation of the experimental signs. Speed observations have not been made at the CR 298 location.

3 These driver looking behavior observations were performed at the Fredonia Street study site approximately six weeks following installation of the experimental signs. Driver looking behavior observations have not been made at the CR 298 location.

4 Driver exit surveys conducted at CR 298 study site, July 1993, and FM 2609 near Applesby, August 1993.

Table K-15. Driver Opinions from Grimes County

RESPONSE	NUMBER	PERCENT
Strongly Agree	17	27.9
Somewhat Agree	31	50.8
No Opinion	3	4.9
Somewhat Disagree	5	8.2
Strongly Disagree	5	8.2
TOTAL	61	100.0

Table K-16. Driver Opinions from Coleman County

RESPONSE	NUMBER	PERCENT
Strongly Agree	23	22.5
Somewhat Agree	51	50.0
No Opinion	9	8.8
Somewhat Disagree	7	6.9
Strongly Disagree	12	11.8
TOTAL	102	100.0

Table K-17. Driver Opinions from San Patricio County

RESPONSE	NUMBER	PERCENT
Strongly Agree	48	41.7
Somewhat Agree	44	38.3
No Opinion	11	9.6
Somewhat Disagree	7	6.1
Strongly Disagree	5	4.3
TOTAL	115	100.0

Table K-18. Driver Opinions from Nacogdoches County

RESPONSE	NUMBER	PERCENT
Strongly Agree	28	49.1
Somewhat Agree	17	29.8
No Opinion	5	8.8
Somewhat Disagree	3	5.3
Strongly Disagree	4	7.0
TOTAL	57	100.0

Table K-19. Driver Opinions: YIELD TO TRAINS System

RESPONSE	NUMBER	PERCENT
Strongly Agree	40	24.5
Somewhat Agree	82	50.3
No Opinion	12	7.4
Somewhat Disagree	12	7.4
Strongly Disagree	17	10.4
TOTAL	163	100.0

Table K-20. Driver Opinions: LOOK FOR TRAINS System

RESPONSE	NUMBER	PERCENT
Strongly Agree	76	44.2
Somewhat Agree	61	35.5
No Opinion	16	9.3
Somewhat Disagree	10	5.8
Strongly Disagree	9	5.2
TOTAL	172	100.0

APPENDIX L

SAS OUTPUT FOR DRIVER LOOKING BEHAVIOR

Table L-1. Chi-Square Test for Grimes County Road 304

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

---------------- STREET=CO RD 304 DIR=EASTBOUND ------------------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	12	7	13	32
	5.97	3.48	6.47	15.92
	37.50	21.87	40.63	
	15.58	10.77	22.03	
2	65	58	46	169
	32.34	28.86	22.89	84.08
	38.46	34.32	27.22	
	84.42	89.23	77.97	
Total	77	65	59	201
	38.31	32.34	29.35	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	2.942	0.230
Likelihood Ratio Chi-Square	2	2.936	0.230
Mantel-Haenszel Chi-Square	1	0.827	0.363
Phi Coefficient		0.121	
Contingency Coefficient		0.120	
Cramer's V		0.121	

Sample Size = 201

Table L-2. Chi-Square Test for Courtney Road Northbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

-------------------- STREET=COURTNEY RD DIR=NORTHBOUND --------------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	11	4	13	28
	7.59	2.76	8.97	19.31
	39.29	14.29	46.43	
	26.83	9.52	20.97	
2	30	38	49	117
	20.69	26.21	33.79	80.69
	25.64	32.48	41.88	
	73.17	90.48	79.03	
Total	41	42	62	145
	28.28	28.97	42.76	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	4.179	0.124
Likelihood Ratio Chi-Square	2	4.518	0.104
Mantel-Haenszel Chi-Square	1	0.269	0.604
Phi Coefficient		0.170	
Contingency Coefficient		0.167	
Cramer's V		0.170	

Sample Size = 145

Table L-3. Chi-Square Test for Courtney Road Southbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

-------------- STREET=COURTNEY RD DIR=SOUTHBOUND ------------

TABLE OF ATTEN BY TIME

ATTEN TIME

Frequency / Percent / Row Pct / Col Pct	0	1	2	Total
1	13	8	5	26
	8.84	5.44	3.40	17.69
	50.00	30.77	19.23	
	23.21	14.29	14.29	
2	43	48	30	121
	29.25	32.65	20.41	82.31
	35.54	39.67	24.79	
	76.79	85.71	85.71	
Total	56	56	35	147
	38.10	38.10	23.81	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	1.898	0.387
Likelihood Ratio Chi-Square	2	1.856	0.395
Mantel-Haenszel Chi-Square	1	1.424	0.233
Phi Coefficient		0.114	
Contingency Coefficient		0.113	
Cramer's V		0.114	

Sample Size = 147

Table L-4. Chi-Square Test for Parker Street Southbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

---------------- STREET=PARKER DIR=SOUTHBOUND ------------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	14	11	7	32
	11.02	8.66	5.51	25.20
	43.75	34.38	21.87	
	28.57	20.37	29.17	
2	35	43	17	95
	27.56	33.86	13.39	74.80
	36.84	45.26	17.89	
	71.43	79.63	70.83	
Total	49	54	24	127
	38.58	42.52	18.90	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	1.164	0.559
Likelihood Ratio Chi-Square	2	1.181	0.554
Mantel-Haenszel Chi-Square	1	0.038	0.845
Phi Coefficient		0.096	
Contingency Coefficient		0.095	
Cramer's V		0.096	

Sample Size = 127

Table L-5. Chi-Square Test for Vale Street Northbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

---------------- STREET=VALE DIR=NORTHBOUND ------------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	5	18	30	53
	3.16	11.39	18.99	33.54
	9.43	33.96	56.60	
	33.33	23.08	46.15	
2	10	60	35	105
	6.33	37.97	22.15	66.46
	9.52	57.14	33.33	
	66.67	76.92	53.85	
Total	15	78	65	158
	9.49	49.37	41.14	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	8.470	0.014
Likelihood Ratio Chi-Square	2	8.506	0.014
Mantel-Haenszel Chi-Square	1	4.702	0.030
Phi Coefficient		0.232	
Contingency Coefficient		0.226	
Cramer's V		0.232	

Sample Size = 158

Table L-6. Chi-Square Test for Vale Street Southbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

------------- STREET=VALE DIR=SOUTHBOUND ----------------

TABLE OF ATTEN BY TIME

ATTEN TIME

Frequency / Percent / Row Pct / Col Pct	0	1	2	Total
1	1 1.11 5.26 5.88	5 5.56 26.32 15.15	13 14.44 68.42 32.50	19 21.11
2	16 17.78 22.54 94.12	28 31.11 39.44 84.85	27 30.00 38.03 67.50	71 78.89
Total	17 18.89	33 36.67	40 44.44	90 100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	6.186	0.045
Likelihood Ratio Chi-Square	2	6.652	0.036
Mantel-Haenszel Chi-Square	1	5.929	0.015
Phi Coefficient		0.262	
Contingency Coefficient		0.254	
Cramer's V		0.262	

