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16. Abstract

This project was established to provide a means of conducting limited scope evaluations of numerous traffic control device issues. During the first year of the study, researchers completed assessments of six issues: dual logo panels in specific service signing, rear-facing beacons for school speed limit sign assemblies, a red border conspicuity treatment for the Speed Limit sign, crashworthiness of a work zone sign support system, retroreflective border for traffic signal backplates, and methods for locating no-passing zones. Evaluation methods included a computer-based driver survey for the dual logo panels, before and after comparisons of vehicle speeds for the rear-facing school beacon and red border conspicuity treatment for the Speed Limit sign, a crash test for the work zone sign support system, red- and yellow-light running for the retroreflective signal backplate, and a synthesis of practices for locating no-passing zones. Based on the results of the evaluations, the researchers recommend that the dual logo sign panels and the rear-facing school speed limit beacons be considered for implementation. Additional evaluations will be conducted for the red border conspicuity treatment for the Speed Limit signs. The sign support system did not pass the crash test criteria and cannot be implemented without refinements and further crash tests. The retroreflective signal backplate border did not indicate beneficial impacts on reducing red- or yellow-light running at night. The synthesis of methods for locating no-passing zones will be distributed to TxDOT personnel for use.

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EVALUATION OF TRAFFIC CONTROL DEVICES: FIRST YEAR ACTIVITIES

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DISCLAIMER

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CHAPTER 1: INTRODUCTION

Traffic control devices provide one of the primary means of communicating vital information to road users. Traffic control devices notify road users of regulations and provide warning and guidance needed for the safe, uniform, and efficient operation of all elements of the traffic stream. There are three basic types of traffic control devices: signs, markings, and signals. These devices promote highway safety and efficiency by providing for orderly movement on streets and highways.

Traffic control devices have been a part of the roadway system almost since the beginning of automobile travel. Throughout that time, research has evaluated various aspects of the design, operation, placement, and maintenance of traffic control devices. Although there have been many different studies over the decades, recent improvements in materials, increases in demands and conflicts for drivers, higher operating speeds, and advances in technologies have created continuing needs for the evaluation of traffic control devices. Some of these research needs are significant and are addressed through stand-alone research studies at state and national levels. Other needs are smaller in scope (funding- or duration-wise) but not smaller in significance.

Unlike many other elements of the surface transportation system (like construction activities, structures, geometric alignment, and pavement structures), the service life of traffic control devices is relatively short (typically anywhere from 2 to 12 years). This increases the relative turnover of devices and presents increased opportunity for implementing research findings. The shorter life also creates the opportunity for incorporating material and technology improvements on more frequent intervals. Also, the capital cost of traffic control devices is usually less than that of these other elements. Research on traffic control devices can also be (but not always) less expensive than research on other infrastructure elements of the system because of the lower capital costs of the devices.

The traditional Texas Department of Transportation (TxDOT) research program planning cycle requires about a year to plan a research project and at least a year to conduct and report the results (often two or more years). With respect to traffic control devices, this type of program is best suited to addressing longer-range traffic control device issues where an implementation decision can wait for two or more years for the research results.

In recent years, elected officials have also become more involved in passing ordinances and legislation that are directly related to traffic control devices. Examples include: creating the logo signing program, establishing signing guidelines for traffic generators such as shopping malls, and revising the *Manual on Uniform Traffic Control Devices* (MUTCD) to include specific signs. When these initiatives are initially proposed, TxDOT has a very limited time in which to respond to the concept. While the advantages and disadvantages of a specific initiative may be apparent, there may not be specific data upon which to base the response. Due to the limited available time, such data cannot be developed within the traditional research program planning cycle.

As a result of these factors (smaller scope, shorter service life, lower capital costs, and the typical research program planning cycle), some traffic control device research needs are not addressed in traditional research program because they do not justify being addressed in a stand-alone project that addresses only one issue. This research project was established to address these types of traffic control device research needs. This project is important for the following reasons:

- It provides TxDOT with the ability to address important traffic control device issues that are not sufficiently large enough (either funding- or duration-wise) to justify research funding as a stand-alone project.
- It provides TxDOT with the ability to respond to traffic control device research needs in a timely manner by modifying the research work plan at any time to add or delete activities (subject to standard contract modification procedures).
- It provides TxDOT with the ability to effectively respond to legislative initiatives associated with traffic control devices.
- It provides TxDOT with the ability to address numerous issues within the scope of a single project.
- It provides TxDOT with the ability to address many research needs within each year of the project.
- It provides TxDOT with the ability to conduct preliminary evaluations of traffic control device performance issues to determine the need for a full-scale (or stand-alone) research effort.

FIRST YEAR RESEARCH ACTIVITIES

During the first year of this research project, the research team undertook the following research activities:

- Evaluate the effectiveness of dual logos (Chapter 2).
- Assess the impacts of rear-facing school speed limit beacons (Chapter 3).
- Evaluate the impacts of improving Speed Limit sign conspicuity (Chapter 4).
- Crash-test a sign support structure (Chapter 5).
- Evaluate the benefits of retroreflective signal backplates (Chapter 6).
- Develop improved methods for locating no-passing zones (Chapter 7).

These activities are described in this report in the chapters indicated in parenthesis. An overall summary for the first year is provided in Chapter 8. Each of the chapters in this report has been prepared so that it can be distributed as a stand-alone document if desired.

CHAPTER 2:
DUAL LOGO SIGNING

INTRODUCTION

Specific service signs are large guide signs with a blue background that provide information to motorists about services available near a particular interchange exit. Graphic images or word messages (business logos) are used to represent a particular business on the sign. For this reason, specific service signs are commonly referred to as logo signs. The *Texas Manual on Uniform Traffic Control Devices* (TxMUTCD) defines specific service signs as "guide signs that provide road users with business identification and directional information for eligible services" (*1*). These signs may be used on any class of highway but are primarily used on interstates and freeways in advance of interchanges. Logo signs in Texas are used to inform the driver of specific services provided at an exit that the driver may need such as food, gas, lodging, and camping. In addition to the four categories described in the TxMUTCD, the national MUTCD also allows logos for some special attractions (*2*). Figure 2-1 shows an example of a logo sign with gas, food, and lodging logos.

Figure 2-1. Specific Service Sign—Three Service Categories and Six Logo Panels.

Study Objectives

Currently, the TxMUTCD and the national MUTCD both allow only one business logo to be placed on a single logo panel. Dual logo panels were proposed by business owners as a solution to the complaint that single businesses operating an expanded menu of services are ignored and unduly restricted to limited highway signing. Business owners are concerned that separate logos do not convey to the public that two brands are available at the same location. Dual logos provide a means of linking services that are combined under the same roof.

The first known application of dual logos began in April 2001 when the Kentucky Transportation Cabinet requested permission from the Federal Highway Administration (FHWA) to experiment with dual logo signs in the field. The experiment is currently and initially limited to same service facilities (two food businesses in the same business space); however, if requests are made by business owners, Kentucky intends to experiment in the future with multiservice facilities such as gas stations with fast food restaurants inside. As of spring 2004, installation of the experimental signs had been delayed, with dual logo signs installed at only one location. As a result, Kentucky has not conducted any evaluations to date of their proposed dual logo signs.

In April 2003, Texas Legislative House Bill No. 1831 was revised to allow dual logos for both same service (i.e., a restaurant that contains two brands/restaurants) and mixed service (i.e., a facility that provides both gas and food brands/businesses) locations in Texas. The use of dual logos raises a variety of concerns related to categorical placement, dual logo recognition/legibility, and information overload:

- **Categorical placement**—Logos are placed on specific service signs according to the type of service. In Texas, service categories include food, gas, lodging, and camping. When a logo panel contains two logos that fall under different service categories, the question raised is one of where to put the logo panel. For example, when a gas station with a fast food restaurant requests a dual logo panel, should that panel be placed under the food or gas category?
- **Dual logo recognition/legibility**—The use of a dual logo panel will likely reduce the size of the individual logos compared to the size of the same logo in a single logo panel. This creates the question of whether drivers will be able to recognize the smaller logos used in a dual logo panel. The smaller size of the logos can also reduce the legibility of the logo panel.

- **Information overload**—Not only does a dual logo present the logo information in a smaller size, it presents more information than would be presented in a sign with only single panels. This creates the potential for information overload in the general proximity of an interchange.

With this research effort, the researcher attempted to address several of these issues through the use of a timed survey where subjects were asked to indicate whether various business logos were present in a series of photographs that included both single and dual logo panels. The ultimate objective was to gain some understanding of whether the use of dual logos would reduce the effectiveness of the logo signs.

The research described herein represented one task of a larger research project focused upon assessing the effectiveness of traffic control devices. The project was sponsored by the Texas Department of Transportation (TxDOT), and the research was conducted by the Texas Transportation Institute (TTI). The task to evaluate logo signing was added to the project in response to legislative activity allowing dual logo panels.

BACKGROUND INFORMATION

Prior to developing the driver survey, the TTI researchers gathered background information about logo signing and related issues.

MUTCD History of Specific Service Signs

Service signs were the predecessors of specific service signs. Service signs are blue background signs with all or a combination of the words "FOOD," "GAS," "LODGING," and/or "PHONE" written in the legend depending upon the available services offered at the next immediate exit. Specific service signs were first incorporated into the MUTCD in the 1971 edition. At that time only two service categories and only two logo panels per service category were allowed on a specific service sign. However, the number of service categories allowed per sign was increased from two to three, and the number of logo panels allowed on each sign was increased from four to six, in the 1988 edition of the MUTCD. Currently minor differences exist between the TxMUTCD and the national MUTCD concerning specific service signs. One of the main differences is that the national MUTCD allows a category for "special attractions"; the

TxMUTCD does not allow a logo category for “special attractions.” Thus there are five possible categories of logos in the national MUTCD and only four in the TxMUTCD.

Eye Movement Research

A literature search found several articles regarding logo signing; however, their subject matter focused on setting up a logo sign database or on the transfer of responsibility for logo signs to an outside agency or contractor. To the researchers’ knowledge, there has been no specific research on the effectiveness of logo signs. Thus, for the literature review, researchers looked elsewhere for applicable material to aid in the development of this experiment. As mentioned previously, one of the concerns is whether the presence of a dual logo on a specific logo panel will present too much information for drivers to process. In order to analyze information overload, researchers looked at eye movement research and found information concerning typical exposure times that a driver requires to understand a sign. In an eye movement study conducted by Bhise and Rockwell, results indicated that a driver uses between 0.5 seconds and 4.0 seconds to read a road sign *(3)*. Most drivers used an average of 1.0 second to 2.5 seconds to comprehend road signs, depending upon the volume of traffic on the road (i.e., in higher volume traffic situations, subjects on average looked at the sign for less time). In Ontario, for an evaluation of prototype tourist signs, 1.5 seconds to 2.5 seconds viewing time was used to measure subjects’ ability to comprehend new pictographs based on an assumption of a 50 mph speed limit and 7.5 inch letter height *(4)*. The time exposures from these two studies were used to select an appropriate time exposure for the pictures of the logo signs in the computer survey for this project.

Current Guidelines and Standards

Currently the guidelines for specific service signs are provided in the TxMUTCD and the Logo Standard Plans. Texas Logos is a logo sign contractor that manages the logo sign program for TxDOT. They are responsible for placing logo signs, producing logo panels, and contacting vendors to see if they would like to participate in the program. They must follow the guidelines given in the TxMUTCD and the Logo Standard Plans. The following paragraphs describe the applicable guidelines and standards given in the TxMUTCD, the national MUTCD, and the Texas Logo Standard Plans.

Both the TxMUTCD and the national MUTCD have placed several limitations on logo signs. The limitations applicable to this research project include:

- no more than three types of services shall be represented on any sign or sign assembly,
- no service type shall appear on more than one sign (in advance of a particular interchange),
- each specific service sign or sign assembly shall be limited to no more than six logo panels, and
- there shall be no more than four logo panels for one of the two service types on the same sign.

Due to the limited number of panels on the sign, dual logos may allow more vendors to participate in the program. The literature review produced no documents justifying the limit of six logo panels on a sign. However, Revision #4 to the 1978 MUTCD significantly revised the MUTCD guidelines for specific services signs, including increasing the maximum number of panels on a sign from four to six. As far as can be determined, there was no research basis for increasing the amount of information that could be presented to drivers in specific service signs when this change was approved.

The Texas Logo Standard sheets provide dimensional information for several variations of the specific service signs. In all specific service sign variations, the dimension of a logo panel is 36 inches high by 48 inches wide. There are seven different sign layout possibilities for signs with the ability to hold six panels. There are five other sign layouts for signs that hold less than six logo panels.

RESEARCH ACTIVITIES

The objective of this research activity was to determine if the use of dual logo signs would have a significant impact on the effectiveness of specific service signs. This objective was met by using a driver survey to assess how well drivers can identify logos in single and dual logo signs. The survey tool was developed as a timed-controlled instrument in order to assess driver accuracy in recognizing whether a specific business was represented in a specific service sign. By comparing the responses for dual logo signs to the responses for single logos, the researchers hoped to get a sense of the impact of dual logos on the overall effectiveness of specific service signs.

Survey Development

The general concept of the survey was to show a subject a series of specific service sign pictures. In each picture of a specific service sign, the subject was asked to indicate whether a specified business was represented in the sign. Subjects gave a response of "yes," "no," or "not sure" to the question of whether a specific business was shown in the specific service sign. There were a total of 40 questions in the survey, plus introductory information. The survey was presented using Microsoft PowerPoint in a timed-controlled presentation. The presentation was presented to subjects using a laptop computer. Appendix 1-A presents the introductory information and the specific service sign images used in the survey.

The survey began with introductory information that explained what logo signs are and then provided instructions on how to answer the survey's questions. Examples of survey questions were provided to prepare subjects for the actual survey questions. The survey also asked some basic demographic questions to record age, zip code, and rural freeway driving experience.

There were three slides for each of the 40 survey questions. The first slide displayed the question to the subject and was thus termed as the "Question Slide." Figure 2-2 shows the format for the "Question Slide." The question wording was identical for all 40 questions except that the name of the business changed in each question. The "Question Slide" was displayed for 4 seconds, and then the presentation automatically advanced to a picture of a specific service sign. This "Picture Slide" presented an image of a specific service sign. To simplify the experiment, all pictures in the survey had two dual logos on the sign, and only logos for food or gas were used. One of two sign layouts was used. One sign layout for the "Picture Slide" is shown in Figure 2-3. This layout is referred to as the 2/4 layout because there are two gas logo panels and four food logo panels. The other sign layout for the "Picture Slide" is shown in Figure 2-4. This layout is referred to as the 3/3 layout because there are three gas logo panels across the top of the sign and three food logo panels across the bottom of the logo sign. Each of these two layouts was modified from two original photographs so that all images for a given layout were the same except for the logo panels. The "Picture Slide" was displayed for a set period of time (0.8, 1.3, or 1.8 seconds as described in the next paragraph), and then the presentation advanced to a slide where the question was restated and the subject was prompted to answer. The third slide was thus termed the "Answer Slide" and was also worded identically for every question except that the name of the business changed. Figure 2-5 shows an example of the format of the "Answer Slide." The answer slide was displayed for 4 seconds before the presentation advanced to the next "Question Slide."

The time of exposure for the "Picture Slide" was varied to assess the accuracy of subject response as a function of exposure time. Two different surveys were administered with different exposure times. In the first survey set (Survey Set A), the exposure times were 0.8 and 1.3 seconds. In the second survey set (Survey Set B), the exposure times were increased by 0.5 seconds so that those slides that had been exposed for 0.8 seconds were shown for 1.3 seconds, and the slides that had been exposed for 1.3 seconds were shown for 1.8 seconds.

A researcher administered the survey to each subject. Subjects gave their answers verbally, and the researchers recorded the responses on a paper answer sheet. To discourage guessing, 16 of the 40 questions did not display the logo of the business identified in the question.

The survey consisted of 40 questions. Of the 40 questions, 16 asked about a business that was located on a dual logo panel, 8 asked about a business that was represented on a single logo panel, and 16 asked about a business whose logo did not appear on the specific service sign shown. Questions were subdivided by whether or not the logo was a familiar chain (based on researchers' subjective judgment of familiarity within Texas), and dual logos were further subdivided by whether the subject was asked about the first or second logo that appeared within a dual panel. If the logo was located on the left, top, or upper left position within a logo panel, it was considered in the first position. If the logo was located on the right, bottom, or lower right position within a logo panel, it was considered in the second position. Table 2-1 shows the distribution of questions for each subdivision of the data.

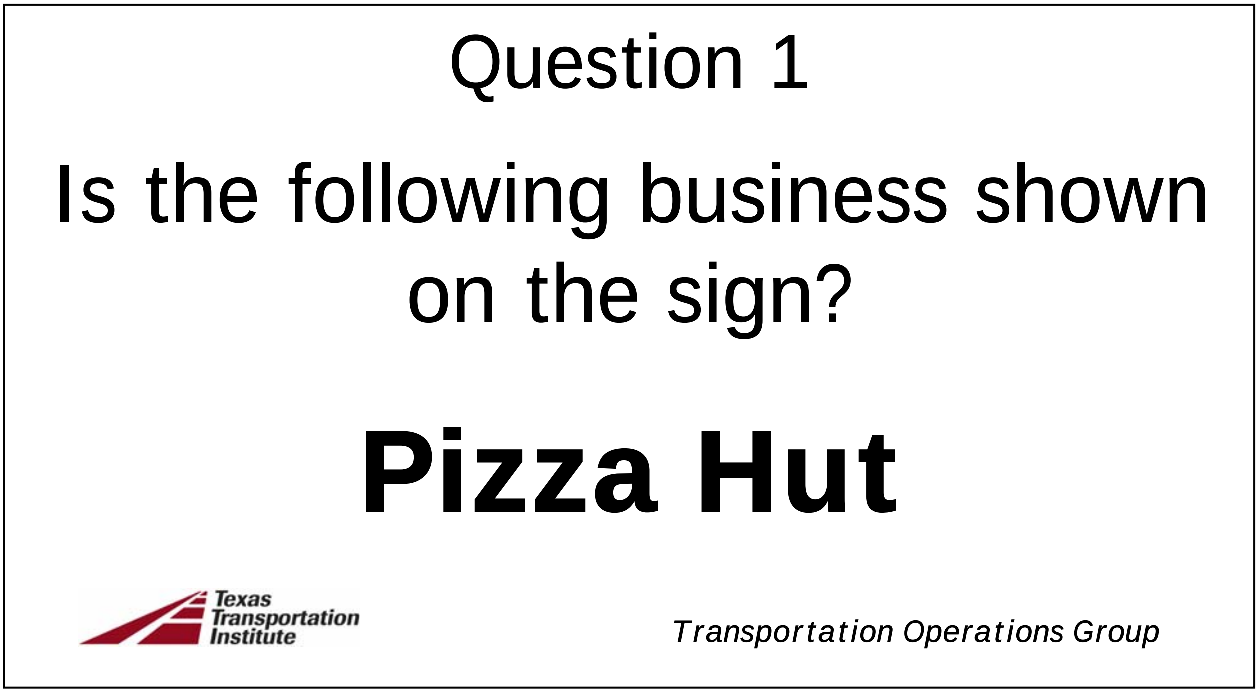

Figure 2-2. Example of the "Question Slide."

Figure 2-3. Example of the 2/4 Specific Service Sign "Picture Slide."

Figure 2-4. Example of the 3/3 Specific Service Sign "Picture Slide."

Answer Question 1

Was a

Pizza Hut

logo on the sign?

YES NO NOT SURE

Texas Transportation Institute *Transportation Operations Group*

Figure 2-5. Example of the Format for Each "Answer Slide" in the Survey.

Table 2-1. Characteristics of the Survey Questions.

Type of Logo	Familiarity	Dual Logo Position	Number of Questions
Dual—Food/Food	Known	First	2
		Second	2
	Unknown	First	2
		Second	2
Dual—Gas/Food	Known	First	0
		Second	1
	Unknown	First	2
		Second	0
Dual—Food/Gas	Known	First	2
		Second	3
	Unknown	First	0
		Second	0
Single—Food	Known	N/A	2
	Unknown	N/A	2
Single—Gas	Known	N/A	2
	Unknown	N/A	2
None—Food	Known	N/A	5
	Unknown	N/A	4
None—Gas	Known	N/A	5
	Unknown	N/A	2

Survey Administration

The survey was administered to individual subjects at three locations in Texas: the Bryan Department of Public Safety (DPS) driver's license office, a San Antonio DPS driver's license office, and on the Texas A&M University campus. The total survey sample for both survey sets (A and B) was 205 subjects. The sample size for Survey Set A (0.8 and 1.3 seconds for exposure times) was 132. The sample size for Survey Set B (1.3 and 1.8 seconds for exposure times) was 73. The surveys were administered by researchers using a laptop computer. Potential subjects were approached and asked if they would like to participate in a survey. Those that responded positively were seated in front of the laptop, and the PowerPoint presentation was initiated. The survey took less than 10 minutes to complete. After completing the survey, subjects were given a state highway map for participating in the survey.

Research Analysis

The subject responses were entered into a spreadsheet for analysis. The data collected from Survey Set A and Survey Set B were analyzed separately. The data from the survey were analyzed using the Chi-Square test for goodness of fit. One important assumption for this test is that data come from independent samples. While this is not entirely true for the samples, researchers assumed that each subject evaluated each picture independently. This analysis technique was used for a similar study in Ontario that examined subjects' ability to interpret new tourist signs (*4*). An a priori decision was made to only analyze the simple effects of the data because the Chi-Square analysis does not provide a way to analyze the interactions for a large number of independent variables.

The Chi-Square analysis was used to compare the proportions of correct responses for single logos to the proportion of correct responses for dual logos at a single time exposure. Initially all the familiar and unfamiliar logos were included in the same analysis. Then the data were split into familiar and unfamiliar logo data, and each was analyzed separately.

A final Chi-Square analysis was performed comparing dual logos with two different types of services—such as gas and food services located in the same panel. One of the concerns is the impact of placing a gas and food dual logo panel under the gas service category—would drivers recognize the presence of the food service under the gas category? Likewise, for a food and gas logo panel located under food, would drivers recognize the gas service? When two different services were included in the same logo, the researchers placed the dual logo under the category of the first logo on the panel (as previously mentioned, the first logo was considered either the top or left logo on the panel). Thus, the data from questions about dual logos with food located in the top or left corner and gas in the bottom or right corner of the panel (in the food category) were compared to logos with gas in the top or left corner with food in the bottom or right corner of the logo panel (located in the gas category).

Initially the correct response rate for both familiar and unfamiliar data was included in the same Chi-Square analysis. The data were analyzed using an alpha of 0.01. A smaller alpha was used than would normally be used because the simple effects were analyzed and not the experiment effects. The alpha for the experiment is actually larger than the alpha for the simple effects.

RESEARCH FINDINGS

The overall results for the two survey sets are shown in Table 2-2. Appendix 1-B presents the results for individual questions. As can be observed from the data in the table, there are significant differences in response rates for the familiar and unfamiliar logos. The differences between single and dual logo response rates are somewhat hidden when viewed within the context of the total data set. Figure 2-6 presents a graphical presentation of the data in Table 2-2.

Chi-Square Analysis for All Data

As previously stated, the first Chi-Square analysis compared the proportion of correct response rates for single logos to the proportion of correct response rates for dual logos at a given time exposure regardless of whether the data pertained to familiar or unfamiliar logos. Table 2-3 shows the results for the first Chi-Square analysis, referred to hereafter as the all data Chi-Square analysis. For both time exposures in Survey Set A (0.8 and 1.3), the proportion of correct responses for dual logos was statistically significantly lower than the proportion of correct responses for single logos, but there was no difference in the correct response rate between single and dual logos for Survey Set B. For Survey Set A at 0.8 seconds, single logos were correctly identified 10 percent more often than dual logos, and at 1.3 seconds single logos were correctly identified 8 percent more often than dual logos. Notice also that there was a significant difference between the proportion of single and dual logo correct response rates at 1.3 seconds between Survey Set A and Survey Set B. There are several possible reasons for this. First, the populations may not be comparable. This could be due to any number of differences in demographic characteristics. Thus, researchers compared the correct response rate for the example question which was the same in both surveys (i.e., same picture, same question, and same time exposure) and found there was no significant difference in the correct response rate between Survey Set A and Survey Set B. Remember the questions in Survey Set A at 1.3 seconds were the same questions shown at 1.8 seconds in Survey Set B. So another possible explanation is that the logos that were shown at 1.3 seconds in Survey Set A and 1.8 seconds in Survey Set B were simply harder to identify than those shown at 0.8 seconds in Survey Set A and 1.3 seconds in Survey Set B. It will become more obvious in the following Chi-Square analyses that the latter explanation seems to be the case.