Sample Size = 90

Table L-7. Chi-Square Test for FM 2131 Northbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

------------ STREET=FM 2131 DIR=NORTHBOUND ----------------

TABLE OF ATTEN BY TIME

ATTEN TIME

Frequency / Percent / Row Pct / Col Pct	0	1	2	Total
1	37	9	22	68
	24.50	5.96	14.57	45.03
	54.41	13.24	32.35	
	64.91	25.71	37.29	
2	20	26	37	83
	13.25	17.22	24.50	54.97
	24.10	31.33	44.58	
	35.09	74.29	62.71	
Total	57	35	59	151
	37.75	23.18	39.07	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	15.807	0.000
Likelihood Ratio Chi-Square	2	16.128	0.000
Mantel-Haenszel Chi-Square	1	8.749	0.003
Phi Coefficient		0.324	
Contingency Coefficient		0.308	
Cramer's V		0.324	

Sample Size = 151

Table L-8. Chi-Square Test for FM 2131 Southbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

---------- STREET=FM 2131 DIR=SOUTHBOUND ----------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency / Percent / Row Pct / Col Pct)	0	1	2	Total
1	43	5	21	69
	30.07	3.50	14.69	48.25
	62.32	7.25	30.43	
	68.25	18.52	39.62	
2	20	22	32	74
	13.99	15.38	22.38	51.75
	27.03	29.73	43.24	
	31.75	81.48	60.38	
Total	63	27	53	143
	44.06	18.88	37.06	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	21.235	0.000
Likelihood Ratio Chi-Square	2	22.274	0.000
Mantel-Haenszel Chi-Square	1	10.174	0.001
Phi Coefficient		0.385	
Contingency Coefficient		0.360	
Cramer's V		0.385	

Sample Size = 143

Table L-9. Chi-Square Test for Baylor Street Eastbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

--------------- STREET=BAYLOR ST DIR=EASTBOUND --------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	68	31	54	153
	19.43	8.86	15.43	43.71
	44.44	20.26	35.29	
	40.00	36.05	57.45	
2	102	55	40	197
	29.14	15.71	11.43	56.29
	51.78	27.92	20.30	
	60.00	63.95	42.55	
Total	170	86	94	350
	48.57	24.57	26.86	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	10.213	0.006
Likelihood Ratio Chi-Square	2	10.180	0.006
Mantel-Haenszel Chi-Square	1	6.051	0.014
Phi Coefficient		0.171	
Contingency Coefficient		0.168	
Cramer's V		0.171	

Sample Size = 350

Table L-10. Chi-Square Test for Avenue A Southbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

----------- STREET=INGLESIDE AVE A DIR=SOUTHBOUND ------------

TABLE OF ATTEN BY TIME

ATTEN / TIME — Frequency, Percent, Row Pct, Col Pct	0	1	2	Total
1	185	19	56	260
	44.15	4.53	13.37	62.05
	71.15	7.31	21.54	
	75.20	26.76	54.90	
2	61	52	46	159
	14.56	12.41	10.98	37.95
	38.36	32.70	28.93	
	24.80	73.24	45.10	
Total	246	71	102	419
	58.71	16.95	24.34	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	57.837	0.000
Likelihood Ratio Chi-Square	2	57.802	0.000
Mantel-Haenszel Chi-Square	1	22.306	0.000
Phi Coefficient		0.372	
Contingency Coefficient		0.348	
Cramer's V		0.372	

Sample Size = 419

Table L-11. Chi-Square Test for Hidden Acres Road Eastbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

--------------- STREET=HIDDEN ACRES DIR=EASTBOUND ---------------

TABLE OF ATTEN BY TIME

ATTEN / TIME (Frequency, Percent, Row Pct, Col Pct)	0	1	2	Total
1	3	25	12	40
	2.78	23.15	11.11	37.04
	7.50	62.50	30.00	
	21.43	44.64	31.58	
2	11	31	26	68
	10.19	28.70	24.07	62.96
	16.18	45.59	38.24	
	78.57	55.36	68.42	
Total	14	56	38	108
	12.96	51.85	35.19	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	2	3.337	0.189
Likelihood Ratio Chi-Square	2	3.443	0.179
Mantel-Haenszel Chi-Square	1	0.001	0.973
Phi Coefficient		0.176	
Contingency Coefficient		0.173	
Cramer's V		0.176	

Sample Size = 108

Table L-12. Chi-Square Test for Hidden Acres Road Westbound

RAILROAD GRADE CROSSING LOOKING BEHAVIOR

---------------- STREET=HIDDEN ACRES DIR=WESTBOUND --------------

TABLE OF ATTEN BY TIME

ATTEN (Frequency / Percent / Row Pct / Col Pct)	TIME 0	TIME 1	Total
1	8	4	12
	7.41	3.70	11.11
	66.67	33.33	
	11.94	9.76	
2	59	37	96
	54.63	34.26	88.89
	61.46	38.54	
	88.06	90.24	
Total	67	41	108
	62.04	37.96	100.00

STATISTICS FOR TABLE OF ATTEN BY TIME

Statistic	DF	Value	Prob
Chi-Square	1	0.123	0.726
Likelihood Ratio Chi-Square	1	0.125	0.724
Continuity Adj. Chi-Square	1	0.001	0.972
Mantel-Haenszel Chi-Square	1	0.122	0.727
Fisher's Exact Test (Left)			0.743
(Right)			0.494
(2-Tail)			1.000
Phi Coefficient		0.034	
Contingency Coefficient		0.034	
Cramer's V		0.034	

Sample Size = 108
WARNING: 25% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

APPENDIX M

SURVEY CODE KEY AND DATABASE

DATA CODING

<u>COUNTY</u>
Coleman = 0
Grimes = 1
Nacogdoches = 2
San Patricio = 3

<u>SIGNS</u>
Yield to Trains = 0
Look for Trains = 1

<u>STREET</u>
County Road 304 = 0
Courtney Road (NB) = 1
County Road 298 = 2
Fredonia Street = 3
County Road 525 = 4
Parker Street = 5
Vale Street (NB) = 6
FM 2131 (NB) = 7
Baylor Street = 8
Avenue A = 9
Hidden Acres Rd.(WB) = 10
Courtney Road (SB) = 11
Vale Street (SB) = 16
FM 2131 (SB) = 17
Hidden Acres Rd.(EB) = 19