Table 2-2. Percent Correct Response Rate.

Logo Panels	Survey Set	Exposure Time (Seconds)	Type of Logo		
			Single	Dual	None
All Logos	A	0.8	74%	64%	62%
		1.3	75%	67%	79%
	B	1.3	84%	77%	78%
		1.8	85%	80%	86%
Familiar Logos	A	0.8	89%	70%	68%
		1.3	92%	72%	84%
	B	1.3	90%	79%	77%
		1.8	96%	82%	93%
Unfamiliar Logos	A	0.8	60%	53%	58%
		1.3	58%	57%	74%
	B	1.3	77%	75%	78%
		1.8	74%	75%	80%

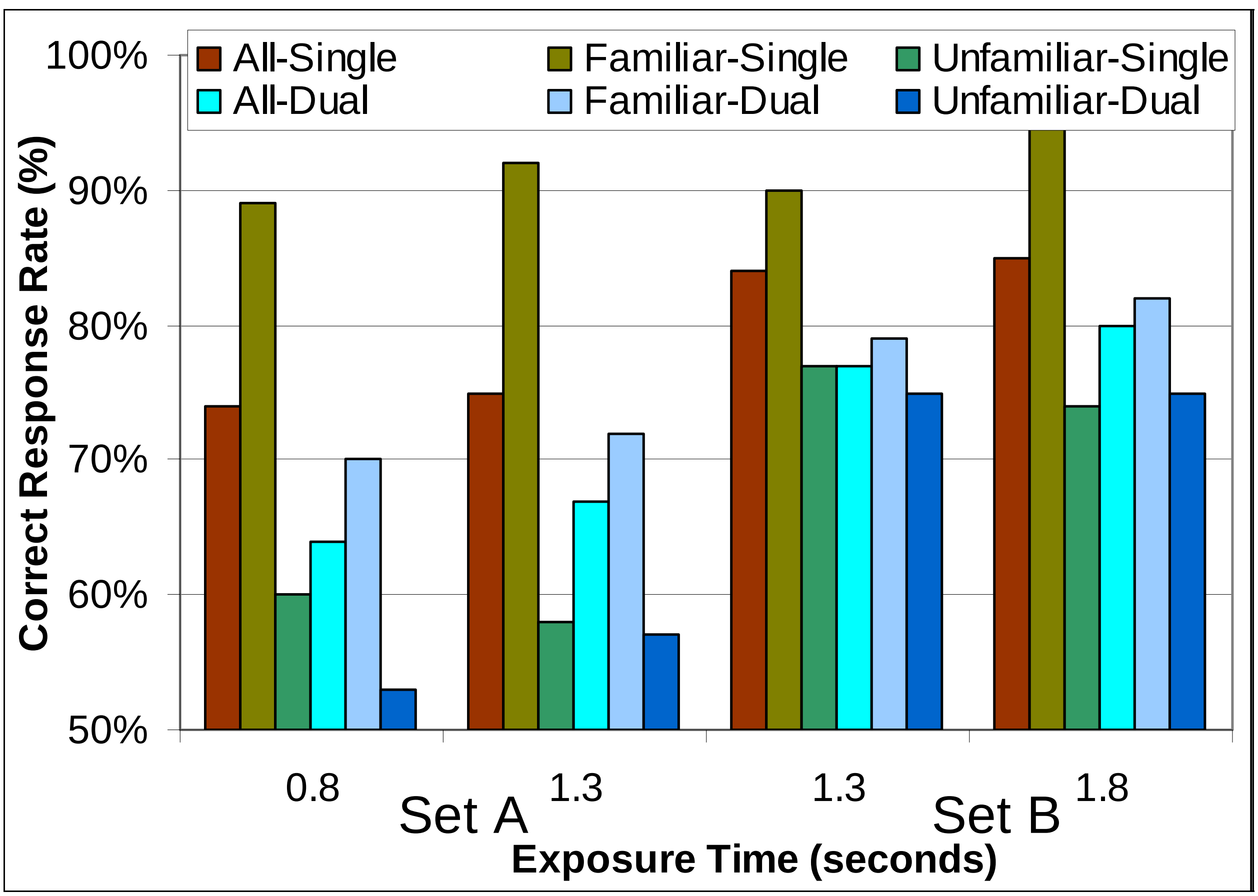

Figure 2-6. Graphical Representation of Survey Results.

Table 2-3. Results for Chi-Square All Data Analysis.

Type of Logo	Set A—% Correct for Exposure Time		Set B—% Correct for Exposure Time		Significant Difference between 1.3 Second Exposures for Sets A and B
	Subset 1 0.8 Seconds	Subset 2 1.3 Seconds	Subset 1 1.3 Seconds	Subset 2 1.8 Seconds	
Single	74	75	84	85	Yes
Dual	64	67	77	80	Yes
Significant Difference between Single and Dual?	Yes	Yes	No	No	

Since there was a significant difference between the correct response rates at 1.3 seconds between Survey Sets A and B, the proportions at the three different time periods cannot be compared. However, the questions at 0.8 seconds for Survey Set A and the questions at 1.3 seconds for Survey Set B were the same, and the example question showed the demographic samples were comparable. The same is true for the questions at 1.3 seconds in Survey Set A and the questions at 1.8 seconds in Survey Set B. Figure 2-7 shows a graphical representation comparing the single and dual logo correct response rates for Subset 1 and Subset 2. Correct response rates for dual logos are represented by dashed lines, and correct response rates for single logos are represented by solid lines. The major point to notice from this figure is that at the differences for correct response rates between single and dual logos decreases as the time exposure increases.

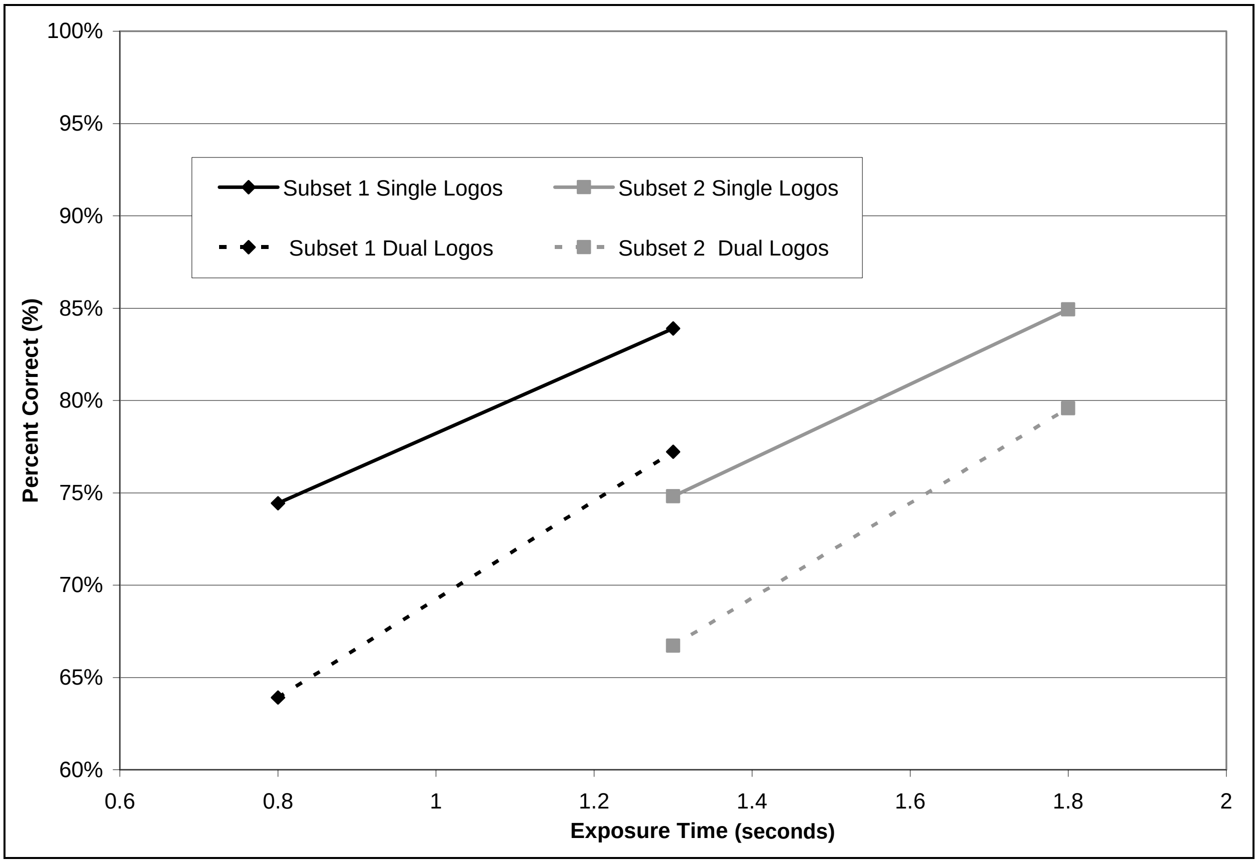

Figure 2-7. Comparison of Proportions Correct between Dual and Single Logos for Subsets 1 and 2.

Chi-Square Analysis for Familiar Data

Researchers hypothesized that subjects would be able to identify a higher percentage of familiar logos than unfamiliar logos. For this reason the data obtained from questions about familiar logos were separated and analyzed independently. Table 2-4 shows the results for the Chi-Square analysis for the familiar logos data. There was a statistically significant difference between the correct response rate for single logos and the correct response rate for dual logos at all time exposures. The differences between the correct response rates for single and dual logos were more dramatic for the familiar data than the total data set discussed previously. For Survey Set A, the difference between the correct response rates for single and dual logos was 19 percent and 20 percent at 0.8 seconds and 1.3 seconds, respectively. This can be compared to a difference of only 10 and 8 percent for 0.8 second and 1.3 second exposure times, respectively, for the total data analysis. This suggests that the unfamiliar data seem to be leveling the difference for the correct response rate between single and dual logos for the total data analysis. As for Survey Set B, the difference between single and dual logos proportions correct were

12 and 13 percent for 1.3 second and 1.8 second exposure times, respectively, for the familiar logo data. Remember, no significant differences were found in the total data Chi-Square analysis for the Survey Set B data. Again this result supports the theory that the unfamiliar data are biasing the proportions in the total data analysis.

Table 2-4. Chi-Square Analysis for Familiar Logos.

Type of Logo	Set A—% Correct for Exposure Time		Set B—% Correct for Exposure Time		Significant Difference between 1.3 Second Exposures for Sets A and B
	Subset 1 0.8 Seconds	Subset 2 1.3 Seconds	Subset 1 1.3 Seconds	Subset 2 1.8 Seconds	
Single	89	92	90	96	No
Dual	70	72	79	82	No
Significant Difference between Single and Dual	Yes	Yes	Yes	Yes	

The proportions correct at 1.3 seconds were again compared between Survey Set A and Survey Set B for both single and dual logo types. There was no significant difference found between the proportion of correct responses for single logos for Survey Set A and the proportion of correct responses for single logos for Survey Set B at 1.3 seconds. Because there is no difference between the correct response rates between Survey Set A and Survey Set B data at 1.3 seconds, the data can be compared across time exposures. A graphical representation of this comparison is represented in Figure 2-8. The data at 1.3 seconds in Figure 2-8 are an average of the data at 1.3 seconds for Survey Set A and Survey Set B.

As shown in Figure 2-8, trendlines were generated for single and dual familiar logo data. It can be seen that the difference in correct response rates for single and dual logos decreases as the time exposure increases. The trendlines were extended to solve for the time exposure at which the correct response rates were equal. This time exposure represents the amount of time necessary for the proportion of familiar dual logos recognized to equal the proportion of familiar single logos recognized. The time exposure for which the two trendlines have equal correct response rates was 3.6 seconds, which correlated to a percent correct of 109 percent. However, it is not possible to have a correct response rate over 100 percent. This indicates that using the trendlines to predict response rates as a function of exposure time may not provide accurate results.

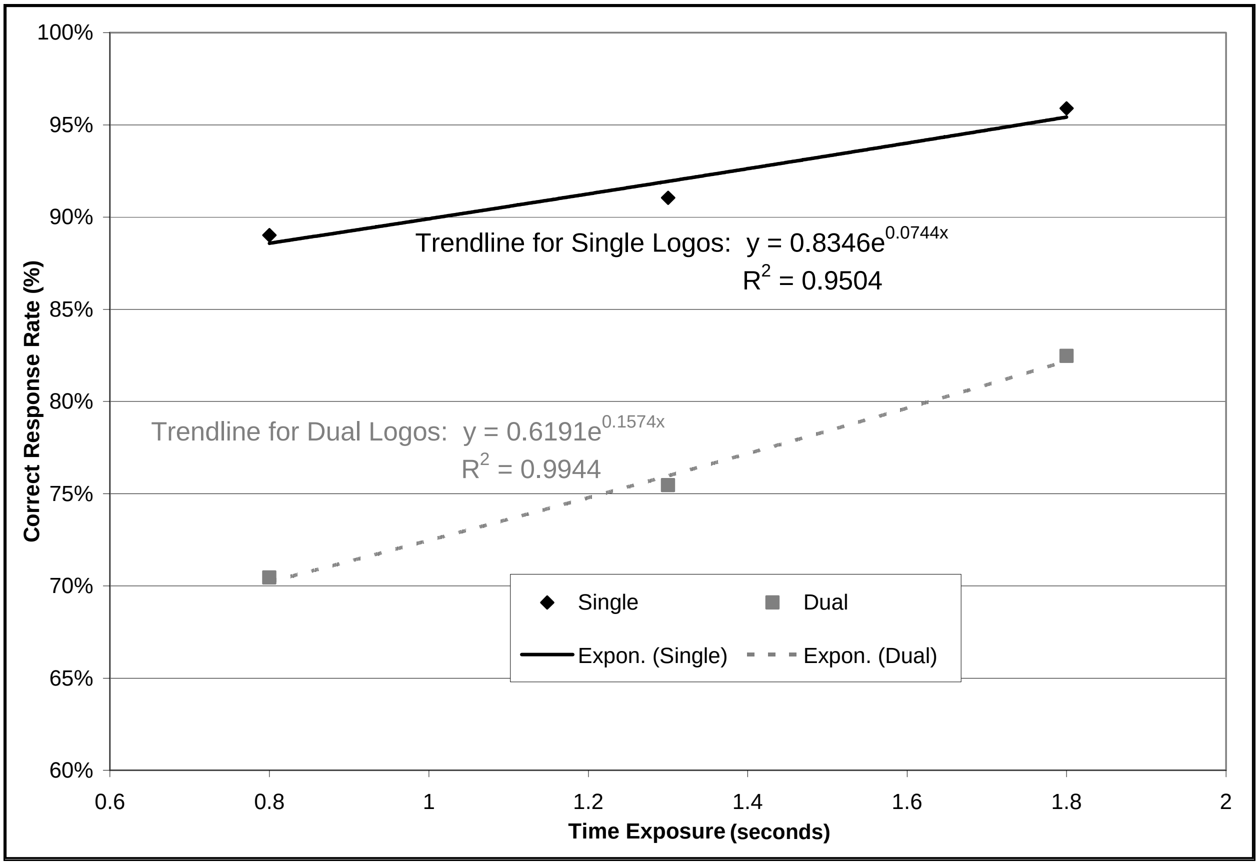

Figure 2-8. Comparisons of Proportions Correct between Single Logos and Dual Logos for Familiar Data.

Even though it may not be accurate to generalize the data beyond the tested evaluation times, the researchers considered the potential response rates for an exposure time that may be typical for real-world situations. As indicated previously in this paper, Bhise and Rockwell found that drivers can view a sign for up to 2.5 seconds (3). By using a 2.5 second viewing time in the trendline equation for familiar single and dual logos, the resulting correct response rate is 100 percent for single logos and 92 percent for dual logos. The 8 percent difference is small and believed to be within the normal variation that can be expected in field observations of driver understanding of traffic signs. However, as indicated previously, it may not be appropriate to predict response rates as a function of exposure time.

Chi-Square Analysis for Unfamiliar Data

For the unfamiliar logo Chi-Square analysis, the data concerning the logos that were considered unfamiliar were separated and analyzed independently. From the total data Chi-Square analysis, it was hypothesized that the unfamiliar data were lowering the average values for the single logos and affecting the data at 1.3 seconds. The results of the Chi-Square analysis for the unfamiliar data, shown in Table 2-5, confirm this hypothesis. The proportions of correct responses for the unfamiliar single logos are 29 and 34 percent lower than the proportions of correct responses for the familiar single logo data at 0.8 seconds and 1.3 seconds, respectively, for Survey Set A. For Survey Set B, the corresponding differences are 13 and 22 percent lower than the familiar single logo data at 1.3 seconds and 1.8 seconds, respectively.

Table 2-5. Chi-Square Analysis for Unfamiliar Logos.

Type of Logo	Survey Set A Percent Correct (%)		Survey Set B Percent Correct (%)		Significant Difference between 1.3 Second Exposures for Sets A and B
	Subset 1 0.8 Seconds	Subset 2 1.3 Seconds	Subset 1 1.3 Seconds	Subset 2 1.8 Seconds	
Single	60	58	77	74	Yes
Dual	53	57	75	75	Yes
Significant Difference between Single and Dual?	No	No	No	No	

Notice also that for both Survey Set A and Survey Set B the correct response rates for the longer time exposure were slightly lower than the correct response rates for the shorter time exposure. This indicates that the unfamiliar logos at the longer time exposure were more difficult to identify, for whatever reason, than the unfamiliar logos at the shorter time period. The cause of this was probably the fact that some logo designs are easier to process and thus the subject was able to identify them easier even with less time. Also notice that no significant differences were found between the proportion of correct responses for single and dual logos at a given time period. This indicates that unfamiliar logos influenced a subject's ability to identify the logo far more than whether the logo was on a single or dual panel.

As in the total data Chi-Square analysis, the data at 1.3 seconds in Survey Set A were significantly different from the data at 1.3 seconds in Survey Set B.

Chi-Square Analysis Comparing Dual Logos in Different Categories

The purpose of this analysis was to compare multiple category (gas and food) dual logos when the business needing to be identified was placed in either the appropriate category or an inappropriate category. In this experiment, dual logo panels were placed in categories according to the first logo shown on the panel. Therefore, if a question was asked about the second logo in the panel, it could be placed in a category not related to the subject of the service. For example, the BP/A&W logo panel in Figure 2-3 is placed under the gas category because the first logo provides a gas service. However, if the question asked the subject whether the A&W logo was present on the sign, the question was focused upon a misplaced logo service.

Table 2-6 shows the results of the Chi-Square analysis. There were no significant differences between the proportions in a given time period regardless of whether the logo was located under the appropriate category. Remember, each time the second logo was requested, the logo the subject was trying to find was under a mismatched category (i.e., a gas logo under the food category or a food logo under the gas category).

Table 2-6. Chi-Square Analysis Dual Logos in Different Categories.

Type of Logo (with Position of Sign Addressed in Question)	Survey Set A Percent Correct (%)		Survey Set B Percent Correct (%)		Significant Difference between 1.3 Second Exposures for Sets A and B
	Subset 1 0.8 Seconds	Subset 2 1.3 Seconds	Subset 1 1.3 Seconds	Subset 2 1.8 Seconds	
Dual Logo 1st Position	70	74	75	82	No
Dual Logo 2nd Position	59	69	77	82	No
Significant Difference between Single and Dual	No	No	No	No	

There were also no significant differences detected between the proportions at 1.3 seconds in Survey Set A compared to the proportions at 1.3 seconds in Survey Set B. This indicates that the data can be compared between the different time exposures. Figure 2-9 shows a graphical comparison of the proportion of correct responses at each time exposure. The data at 1.3 seconds are an average of the data from Survey Set A and the data from Survey Set B. As can be seen, even though there is no statistically significant difference, the expected trend exists. The difference in the correct response rate between the logo/logo-1st position category and the logo/logo-2nd position category decreases as the time exposure increases. At 1.8 seconds there is no difference between the two. This result, coupled with the results from the familiar data

Chi-Square analysis, indicates that there is no reason to prevent the use of dual category dual logos.

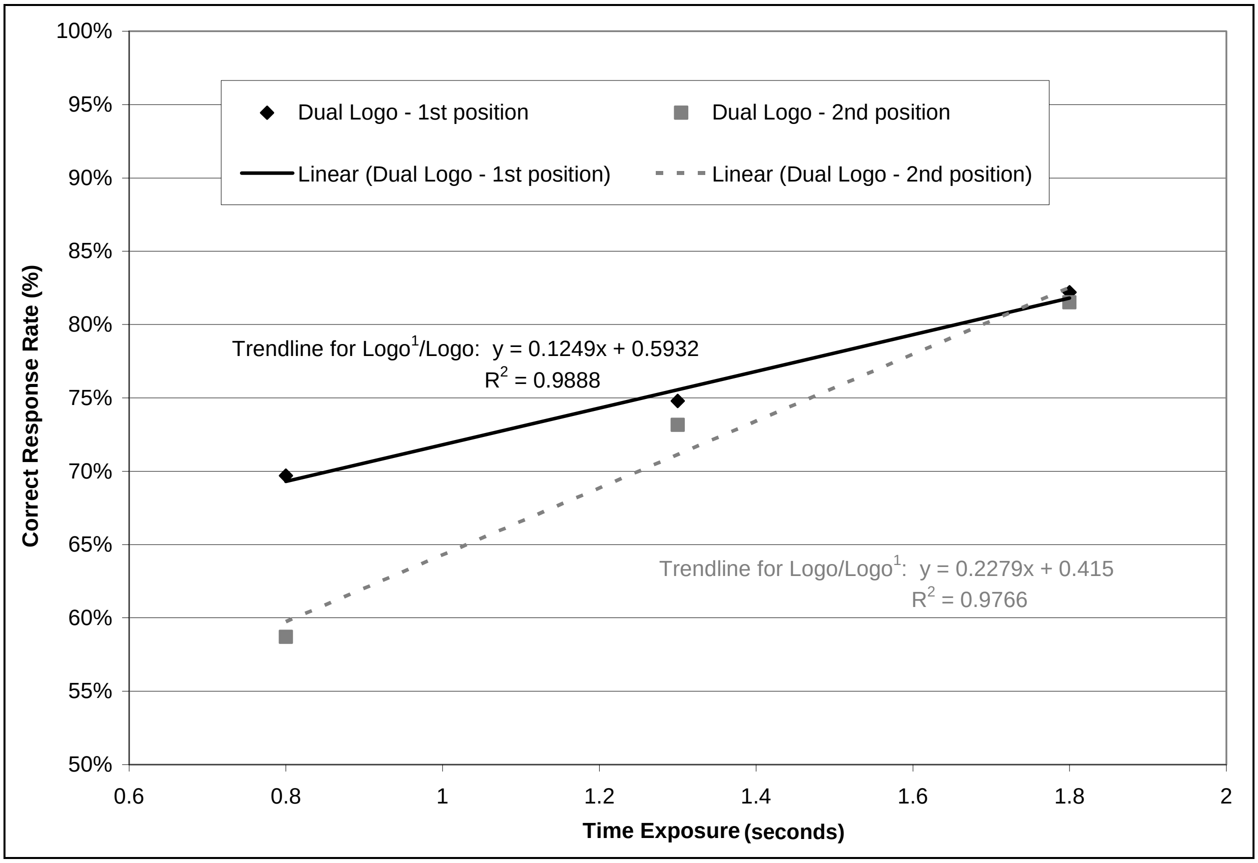

Figure 2-9. Comparing Proportions Correct for Dual Logos in Different Categories.

SUMMARY OF FINDINGS

The following findings summarize the results of the data analysis:

- The results for all data combined disguised significant trends that became apparent by analyzing the familiar and unfamiliar logos separately.
- Single familiar logos were correctly recognized more often than dual familiar logos.
- The difference in correct response rate between single and dual familiar logos diminished with longer time exposures.
- The exposure time at which the single and dual familiar logos were estimated to have equal correct comprehension rates was estimated to be over 3 seconds.

- The ability to recognize a logo is more dependent on driver familiarity with the logo than whether the business is located in a dual or single panel.

RECOMMENDATIONS

The results of the driver survey of dual logos indicate that dual logos have lower comprehension levels at the shorter response times but that, in general, the difference in recognition levels between single and dual logos decreases as the exposure time increases and as driver familiarity with the business increases. Based on these findings, the researchers offer the following recommendations:

- The research results did not indicate a need to prohibit the use of dual logo panels.
- Because the research evaluation did not include a field evaluation, the initial implementation efforts should be closely monitored for potential adverse operational or safety impacts.
- Dual logo panels may be implemented on specific service signs with qualifications:
    - To minimize the potential for information overload and to maximize the legibility of specific service signs, dual logos should be utilized on a specific service sign only when all available logo panels are already in use and there is no room for additional logos.
    - The research did not evaluate the maximum number of dual logo panels that should be presented on a single specific service sign. The signs evaluated in the survey contained two dual logo panels, and the researchers recommend that this be the maximum number of dual panels permitted on a specific service sign. Additional evaluations may be necessary to determine whether more than two dual logos should be permitted.
- The research found that mixing food and gas logos in a dual logo panel did not significantly impact the effectiveness of the dual logo.
- Another factor supporting the implementation of dual logo panels is that there are no design standards for logo panels other than the overall size of the panel. While traffic signs have well-established standards defining the size and font for the legend, logo panels can take any appearance. As a result, a well-designed dual logo may have greater legibility than a poorly designed single logo. The lack of logo

panel design criteria makes it difficult to restrict the use of dual logos based on performance criteria.

REFERENCES

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CHAPTER 3: REAR-FACING SCHOOL SPEED LIMIT BEACONS

INTRODUCTION

Achieving safe speeds on our roads is a challenge in many different roadway scenarios. In school zones it is particularly important for drivers to travel at safe speeds. During school zone times more situations are created that require the driver to pay attention and react. For example, more vehicles will be slowing down to enter the school, more vehicles will be entering the traffic stream leaving the school, and potentially more pedestrians will be on the road. Despite important reasons for drivers to maintain a safe speed through the school zone, compliance with school zone speed limits remains a challenge. Several reasons for this noncompliance have been hypothesized and researched. Two important findings were:

- Motorists' noncompliance with school speed limits is a direct result of minimal or no police enforcement (*1*).
- The reluctance of drivers to follow School Speed Limit signs worsens if the school speed limit reduction is unreasonably low, regardless of the signage used (*2*, 3).

These findings suggest that without police enforcement, many drivers do not comply with school speed limits possibly because they find these speed limits to be excessively low. However, it is possible that under certain circumstances, noncompliance may actually occur because drivers' attention is diverted to other tasks, causing them to forget that they are in a school speed zone. These circumstances may include excessively long school speed limits and school speed zones bisected by a stop-controlled or signalized intersection.

Experimental Treatment

The flashing beacon that is often used with school speed limits is intended to inform drivers entering a school speed limit zone that the school speed limit is in effect. However, once they enter the zone, there is no active means of reminding drivers that they are still in the school speed limit zone. This is not normally an issue, unless one of the circumstances described above exists and there is a potential for drivers to forget that they are subject to the reduced speed limit. The research team believes that an active device located within the school speed limit zone would provide the most effective means of reminding drivers to maintain a reduced speed. The most efficient means of providing this type of device is to mount a rear-facing beacon on the

School Speed Limit sign assembly. The front and back of such an installation is pictured in Figure 3-1. Each beacon was aimed in a rear-facing manner towards traffic already in the school zone. The flashing rate was identical to the front-facing beacons—approximately 1 flash per second. The rear-facing beacons were mounted on the left side of the street (as opposed to the right side) to utilize the power source from the existing front-facing beacons. Because power is already provided to the assembly, the only additional cost is that associated with the installation of the rear-facing beacon and the End School Zone sign. Because the rear-facing beacon and associated sign are located on the left side of the roadway, there should be an End School Zone or Speed Limit sign on the right side of the roadway although this sign installation will not have the rear-facing beacon.

Figure 3-1. Rear-Facing Beacon Installation.

Study Objectives

The objective of this research was to determine whether a rear-facing flashing amber beacon mounted at the end of a school speed zone would improve compliance with the school speed limit for vehicles traveling in the school speed zone.

Study Design

The study design for this effort was a classic before and after study. At the selected study sites, the researchers collected speed data when the school speed limit was in effect and during a period before or after the school speed limit was in effect. After collecting the data, the researchers worked with the responsible jurisdiction to have a rear-facing beacon installed on the School Speed Limit sign assembly. The researchers then returned to the study site to collect the same data as collected in the pre-treatment condition.

LITERATURE REVIEW

The use of rear-facing beacons is not new, but there has been little evaluation of their effectiveness. In spring 2003, Gates et al. conducted an independent one-site evaluation of a rear-facing beacon installation at an elementary school in College Station, Texas (*4*). That evaluation was used as the model for this study. Several positive effects were observed after the installation of the rear-facing beacon in that study. A 1 mph statistically significant reduction in average speeds was observed as well as a reduction of 2 to 3 mph in the 85th percentile speeds. Also, a small reduction in the variance of traffic speeds was found after the installation of the rear-facing beacon. One of the recommendations that came from the study was to include an End School Zone sign below the rear-facing beacon to inform the motorists of the purpose of the rear-facing beacon. The study included a brief summary of several studies performed on school area safety treatments. The studies predominately evaluated the effectiveness of various traffic control treatments in improving compliance of the school speed limits. These countermeasures included: flashing beacons, special sign messages, and special pavement markings. Table 3-1 is a reproduction of the major finding from the literature review performed in the previous evaluation.

Table 3-1. Literature Summary of School Area Traffic Control Devices.

Author	School Zone Treatment(s)	Measures of Effectiveness	Primary Finding(s)
Schrader (1)	• Post-mounted yellow beacons • Transverse lavender stripes • Spanwire-mounted flashing yellow beacons • Fiber-optic signs with the message "School Speed Limit 20" • 2.44 m legends reading "20" painted on the pavement at the entrance to the school zone	Speed Reduction	• Fiber-optic speed limit signing produced a statistically significant long-term decrease in mean speed of 3 mph. • All other treatments, including flashing beacons, were mostly ineffective in the long term.
Hawkins (2)	• 25 mph school zone speed limit signs with twin post-mounted flashing beacons	Speed Reduction	• Mean speeds were significantly reduced in the long term by an average of 7 percent at all four treatment sites.
Saibel et al. (5)	• Signs indicating specific times for the 20 mph speed limit • Signs with yellow beacons that flashed during school zone hours • Signs indicating that the 20 mph speed limit was in effect when children were present • Signs indicating that the 20 mph speed limit was in effect when a pair of orange flags were attached to the sign post	Speed Reduction	• School zone speed limit signs with flashing lights were effective in reducing school zone speeds.

FIELD EVALUATION

Four sites were selected to evaluate the rear-facing beacon (RFB). Two sites were selected that were intersected by a signalized intersection; one site was selected that was considered an unusually long school zone; and one site was selected that was considered a normal length school zone. The data from one additional site will also be reported. Table 3-2 summarizes the key characteristics of the four study sites. The following section describes each site in greater detail.

Table 3-2. Summary of Study Site Characteristics.

Site Name	Length (ft)	Normal Speed Limit (mph)	School Speed Limit (mph)	Road Cross Section
Thorndale	2675	45	30	4 lanes + TWLTL
Brenham	1820	45	30	2 lanes + TWLTL
Huntsville	1750	50	30	4 lanes + TWLTL
College Station	1000	35	20	2 lanes + TWLTL

Description of Study Sites

Site 1 is located on US 79 in Thorndale, Texas. The school zone is 2675 ft long, and a signalized intersection is located within the boundaries of the school zone. Traveling west, the signalized intersection is located about 1825 ft from the end of the school zone. An RFB and End School Zone sign were installed on the rear side of the east-facing school zone beacon and school zone speed limit sign. Figure 3-2 shows a closeup of the RFB and End School Zone sign on US 79. The cross section at this location consists of five lanes with two lanes in each direction and a two-way left-turn lane (TWLTL). The speed limit on the road is 45 mph when the school zone is not active. Figure 3-3 is a picture taken from the westbound lanes to illustrate what the driver sees when exiting the school zone. The school zone is active Monday through Friday (when school is in session) from 7:15 to 8:45 am and from 2:30 to 4:15 pm. The school zone speed limit is 30 mph. The school zone is active for an unusually long period of time in both the morning and the afternoon because there are four different schools within the zone—an elementary school, a middle school, a high school, and a small private school.

Figure 3-2. Site 1—Thorndale Schools, Closeup of RFB.

Figure 3-3. Site 1—Thorndale Schools, Long School Zone with a Signalized Intersection.

Site 2 is another school zone with a signalized intersection within its boundaries. Site 2 is located in Brenham, Texas, on Business 36 (North Park Street) and runs adjacent to the Brenham High School campus. Site 2 is about 1800 ft long. The intersection is located about 1000 ft from the end of the school zone traveling southbound. The cross section at this location consists of three lanes—one lane in each direction and one TWLTL. The school zone is active between 7:45 and 8:45 am and between 3:30 and 4:30 pm. Figure 3-4 shows the RFB at Site 2.

Figure 3-4. Site 2—Brenham High School, School Zone with a Signalized Intersection.

Site 3 is located in Huntsville, Texas, on US 190. This site was selected because it is a long school zone with no stop- or signal-controlled intersections. The school zone is about 1750 ft long and is located on a five-lane road (two lanes in each direction with a TWLTL). The speed limit within the school zone is 30 mph when the school zone is active and 45 mph when the school zone is not active. However, the speed limit increases to 50 mph as the driver exits the school zone traveling in the eastbound direction because the driver is leaving a small town area and entering a more rural area. An elementary school and an intermediate school are located within the school zone. The school zone is active from 7:25 to 8:10 am and from 3:15 to 4:00 pm. Figure 3-5 shows a photograph of the westbound direction school zone sign. The eastbound traffic saw the RFB on this sign.

Figure 3-5. Site 3—Scott Johnson Elementary and Huntsville Intermediate, Long School Zone.

Site 4 is located in College Station on Anderson Street. The speed limit on this road when the school zone is not active is 35 mph and 20 mph when the school zone is active. The cross section at this site consists of three lanes for motor vehicle traffic—one lane in each direction and a TWLTL and a bike lane on either side of the roadway that runs through the length of the school zone but tapers off shortly after the end of the school zone. The school zone is active at this site Monday through Friday (when school is in session) from 7:45 to 8:45 am and from 3:15 to 4:00 pm. This site is about 1000 ft long and was considered an average length for a school zone. Figure 3-6 is a picture of the RFB at Site 4. Anderson Street T-intersects with George Bush 200 ft beyond the far north end of the school zone. Researchers collected speed data for the southbound traffic at this site. Researchers assumed that since speed limits were low at this site, drivers would have plenty of distance to reach the speed limit before they were tracked through the end of the school zone.

Figure 3-6. Site 4—A&M Consolidated Middle School and Oakwood Intermediate School, Average Length School Zone.

Data Collection Procedures

To test the effectiveness of the rear-facing flashing beacon, speeds of vehicles were measured while they traversed the last several hundred feet of the school zone at each site. The rear-facing beacon was visible at each site for a greater distance than the distance researchers were able to track the vehicles. Horizontal and vertical curvature and heavy tree cover were sight obstructions that limited the distance vehicles were tracked. At three sites, no pedestrian crosswalks existed in the speed measurement section. At Site 4 in College Station, however, a crosswalk existed within the section, but no pedestrians crossed during the study. Police officers informed researchers that very few pedestrians crossed the road at this school zone. Speeds were collected at each site before the RFB and End School Zone sign were installed, and again shortly after the treatment was installed. Data were collected in only one direction at each site. This study is intended to show the short-term novelty effects of this treatment.

Data were collected during four different intervals (active school zone morning, active school zone afternoon, non-active school zone morning, and non-active school zone afternoon) both before and after installation of the rear-facing beacon and End School Zone sign. Data were collected when school zone speed limits were both in effect (beacons flashing) and not in effect (beacons not flashing), the latter of which was used as control data. Data were only collected under dry pavement conditions.

The data collector used a handheld light detection and ranging (LIDAR) device, to continuously measure speeds and distances of individual vehicles as they traversed through the study site. When tracking individual vehicles, the LIDAR unit was capable of four speed/range measurements per second. Speed and range data were instantaneously recorded and stored in a laptop computer that was connected to the LIDAR device via serial cable. The data collector was positioned near the edge of the street in the same location during each data collection period at each site; thus the effect of cosine error on the speed data was considered negligible. The data collector also noted the lane positioning (right versus left) of each vehicle for which speeds were measured.

Certain constraints were placed on sample vehicles in an effort to reduce data collection bias. Representative vehicles met the following requirements:

- passenger vehicle (cars, pickup trucks, vans, and sports utility vehicles) not towing trailers;
- uninfluenced by other vehicles;
- traversing the entire study site;
- non-erratic behavior (lane changing); and
- greater than a 6 second headway.

The local police were informed prior to each data collection event and thus did not patrol the study site while data collection was performed. It was necessary to inform the police of the data collection effort because of regular speed enforcement activities that occur at several of the sites.

Data Reduction

Data collection with the LIDAR unit produced several spot speeds for each individual vehicle. In order to reduce the amount of data, distances were selected for each site, and linear interpolation was used to determine the speed at each of the selected distances for each sample vehicle. Distances were selected for each site based on the distance that the data collectors were able to track the sample vehicles. At Sites 1, 2, and 4 the data were reduced such that a spot speed was calculated at 500 ft, 400 ft, 300 ft, 200 ft, and 100 ft from the rear-facing beacon for each tracked vehicle. At Site 3, the data were interpolated such that a speed was calculated for 650 ft, 550 ft, 450 ft, 350 ft, 250 ft, and 150 ft from the rear-facing beacon. Vertical curvature at Site 3 allowed researchers to track sample vehicles a slightly longer distance than at the other three sites; however, high grass and many tree limbs prevented researchers from being able to track the majority of vehicles to as close as 100 ft from the rear-facing beacon. Most vehicles had been tracked to as close as 150 ft from the rear-facing beacon. Vehicles were deleted from the sample if spot speeds could not be interpolated for at least four out of five of the selected distances at Sites 1, 2, and 4 and at least five out of six of the selected distances at Site 3. Interpolation was performed by selecting the two consecutive spot speeds, one at a distance higher than the selected distance and the other at a distance lower than the selected distance; thus if the vehicle had been tracked only from 575 ft in advance of the rear-facing beacon at Site 3, a speed was not calculated for the distance of 650 ft.

Data Analysis

The data for each site were analyzed separately. The mean speeds at each selected distance were compared using independent samples t-tests. z-tests were used to determine if there were statically significant differences in the percentage of vehicles exceeding the speed limit after the treatment was installed, and F-tests were used to identify significant changes in speed variance.

Independent variables included the following:

- presence versus absence of rear-facing flashing beacon (before versus after) and
- school-zone data collection period (am versus pm).

Dependent variables (i.e., measures of effectiveness) were selected to reflect the speed-related characteristics that researchers hypothesized would be affected by the rear-facing beacon.

Dependent variables included the following:

- mean vehicular speeds measured at 100 ft intervals through the study site;
- percentage of drivers exceeding: the school speed limit, the speed limit +5 mph, and the speed limit +10 mph at each selected distance; and
- speed variance at each selected distance.

The computer software program SPSS version 12.0 was used to perform t-tests and F-tests. Microsoft Excel was used for z-tests. All statistical tests were two-tailed tests, performed at a 95 percent confidence level.

RESULTS

At each site, two t-tests were performed only on the data collected while the school zone was not active. The before data and the after data were analyzed separately for these two tests. These t-tests compared the average speeds collected in the morning to the average speed collected in the afternoon. If the test showed that there was no significant difference between the data collected in the morning and the data collected in the afternoon while the beacons were not flashing in both the before and after studies, then the data were collapsed by combining the morning and afternoon data and an additional t-test was performed to determine if there was a significant difference between the before and after average speeds. If a significant difference was found for either, then the morning and afternoon data were kept separate and the before data were compared to the after data in two separate t-tests—one comparing before and after morning data and one comparing before and after afternoon data. The same technique was used to analyze the data collected during the active school zone.

An F-test, testing for a significant difference in the variance of the data, was calculated during each t-test. The 85th percentile speeds were calculated but not analyzed for significant differences. A study of the percent exceeding various speed thresholds was performed to determine if the treatment had a greater influence on faster vehicles.

Site 1—Thorndale Schools, US 79

At Site 1 the t-test on the data collected while the school zone was not active revealed that there was a significant difference between the mean speeds collected in the morning compared to the mean speeds collected in the afternoon, but only in the after study data. The data were analyzed separately, and the t-test showed no significant difference in mean speeds when before morning data were compared to after morning data. However, a significant difference was found only at a distance of 500 ft from the treatment between the before and after afternoon data. The mean speed in the before study for afternoon data was 39.6 mph, and in the after study the mean speed was 44.1 mph. The number of vehicles collected at 500 ft from the treatment was very small (only 9 vehicles in the afternoon collected during the before study and only 23 collected in the after study). The number of vehicles at the other distances were higher, and no significant differences were found between the before and after afternoon data at distances of 400, 300, 200, and 100 ft from the treatment. Thus, the afternoon data at 500 ft from the treatment were considered to be too small of a sample, and the results at the other locations indicated that the traffic speeds had been similar during the before and after studies.

The data collected while the school zone was active were analyzed, and no significant differences were found between the morning and afternoon data for both the before and after studies, so the data were collapsed. All the before data collected while the school zone was active were compared to all the after data collected while the school zone was active. The mean speeds, standard deviation, and 85th percentile speeds for data collected during the active school zone are shown in Table 3-3.

Table 3-3. Site 1—Effect of Rear-Facing Flashing Beacon on School Zone Speeds.

Measure	Distance from End of School Zone (ft)									
	500 ft		400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After
No. of Vehicles	141	166	365	318	365	318	365	318	359	309
Mean (mph)	33.5	31.7*	35.4	33.5*	35.6	33.7*	35.8	33.9*	36.2	34.3*
Standard Deviation (mph)	4.8	4.1*	5.9	5.1*	6.0	5.3*	6.0	5.4*	6.1	5.6
85th Pct. (mph)	39	36	41	39	42	39	42	40	43	41

Note: * indicates the before and after values are significantly different at 95 percent confidence level.

Table 3-3 shows that there was a significant difference in mean speeds at each spot speed location for the data collected during the active school zone. At each location, the average speed in the after study was almost 2 mph less than the average speed in the before study. Figure 3-7 illustrates the difference in mean and 85th percentile speeds between the before and after studies.

In most cases, the standard deviation of speed was also reduced after installation of the treatment. The reduction was small, on the order of 0.6-0.7 mph, but statistically significant.

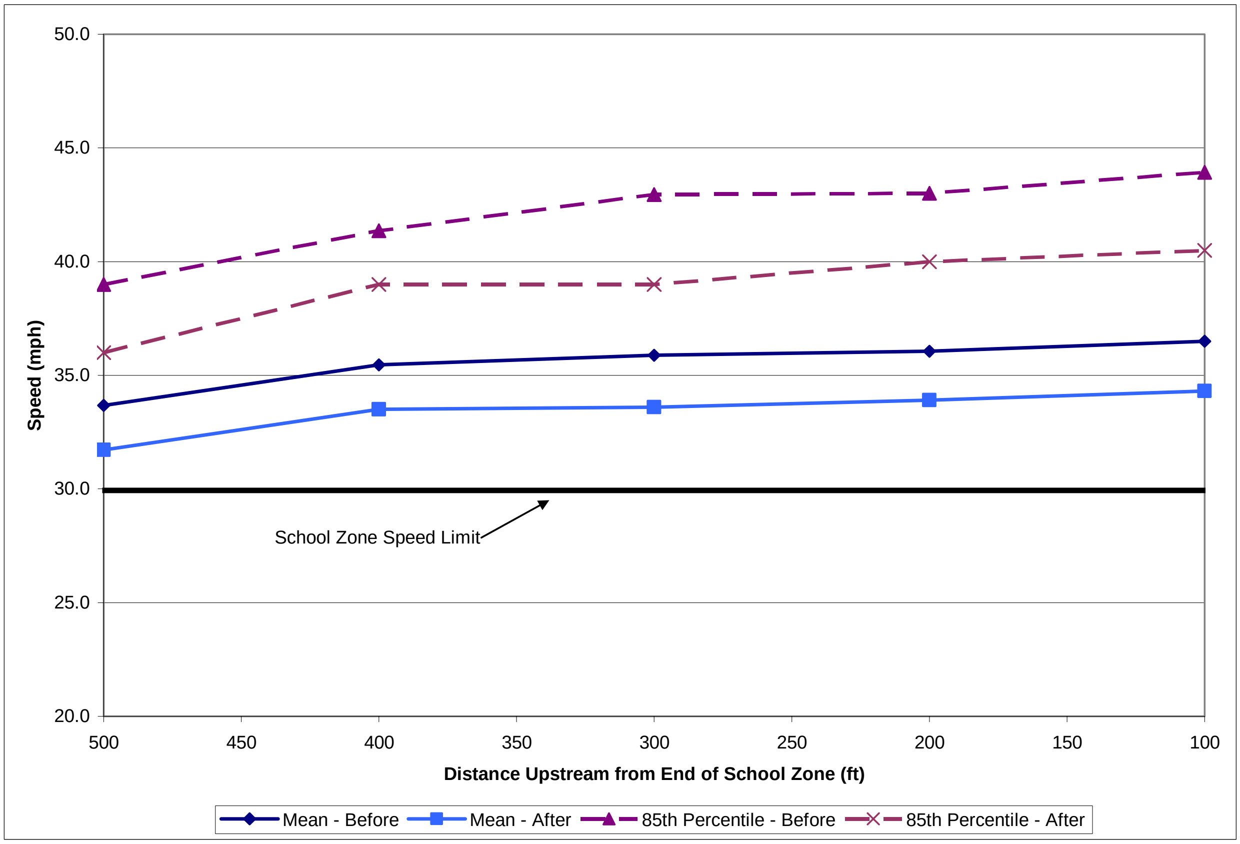

Figure 3-7. Site 1—Mean and 85th Percentile School Zone Speeds before and after Rear-Facing Beacon Installation.

Researchers also examined the percent of vehicles exceeding various thresholds between the before and after studies to see if the treatment had an effect on faster traffic. A z-test was used to compare these data. The speed thresholds examined in this analysis included:

- the percent of vehicles exceeding the speed limit (45 mph during non-active school zone and 30 mph during active school zone),
- the percent of vehicles exceeding 5 mph over the speed limit (35 mph in an active school zone only),
- the percent of vehicles exceeding 10 mph over the speed limit (40 mph in an active school zone only), and
- the percent of vehicles exceeding 10 mph over the speed limit (45 mph in an active school zone only).

Because the t-test performed previously had indicated that the data collected while the school zone was not active could not be collapsed between the morning and afternoon data, researchers analyzed the morning and afternoon data separately for this analysis as well. Microsoft Excel was used to perform the z-test on the data. There were no differences found between the percent of vehicles exceeding the speed limit in the before study and the percent of vehicles exceeding the speed limit in the after study for the data collected while the school zone was not active for both the morning and afternoon data. This result supports the conclusion that nothing had affected traffic speeds between the before and after studies.

Z-tests were also performed on the data collected during the active school zone. Because the t-test analysis indicated that the morning and afternoon data could be collapsed, the z-tests were performed on the collapsed data (i.e., morning and afternoon data were combined). The analysis compares the morning and afternoon data collected in the before study to the morning and afternoon data collected in the after study. Table 3-4 shows the results of this analysis.

Table 3-4. Site 1—Effect of Rear-Facing Flashing Beacon on the Percent of Vehicles Exceeding Various Speed Thresholds during the Active School Zone.

Percent of Vehicles Exceeding:	Distance from End of School Zone (ft)									
	500 ft		400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After
30 mph (%)	70.2	59.0*	78.4	70.2*	79.5	71.4*	80.3	72.6*	82.2	72.5*
35 mph (%)	30.5	17.5*	44.9	29.5*	46.0	31.4*	47.1	33.0*	50.1	36.9*
40 mph (%)	11.3	3.0*	20.5	11.6*	19.7	12.6*	21.6	13.5*	24.0	15.2*
45 mph (%)	1.4	0.6	6.0	1.9*	6.8	2.2*	7.7	2.8*	7.5	4.2
No. of Veh.	141	166	365	319	365	318	362	318	359	309

Note: * indicates the before and after values are significantly different a 95 percent confidence level.

Table 3-4 shows that the percent exceeding the speed limit (30 mph), 5 mph over the speed limit (35 mph), and 10 mph over the speed limit (40 mph) was significantly reduced at all five distances. The percent of vehicles exceeding 15 mph over the speed limit (45 mph) was significantly reduced at 400, 300, and 200 ft in advance of the rear-facing beacon. At 500 ft and 100 ft in advance of the rear-facing beacon, the percent exceeding 15 mph over the speed limit was lower in the after study, but the difference was not statistically significant. Figure 3-8 illustrates the differences found at the various speed thresholds between the percent of vehicles exceeding these thresholds in the before study and the percent of vehicles exceeding these thresholds in the after study.