<u>TIME</u>
Before = 0
After = 0

<u>ATTENTION</u>
None = 0
One Way = 1
Both Ways = 2

<u>LOOK</u>
Did Action = 0
Did No Action = 1

<u>GENDER</u>
Female = 0
Male = 1

<u>DRIVER'S LICENSE</u>
0-14 Years = 0
15-29 Years = 1
29+ Years = 2

<u>LANGUAGE</u>
English = 0
Spanish = 1
Other = 2

<u>AGE</u>
< 20 = 1
20-35 = 2
36-50 = 3
> 50 = 4

<u>CROSSING FREQUENCY</u>
Once a week or more = 1
Once a month = 2
Once a year = 3
First time = 4

<u>SIGN SEEN</u>
None (after) = 0
Standard Signs = 1
Experimental Signs = 2
Both Stnd. and Exp. = 3
None (before) = 4
Crossbuck Only = 5
AWS Only = 6
Pavement Marking Only = 7
AWS & Crossbuck = 8
Crossbuck & Pvmt.Mark. = 9
All = 10
AWS & Pvmt.Mark. = 11

<u>SIGN MEANINGS AND POSITIONS</u>
Correct = 0
Incorrect = 1

<u>OPINION</u>
Strongly Agree = 4
Somewhat Agree = 3
No Opinion = 2
Somewhat Disagree = 1
Strongly Disagree = 0

Table M-1. Survey Database

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
1	0	0	0	0	0	2	1		0		0		
1	0	0	0	2	0	4	1		1		0		
1	0	0	0	2	0	3	1		1		0		
1	0	0	0	0	0	2	1		1		1		
1	0	0	0	2	0	4	2		1		1		
1	0	0	0	0	0	2	2		0		0		
1	0	0	0	1	0	3	2		0		1		
1	0	0	0	0	0	2	2		0		1		
1	0	0	0	2	0	4	1		1		0		
1	0	0	1	1	0	2	1		1		1		
1	0	0	1	2	0	3	1		1		0		
1	0	0	1	2	0	3	1		1		1		
1	0	0	1	1	0	3	1		1		0		
1	0	0	0	2	0	3	1		1		1		
1	0	0	1	1	0	3	2		0		0		
1	0	0	0	0	0	2	1		0		0		
1	0	0	1	1	0	3	2		0		1		
1	0	0	0	1	0	3	1		0		0		
1	0	0	1	2	0	4	1		1		0		
1	0	0	1	2	0	3	1		1		0		
1	0	0	1	2	0	4	3		1		1		
1	0	0	1	1	0	3	1		1		0		
1	0	0	1	2	0	4	1		0		1		
1	0	0	1	0	0	2	1		1		0		
1	0	0	0	1	0	3	1		0		1		
1	0	0	1	1	0	4	1		0		0		
1	0	0	0	1	0	3	1		0		1		
1	0	0	1	2	0	4	1		1		1		
1	0	0	1	2	0	3	1		1		1		
1	0	0	0	2	0	3	1		0		1		
1	0	0	0	1	0	2	1		0		0		
1	0	0	1	0	0	1	1		1		1		
1	0	0	1	1	0	4	3		1		0		
1	0	0	1	1	0	3	1		0		0		
1	0	0	0	1	0	4	1		1		0		
1	0	0	1	1	0	3	1		1		1		
1	0	0	1	2	0	3	1	2	0	1	1	1	3
1	0	0	1	2	0	4	1	3	1	1	1	1	4
1	0	0	0	1	0	2	1	3					3
1	0	0	1		0	3	1	3	0	1	0	0	3
1	0	0	1	0	0	2	1	0	1	1	1	1	1
1	0	0	1	1	0	2	1	3	0	1	1	1	1
1	0	0	0	2	0	4	1	2	1	1	0	1	3
1	0	0	1	0	0	2	1	2	1	1	0	0	3
1	0	0	1	1	0	2	1	3	0	0	0		3
1	0	0	1		0			3				0	4
1	0	0	1	0	0	2	1	3	1	1	0		2
1	0	0	0	2		4	1	3				0	0
1	0	0	1	2	0	4	1	2					3
1	0	0	1		0			3	1	1	1	1	3
1	0	0	1	2	0	3	1	1					3
1	0	0	0	1	0	3	3	0	1	0	0	0	3
1	0	0	0	1	0	2	1	1	1	1	1	1	3
1	0	0	0	2	0	4	1	2					3
1	0	0	0	2	0	4	1	3					4
1	0	0	1	1	0	3	1	2	1	0	1	1	3
1	0	0	0	2	0	4	1	2	1	1	0	0	4
1	0	0	1	1	0	1	1	3	0	0	0	0	4
1	0	0	1	2	0	4	1	3	0	0	1	1	0
1	0	0	1	1	0	3	3	2	1	0	1	1	3
1	0	0	0	0	0	2	1	2	1	0	0	0	0
1	0	0	0	1	0	3	1	1	1	0	1	1	3
1	0	0	0	0	0	2	1	0					3
1	0	0	1	2	0	3	1	3	1	1	0	0	4
1	1	0	1	2	0	4	1	0	1	1	0	0	3
1	1	0	0	1	0	2	1	2	0	0	1	1	4

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
1	1	0	1	0	0	2	1	2	1	1	1	1	3
1	1	0	1				1	2	0	0	0	0	3
1	1	0	0	1	0	2	4	2	1	1	1	1	1
1	1	0	0	0	0	2	1	2	1	0	0	1	4
1	1	0	1				1	2	1	0	0	1	4
1	1	0	0	1	0	2	1	2	1	1	0	0	3
1	1	0	1	0	0	2	2	0	1	0	0	0	3
1	1	0	1	1	0	2	1	2	0	0	0	0	4
1	1	0	1	0	0	2	2	1	1	1	0	1	1
1	1	0	1	1	0	3	1	2	1	1	0	0	4
1	1	0	1	0	0	2	1	2	1	0	0	0	3
1	1	0	0	1	0	3	1	2	1	1	0	1	3
1	1	0	0	1	0	3	1	2	1	1	0	1	3
1	1	0	1	0	0	1	1	0	1	1	0	1	4
1	1	0	1	1	0	3	1	1	1	1	1	1	4
1	1	0	1	1	0	2	3	2	0	0	0	0	2
1	1	0	0	0	0	2	1	0	1	1	0	0	3
1	1	0	1	1	0	3	1	2	1	1	0	0	3
1	1	0	1	1	0	2	1	3	1	0	0	0	3
1	1	0	1	1	0	3	1	3	1	1	0	0	4
1	1	0	1	1	0	3	1	2					3
1	1	0	0	1	0	2	2	2	1	1	0	1	3
1	1	0	0	2	0	4	1	2	1	1	0	1	2
1	1	0	1	0	0	2	2	2	1	1	1	0	3
1	1	0	1	1	0	2	2	0	1	0	0	0	1
1	1	0	1		0		2	2	0	0	0	0	4
1	1	0	1	0	0	2	2	2					4
1	1	0	1	0	0	2	1	3					3
1	1	0	1	2	0	4	1	3					4
1	1	0	1	1	0	3	1	2	1	1	0	0	0
1	1	0	1	0	0	2	1	0	1	1	1	1	0
0	5	0	1	2	0	4	1		1	0	0	1	
0	5	0	0	2	0	4	1		1	1	1	1	
0	5	0	1	2	0	3	1		1	0	0	1	
0	5	0	1	0	0	1	4		0	0	0	0	
0	5	0	1	2	1	3	1		0	0	0	0	
0	5	0	1	2	0	4	1		1	1	0	1	
0	5	0	1	1	0	3	1		1	0	0	0	
0	5	0	1	2	0	3	1		1	1	1	1	
0	5	0	0	0	1	1	1		1	1	0	1	
0	5	0	0	0	1	2	1		1	1	1	1	
0	5	0	1	0	1	1	1		1	1	0	1	
0	5	0	1	0	0	1	1		1	0	0	0	
0	5	0	0	1	0	3	1		0	0	0	0	
0	5	0	0	0	1	2	1		1	1	1	1	
0	5	0	0	0	1	1	1		1	0	0	0	
0	5	0	1	1	1	3	1		1	0	0	0	
0	5	0	1	1	0	2	1		1	0	0	0	
0	5	0	1	1	0	3	1		1	0	0	0	
0	5	0	1	2	1	4	1		0	0	0	0	
0	5	0	0	0	1	1	1		1	1	1	1	
0	5	0	0	0	0	1	1		1	0	0	0	
0	5	0	1	0	0	1	1		1	0	0	0	
0	5	0	1	1	0	3	1		1	0	0	0	
0	5	0	1	0	0	2	1		1	0	0	0	
0	5	0	1	0	0	2	2		1	1	1	1	
0	5	0	1	1	0	3	1		1	0	0	0	
0	5	0	1	0	1	1	1		1	0	0	0	
0	5	0		0	1	2	1		1	1	0	1	
0	5	0	1	2	0	4	1		1	0	0	0	
0	5	0	0	2	0	3	1		1	0	0	0	
0	5	0	0	0	1	2	1		1	0	0	0	
0	5	0	0	2	0	4	1		1	1	0	1	
0	5	0	1	1	0	2	1	0	1	0	0	0	3
0	5	0	0	1	0	2	1	3	1	0	0	0	4
0	5	0	1	2	0	4	1	2	1	1	1	1	3

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
0	5	0	1	0	0	2	1	3	1	1	0	1	4
0	5	0	0	2	0	4	2	0	0	0	0	0	4
0	5	0	0	0	0	2	1	0	1	0	0	1	1
0	5	0	0	1	0	3	1	0	1	1	1	1	3
0	5	0	0	0	0	2	1	2	1	1	0	0	3
0	5	0	1	2	0	4	1	3	1	1	0	1	3
0	5	0	1	0	0	2	1	2	0	0	1	0	3
0	5	0	1	0	0	3	1	0	1	0	1	0	1
0	5	0	1	1	0	3	1	2	1	0	0	1	4
0	5	0	0	0	1	2	1	3	1	0	0	1	2
0	5	0	1	1	0	3	1	1					3
0	5	0	1	2	0	4	2	0	1	0	0	0	2
0	5	0	1	1	0	2	1	3					3
0	5	0	0	2	0	4	1	2					4
0	5	0	1	2	1	3	1	2	1	0	0	0	4
0	5	0	1	2	0	4	1	0	0	0	0	0	3
0	5	0	1	2	0	4	1	2					3
0	5	0	1	2	1	3	4	0	1	1	0	1	3
0	5	0	1	0	0	2	1	0	1	1	0	0	2
0	5	0	1	1	1	2	4	0	1	1	0	1	2
0	5	0	1	1	0	3	1	2					4
0	5	0	1	1	0	3	1	3	0	0	0	1	3
0	5	0	1	0	0	2	1	3					4
0	5	0	1	1	0	4	1	2					4
0	5	0	1	0	1	2	1	3	1	1	0	1	3
0	5	0	1	2	1	3	1	2	1	1	0	1	3
0	5	0	0	0	0	2	1	3	1	1	1	1	1
0	5	0	0	1	0	3	4	2	1	1	0	1	0
0	5	0	1	0	0	2	2	2					1
0	5	0	0	1	0	4	1	2					0
0	5	0	0	2	0	4	1	2					3
0	6	0	1	2	0	3	1		1	0	0	0	
0	6	0	1	1	0	2	1		0	0	0	0	
0	6	0	1	2	0	4	1		0	0	0	0	
0	6	0	0	2	0	4	1		1	0	0	1	
0	6	0	1	2	0	4	1		1	0	0	1	
0	6	0	1	1	0	3	1		0	0	0	0	
0	6	0	0	0	0	2	1		1	0	0	0	
0	6	0	0	2	0	3	1		1	1	0	0	
0	6	0	1	1	0	2	1		1	0	0	0	
0	6	0	1	0	0	2	1		1	0	1	1	
0	6	0	0	0	0	2	1		1	0	0	0	
0	6	0	1	2	0	4	1		1	1	0	0	
0	6	0	1	2	0	4	1		1	1	0	0	
0	6	0	1	0	0	4	1		0	0	0	0	
0	6	0	0	0	1	3	1						4
0	6	0	0	0	0	1	1		1	1	0	1	3
0	6	0	1	1	0	2	1		1	0	1	0	2
0	6	0	1	0	0	2	1		1	1	0	1	3
0	6	0	1	0	0	2	1		1	0	0	0	3
0	6	0	0	1	0	3	1						4
0	6	0	1	0	0	3	1	3	1	0	0	1	1
0	6	0	1	0	0	2	1	1	0	0	0	0	4
0	6	0	1	2	0	4	1	3	1	1	0	1	3
0	6	0	0	2	0	4	1	4	1	0	0	0	4
0	6	0	0	2	0	3	1	0	1	0	0	0	0
0	6	0	1	2	0	4	1	1	1	1	0	1	3
0	6	0	0	0	0	4	1	0	0	1	0	1	2
0	6	0	1	2	0	4	1	2	1	1	0	1	4
0	6	0	1	1	0	3	1	1	1	1	0	1	3
0	6	0	1	1	0	3	1	3	1	1	0	1	3
0	6	0	0	1	0	2	1	2	1	1	0	1	3
0	6	0	1	0	0	2	3	0	1	1	0	1	0
0	6	0	0	2	0	3	1	0	1	0	0	0	4
0	6	0	1	2	0	3	1	2	1	1	0	1	4
0	6	0	0	1	0	2	1	3	0	0	0	0	3