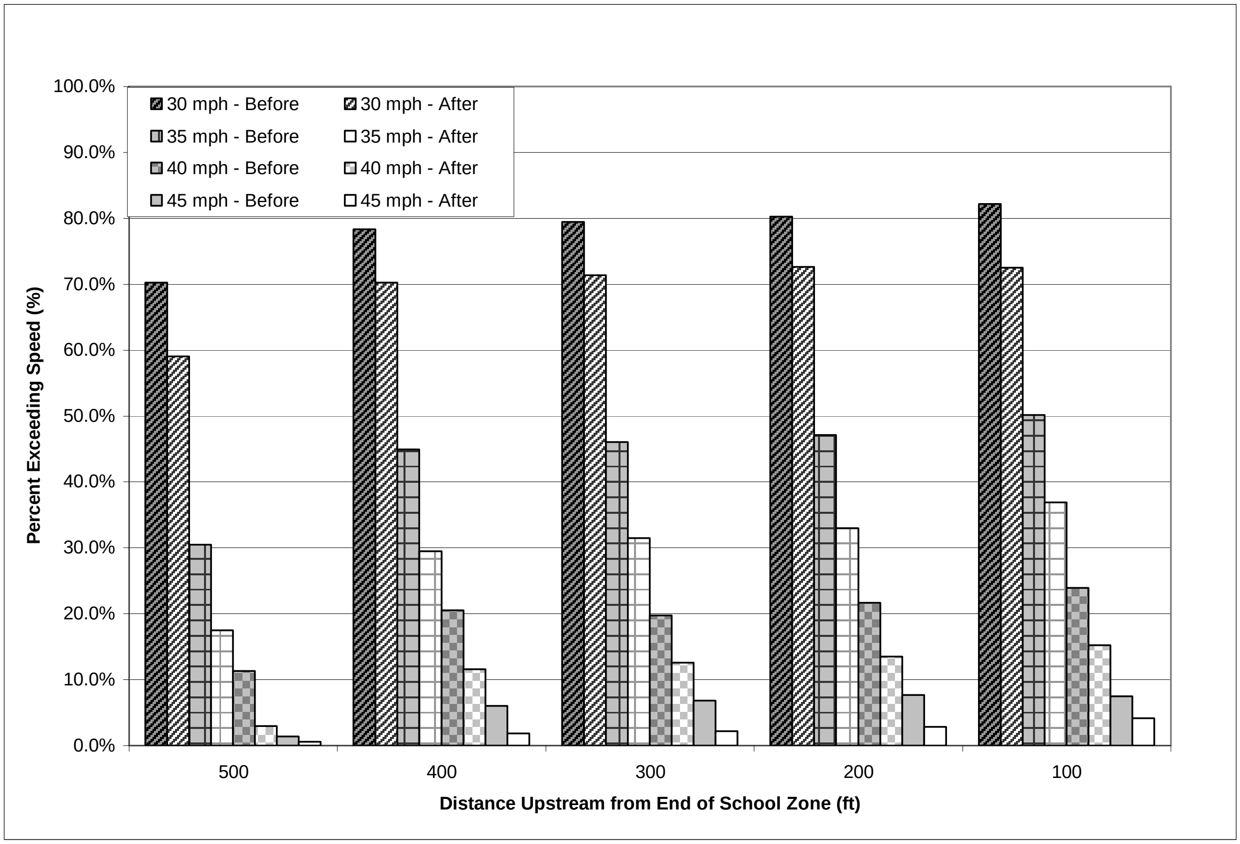

Figure 3-8. Site 1—Percent of Vehicles Exceeding Various Speed Thresholds before and after Rear-Facing Beacon Installation.

Site 2—Brenham High School, Business 36

The sample size of data collected at Site 2 was small. The ideal amounts of data were not collected because the data collection at this site started close to the end of the school year so the data collection was rushed. Data were collected on two days other than the days used in the analysis, but due to equipment problems these data were not used.

T-tests and F-tests were performed on the data collected while the school zone was not active. All the data collected while the school zone was not active were collected during the morning, so there was no need to collapse any data. A significant difference in average speeds was found at each distance tested (400, 300, 200, and 100 ft in advance of the RFB). The difference in average speed was between 2.1 and 2.7 mph slower in the after study. There was a large difference in the number of samples collected between the two studies. In the before study the sample was very small (only 30 sample vehicles) because of the equipment problems mentioned earlier. In the after study, the sample size was 103 vehicles. Even fewer vehicles were tracked from a distance of 500 ft, so these data were excluded. The large difference in the sample size was probably one major reason a significant difference was found in the speeds collected while the school zone was not active.

The fact that a significant difference was found for the control data weakens any conclusions researchers can draw from the results of the analyses performed on the data collected while the school zone was active. However, t-tests and F-tests were performed on these data as well. Again, data were only collected during the morning when the school zone was active. The sample size for the data collected while the school zone was active was slightly larger; 63 samples were collected in the before study, and 97 samples were collected in the after study. The t-test indicated at each distance (400, 300, 200, and 100 ft in advance of the RFB) that there was no significant difference between the average speeds traveled in the before study and the average speeds traveled in the after study. Table 3-5 shows the average speeds, 85th percentile speeds, and standard deviation of the data collected during the active school zone. There were no significant differences found at any location between the before and after studies for average speeds or standard deviations. This indicates that the treatment had no effect on traffic speeds. The control data indicated that traffic was traveling about 2 mph slower in the after study while the school zone was not active, so one might expect the after speeds to be slower during the active school zone as well. The sample size is smaller than desirable, and that could influence the results. The data indicate that the treatment did not have any effect on average speeds or the variance of speeds at this site. The 85th percentile speeds were also the same at 300, 200, and 100 ft away from the RFB and within 1 mph at 400 ft from the RFB. Figure 3-9 shows the mean and 85th percentile speeds in a graphical format.

Table 3-5. Site 2—Effect of Rear-Facing Flashing Beacon on School Zone Speeds.

Measure	Distance from End of School Zone (ft)							
	400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After
No. of Vehicles	63	97	63	97	63	97	63	97
Mean (mph)	33.9	33.6	34.5	34.0	34.4	34.3	34.3	34.2
Standard Deviation (mph)	4.2	4.5	4.4	4.3	4.4	4.3	4.4	4.3
85th Pct. (mph)	38	39	39	39	39	39	39	39

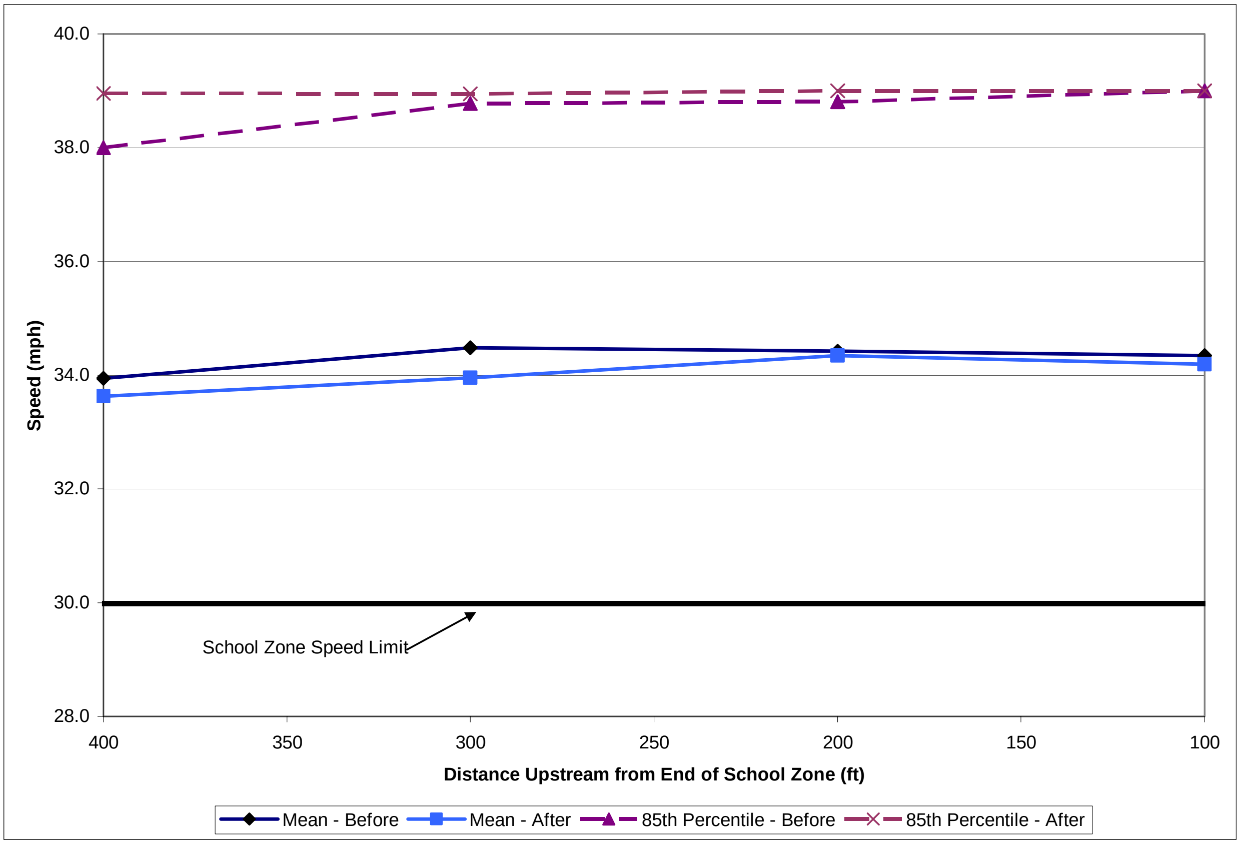

Figure 3-9. Site 2—Mean and 85th Percentile School Zone Speeds before and after Rear-Facing Beacon Installation.

Z-test were also performed on the data collected at this site. No significant differences were detected in the number of vehicles exceeding the speed limit at this site when the school zone was not active. Thus z-tests were then performed at the thresholds mentioned previously. Again, no significant differences were found at any of the speed thresholds for any distance from the rear-facing beacon treatment. Table 3-6 lists the percentage of vehicles exceeding the various thresholds for both the before and after study. Figure 3-10 shows a graphical representation of the data.

Table 3-6. Site 2—Effect of Rear-Facing Flashing Beacon on the Percent of Vehicles Exceeding Various Speed Thresholds during the Active School Zone.

Percent of Vehicles Exceeding:	Distance from End of School Zone (ft)							
	400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After
30 mph (%)	77.8	74.2	79.4	77.3	76.2	79.4	76.2	75.3
35 mph (%)	39.7	35.1	46.0	38.1	46.0	40.2	42.9	39.2
40 mph (%)	4.8	6.2	7.9	7.2	9.5	7.2	6.3	6.2
45 mph (%)	1.6	0.0	1.6	0.0	1.6	1.0	1.6	0.0
No. of Veh.	63	97	63	97	63	97	63	97

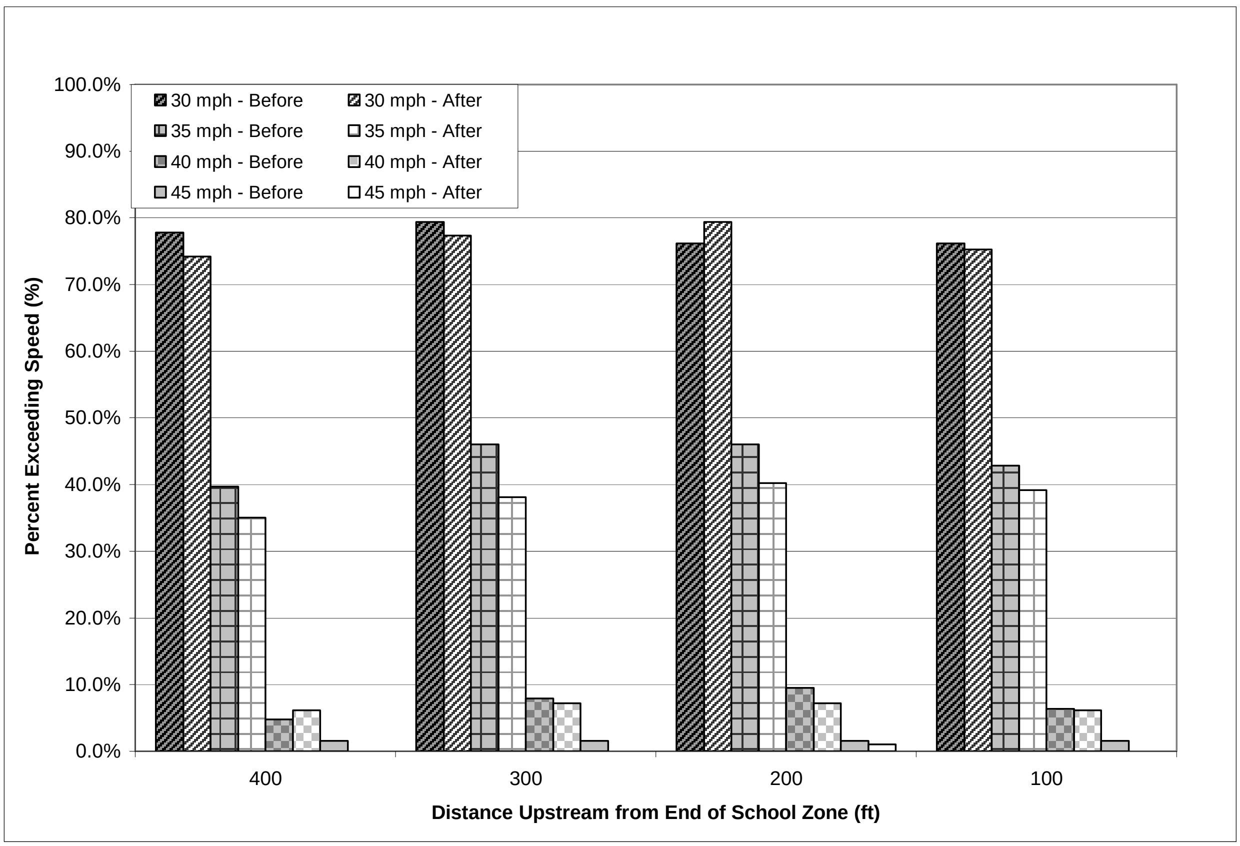

Figure 3-10. Site 2—Percent of Vehicles Exceeding Various Speed Thresholds before and after Rear-Facing Beacon Installation.

Site 3—Scott Johnson Elementary, Highway 190

The data at Site 3 were interpolated such that a speed was calculated at a distance of 650 ft, 550 ft, 450 ft, 350 ft, 250 ft, and 150 ft in advance of the rear-facing beacon treatment. T-tests and F-tests were performed on the data collected while the school zone was not active. No significant differences in the average speeds were found when morning data were compared to afternoon data for both the data collected during the before study and the data collected during the after study, so the morning and afternoon data were collapsed. Then a t-test was performed on the collapsed data comparing before study data to after study data collected while the school zone was not active. No significant differences were found in average speeds or standard deviations between the before and after data collected while the school zone was not active. This result indicates that the traffic was similar between the before and after studies and probably not influenced by anything other than the treatment while the school zone was active.

Next, average speeds and standard deviations of the data collected while the school zone was active were analyzed. Again, no significant differences in average speeds were found between the morning and afternoon data for both before and after studies, so the morning and afternoon data were collapsed. Another t-test was performed on the collapsed data to compare the before data to the after data collected while the school zone was active. The test indicated that there was a significant difference in average speeds for the last 550 ft of the school zone. The difference in average speeds was not found to be significant at 650 ft from the school zone. No significant differences were found in the standard deviation.

Table 3-7 shows that the difference between the before and after average speeds was between 1.9 mph and 2.3 mph. The differences between before and after 85th percentile speeds are less consistent. The difference between the before and after 85th percentile speeds was only 1 mph between 550 ft and 350 ft in advance of the rear-facing beacon treatment. However, the difference was as much as 4 mph at 650 ft in advance of the rear-facing beacon. Figure 3-11 illustrates the differences between before and after average and 85th percentile speeds at Site 3.

Table 3-7. Site 3—Effect of Rear-Facing Flashing Beacon on School Zone Speeds.

Measure	Distance from End of School Zone (ft)											
	650 ft		550 ft		450 ft		350 ft		250 ft		150 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
No. of Vehicles	107	65	115	88	115	88	115	88	115	88	100	61
Mean (mph)	36.4	34.5*	37.3	35.4*	37.6	35.5*	37.6	35.6*	37.5	35.3*	37.3	35.1*
Standard Deviation (mph)	6.2	6.0	6.4	6.3	6.6	6.5	6.8	6.5	6.9	6.6	6.9	6.4
85th Pct. (mph)	43	39	44	43	45	44	44	43	45	43	45	41

Note: * indicates the before and after values are significantly different a 95 percent confidence level.

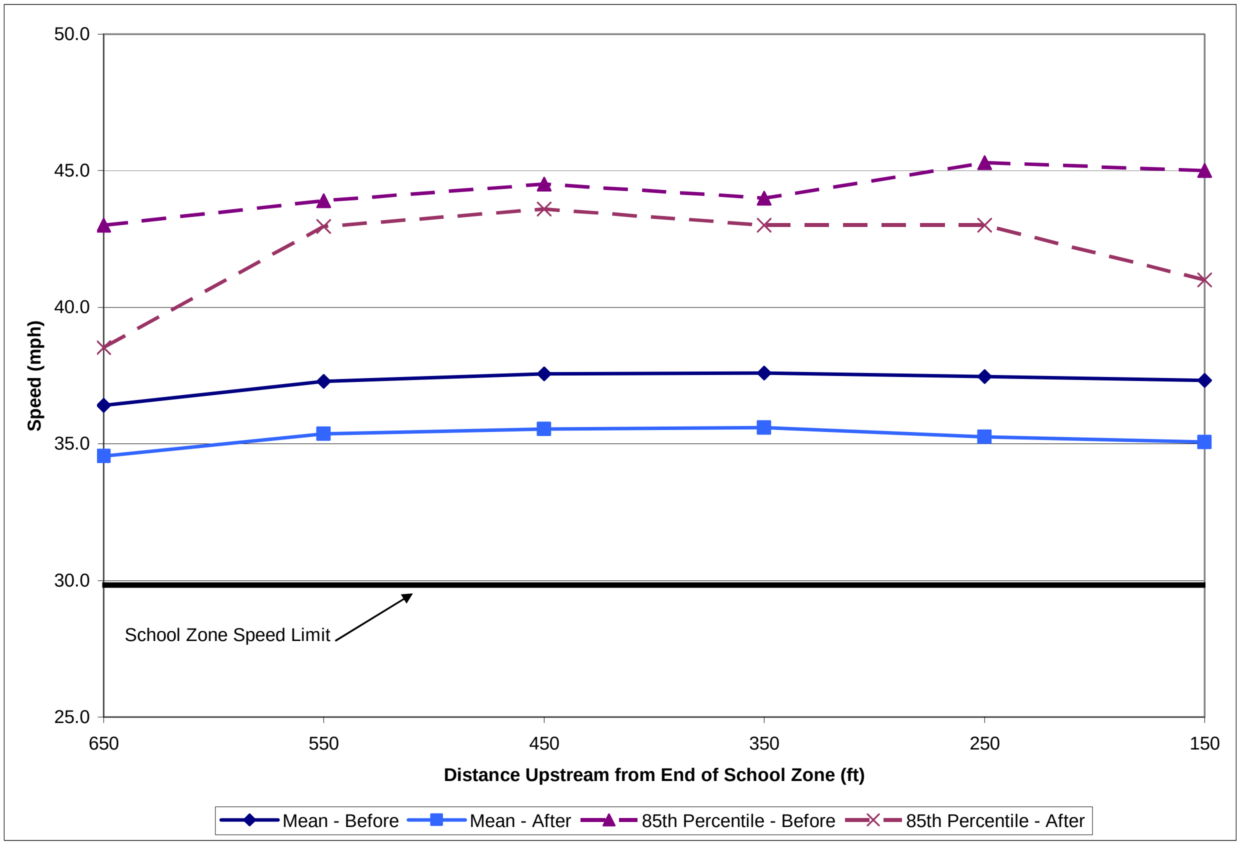

Figure 3-11. Site 3—Mean and 85th Percentile School Zone Speeds before and after Rear-Facing Beacon Installation.

The percent of vehicles exceeding various speed limits was also examined at this site. No significant differences in the percent of vehicles exceeding the speed limit were found in the non-active school zone data analysis.

Significant differences were found between the percent of vehicles exceeding the speed limit, 5 mph over the speed limit, and 10 mph over the speed limit for the active school zone data. The difference between the percent of vehicles exceeding the speed limit in the after study was significantly lower than the percent of vehicles exceeding the speed limit in the before study at 550 and 150 ft in advance of the rear-facing beacon. At 5 mph over the speed limit (35 mph) a significant difference was seen at 550, 450, 350, and 250 ft in advance of the rear-facing beacon, and at 10 mph over the speed limit the percent of vehicles exceeding 40 mph was significantly lower at 450, 350, and 250 ft in advance of the rear-facing beacon. Table 3-8 shows the results for the percent of vehicles exceeding various threshold speeds, and Figure 3-12 is a graphical illustration of the results.

Table 3-8. Site 3—Effect of Rear-Facing Flashing Beacon on the Percent of Vehicles Exceeding Various Speed Thresholds during the Active School Zone.

Percent of Vehicles Exceeding:	Distance from End of School Zone (ft)											
	650 ft		550 ft		450 ft		350 ft		250 ft		150 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
30 mph (%)	88.8	80.0	91.3	81.8*	89.6	80.7	88.7	80.7	87.8	78.4	86.0	68.9*
35 mph (%)	50.5	35.4	57.4	38.6*	59.1	39.8*	55.7	40.9*	54.8*	39.8*	52.0	45.9
40 mph (%)	22.4	13.8	27.8	17.0	31.3	18.2*	33.9	19.3*	32.2	19.3*	30.0	19.7
45 mph (%)	8.4	9.2	8.7	10.2	11.3	11.4	13.9	10.2	15.7	9.1	13.0	6.6
No. of Veh.	107	65	115	88	115	88	115	88	115	88	100	61

Note: * indicates the before and after values are significantly different a 95 percent confidence level.

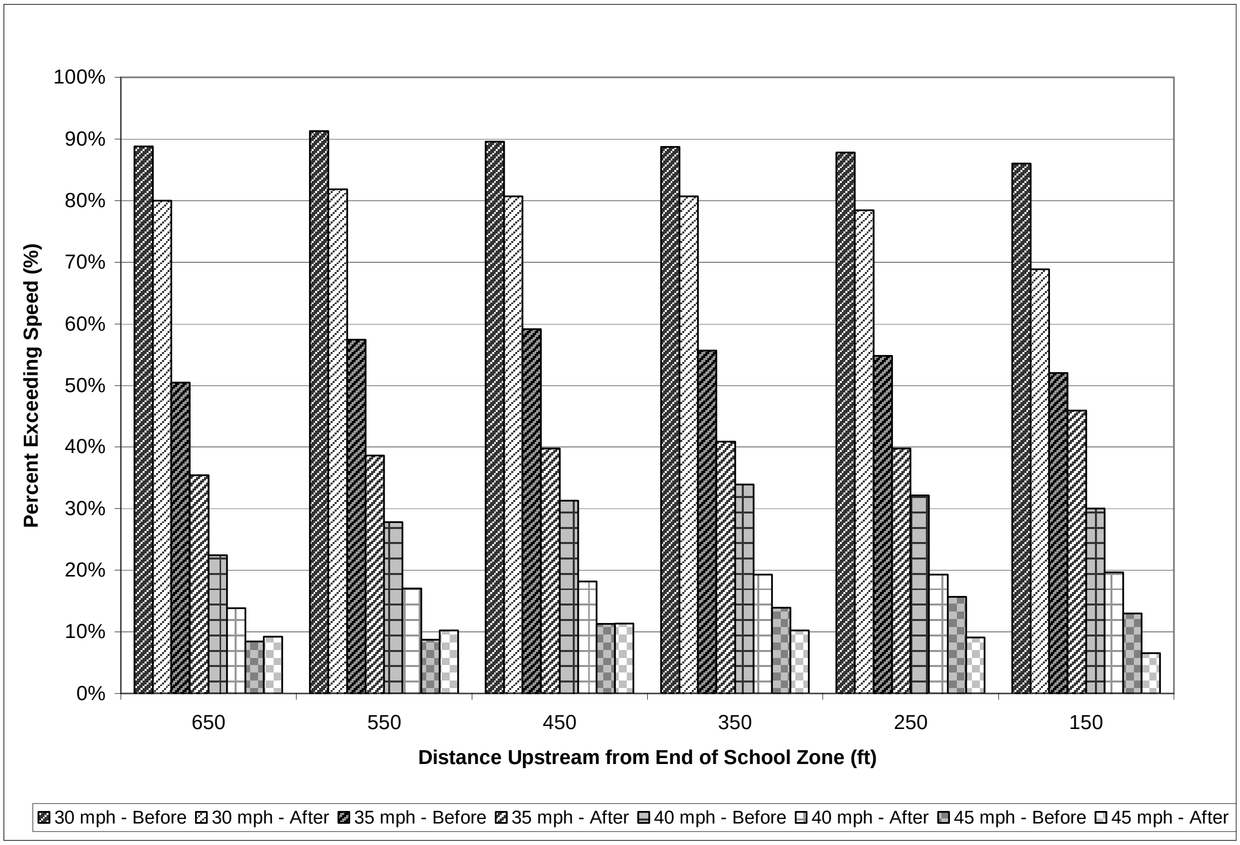

Figure 3-12. Site 3—Percent of Vehicles Exceeding Various Speed Thresholds before and after Rear-Facing Beacon Installation.