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI UC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
0	6	0	0	2	0	3	1	2	1	1	0	1	0
0	6	0	0	1	0	2	1	2	0	0	0	0	0
0	6	0	1	1	0	3	2	2	1	1	1	1	3
0	6	0	1	1	0	3	1	2	1	1	0	1	3
0	6	0	0	1	0	3	1	3	0	0	0	0	3
0	6	0	0	1	0	2	1	3	1	1	1	1	3
0	6	0	1	1	0	2	1	1	0	0	0	0	0
0	6	0	1	2	0	4	2	3	0	0	0	0	4
0	6	0	1	1	0	2	1	3	1	0	0	1	2
0	6	0	1	0	0	2	1	1	1	1	0	0	1
0	6	0	0	1	0	3	1	2	1	0	0	1	3
0	6	0	1	2	0	4	2	0	1	1	0	1	3
0	6	0	0	1	0	3	1	3	1	0	0	0	3
0	6	0	0	2	0	4	1	3	1	1	0	1	3
0	6	0	1	1	0	3	1	0	1	0	1	0	
0	6	0	1	0	0	2	1	0	1	0	0	0	
0	6	0	0	1	0	3	1	2	1	1	0	1	
0	6	0	1	2	0	4	1	3	1	0	0	0	
0	6	0	1	0	0	1	1	0	1	0	0	0	
0	6	0	1	1	0	3	1	2	1	1	0	0	
0	7	0	1	2	0	4	3		1	1	0	1	
0	7	0		0	0	2	1		0	0	0	0	
0	7	0	0	0	0	2	1		0	0	0	0	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	1	1	0	3	1		0	0	0	0	
0	7	0	0	1	0	2	1		1	1	0	1	
0	7	0	1	0	0	2	1		1	1	0	0	
0	7	0	1	2	0	3	1		1	0	0	0	
0	7	0	0	1	0	3	1		0	0	1	1	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	0	2	0	4	1		0	0	1	0	
0	7	0	1	2	0	4	1		1	0	0	1	
0	7	0	0	1	0	3	1		1	0	0	0	
0	7	0	0	0	0	2	1		1	0	0	1	
0	7	0	0	0	0	2	1		0	0	0	0	
0	7	0	0	2	0	4	1		1	0	0	1	
0	7	0	1	0	0	2	1		1	0	0	0	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	0	0	0	2	1		1	0	0	0	
0	7	0	0	2	0	4	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	1	0	
0	7	0	0	2	0	3	1		1	0	1	1	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	1	2	0	3	1		1	0	0	1	
0	7	0	1	2	0	4	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	0	0	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	1	0	0	1	1		1	0	0	0	
0	7	0	1	1	0	2	1		1	0	0	1	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	0	1	0	2	1		1	0	0	1	
0	7	0	1	1	0	3	2		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	0	0	
0	7	0	0	1	0	2	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	1	0	
0	7	0	1	1	0	3	1		1	0	0	1	
0	7	0	1	1	0	3	1		1	1	1	1	
0	7	0	0	1	1	3	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	0	0	0	
0	7	0	0	2	0	4	1		1	0	0	1	
0	7	0	1	2		4	1		1	0	0	1	
0	7	0	0	0	0	2	1		1	0	0	0	
0	7	0	0	1	0	3	1		1	0	0	0	
0	7	0	0	1	0	2	1		1	1	0	1	
0	7	0	0	1	0	3	1		1	0	1	0	

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
0	7	0	1	1	0	3	1		1	1	1	1	
0	7	0	1	1	0	3	1		1	0	0	0	
0	7	0	1	2	0	4	1		1	1	1	1	
0	7	0	1	2	0	4	1		1	0	0	1	
0	7	0	0	0	0	1	1		1	0	0	0	
0	7	0	1	2	0	4	1	0					4
0	7	0	1	1	0	2	1	3	1	0	0	0	3
0	7	0	1	2		3	1	2	1	0	0	1	3
0	7	0	1	2	0	3	1	3					4
0	7	0	1	2	0	4	1	3	1	0	0	1	3
0	7	0	0	0	0	2	1	2	1	0	1	1	3
0	7	0	1	2	0	4	2	3	1	0	0	0	2
0	7	0	1	1	0	2	2	2	0	0	0	1	3
0	7	0	0	1	0	3	1	1					3
0	7	0	1	1	0	3	1	3	1	0	0	0	4
0	7	0	0	1	0	3	1	2	1	0	1	0	3
0	7	0	0	2	0	4	1	2	1	1	1	1	0
0	7	0	1	2	0	3	1	1	1	0	0	1	3
0	7	0	1	2	0	4	1	3	1	0	0	0	3
0	7	0	0	1	0	4	1	0	1	1	1	1	1
0	7	0	0	2	0	4	1	3					4
0	7	0	1	2	0	4	1	3					3
0	7	0	1	0	0	2	1	3	1	0	0	0	3
0	7	0	0	1	0	3	1	2	1	0	0	0	4
0	7	0	1	1	0	3	1	1	1	0	0	0	0
0	7	0	0	2	0	1	1	3					0
0	7	0	1	0	0	3	1	3					3
0	7	0	0	1	0	4	1	2					3
0	7	0	1	2	0	4	1	3	1	1	0	1	0
0	7	0	1	1	0	3	1	3					3
0	7	0	1	2	0	4	1	3					3
0	7	0	1	2	0	4	1	3	0	0	0	0	3
0	7	0	0	1	0	3	1	2	0	0	0	0	3
0	7	0	1	2	0	4	1	3	1	1	0	1	2
0	7	0	0	1	0	3	1	2	1	0	0	0	3
0	7	0	1	1	0	3	1	3	0	0	0	0	4
0	7	0	0	2	0	4	1	2	1	0	0	1	0
0	7	0	0	1	0	2	1	3	0	0	0	0	3
3	8	1	1	1	1	2	1		0	0	0	0	
3	8	1	0	0	1	2	1		1	1	0	0	
3	8	1	1	2	0	4	1		1	1	0	0	
3	8	1	1	2	0	4	1		1	0	0	0	
3	8	1	1	2	0	4	1		1	0	0	0	
3	8	1	0	2	0	4	1		1	0	0	0	
3	8	1	0	1	1	3	1		1	0	0	0	
3	8	1	1	2	0	4	3		1	1	1	1	
3	8	1	0	1	0	3	1		1	1	0	0	
3	8	1	1	1	1	4	1		1	0	0	0	
3	8	1	0	1	1	3	1		0	0	0	0	
3	8	1	1	1	0	3	1		1	1	0	1	
3	8	1	0	0	0	2	1		1	1	1	1	
3	8	1	0	1	1	3	1		1	0	0	0	
3	8	1	1	0	1	2	1		1	1	0	1	
3	8	1	0	1	1	2	1		1	0	0	0	
3	8	1	0	0	0	2	1		1	0	0	0	
3	8	1	1	0	1	2	1		0	0	0	0	
3	8	1	1	1	1	3	2		1	1	0	1	
3	8	1	1	0	1	2	1		0	0	0	0	
3	8	1	1	0	1	2	1		1	0	0	0	
3	8	1	1	0	0	2	1		1	1	1	1	
3	8	1	1	0	1	2	1		1	1	1	1	
3	8	1	1	0	0	1	1		1	0	0	0	
3	8	1	0	0	0	1	1		0	0	0	0	
3	8	1	0	1	1	3	1		1	1	1	1	
3	8	1	0	0	0	2	1		1	0	0	0	
3	8	1	0	1	0	2	1		1	0	0	1	

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
3	8	1	0	1	1	3	1		1	1	0	1	
3	8	1	1	2	0	3	1		1	0	0	0	
3	8	1	0	1	0	3	1	4	1	0	1	1	
3	8	1	0	0	0	2	1	4	1	1	0	1	
3	8	1	0	0	0	3	1	4	1	1	0	0	
3	8	1	1	0	1	2	1	10					
3	8	1	0	1	0	2	1	4	1	1	0	0	
3	8	1	1	2	1	4	1	6	1	1	0	1	
3	8	1	1	1	0	3	1	7					
3	8	1	1	1	1	3	1	4	1	0	0	1	
3	8	1	0	1	0	3	1	4	1	1	1	1	
3	8	1	1	1	0	3	1	7	1	1	0	1	
3	8	1	1	0	1	2	4	4	1	0	0	1	
3	8	1	0	0	0	2	1	4	0	0	0	0	
3	8	1	0	1	0	3	1	8	1	0	0	0	
3	8	1	0	1	0	3	1	4	1	0	0	0	
3	8	1	1	2	1	4	1	4	0	0	0	0	
3	8	1	1	2		3	1	7	1	1	0	1	
3	8	1	0	1	0	3	1	4	1	0	0	0	
3	8	1	0	1	0	4	1	4	1	0	0	1	
3	8	1	1	1	0	2	1	4	1	0	0	1	
3	8	1	0	1	1	3	1	7	1	0	0	0	
3	8	1	1	2	1	4	1	5	1	0	0	0	
3	8	1	0	0	1	2	1	4	0	0	0	0	
3	8	1	0	0	0	2	1	4	1	0	0	0	
3	8	1	0	1	0	3	1	4	1	0	0	1	
3	8	1	1	1	0	3	1	9	1	1	0	1	
3	8	1	0	1	1	2	1	4	1	0	1	1	
3	8	1	0	2	1	3	1	7	0	0	0	0	
3	8	1	1	2	1	4	1	4	0	0	0	1	
3	8	1	0	0	0	2	1	4	1	1	0	0	
3	8	1	1	0	0	2	1	4	1	1	0	0	
3	8	1	0	0	0	1	1	3	1	0	0	0	4
3	8	1	0	0	0	2	1	0	1	1	1	1	3
3	8	1	1	0	0	2	1	2	1	1	1	1	4
3	8	1	0	0	1	2	1	2	1	1	0	1	3
3	8	1	0	0	0	1	2	2	0	0	0	1	3
3	8	1	1	1	0	3	1	3	0	0	0	0	3
3	8	1	0	1	0	2	1	0	1	1	1	1	2
3	8	1	1	2	0	3	1	2	1	1	1	1	3
3	8	1	0	1	0	2	1	1	1	1	0	1	4
3	8	1	0	2	0	4	1	2	1	0	0	0	3
3	8	1	0	0	0	1	1	1	1	1	0	1	3
3	8	1	1	0	0	2	1	0	0	0	0	0	1
3	8	1	0	2	0	4	1	2	0	0	0	0	3
3	8	1	1	0	0	2	1	2	1	1	1	1	4
3	8	1	1	0	0	2	1	3	0	1	0	0	4
3	8	1	0	1	0	3	1	2					4
3	8	1	1	1	0	3	1	2					1
3	8	1	1	2	0	4	1	2	1	1	1	1	3
3	8	1	0	1	0	3	1	2	1	0	0	0	4
3	8	1	0	2	0	4	1	0	0	0	0	0	2
3	8	1	0	0	1	2	1	1	1	1	0	1	1
3	8	1	0	1	0	3	1	3	1	0	0	0	4
3	8	1	1	0	0	2	1	2	1	1	0	1	3
3	8	1	1	0	0	1	1	0	0	1	0	1	4
3	8	1	0	1	0	3	1	3	1	1	1	1	3
3	8	1	0	1	0	3	1	2	1	1	1	1	3
3	8	1	1	0	0	2	1	1	0	0	0	1	3
3	8	1	1	2	0	4	1	3	1	1	0	0	3
3	8	1	0	0	0	2	1	0	1	0	0	0	3
3	8	1	0	2	0	4	1	3	1	0	0	0	4
3	8	1	1	2	0	3	1	2	1	0	0	1	3
3	8	1	1	1	0	3	1	2					4
3	8	1	1	2	0	4	1	2					3
3	8	1	0	2	0	3	1	3	1	0	0	0	1