Site 4—A&M Consolidated Middle School, Anderson Street

Site 4 served as the average length school zone. Traffic queuing up at the school during the active school zone and a large percentage of vehicles turning left near the end of the school zone resulted in a smaller than desired sample size at this site. The t-tests for the non-active school zone data indicated that the morning and afternoon data could be collapsed. Then a t-test was performed on the collapsed data comparing average speeds before the treatment to average speeds after the installation of the treatment. No significant differences in average speeds were found for the non-active school zone data (control point). This result indicates that the rear-facing beacon and end of school zone treatment was probably the only influence on traffic speeds during before and after studies.

Next researchers examined the data collected during the active school zone. Again, results of t-tests indicated that the morning and afternoon data could be collapsed for both the before and after data sets. Then a t-test and F-test were performed on the collapsed data to compare the before speeds collected to after speeds. Table 3-9 shows the results of the t-test and F-test performed on the active school zone data. No significant differences were found in average speeds at 500 ft, 400 ft, 300 ft, and 200 ft in advance of the rear-facing beacon; however, after speeds are approximately 1 mph less in the after study at distances of 400 ft, 300 ft, and 200 ft from the rear-facing beacon. A significant difference in the average speed at a distance of 100 ft from the end of the school zone was detected. The difference between the before and after speeds at a distance of 100 ft from the rear-facing beacon was 1.1 mph. The results of the t-tests indicate that the treatment had only a minor effect on average traffic speeds. It is interesting to note that the average speeds in the before study were just slightly above the school zone speed limit, but the average speeds in the after study were all slightly below the speed limit.

F-tests for the active school zone data indicated that there was no change in the variance of traffic speeds at this site. The 85th percentile speeds were consistent in both studies through the school zone. Observed 85th percentile speeds in the after study were 1 mph less than in the before study. Figure 3-13 shows a graphical representation of the before and after 85th percentile speeds and average speeds.

Table 3-9. Site 4—Effect of Rear-Facing Flashing Beacon on School Zone Speeds.

Measure	Distance from End of School Zone (ft)									
	500 ft		400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After
No. of Vehicles	70	63	83	72	83	72	83	72	75	70
Mean (mph)	20.2	19.8	20.6	19.6	20.7	19.7	20.8	19.9	21.0	19.9*
Standard Deviation (mph)	3.4	3.9	3.3	3.7	3.3	3.5	3.3	3.5	3.4	3.2
85th Pct. (mph)	23	22	23	22	23	22	23	22	23	22

Note: * indicates the before and after values are significantly different a 95 percent confidence level.

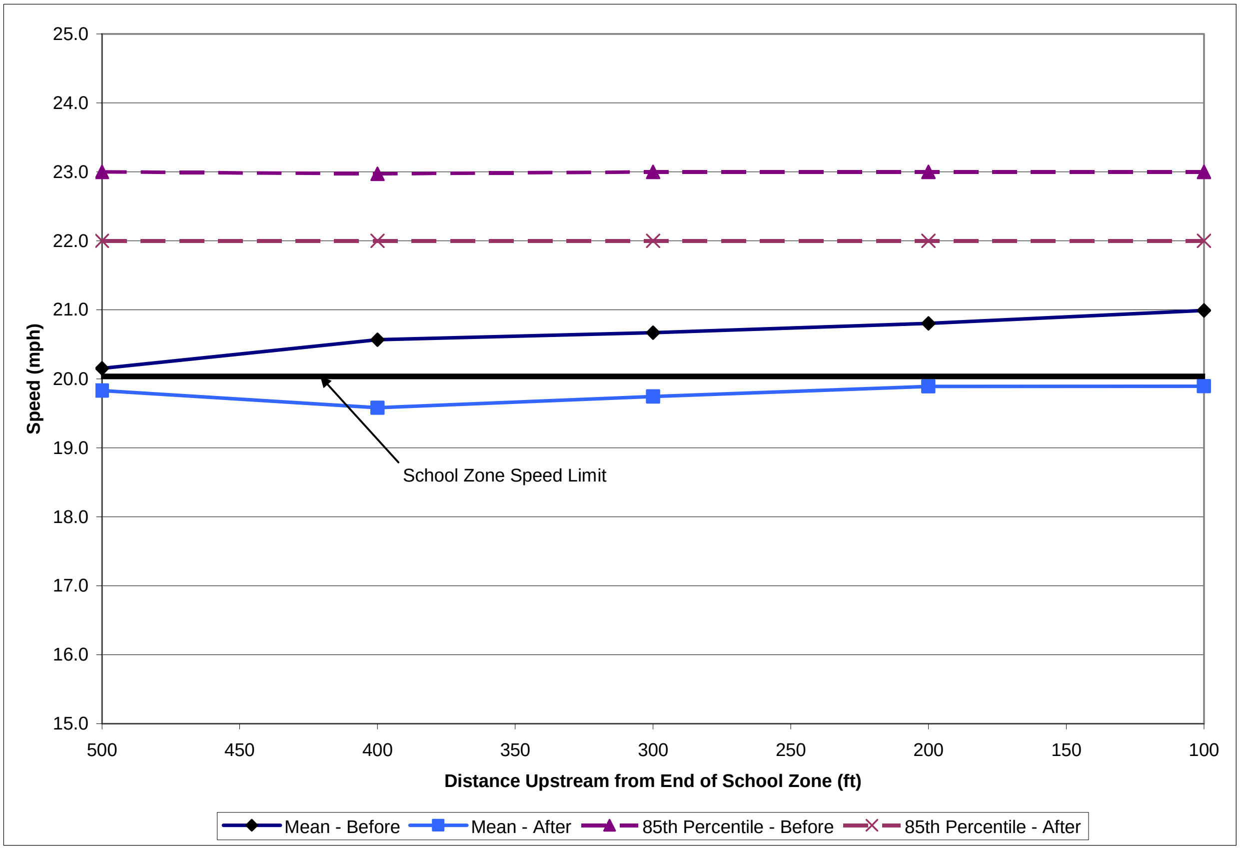

Figure 3-13. Site 4—Mean and 85th Percentile School Zone Speeds before and after Rear-Facing Beacon Installation.

The percent of vehicles exceeding the various thresholds mentioned previously was also examined for the data collected at this site. No significant differences between before and after percentages exceeding the various speed thresholds were found for either the active and non-active school zone data. Table 3-10 shows the results for the z-tests performed on the active school zone data. Percentages are consistently, but not significantly, lower during the after study for both the percentage of vehicles exceeding the school zone speed limit. However, the percentage of vehicles exceeding 5 mph over the school zone speed limit (25 mph) and the percentage of vehicles exceeding 10 mph over the school zone speed limit (30 mph) is higher in the after study at four out of the five distances analyzed. The fact that there were no statistically significant differences at any speed threshold indicates that the treatment did not have any effect on the faster vehicles at this site. This result was probably influenced by the small sample size. Figure 3-14 is a graphical illustration of the results of the z-tests performed on the active school zone data.

Table 3-10. Site 4—Effect of Rear-Facing Flashing Beacon on the Percent of Vehicles Exceeding Various Speed Thresholds during the Active School Zone.

Percent of Vehicles Exceeding:	Distance from End of School Zone (ft)									
	500 ft		400 ft		300 ft		200 ft		100 ft	
	Before	After	Before	After	Before	After	Before	After	Before	After
20 mph (%)	34.3	28.6	43.4	27.8	44.6	33.3	45.8	34.7	46.7	34.3
25 mph (%)	7.1	9.5	7.2	8.3	9.6	5.6	9.6	5.6	10.7	4.3
30 mph (%)	1.4	1.6	2.4	2.8	2.8	2.8	1.2	2.8	1.3	2.9
35 mph (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No. of Veh.	70	63	83	72	83	72	83	72	75	70

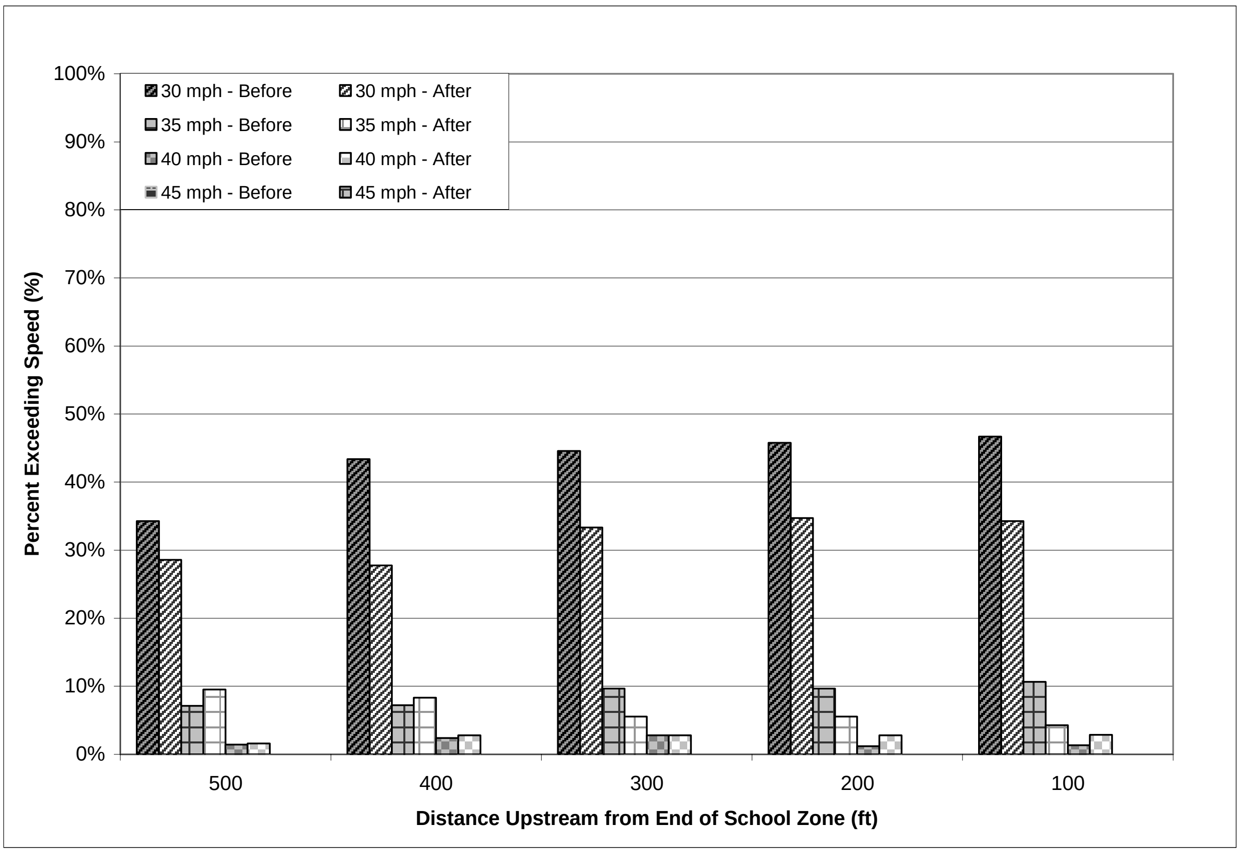

Figure 3-14. Site 3—Percent of Vehicles Exceeding Various Speed Thresholds before and after Rear-Facing Beacon Installation.

SUMMARY AND CONCLUSIONS

This study examined the effectiveness of a flashing amber beacon mounted at the end of a school speed zone as well as an End School Zone sign mounted below the beacon. The intent of this study was to determine if the treatment was effective in the short term (less than two weeks) at improving school speed limit compliance for vehicles departing from the school speed zone boundaries. Researchers hypothesized that the rear-facing beacon would help remind drivers that they were still subject to the school speed limit. Two school zones with signalized intersections within the boundary of the zone were examined, as well as one school zone that was considered to be longer than average and one school zone that was considered to be average length. Statistically significant reductions in speeds and other speed-related measures were observed after the rear-facing flashing beacon was installed at two of the study sites (Sites 1 and 3). The following items are important findings from this study:

- Statistically significant reductions in average speeds of approximately 2 mph were observed through the final 500 ft of the school zone at Site 1 and through the final 650 ft of the school zone at Site 3 after installation of the rear-facing beacon and End School Zone sign.
- The percent of vehicles exceeding the posted school zone speed limit at Site 1 was significantly reduced from about 10 to 15 percent through the last 500 ft of the school zone. At Site 3, at most distances examined a reduction of about 10 percent in the percent of vehicles exceeding the speed limit was observed. However, significant reductions were only observed at 550 ft and 150 ft from the end of the school zone.
- The percent of vehicles exceeding 35 mph at Site 1 was statistically significantly reduced during school zone periods by about 25 to 40 percent, after installation of the rear-facing flashing beacon. At Site 3, the percent of vehicles exceeding 35 mph was significantly reduced by approximately 25 to 30 percent at distances between 550 ft and 250 ft from the end of the school zone.
- At Site 1, speed variability was statistically significantly reduced after installation of the rear-facing beacon, between 500 and 200 ft from the end of the school zone, generally on the order of 0.6-0.7 mph. However, no changes in speed variability were observed at any of the other sites.
- At Site 2 no differences were found in average speeds while the school zone was active. At Site 4, a significant difference in average speeds was only seen at 100 ft from the end of the school zone, and the average speed was only about 1 mph less

than in the before study. No statistically significant changes were found in the percent of vehicles exceeding the various speed thresholds examined. Both sites had small sample sizes, which probably contributed to the fact that so few differences in speeds were detected at these sites.

Based on the research findings from Sites 1 and 3, the researchers concluded that a flashing beacon mounted at the end of the school zone is a potentially effective means of improving compliance with school speed limits in school speed zones. However, this conclusion was drawn from data collected shortly after the rear-facing beacon treatment was installed. A follow-up study after the treatment has been in place for at least six months may be useful to identify whether the treatment will maintain the effect when the usual traffic is accustomed to the treatment.

RECOMMENDATIONS

Based on the results of this study, a follow-up study to be performed approximately six months after the installation of the rear-facing beacon treatment is recommended for Sites 1 and 3. Because the sample sizes for the data collected at Sites 2 and 4 were so small, researchers do not recommend these sites be used for the follow-up study. Instead, two additional sites are suggested. The first site is located on FM 1179 at Brazos Christian in Bryan, Texas. Before data were collected at this site in an effort to include it in this study; however, due to installation challenges, the treatment was not installed in time to collect after data for this report. The second site recommended is Brenham High School for traffic traveling in the northbound direction. A third option researchers could examine is South Knoll Elementary School on Southwest Parkway in College Station, Texas. The rear-facing beacon treatment was installed at this site in the spring of 2003 for initial investigation into the potential effects of the rear-facing beacon treatment. Results from that study were positive. Significant reductions in average and 85th percentile speeds were observed. Researchers also found significant reductions in the percentages of vehicles exceeding the school zone speed limit and several other speed thresholds after the installation of the rear-facing beacon at this site.

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CHAPTER 4:
SPEED LIMIT SIGN CONSPICUITY

INTRODUCTION

Many traffic control devices today aim to reduce the speed of traffic or influence drivers to comply with speed limits because excessive speeds create dangerous situations on our roadways, not only for the speeding motorists but also for other road users. In 2002, 41 percent of fatal crashes in Texas were speed-related accidents according to the National Highway Traffic Safety Administration (*1*). For these reasons, it is easy to see why improving compliance with safe speed limits is a priority. Researchers hypothesized that sometimes motorists do not comply with speed limits because the Speed Limit sign does not stand out (i.e., motorists do not see the sign) or the reason for the decrease in the speed limit is not apparent to the motorist. Often, speed zones on the highway system, such as those approaching cities or municipalities, begin well outside of the city limits at locations that are unexpected by drivers. In many of these cases, the initial reduction in posted speed limit is unexpected because it occurs prior to any physical indication of a need to slow down. Unexpected changes in speed limit may result in unfavorable traffic operational characteristics such as high speeds, high-speed variances, and erratic decelerations, each of which may be associated with higher crash occurrence.

Experimental Treatment

The researchers believe that applying a conspicuity treatment to the Speed Limit sign would improve driver awareness of the sign and therefore improve driver compliance with the speed limit. Such treatments have been utilized in the past, as indicated in Figure 4-1.

Figure 4-1d illustrates the use of a 3 inch red border around the standard Speed Limit sign. This particular treatment was evaluated as part of a prior Texas Transportation Institute (TTI) research project evaluating the impacts of higher performance sign sheeting materials (*2*). However, the prior TTI study evaluated the treatment at only one location. For the current project, researchers expanded the evaluation to several additional sites.

As part of the prior TTI study, the researchers considered the use of several border colors prior to selecting red for field experimentation. Four colors were initially considered as indicated below. Advantages and disadvantages of each color are also listed.

a. Fluorescent Yellow Border on Three Sides

b. Fluorescent Yellow Green Border

c. Yellow and Black Border

d. Red Border used in Prior TTI Project

Figure 4-1. Examples of Speed Limit Conspicuity Treatments.

- **Red—**Red is internationally recognized as the color that signifies danger. Failing to comply with the speed limit is one of the major causes of traffic crashes. Red is defined in the *Manual on Uniform Traffic Control Devices* (MUTCD) as a regulatory sign color, which is consistent with its use in a Speed Limit sign. However, the MUTCD also indicates that red is used to indicate stop or a prohibition. There is a potential that drivers might associate the use of red in a

Speed Limit sign with a stop message when it is intended to indicate a prohibition (i.e., do not exceed the speed limit).

- **Fluorescent yellow—**Fluorescent yellow has a high level of conspicuity. However, the use of a light color with a white background sign may not provide the level of contrast needed to draw attention to the Speed Limit sign. Furthermore, yellow is a warning color, and combining it with a regulatory sign creates an inconsistency in the sign color code.
- **Fluorescent orange—**This color has high conspicuity, and orange flags/panels have been used in Texas in the past to increase driver awareness of Speed Limit signs. However, orange is reserved for use in temporary traffic control applications. Using it with a standard Speed Limit sign in a non-work zone application could mislead a road user. Therefore, orange was not considered for field evaluation as part of this project. However, the use of an orange border Speed Limit sign is being considered as a potential treatment in Project 0-4707, "Development of Measures for Motivating Drivers to Comply with Speed Limits in Work Zones."
- **Fluorescent yellow-green—**This color also has a high level of conspicuity, but its use is specifically limited to pedestrian, bicycle, and school-related applications. Therefore, it would be inappropriate to use this color with the Speed Limit sign unless the MUTCD color code were also modified.

Based on these factors, the researchers in the prior TTI study narrowed the choices down to red or yellow and conducted focus groups to solicit driver opinion. Participants in seven different focus groups were shown two pictures of Speed Limit signs. The first picture was of a Speed Limit sign with a red border, and the second picture was of a Speed Limit sign with a yellow border. All of the subjects decided that a red border had a stronger meaning that would stand out better during the daytime, but most were concerned about nighttime visibility of the red border. Subjects tended to associate the red border with a more serious indication such as warning, while yellow was associated with caution. The results of the focus groups led the researchers to select the red border for the field evaluations.

For the experimental evaluations, the red border Speed Limit sign was created by placing a sign blank with red sheeting behind the existing Speed Limit sign. Utilizing this approach allowed the existing Speed Limit sign to be used in both the before and after conditions, with the red border being the only difference between the before and after conditions. Type VIII sheeting was used for the red border in all of the experimental evaluations.

Study Objectives

The principal objective of this research was to determine if the 3 inch red border around a Speed Limit sign would influence a greater portion of the population to comply with the speed limit. The intent of the red border is to provide increased conspicuity of the Speed Limit sign with the hope that the red border will draw attention to the sign and more motorists will be aware of the change in the speed limit; it would also add emphasis with the hope that motorists who see the Speed Limit sign will perceive an elevated level of importance despite the fact that no physical indications of a need to slow down are present. The effectiveness of the treatment was evaluated by collecting speed data at several locations upstream and downstream of the Speed Limit sign before and after the red border was installed.

BACKGROUND INFORMATION

Red borders are used around the speed limit in signs in many different countries. Figure 4-2a and 4-2b are illustrations of international speed limit signs established at the Convention on the Unification of Road Signs held in Vienna in 1931 *(3)*. In France, both the international speed limit sign and the sign shown in Figure 4-2c are used to indicate the speed limit to motorists *(4)*.

(a) International Speed Limit	(b) International Speed Limit with Alternative Coloring (Used in Sweden)	(c) Speed Limit Sign Used in France

Figure 4-2. International Speed Limit Sign (Speed Limit in km/h).

The idea of putting a red border around a standard U.S. Speed Limit sign was initially investigated on a limited scale in a recent study conducted by Gates et al. (*2*), exploring the benefits of higher-conspicuity sheeting materials. The primary objective of the study was to determine if the microprismatic sheeting material would increase the conspicuity of the Speed Limit sign. The 3 inch red border was installed on a 55 mph Speed Limit sign on SH 7 approaching Marlin, Texas. A significant reduction of almost 2 mph was seen in average speeds at the 55 mph sign for passenger cars during the daytime. Downstream of the sign, significant reductions in average speeds were seen for both passenger and heavy vehicles during the daytime (2.0 mph and 3.9 mph, respectively), and a significant reduction of 0.8 mph was observed for passenger vehicles at night. The proportion of passenger vehicles exceeding the speed limit dropped significantly during the daytime as well (9.6 percent at the Speed Limit sign and 16.3 percent downstream of the sign).

Because the results of this one site study were positive, the advisory panel for the current project decided to expand this study to include more sites.

FIELD EVALUATION

Four locations were selected as study sites for the installation of a 3 inch border around a Speed Limit sign. Criteria for selecting locations included:

1. location where the speed limit has dropped by at least 10 mph, preferably 15 mph;
2. location where there is no change in the cross section of the roadway visible when approaching the Speed Limit sign;
3. location where there is no visible change in the land use (i.e., increase in the density of driveways, especially business entrances); and
4. location where no geometric features that would effect the speed motorists were capable of attaining existed, such as sharp horizontal curves.

Based on the criteria, the following four sites were selected:

1. Site 1—SH 21 westbound traffic approaching Caldwell,
2. Site 2—FM 60 eastbound traffic approaching Snook,
3. Site 3—SH 36 northbound traffic approaching Milano, and
4. Site 4—US 79 southbound traffic approaching Franklin.

The following sections provide additional details about the sites selected.

Site 1—SH 21 Westbound Traffic Approaching Caldwell

The cross section on SH 21 at Site 1 consists of two lanes in each direction separated by a wide median with wide shoulders on the right side of the road in either direction. The speed on the road is 70 mph upstream of the 55 mph Speed Limit sign. The area is rural approaching the town, and the Caldwell City Limits sign is approximately one half a mile downstream. A flashing beacon is located at the bottom of the hill, downstream of the 55 mph transition Speed Limit sign but was considered far enough away from the reduced speed as to not influence the speed of the motorists within the test site. Figure 4-3 shows the site before the 3 inch red border treatment; Figure 4-4 shows the site after treatment. The data at this site were collected using portable automated classifiers connected to pneumatic tubes.

Site 2—FM 60 Eastbound Traffic Approaching Snook

The cross section on FM 60 approaching Snook consists of two lanes, one lane in each direction and almost no shoulder. The speed limit drops from 70 mph to 55 mph at the Snook city limits. At Site 2, the area is rural with mostly open fields and sparse residences. About one mile downstream of the 55 mph sign, there are a few small businesses, but nothing is visible from the locations where speed data were collected. Figure 4-5 is a picture of the 55 mph sign in Snook after the 3 inch red border was installed. The data at this site were collected using portable automated classifiers connected to piezoelectric sensors.

Site 3—SH 36 Northbound Traffic Approaching Milano

Site 3 is also located in advance of a small town. The cross section at this location consists of a two-lane road with 12 ft wide shoulders in either direction. The red border was installed on a 55 mph Speed Limit sign located just upstream of the Milano city limits sign. The speed limit in advance of this sign is 70 mph. Figure 4-6 shows the site before the 3 inch red border treatment. The data at this site were collected using portable automated classifiers connected to piezoelectric sensors.