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
3	8	1	1	2	1	4	1	0					3
3	8	1	1	0	0	2	1	0	1	1	1	1	3
3	8	1	0	0	0	2	1	0	1	0	0	0	2
3	8	1	0	0	0	2	1	2	1	1	1	1	3
3	8	1	1	0	0	1	1	0					4
3	8	1	1	2	0	4	1	0	1	0	0	0	4
3	8	1	0	0	0	1	1	1	0	0	0	0	4
3	8	1	1	1	0	3	1	0					0
3	8	1	1	1	0	3	1	2	1	1	0	1	4
3	8	1	1	0	0	1	1	3	1	0	0	0	4
3	8	1	0	1	0	2	1	1	1	0	0	0	3
3	8	1	1	1	0	3	2	2					2
3	8	1	1	1	0	2	1	2					1
3	8	1	0	1	0	3	2	3	1	1	0	1	3
3	8	1	0	1	0	3	1	2	1	1	1	1	4
3	8	1	1	1	1	3	1	0	1	1	1	1	4
3	8	1	1	2	0	3	1	0					4
3	8	1	1	0	0	2	1	3	0	0	0	0	3
3	8	1	1	0	0	1	1	2					3
3	8	1	0	1	0	2	1	0	1	1	0	0	3
3	8	1	0	1	0	3	1	0	1	0	0	1	2
3	8	1	1	1	0	3	1	1	1	1	0	0	4
3	8	1	1	1	0	2	1	3					0
3	8	1	1	0	0	1	1	3	1	0	0	0	4
3	8	1	0	2	0	3	1	0	1	0	0	1	1
3	8	1	1	2	0	4	1	2	0	0	0	0	3
3	9	1	1	2	0	4	1		1	0	0	0	
3	9	1	0	2	0	3	1		1	1	0	0	
3	9	1	1	1	1	2	1		1	1	0	0	
3	9	1	1	2	0	4	1		1	0	0	0	
3	9	1	1	2	0	4	1		1	1	0	0	
3	9	1	1	2	0	4	1		1	0	0	0	
3	9	1	1	0	0	2	1		1	1	0	1	
3	9	1	1	2	0	4	3		1	1	0	0	
3	9	1	1	2	0	4	1		1	0	0	0	
3	9	1	0	1	0	2	1		1	1	1	1	
3	9	1	0	2	0	3	1		1	1	0	1	
3	9	1	0	0	0	2	1		1	0	0	0	
3	9	1	1	1	0	2	1		1	1	0	1	
3	9	1	1	2	0	3	1		1	0	0	0	
3	9	1	1	1	1	3	1		1	0	0	1	
3	9	1	0	0	2		1		1	1	0	1	
3	9	1	0	1	0	3	1		1	0	0	0	
3	9	1	0	0	0	2	1		0	0	0	0	
3	9	1	0	1	0	3	1		0	0	0	0	
3	9	1	1	2	0	4	1		1	1	0	0	
3	9	1	1	2	0	4	1		1	1	0	0	
3	9	1	1	1	1	3	3		1	1	0	0	
3	9	1	1	2	0	4	1		1	0	1	0	
3	9	1	0	0	1	2	1		1	1	1	1	
3	9	1	1	2	0	4	1		1	1	1	1	
3	9	1	1	1	1	2	1		1	0	0	0	
3	9	1	1	0	0	2	4		1	0	0	0	
3	9	1	1	0	1	2	2		1	0	0	0	
3	9	1	1	2	0	4	1		1	0	0	0	
3	9	1	1	0	0	1	1		1	1	1	1	
3	9	1	0	2	0	4	1		1	1	0	0	
3	9	1	1	0	0	2	1		1	0	1	1	
3	9	1	0	2	0	4	1		0	0	0	0	
3	9	1	0	0	0	2	1		1	0	0	1	
3	9	1	0	1	0	3	1		1	0	0	0	
3	9	1	0	2	0	4	1	4	1	1	0	0	
3	9	1	1	1	0	3	1	5	1	1	1	1	
3	9	1	1	2	0	4	1	4					
3	9	1	0	2	1	4	1	4	0	1	0	0	
3	9	1	0	1		3	1	4	1	1	1	1	

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
3	9	1	1	0	0	1	1	4	1	1	0	1	
3	9	1	1	1	0	3	1	4	0	0	0	0	
3	9	1	1	0	0	2	1	4	1	0	0	0	
3	9	1	1	0	0	2	1	4	1	0	0	1	
3	9	1	0	2	0	4	1	4	1	1	0	0	
3	9	1	1	2	0	4	3	4	0	1	1	1	
3	9	1	0	0	0	2	1	6	1	0	0	0	
3	9	1	0	0	1	2	1	4	1	1	0	0	
3	9	1	1	1	0	3	1	4	1	1	0	1	
3	9	1	1	2	0	4	1	7	0	0	0	1	
3	9	1	1	2	0	4	1	8	1	0	0	0	
3	9	1	0	1	0	2	1	4	1	0	0	1	
3	9	1	1	2	0	4	2	4	1	1	1	1	
3	9	1	1	2		3	1	4	1	1	1	1	
3	9	1	0	1	0	3	1	4	1	1	0	1	
3	9	1	0	1	0	3	1	4	1	1	0	0	
3	9	1	1	2	1	4	4	7	1	0	1	1	
3	9	1	0	2	0	4	1	4	0	0	0	0	
3	9	1	0	1	0	4	1	4	1	1	0	1	
3	9	1	0	0	0	2	1	6	1	1	0	0	
3	9	1	0	2	0	4	1	4					
3	9	1	0	2	0	4	1	4	1	1	1	1	
3	9	1	1	1	0	3	1	9	1	0	0	1	
3	9	1	1	0	0	2	1	4	1	1	0	0	
3	9	1	0	0	0	2	1	4	1	1	0	1	
3	9	1	0	1	0	3	1	4	1	1	0	0	
3	9	1	1	1	0	3	1	6	1	1	0	1	
3	9	1	1	1	0	3	1	5	1	0	0	0	
3	9	1	0	0		2	1	5	1	1	0	1	
3	9	1	0	1	0	3	1	7	1	0	0	1	
3	9	1	0	1	0	3	2	1	1	1	0	0	3
3	9	1	1	0	0	1	3	2	1	1	0	0	4
3	9	1	1	2	0		1	0	1	0	0	0	2
3	9	1	1	0	0	2	1	2	1	1	0	1	3
3	9	1	1	0	0	2	1	2					4
3	9	1	1	2	0	2	1	0	1	1	1	1	4
3	9	1	0	2	0	3	1	0	1	1	0	0	4
3	9	1	0	2	0	2	1	3	1	1	1	0	4
3	9	1	0	2	0	3	1	1	1	1	0	0	4
3	9	1	0	0	0	1	1	0	1	0	0	0	3
3	9	1	0	2	0	4	1	2	1	1	1	1	3
3	9	1	1	2	0	4	1	3	0	0	0	0	4
3	9	1	1	1	0	2	1	1	1	1	0	0	2
3	9	1	1	0	0	2	1	3	0	0	0	1	3
3	9	1	0	2	0	4	1	2	1	0	0	0	4
3	10	1	1	2	0	4	1		0	1	1	1	
3	10	1	1	2	0	4	1		1	1	0	0	
3	10	1	1	1	0	3	1		1	0	0	0	
3	10	1	1	0	0	2	1		0	0	0	0	
3	10	1	0	2	0	3	1		1	0	0	0	
3	10	1	0	2	0	4	1		1	0	0	1	
3	10	1	0	0	0	1	1		0	0	0	0	
3	10	1	0	2	0	4	1		1	0	0	0	
3	10	1	1	2	0	4	1		1	0	0	0	
3	10	1	0	1	0	3	1		1	1	0	0	
3	10	1	0	2		4	1		1	1	0	1	
3	10	1	1	0	0	2	1		1	1	0	0	
3	10	1	1				1		1	1	0	0	
3	10	1	0	0	1	2	1		0	0	0	0	
3	10	1	1	1	0	3	1		0	0	0	0	
3	10	1	0	2		4	1		1	0	0	0	
3	10	1	1	1	0	3	1		1	1	0	1	
3	10	1	0	1	0	3	1		0	1	0	0	
3	10	1	1	2	0	4	1		0	0	0	0	
3	10	1	1	2	0	3	2		1	1	0	0	
3	10	1	0	2	0	3	1		1	1	0	0	