Site 4—US 79 Southbound Traffic Approaching Franklin

Site 4 is also located in advance of a small town. The speed limit drops from 70 mph to 60 mph. The speed limit drops again closer to town, but the red border was installed on the 60 mph sign since it is further out of town and there are less indications of a need to slow down.

The cross section at the site is a two-lane road with 12 ft wide shoulders in either direction. The data at this site were collected using portable automated classifiers connected to piezoelectric sensors.

Figure 4-3. Site 1—Caldwell before 3 Inch Red Border Treatment.

Figure 4-4. Site 1—Caldwell after 3 Inch Red Border Treatment.

Figure 4-5. Site 2—Snook after 3 Inch Red Border Treatment.

Figure 4-6. Site 3—Franklin before 3 Inch Red Border Treatment.

DATA COLLECTION PROCEDURES

Speeds were measured by using a series of five automated vehicle classifiers, each connected to a pair of pneumatic tubes or piezoelectric sensors placed on the pavement. Whichever type of sensor was used in the before study to collect data was also used in the after study. Figure 4-7 shows the basic data collection layout. The location for each of the five classifiers was based on the following factors:

- **Point 1**—This classifier was located upstream of the treatment location such that the Speed Limit sign could not be seen at this location and driver behavior would not be affected by any changes to the treatment Speed Limit sign. This point was referred to as the control point, and data collected at this point were used to determine if the before and after traveling speeds were comparable.
- **Point 2**—This classifier was located at approximately the legibility threshold distance. The legibility threshold distance is the approximate distance at which the motorist can read the sign.
- **Point 3**—This classifier was located halfway between the threshold distance (i.e., point 2) and the Speed Limit sign.
- **Point 4**—This classifier was located at the Speed Limit sign where the red border was installed for the after study.
- **Point 5**—This classifier was located 300 to 500 ft downstream of the Speed Limit sign.

Data were collected on either week days or on weekends. Due to many rain days researchers could not limit the data collection to just week days. However, if data were collected on the weekend in the before study, the after study was also performed on the weekend. Table 4-1 shows the data collection dates for each site.

Data Reduction

The raw speed data measured at the project sites were screened to create a random and unbiased sample of speeds for free-flowing, uninhibited passenger vehicles. The objective of the data reduction process was to isolate the effect of the red border on driver behavior by identifying and eliminating potentially biased data. Therefore, the purpose of this task was to identify anomalous vehicles and exclude them from the final data set.

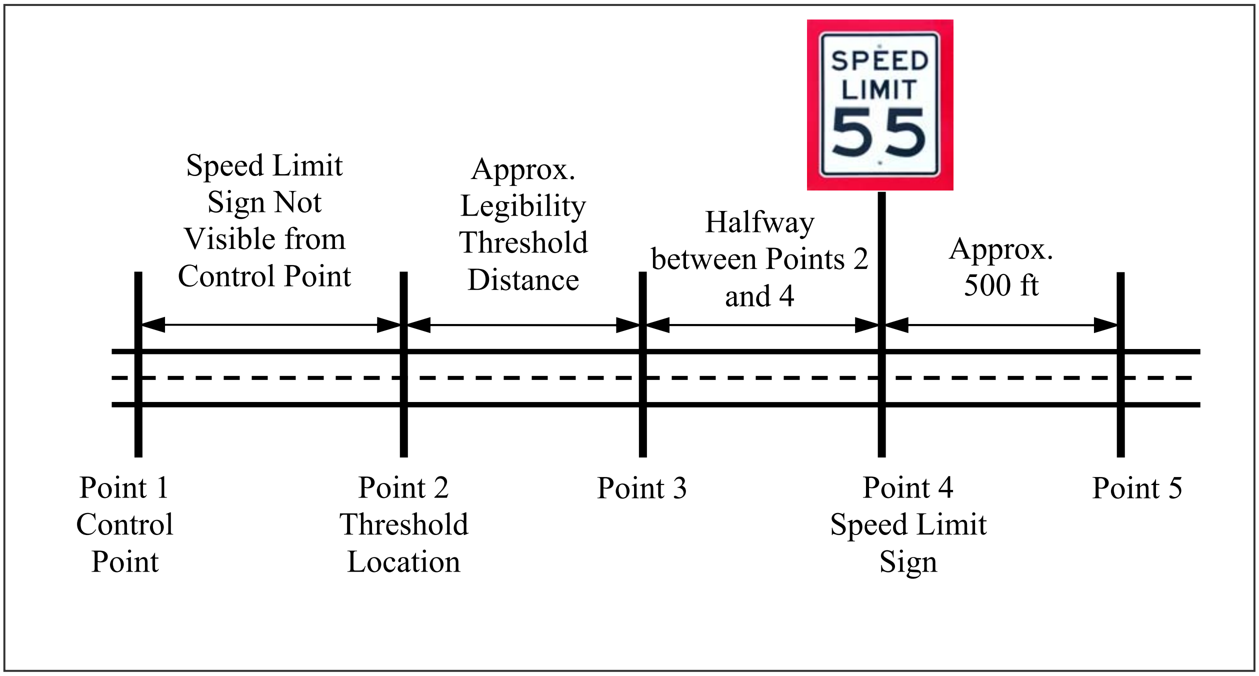

Figure 4-7. Spot Speed Data Collection Locations.

Table 4-1. Data Collection Schedule.

Test Sites	Before Dates	After Dates
Caldwell—SH 21 West	6/16, 6/17, 6/18	7/8, 7/9
Snook—SH 60 East	7/1, 7/2, 7/3	7/16, 7/17, 7/18
Milano—SH 36 North	6/28, 6/29, 6/30	7/14, 7/15
Franklin—US 79 South	8/14, 8/15	8/21, 8/22

Definitions of Anomalous and Representative Vehicles

During data collection, the researchers were interested in obtaining data from a sample of free-flowing passenger vehicles that were traveling through the site uninfluenced by other vehicles. However, a certain percentage of vehicles passing through a site during data collection were influenced by factors external to the experiment and deemed anomalous to the experiment. The researchers made every attempt to identify these anomalous vehicles and exclude them from the data set. Researchers defined anomalous vehicles and representative vehicles by the following conditions:

- non-free-flowing (≤ 6 second headway);

- traversing through the curve when a vehicle is present in the opposing lane (encroachment data only);
- approaching Stop sign when queue is present (stop-controlled intersection sites only);
- motorcycles;
- erratic behavior; and
- uninhibited upstream speed was deemed excessively slow (e.g., <20 mph or more under the speed limit).

Anomalous vehicles were deleted from the data set and not included in any statistical analyses performed. The data for each site were analyzed separately, and heavy vehicle speed data were analyzed separately from passenger vehicle data.

DATA ANALYSIS

The researchers analyzed the collected data to assess differences in vehicle speeds in the before and after conditions. The data were analyzed using several different approaches in an effort to assess the effectiveness of the red border treatment.

Analysis of Variance (ANOVA)

A univariate multiple-factor ANOVA was the statistical analysis used to test for differences in the average speeds and deceleration data for each site. ANOVA allows for testing of differences between mean values of multiple populations as a function of the independent variables (i.e., sign treatments, light conditions, etc.) and interactions between the independent variables. For cases with only one independent variable, one-way ANOVA or t-tests were performed. SPSS was used to perform all ANOVA tests.

The upstream control point speed was entered into the analysis as a covariate for most sites. Adding upstream speed as a covariate provides for correction due to vehicles having different speeds prior to entering the project site. Covariate analysis accounts for the fact that vehicles traveling faster at the control point are also likely to travel faster through the site.

Binomial Proportions Z-Test

Z-tests of proportions were used to test for differences in percent exceeding a specified threshold speed. A z-test was performed to test if the proportion of vehicles exceeding the speed threshold differed as a function of the sign treatment. These tests were useful for testing the effect of the red border treatment on the "upper extremities" of the speed data.

Several binomial proportions z-tests were performed on the data collected at each site. The proportions of vehicles exceeding the speed limit—5 mph over the speed limit, 10 mph over the speed limit, and, for Snook, Caldwell, and Milano, 15 mph over the speed limit—were calculated. The binomial proportions z-tests compared the before proportions for each threshold to the after proportions for each threshold.

Standard Deviation and 85th Percentile Speeds

The standard deviation was calculated for each data set. The Levene's test for equality of variances was generated by SPSS for each ANOVA test. If no significant difference was found between the variances in the before and after data sets, the treatment did not increase the variability in speed at that site.

The 85th percentile speeds were calculated for each data set; however, no direct statistical tests were performed on the 85th percentile data. The binomial proportions tests were used to measure the treatment's effect on faster traffic.

RESULTS

At three of the four selected sites ANOVA tests were performed on both mean speeds and decelerations speeds between each data point.

Site 1—SH 21 Westbound Traffic Approaching Caldwell

In Caldwell the passenger vehicle data were analyzed separately from the heavy vehicle data. Light condition was a significant factor in most cases; however, there was no interaction between light condition and study for the ANOVA analyses on the mean speed data. The passenger vehicle data will be presented first. One important note about this site is that there is no point 3. There was an equipment problem at point 3 during the collection of before data, so this point was omitted for the evaluation.

Results for Passenger Vehicle Data

Table 4-2 shows the ANOVA results for the passenger vehicle data collected during daylight, and Table 4-3 shows the ANOVA results for passenger vehicle data collected at night. At the control point during daylight, the average speed is statistically significantly higher in the after study. This finding makes it difficult to draw conclusions from these data because it indicates that the traffic sample in the after study was, in general, slightly faster than the traffic in the before study. At point 2 similar results are seen. At point 4, the speed during the after study is still a little higher than the speed during the before study, but the difference is not significant. The difference is probably not significant because of the upstream speeds entered as the covariate. At point 5, however, the average speed during the after study is 0.8 mph slower than the average speed during the before study. Though the reduction is small, it is important, especially since the speeds at the control point were higher during the after study.

The 85th percentile speeds show a similar trend. The 85th percentile speeds at points 1, 2, and 4 are higher in the after study than in the before study; however, at point 5 the 85th percentile speed drops from 71 mph in the before study to 69 mph in the after study. There were significant differences found between the variances at the control point and point 4. At point 5, however, there was no significant difference detected between the before and after speed variances. Figure 4-8 is a graphical representation of the mean and 85th percentile results for passenger vehicle data collected during daylight.

Table 4-3 shows the results from the ANOVA analysis and the 85th percentile speeds for passenger vehicle data collected at night. Night speeds were slower than daytime speeds, but they followed a similar trend. Again the average speed in the after study was slightly higher than the average speed in the before study, and again by point 5 the average speed was significantly slower in the after study than the average speed in the before study. At point 5 the average speed dropped from 60.2 mph in the before study to 58.3 mph in the after study, a difference of 1.9 mph. Figure 4-9 shows a graphical representation of the average and 85th percentile results for passenger vehicle data collected at night.

Table 4-2. Results for SH 21 Approaching Caldwell, Daytime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	69.3	70.6*	1.3
	85th Speed (mph)	74	75	1.0
	Std. Dev. (mph)	5.2	4.8*	−0.4
	Sample Size	1176	1075	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)[1]	68.7	70.7*	2.0
	85th Speed (mph)	74	76	2.0
	Std. Dev. (mph)	5.8	5.9	0.1
	Sample Size	1176	1075	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph) [1]	63.5	64.7	1.2
	85th Speed (mph)	70	71	1.0
	Std. Dev. (mph)	6.4	6.5*	0.1
	Sample Size	1176	1075	NA
Point 5: Downstream of Sign	Mean Speed (mph) [1]	63.1	62.3*	−0.8
	85th Speed (mph)	71	69	−2.0
	Std. Dev. (mph)	6.8	6.6	−0.2
	Sample Size	1176	1075	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

Table 4-3. Results for SH 21 Approaching Caldwell, Nighttime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	65.8	66.3*	0.5
	85th Speed (mph)	71	72	1.0
	Std. Dev. (mph)	5.6	5.9*	0.3
	Sample Size	335	225	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)[1]	65.0	65.7*	0.7
	85th Speed (mph)	71	73	1.0
	Std. Dev. (mph)	6.4	6.5	0.1
	Sample Size	335	225	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph)[1]	60.1	60.3	0.2
	85th Speed (mph)	67	68	1.0
	Std. Dev. (mph)	6.5	7.1*	0.6
	Sample Size	335	225	NA
Point 5: Downstream of Sign	Mean Speed (mph)[1]	60.2	58.3*	−1.9
	85th Speed (mph)	67	66	−1.0
	Std. Dev. (mph)	6.8	6.8*	0.0
	Sample Size	335	225	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

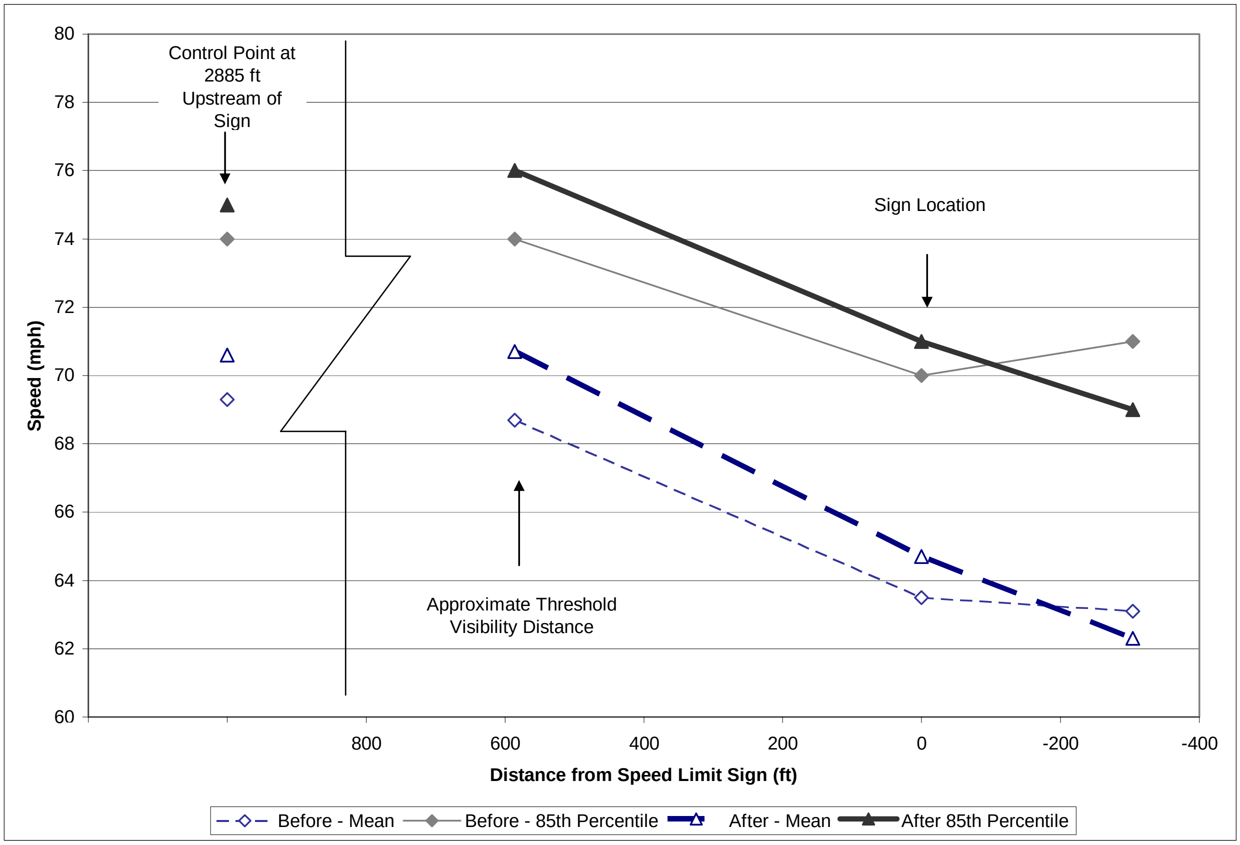

Figure 4-8. SH 21, Caldwell—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Day Data Only.

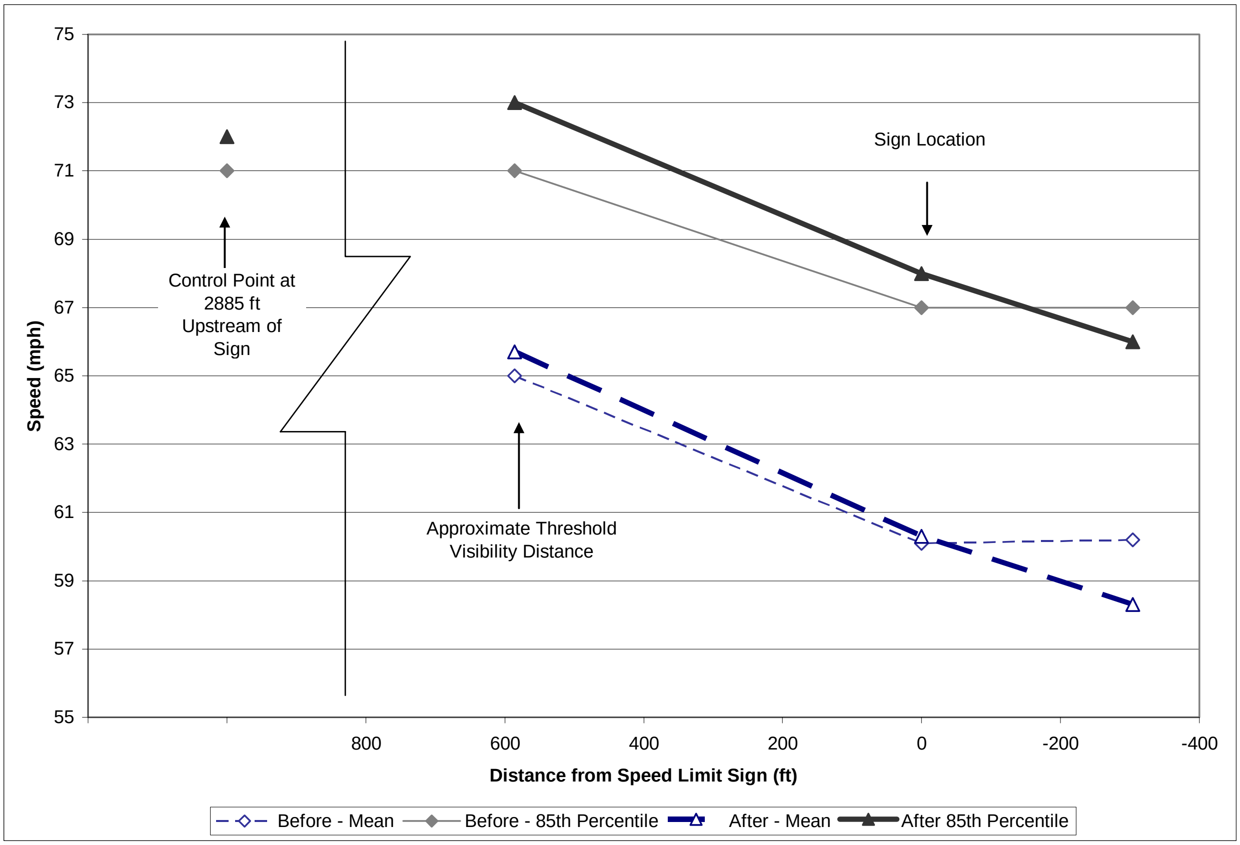

Figure 4-9. SH 21, Caldwell—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Night Data Only.

ANOVA analyses were performed on the deceleration data. The downstream point was subtracted from the upstream point for each sample, and the control point value was entered as the covariate for each analysis. These analyses were performed to see if the difference in average deceleration was a better way to quantify the effects of the red border. Table 4-4 shows the results of the deceleration analysis for passenger vehicle data collected during daylight. Passenger vehicles were going a little faster at the control point in the after study, which is to be expected since the average speed data indicated similar results. The deceleration between point 2 and point 4 dropped from −5.2 mph in the before study to −6.1 mph in the after study; thus, on average, vehicles slowed down about 1 mph more in the after study than they had in the before study. The deceleration between points 4 and 5 increased from −0.3 mph in the before study (i.e., vehicles were barely slowing down at all between the Speed Limit sign and downstream of the sign) to −2.4 mph in the after study.

Table 4-4. Deceleration Analysis Results for SH 21 Approaching Caldwell, Daytime Passenger Vehicles.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−0.6	0.2*
Deceleration between Point 2 and Point 4	−5.2	−6.1*
Deceleration between Point 4 and Point 5	−0.3	−2.4*

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Table 4-5 shows the results for the ANOVA analysis performed on the deceleration data for passenger vehicles collected at night. The results are similar to the results from the passenger vehicle data. Again the average deceleration is greater in the before study than in the after study between the control point and point 2. The deceleration between point 2 and point 4 drops from −4.9 mph in the before study to −5.3 mph in the after study, a difference of 0.4 mph. Between point 4 and point 5 vehicles sped up by 0.6 mph on average in the before study, but in the after study the average vehicle was now decelerating by 2.0 mph, a difference of 2.6 mph. The results of this analysis indicate that even though the actual speeds were slightly higher in the after study at points 1, 2 and 4, vehicles on average were slowing down more between each location where spot speeds were collected than they had been in the before study.

Table 4-5. Deceleration Analysis Results for SH 21 Approaching Caldwell, Nighttime Passenger Vehicles.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−0.8	−0.6*
Deceleration between Point 2 and Point 4	−4.9	−5.3*
Deceleration between Point 4 and Point 5	0.6	−2.0*

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Results for Heavy Vehicle Data

Initially, ANOVA analyses were performed on day and night heavy vehicle data together; however, there were several cases where there was a significant interaction between study and light condition. The interaction indicates that something completely different happened during day before conditions compared to day after or night before conditions compared to night after conditions or both. When there is no interaction but the light condition is significant, that could mean that vehicles during the day slowed down a little less than vehicles at night in the after study. But, when there is an interaction, it could mean that vehicles during the day slowed down during the after period and vehicles at night sped up during the after period for a specific location. So day data had to be analyzed separately from night data. However, the sample size for heavy vehicles at night was extremely small.

Table 4-6 gives the results for the ANOVA analyses performed on the heavy vehicle data collected during daylight. There was no significant difference in the speeds at the control point between the before and after studies. This indicates that probably there were no additional factors influencing traffic in the after study. At point 2, average speed actually increased from 65.7 mph in the before study to 66.8 mph in the after study, a difference of 1.1 mph. By the time heavy vehicles reached point 4, the average speed was about the same as it was in the before study. At point 5, downstream of the red border treatment, the average speed of heavy vehicles during daylight dropped from 61.0 mph in the before study to 59.3 mph in the after study, a difference of 1.7 mph. The 85th percentile speed at point 5 declined from 69 mph in the before study to 66 mph in the after study. Figure 4-10 shows a graphical representation of the average and 85th percentile speeds for the heavy vehicle data collected during daylight at Caldwell. No significant differences in variance were detected by the Levene's test.

Table 4-6. Results for SH 21 Approaching Caldwell, Daytime Heavy Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign)	Mean Speed (mph)	66.1	66.3	0.2
	85th Speed (mph)	73	72	-1.0
	Std. Dev. (mph)	5.8	4.8	1.0
	Sample Size	109	107	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)[1]	65.7	66.8*	1.1
	85th Speed (mph)	73	73	0.0
	Std. Dev. (mph)	5.9	4.9	1.0
	Sample Size	109	107	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph) [1]	61.1	61.2	0.1
	85th Speed (mph)	69	67	-2.0
	Std. Dev. (mph)	6.2	5.7	-0.5
	Sample Size	109	107	NA
Point 5: Downstream of Sign	Mean Speed (mph) [1]	61.0	59.3*	-1.7
	85th Speed (mph)	69	66	-3.0
	Std. Dev. (mph)	6.7	5.3	-1.4
	Sample Size	109	107	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

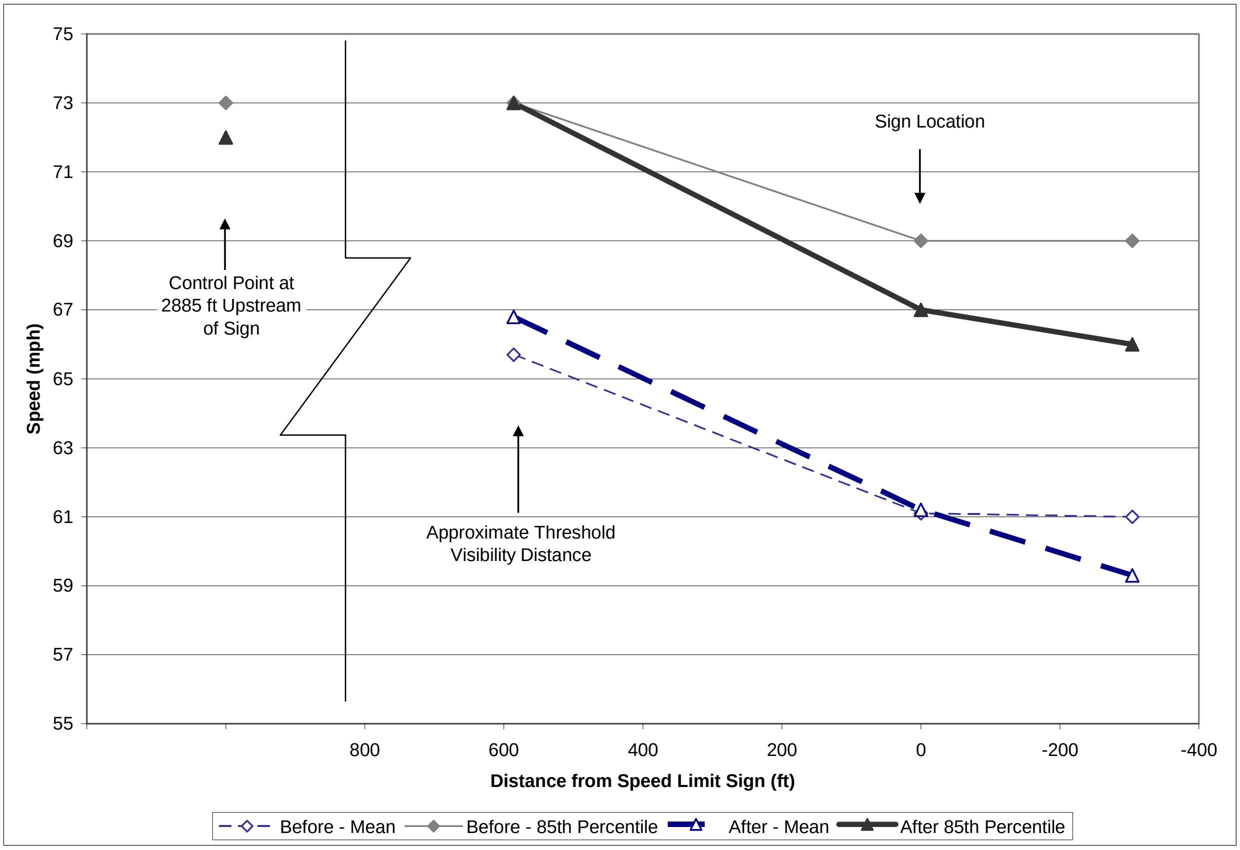

Figure 4-10. SH 21, Caldwell—Mean and 85th Percentile Speeds before and after Red Border Installation.

ANOVA analyses were also performed on the deceleration data for the heavy vehicle sample collected at this site. Table 4-7 shows the results for these analyses. Between point 1 and point 2 the average change in speed increased by 0.5 mph during the after study. This result was expected because of the higher average speeds seen at point 1 and point 2 in the after study data. Between point 2 and point 4 the deceleration in the after study was −5.6 mph. Vehicles were slowing down about 1 mph more in the after study than in the before study. Between point 4 and point 5 deceleration in the after study was −2.0 mph compared to only −0.6 mph in the before study. These results offer more evidence that the red border provides a positive benefit to the motorist.

Table 4-7. Deceleration Analysis Results for SH 21 Approaching Caldwell, Nighttime Passenger Vehicles.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−0.4	0.5*
Deceleration between Point 2 and Point 4	−4.6	−5.6*
Deceleration between Point 4 and Point 5	−0.6	−2.0

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Another measure of the effectiveness of the red border treatment is a comparison of the percentage of vehicles exceeding certain speed thresholds. This test examines any changes in behavior of the upper extremity of the sample. Table 4-8 presents the results of the analysis. For passenger vehicle data collected during daylight, the percent of vehicles exceeding 70 mph and 60 mph was actually greater in the after study at points 1, 2, and 4 than in the before study. However, at point 5, the percent of vehicles exceeding 70 and 60 mph dropped from 16.0 percent in the before study to 12.3 percent in the after study and from 63.2 percent in the before study to 59.1 percent in the after study, respectively. At point 5 the percent of passenger vehicles exceeding 55 mph dropped from 87.0 percent in the before study to 84.1 percent in the after study, but the difference was not statistically significant.

For passenger vehicle data collected at night, the percent of vehicles exceeding the speed limit was not statistically different for any of the speed thresholds for points 1, 2, and 4. However, at point 5 the percent of vehicles exceeding 70 mph was reduced from 8.1 percent to 3.6 percent, and the percent of vehicles exceeding 55 mph was reduced from 76.7 percent in the before study to 63.1 percent in the after study.

For heavy vehicle data collected during daylight, the percent of vehicles exceeding 70 mph at point 5 dropped from 11.0 percent in the before study to 1.9 percent in the after study, a reduction of 9.1 percent. The percent of heavy vehicles exceeding 60 mph was reduced from 51.4 percent in the before study to 34.6 percent in the after study, a difference of 16.8 percent. Figures 4-11, 4-12, and 4-13 show graphical representations of the results for the binomial proportions analysis.

Table 4-8. Percent Exceeding Specific Speed Thresholds in Caldwell.

Condition	Point	Percent Exceeding 70 mph		Percent Exceeding 60 mph		Percent Exceeding 55 mph	
		Before	After	Before	After	Before	After
Passenger Day	1	40.0	56.1*	94.2	96.4*	99.4	99.0
	2	38.3	57.4*	91.3	93.5*	98.7	98.5
	4	14.5	18.5*	67.9	74.7*	87.9	90.5*
	5	16.0	12.3*	63.2	59.1*	87.0	84.1
Passenger Night	1	17.9	22.7	86.9	84.4	96.1	95.1
	2	18.2	24.9	74.9	75.1	94.9	95.1
	4	6.6	7.6	43.0	51.1	75.2	72.0
	5	8.1	3.6*	41.2	36.9	76.7	63.1*
Heavy Vehicles Day	1	21.1	22.4	89.0	86.9	95.4	98.1
	2	21.1	24.3	81.7	92.5*	95.4	99.1
	4	8.3	3.7	52.3	52.3	78.9	86.9
	5	11.0	1.9*	51.4	34.6*	78.9	76.6

Note: * indicates the before and after values are significantly different a 95 percent confidence level.

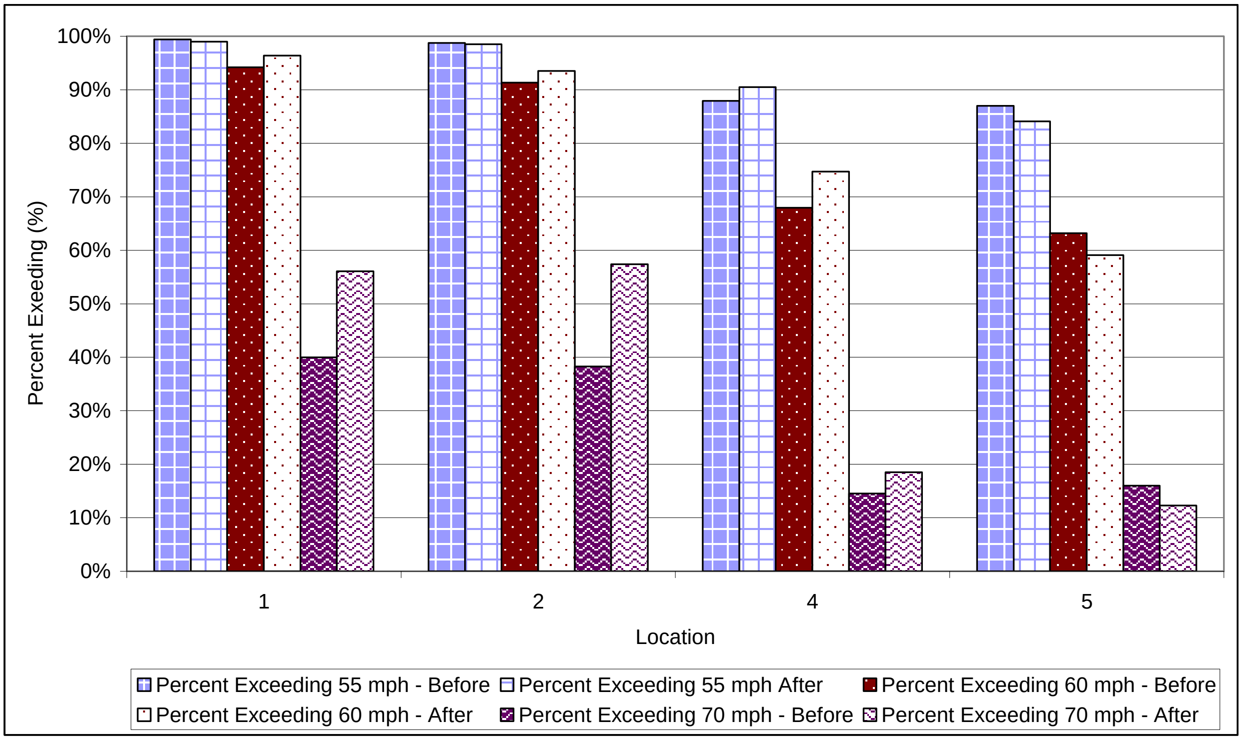

Figure 4-11. Percent of Passenger Vehicles during Daylight Exceeding Specific Thresholds in Caldwell.

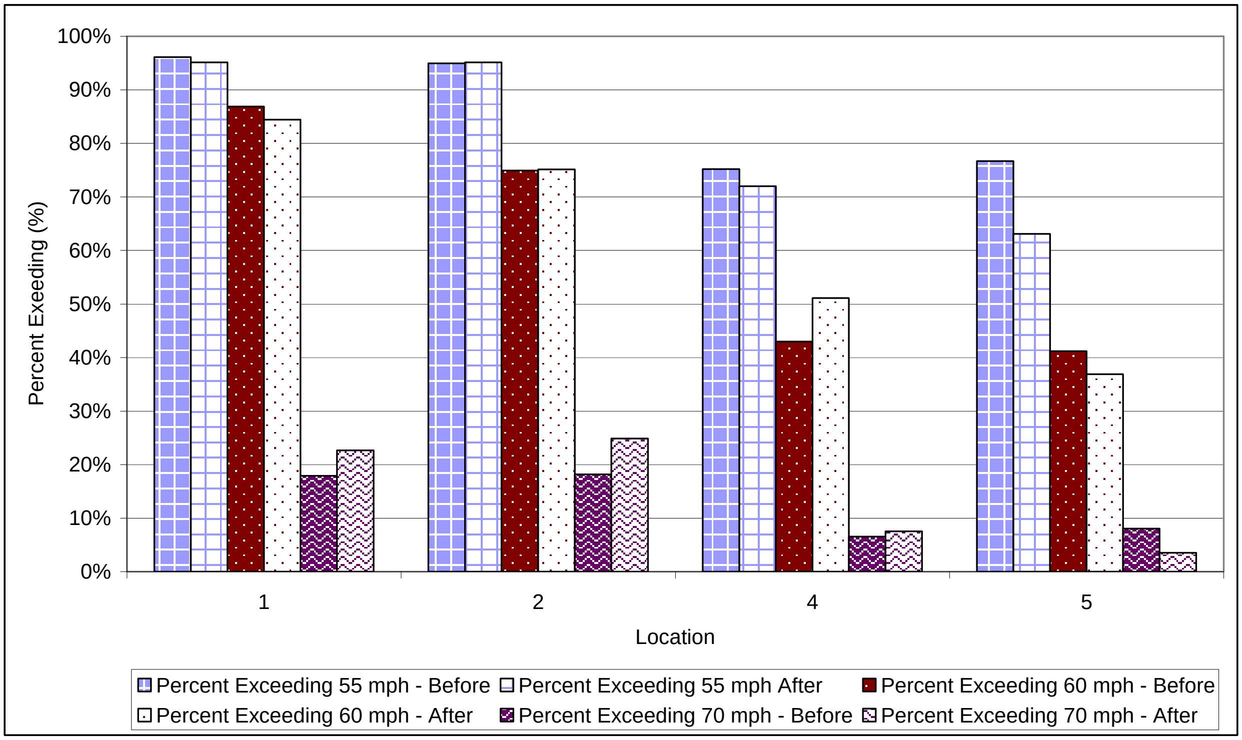

Figure 4-12. Percent of Passenger Vehicles during Night Exceeding Specific Thresholds in Caldwell.

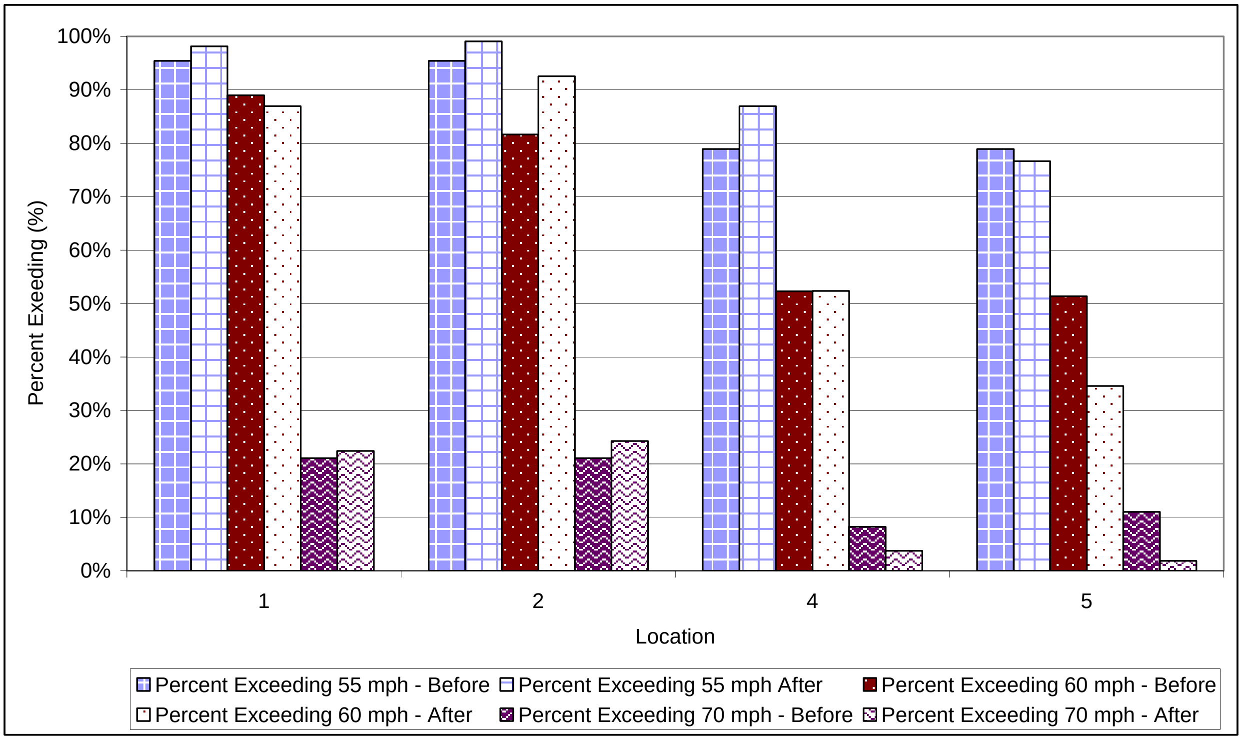

Figure 4-13. Percent of Heavy Vehicles during Daylight Exceeding Specific Thresholds in Caldwell.

Site 2—FM 60 Eastbound Traffic Approaching Snook

Due to equipment problems, the sample of vehicles collected during the after study is much smaller than the sample of vehicles collected in the before study. In an attempt to be as concise as possible, the data presented within the body of this report are summary information. An ANOVA analysis was initially performed on the passenger vehicles data set, and a separate ANOVA analysis was performed on the heavy vehicles data set. In both cases, light condition (i.e., data collected during the day versus collected during the night) was a significant factor that influenced the speeds vehicles were traveling at each data collection point. Thus the day data and night data were also analyzed separately.

Results for Passenger Vehicle Data Collected during Daylight

The results for passenger vehicle data collected during daylight will be discussed first. Table 4-9 shows the results from the ANOVA analysis performed on only the passenger vehicle data collected during daylight hours.

Table 4-9. Results for FM 60 Approaching Snook, Daytime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	70.3	70.8	0.5
	85th Speed (mph)	76	76	0
	Std. Dev. (mph)	5.8	5.6	−0.2
	Sample Size	1401	333	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)[1]	68.5	67.6*	−0.9
	85th Speed (mph)	75	73	−2
	Std. Dev. (mph)	6.2	6.1	−0.1
	Sample Size	1401	333	NA
Point 3: Halfway between Threshold and Sign	Mean Speed (mph) [1]	66.3	66.4	0.1
	85th Speed (mph)	72	73	1
	Std. Dev. (mph)	5.9	6.1	0.2
	Sample Size	1401	333	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph) [1]	67.2	66.3*	−0.9
	85th Speed (mph)	73	73	0
	Std. Dev. (mph)	6.3	6.4	0.1
	Sample Size	1401	333	NA
Point 5: Downstream of Sign	Mean Speed (mph) [1]	65.1	64.7*	−0.4
	85th Speed (mph)	72	71	−1
	Std. Dev. (mph)	6.3	6.6*	0.3
	Sample Size	1401	333	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

Table 4-9 shows that a small but statistically significant reduction in mean speeds at points 2, 4, and 5. At point 2, defined as the approximate legibility threshold distance, a reduction of about 1 mph was observed. A similar reduction in speed was also seen at the Speed Limit sign (point 4). However, downstream of the Speed Limit sign the reduction is less than 0.5 mph. It would seem this result is counterintuitive. Figure 4-14 graphically represents the results for the mean and 85th percentile speeds found for passenger vehicles collected during daylight.

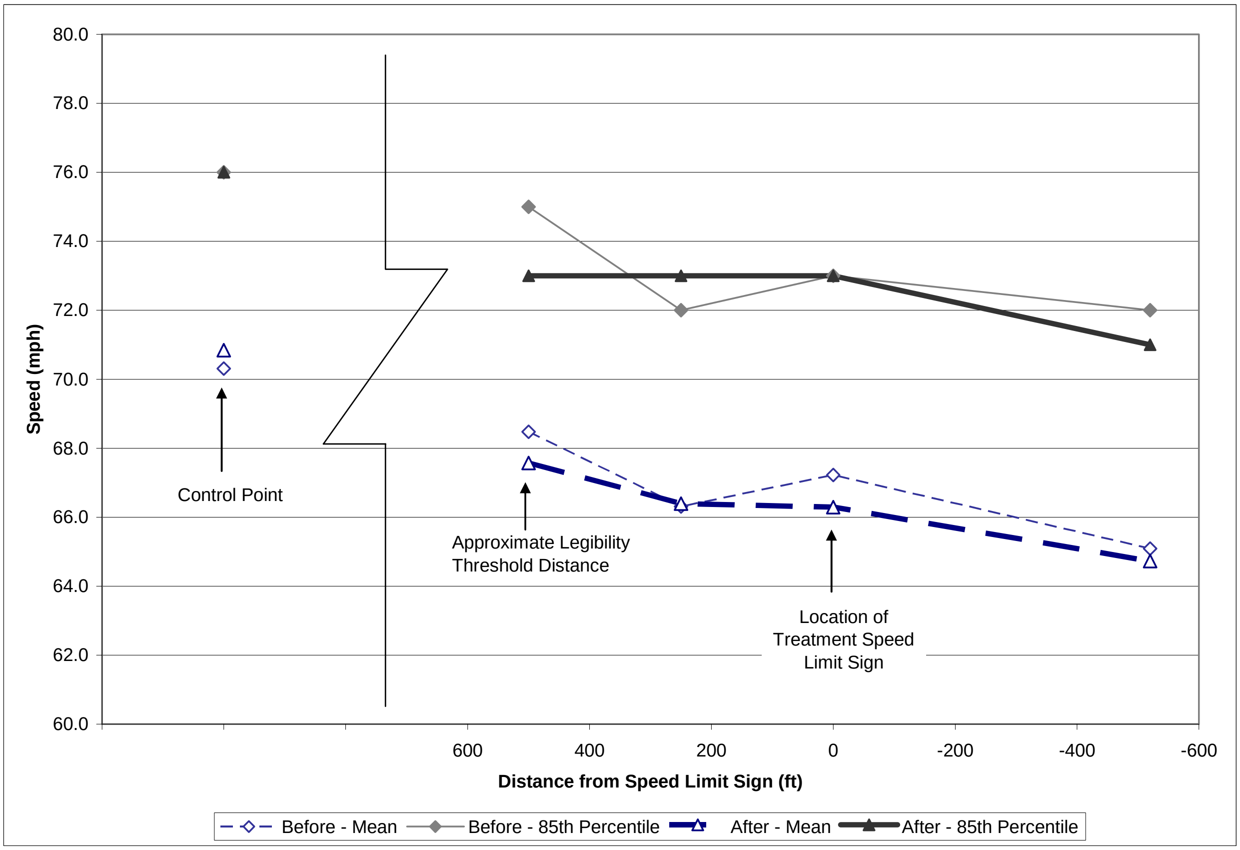

Figure 4-14. FM 60, Snook—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Day Data Only.

Table 4-9 also shows that no significant differences between the standard deviations were found at points 1 through 4. A statistically significant difference in the standard deviation was detected at point 5, but the difference is small and probably only significant because of the rather large sample sizes.

It is also interesting to note that the 85th percentile speed dropped by 2 mph at point 2 and by 1 mph at point 5, but actually increased by 1 mph at point 4. As mentioned earlier no statistical tests were performed directly on 85th percentile data.

ANOVA tests were also performed on deceleration data. Table 4-10 shows that a significant difference in the average deceleration between each counter was detected. One would expect vehicles to slow down more after the installation of the red border treatment, and this was observed between points 1 and 2. The average deceleration between points 1 and 2 increased from 1.8 mph in the before study to 3.3 mph in the after study. Similar results were also observed between points 3 and 4. In the before study vehicles had actually sped up on average 0.9 mph between point 3 and point 4; however, in the after study vehicles slowed down by 0.1 mph. The average deceleration observed in the after study is small, but the difference between the before and after studies is a reduction of 1 mph. Strangely, the average deceleration between points 2 and 3 was actually greater in the before study than in the after study. Vehicles slowed down on average 0.6 mph more during the before study. Similar results were seen between points 4 and 5. Vehicles reduced their speed on average 0.5 mph more during the before study. This could be an indication that the red border draws the driver's attention faster and thus people react sooner.

Table 4-10. Deceleration Analysis Results for FM 60 Approaching Snook, Daytime Passenger Vehicles.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−1.8	−3.3*
Deceleration between Point 2 and Point 3	−2.2	−1.2*
Deceleration between Point 3 and Point 4	0.9	−0.1*
Deceleration between Point 4 and Point 5	−2.1	−1.6*

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Results for Passenger Vehicle Data Collected during Night

As mentioned previously, light condition was a significant factor that influenced the speed of vehicles. Thus the data collected at night was analyzed separately from the day data for passenger vehicles. Some of the results from the passenger data collected at night are presented in Table 4-11.

One of the first interesting things to note about the results presented in Table 4-11 is that the average speed at the control point is statistically significantly higher in the after study than in the before study. This is important because the speed at the control point is entered as a covariate in the analyses at the other points. Statistical differences between before and after average speeds were found at points 2 through 5 as well. This seems odd at points 2 and 3. The difference between the before and after speeds are 0.1 and 0 mph, respectively, for points 2 and 3. The reason that the speeds at points 2 and 3 were found to be statistically different is because the control point was entered as the covariate. At points 4 and 5 small but statistically significant reductions of 0.4 and 0.5 mph between the before and after studies were observed.

Table 4-11. Results for FM 60 Approaching Snook, Nightime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	67.0	68.6*	1.6
	85th Speed (mph)	73	75	2
	Std. Dev. (mph)	5.8	6.1	0.3
	Sample Size	473	174	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)[1]	63.4	63.3*	−0.1
	85th Speed (mph)	70	69	−1
	Std. Dev. (mph)	6.3	5.6	−0.7
	Sample Size	473	174	NA
Point 3: Halfway between Threshold and Sign	Mean Speed (mph)[1]	62.2	62.2*	0
	85th Speed (mph)	69	68	−1
	Std. Dev. (mph)	6.3	5.8*	−0.5
	Sample Size	473	174	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph)[1]	62.0	61.6*	−0.4
	85th Speed (mph)	69	68	−1
	Std. Dev. (mph)	6.7	6.2	−0.5
	Sample Size	473	174	NA
Point 5: Downstream of Sign	Mean Speed (mph)[1]	60.8	60.3*	−0.5
	85th Speed (mph)	68	67	−1
	Std. Dev. (mph)	6.5	6.0	−0.5
	Sample Size	473	174	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

The Levene's test was again used to test for differences between before and after speed variances at each point. A significant difference in the variance was detected at point 3. The variance dropped from 6.3 mph in the before study to 5.8 mph in the after study. The reduction was small and probably only significant because of the fairly large sample size.