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
3	10	1	1	2	0	4	1		1	0	0	0	
3	10	1	0	1	0	3	1		0	0	0	0	
3	10	1	0	2	0	4	1		0	1	0	0	
3	10	1	1	0	0	1	1		1	0	0	0	
3	10	1	1	0	0	2	1		1	1	0	0	
3	10	1	1	2	0	4	1		1	1	0	0	
3	10	1	1	0	0	1	1		1	0	0	0	
3	10	1	1	2	0	4	1		1	0	0	0	
3	10	1	0	1	0	3	1		1	0	1	0	
3	10	1	1	0	0	2	1		1	1	0	1	
3	10	1	1	0	0	1	1		1	0	0	0	
3	10	1	0	2	0	4	1		1	0	0	0	
3	10	1	1	0	1	1	1		1	0	0	0	
3	10	1	0	1		3	1		0	0	0	0	
3	10	1	1	2	0	4	1		1	0	0	0	
3	10	1	1	1	0	3	1		1	0	0	1	
3	10	1	0	1	0	3	1	11					
3	10	1	1	2	1	4	1	4	1	0	0	0	
3	10	1	0	2	0	4	2	4	1	1	0	0	
3	10	1	1	2	0	4	1	7	0	1	0	1	
3	10	1	0	2	0	3	1	4	1	1	0	0	
3	10	1	1	0	0	2	1	4	1	1	0	1	
3	10	1	0	1	0	3	1	4	1	1	0	1	
3	10	1	1	2	0	4	1	9	1	0	0	0	
3	10	1	0	1	0	4	1	7	1	0	0	0	
3	10	1	0	0	1	3	1	4	1	1	1	1	
3	10	1	0	0	0	2	1	7	0	0	1	1	
3	10	1	1	2	0	4	1	6					
3	10	1	0	2	0	4	1	5					
3	10	1	0	0	0	2	1	4	1	0	0	1	
3	10	1	1	2	0	4	1	8	1	0	0	0	
3	10	1	1	2	0	4	1	4	1	1	0	0	
3	10	1	1	1	1	2	1	10	1	0	0	1	
3	10	1	1	0	1	2	1	4	1	1	0	0	
3	10	1	0	2	0	4	1	4	0	0	0	1	
3	10	1	0	0	0	2	1	4	1	0	0	0	
3	10	1	0	2	0	4	1	7	1	0	0	1	
3	10	1	0	1	0	3	1	7	0	0	0	0	
3	10	1	0	1	1	3	1	7	1	1	0	1	
3	10	1	1	1	1	2	1	4	1	0	0	0	
3	10	1	1	1	0	3	1	5	1	0	0	0	
3	10	1	0	2	0	3	1	4	1	0	0	0	
3	10	1	1	2	0	4	1	10	1	1	0	1	
3	10	1	0	2	0	4	1	8					
3	10	1	1	2	0	4	1	8					
3	10	1	1	2	0	4	2	4	1	1	0	1	
3	10	1	0	0	0	2	1	4	1	0	0	0	
3	10	1	0	1	0	3	1	4	1	0	0	0	
3	10	1	1	0	0	1	1	8	1	1	1	1	
3	10	1	1	0	0	2	1	5	1	0	0	0	
3	10	1	0	2	0	4	1	8	1	1	0	1	
3	10	1	0	1	1	3	1	4	1	1	0	1	
3	10	1	1	2	0	3	1	4	1	0	0	0	
3	10	1	1	2	1	4	1	7	1	1	0	0	
3	10	1	1	1	0	4	1	4	1	0	0	1	
3	10	1	0	0	0	2	1	4	1	1	0	0	
3	10	1	0	2	1	4	1	0	1	1	0	1	2
3	10	1	0	1	0	3	1	1					4
3	10	1	0			3	1	0	1	1	0	0	0
3	10	1	1	1	1	3	2	0	1	1	1	1	3
3	10	1	1	0		2	2	1	1	0	0	0	3
3	10	1	0	1	0	3	3	2	1	0	0	0	4
3	10	1	0	1	1	2	1	2	0	0	0	1	4
3	10	1	1	2	0	4	1	2					4
3	10	1	1	2	0	4	1	0					0
3	10	1	1	2		3	1	1					3

Table M-1. Continued

COUNTY	STREET	SIGN	GEN	DRI LIC	LANG	AGE	XING	SEEN	AWS	APOS	XBUC	XPOS	OPIN
3	10	1	0	1	0	3	1	2	0	0	0	1	4
3	10	1	0	0	0	2	1	2					4
3	10	1	0	0		2	1	1	1	1	1	1	1
3	10	1	0	1	0	3	1	1					3
3	10	1	1	2	0	3	1	2					4
3	10	1	0	1	0	3	2	2	1	0	0	0	3
3	10	1	0	1		3	1	1					4
3	10	1	0	1	0	4	1	2					4
3	10	1	0	2	0	4	1	3					2
3	10	1	1	2	0	4	1	2	1	0	0	0	4
3	10	1	0	1		3	1	1	1	1	1	1	4
3	10	1	0	2	0	4	3	2	0	0	0	0	2
3	10	1	0	1		3	1	0	1	1	1	1	3
3	10	1	0	0	0	2	1	2	1	1	1	1	3
3	10	1	0	0		2	1	0					4
3	10	1	1	2	0	4	3	0	1	1	1	1	4
3	10	1	0	0		2	1	0	0	0	0	0	3
3	10	1	1	0	0	2	1	1	0	0	0	0	3
3	10	1	0	0		2	1	0	0	0	0	0	3
3	10	1	0	2	0	4	1	2					3
3	10	1	0			4	1	0	1	1	1	1	0
3	10	1	1	2	0	4	1	2					3
3	10	1	0	0		2	1	2	0	0	0	0	4
3	10	1	1	0	0	1	1	2					4
3	10	1	0			2	1	2					4
3	10	1	0	0		2	1	2	1	0	0	0	4
3	10	1	0	0	1	2	3	0	1	1	1	1	2
3	10	1	1	1	0	3	1	2	1	1	1	1	3
3	10	1	0				1	2	1	1	1	1	4
3	10	1	0	0	0	2	1	2					4

APPENDIX N

SELECTED COMMENTS FROM SURVEY

Comments on YIELD TO TRAINS Sign:

Red color catches your attention

Good sign - folks know what YIELD sign means

Silly sign, funny sign

Thought that it meant "two trains"

Thought that it meant "to train station"

Needs to be placed further from crossing

Comments on LOOK FOR TRAINS Sign:

Highly noticeable

Good sign - easy to understand

Stands out at night

Will be good for illiterate or non-English speaking drivers

Effective

Cute, catches your attention

Redundant - people know to look for trains

Comments on Passive Signs at Crossings in General:

Signs not effective, all crossings should have signals and gates

Need to change signs every six months so that drivers won't get used to them

Grade separations are the only effective means to safety at crossings

Drivers are too accustomed to seeing the standard signs

I look to the signal down the track to tell me if it is safe to cross

Comments on the Study in General:

Very glad to see someone is doing something about these crossings

Good project, but still needs signals and gates

Waste of time and money

Hopefully your efforts will save lives