Figure 4-15 is a graphical representation of the average and 85th percentile speeds at each point. A consistent reduction in the 85th percentile speeds of about 1 mph is seen. As mentioned previously no statistical tests were performed directly on the 85th percentile speeds. Smaller reductions are also seen in the average speed as well. Though the mean speed reductions are small, it is important to remember that the upstream speed was higher during the after study. An analysis of the mean deceleration speeds may better quantify the effect of the red border in this case.

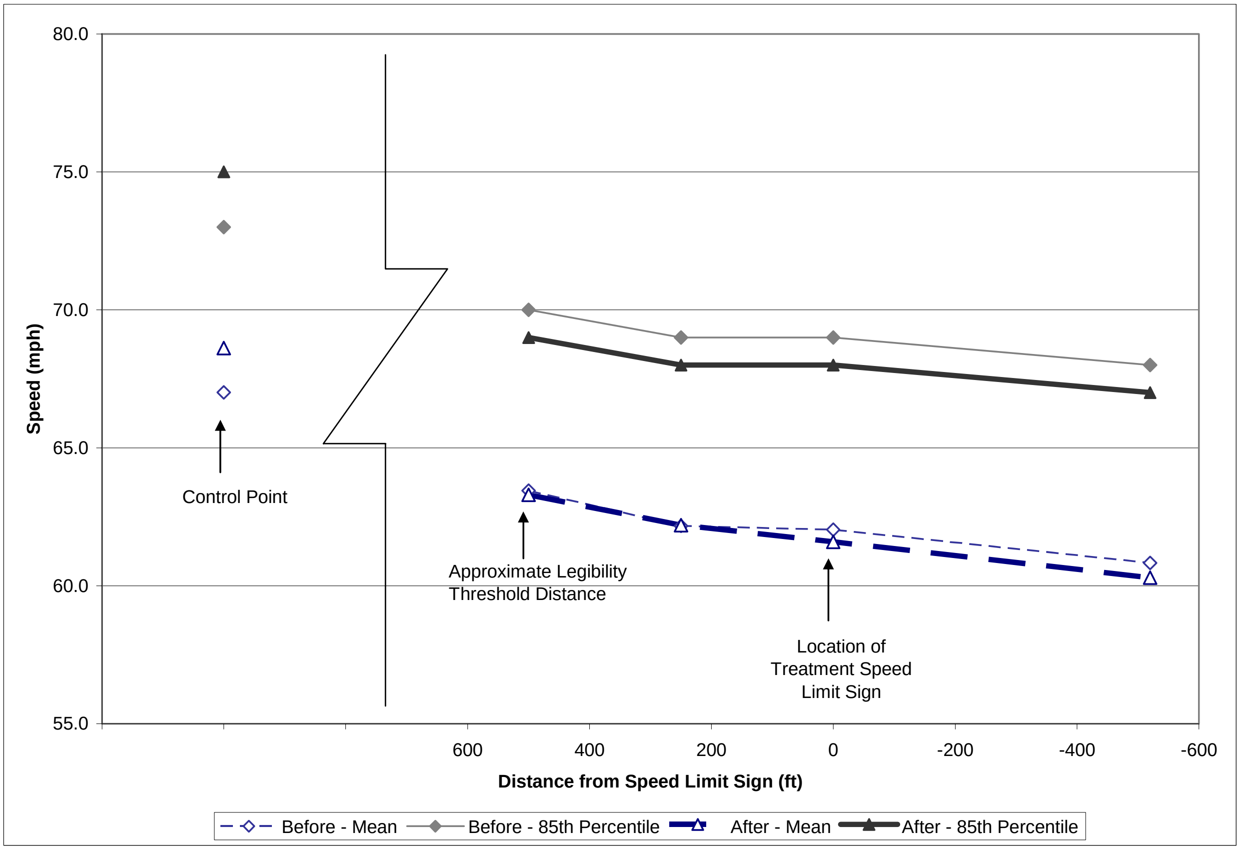

Figure 4-15. FM 60, Snook—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Night Data Only.

Table 4-12 lists the results from the ANOVA analysis on deceleration. The largest deceleration difference is between points 1 and 2. On average passenger vehicles traveling at night slowed down 1.7 mph more after the red border was installed. Smaller differences in mean decelerations are seen between points 3 and 4 and between points 4 and 5. Again the control point speed was entered as a covariate for each analysis. A greater effect was again seen at the legibility threshold instead of downstream of the red border Speed Limit sign as was initially expected.

Table 4-12. Deceleration Analysis Results for FM 60 Approaching Snook, Nighttime Passenger Vehicles.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−3.6	−5.3*
Deceleration between Point 2 and Point 3	−1.3	−1.1
Deceleration between Point 3 and Point 4	−0.1	−0.6*
Deceleration between Point 4 and Point 5	−1.2	−1.3*

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Binomial proportions tests were also performed on the speed data. For the most part few statistical differences were observed between the before and after proportions of vehicles exceeding certain speed thresholds. Table 4-13 shows the results of the binomial analyses for day and night passenger vehicle data. For passenger vehicle data collected during daylight and at night, the proportion of vehicles exceeding 70 mph was statistically lower in the before data than in the after data. This is likely influenced by the fact that the sample size was much smaller in the after data. No other statistical differences were found at points 2 through 5 between the proportions of passenger vehicles exceeding the 70 mph in the before study compared with the same in the after study. However, at points 2, 4, and 5 the proportion of vehicles exceeding 70 mph is lower during the after study, though the difference is not statistically significant. For the proportion of vehicles exceeding 60 mph, no statistical differences between before and after proportions were found. For the proportion of vehicles exceeding 60 mph, the proportion of vehicles at the treatment Speed Limit sign (point 4) was significantly different between the before and after studies for passenger vehicles collected during daylight. In the before study, 85.4 percent of passenger vehicles collected during daylight were exceeding 60 mph at the treatment Speed Limit sign. This dropped to 80.8 percent in the after study, a reduction of 4.6 percent. At points 2, 3, and 5 the proportion of vehicles exceeding 60 mph did drop between the before and after period; however, the difference was not significant. No significant differences in the proportion of vehicles exceeding 70 mph were seen for the passenger vehicle data collected at night, though again the general trend was that a slightly smaller proportion of vehicles were exceeding 60 mph in the after study.

Table 4-13. Percent Exceeding Specific Speed Thresholds in Snook, Passenger Vehicle Data.

Condition	Point	Percent Exceeding 70 mph		Percent Exceeding 60 mph		Percent Exceeding 55 mph	
		Before	After	Before	After	Before	After
Passenger Day	1	46.7	54.4*	94.6	95.2	99.0	98.5
	2	36.3	32.7	90.0	86.5	97.6	96.1
	3	20.9	23.1	84.2	82.9	96.5	93.7*
	4	28.5	24.3	85.4	80.8*	96.7	93.7*
	5	18.1	18.0	74.9	71.8	93.6	90.7
Passenger Night	1	24.1	40.2*	88.2	90.8	98.1	97.7
	2	12.5	9.2	65.3	67.2	90.5	89.7
	3	9.5	6.5	58.1	58.6	85.8	86.2
	4	8.7	6.3	56.0	55.2	81.0	81.6
	5	8.7	5.2	46.7	45.4	75.1	75.9

* indicates the before and after values are significantly different a 95 percent confidence level.

For the proportion of vehicles exceeding 55 mph, statistically significant differences between before and after data for passenger vehicle data collected during daylight were found at points 3 and 4. At point 3 (halfway between the legibility threshold and the treatment Speed Limit sign), the proportion of vehicles exceeding 55 mph dropped from 96.5 to 93.7 percent, a difference of 2.8 percent. The proportion is still quite high, but technically the speed limit has not changed to 55 mph at point 3. At point 4, the location of the 55 mph treatment Speed Limit sign, the proportion of vehicles exceeding 55 mph dropped from 96.7 to 93.7 percent. The proportion of vehicles at point 5 dropped from 93.6 to 90.7 percent between the before and after study, but the reduction was not statistically significant. No significant differences were found between before and after night, passenger vehicle data exceeding 55 mph. Figure 4-16 shows the comparisons of proportions of passenger vehicles exceeding the various speed thresholds during daylight at point 4. Figure 4-17 shows the proportion of passenger vehicles exceeding the various speed thresholds during daylight at point 5. Figure 4-18 shows the proportion of passenger vehicles exceeding the various speed thresholds at night at point 5.

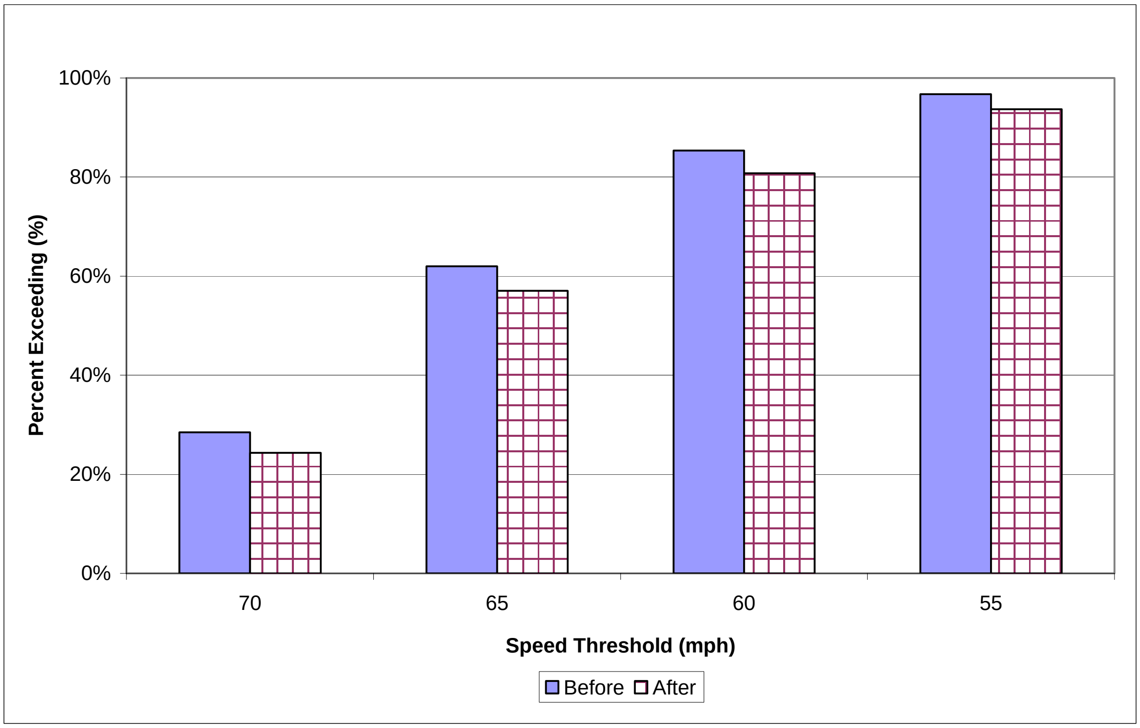

Figure 4-16. FM 60, Snook—Percent of Passenger Vehicles during Daylight Exceeding Speed Thresholds at Speed Sign before and after the Installation of the Red Border.

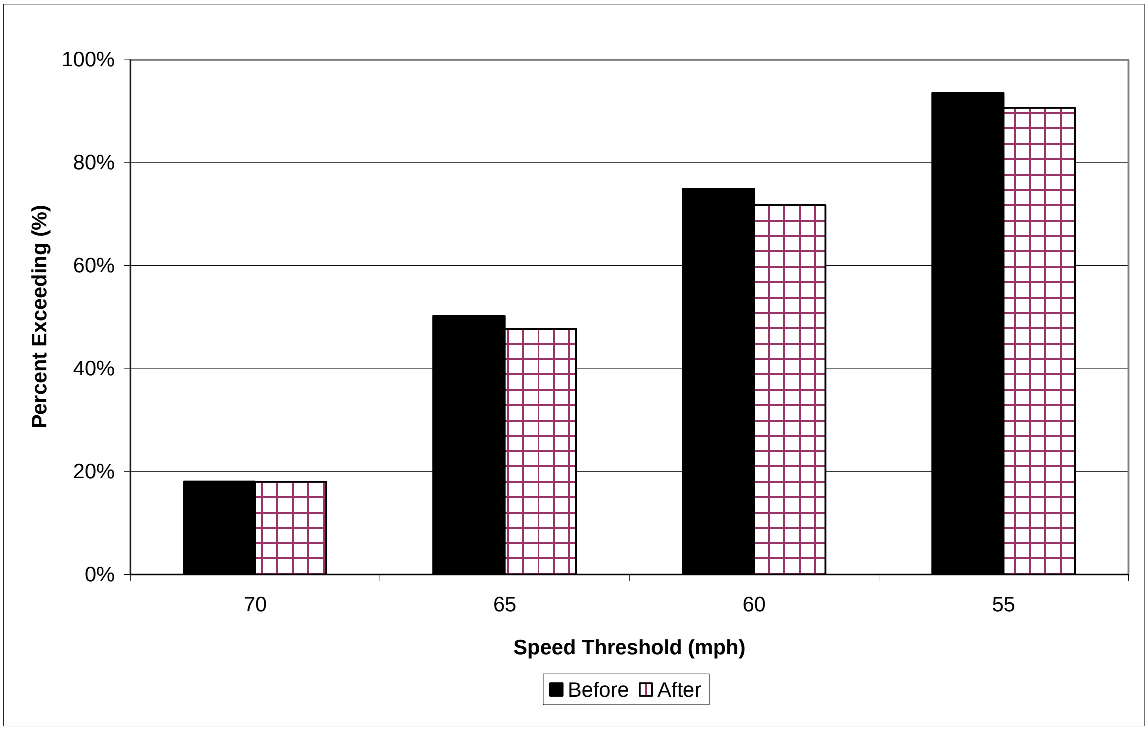

Figure 4-17. FM 60, Snook—Percent of Passenger Vehicles during Daylight Exceeding Speed Thresholds Downstream of Speed Sign before and after the Installation of the Red Border.

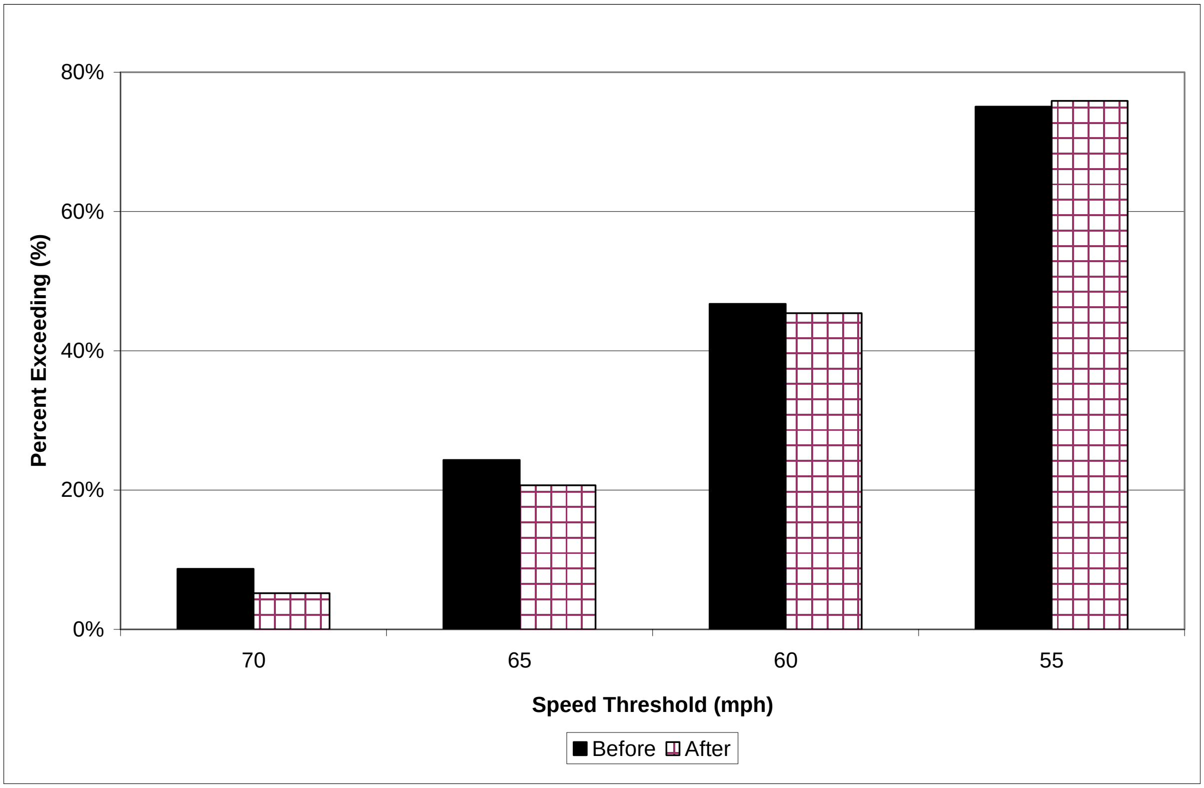

Figure 4-18. FM 60, Snook—Percent of Passenger Vehicles during Night Exceeding Speed Thresholds Downstream of Speed Sign before and after the Installation of the Red Border.

Results for Heavy Vehicle Data

Due to equipment problems the sample of heavy vehicles collected during the after study was extremely small, only 31 heavy vehicles total. However, no statistical tests were performed on the data.

Site 3—SH 36 Northbound Traffic Approaching Milano

ANOVA analyses were used to compare mean speeds. Again light condition was a significant factor, so the day and night data are presented separately.

Results for Passenger Vehicle Data Collected during Daylight

Table 4-14 shows the results for the passenger vehicle data collected during daylight hours. One significant finding at this site was that the after control point data were significantly different from the before data. The average speed in the after study was 1.8 mph faster than the average speed in the before study. This makes the results a little more confusing. Table 4-14 also shows that a significant difference between the before and after average speeds was found at all five locations where speed data were collected. Because the control point data were entered into the analysis as the covariate, the speed each vehicle was going at the control point is taken into consideration using this analysis. The results actually indicate that considering the upstream speeds, even though the actual before average is not less than the after average, vehicles tend to be slowing down more. At point 5, downstream of the treatment Speed Limit sign, the effect of the red border is more evident. Average speeds were reduced from 66.2 mph to 65.3 mph, a decrease of 0.9 mph.

Table 4-14. Results for FM 36 Approaching Milano, Daytime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	71.0	72.8*	1.8
	85th Speed (mph)	76	77	1
	Std. Dev. (mph)	5.5	5.2	−0.3
	Sample Size	361	364	NA
Point 2: Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph)*	68.7	69.2*	0.5
	85th Speed (mph)	73	74	1
	Std. Dev. (mph)	5.8	5.1	−0.7
	Sample Size	361	364	NA
Point 3: Halfway between Threshold and Sign	Mean Speed (mph)*	68.2	68.5*	0.3
	85th Speed (mph)	73	74	1
	Std. Dev. (mph)	6.0	5.7	−0.3
	Sample Size	361	364	NA
Point 4: At Speed Limit Sign Treatment Sign	Mean Speed (mph)*	66.2	65.9*	−0.3
	85th Speed (mph)	72	72	0
	Std. Dev. (mph)	6.0	5.9	−0.1
	Sample Size	361	364	NA
Point 5: Downstream of Sign	Mean Speed (mph)*	66.2	65.3*	−0.9
	85th Speed (mph)	73	72	−1
	Std. Dev. (mph)	6.4	6.3	−0.1
	Sample Size	361	364	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

No significant differences were found between the before and after variances at each spot speed location. The 85th percentile speeds for after study data were slightly higher at the control point and the approximate legibility threshold point (point 2), and slightly lower downstream of the treatment. No statistical tests were performed directly on the 85th percentile data; however, the upper extremities were examined using a binomial proportions test. Figure 4-19 shows a graphical representation of the average speed and 85th percentile speed data for passenger vehicle data collected during daylight.

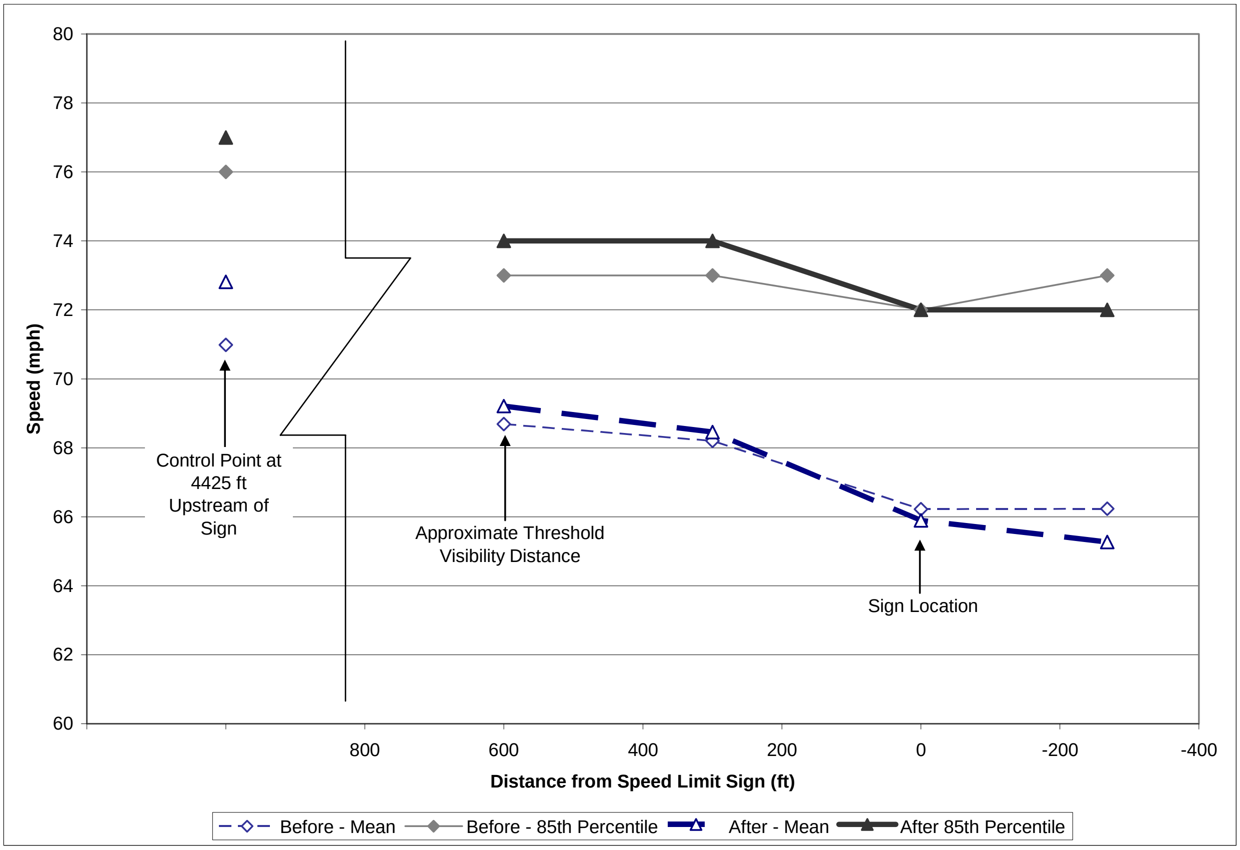

Figure 4-19. FM 36, Milano—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Day Data Only.

ANOVA analyses were also performed on the deceleration data. Table 4-15 shows the results from these analyses. Significant differences in the magnitude of deceleration were found in two places, first between the control point and point 2 and second between point 4 and point 5. It makes intuitive sense that vehicles in the after study would be slowing down more between the control point and point 2 because in the after study speeds at the control point were a little higher than they were in the before study. Potentially vehicles slowed down more because motorists saw the sign just before this point. The average change in speed between point 4 and point 5 was 0.1 mph in the before study (i.e., on average vehicles sped up 0.1 mph between point 4 and point 5) and −0.6 mph in the after study, a difference of 0.7 mph.

Table 4-15. Deceleration Analysis Results for SH 36 Approaching Milano, Daytime Passenger Vehicle Data.

Measure of Effectiveness	Before	After
Deceleration between Point 1 and Point 2	−2.3	−3.6*
Deceleration between Point 2 and Point 3	−0.5	−0.8
Deceleration between Point 3 and Point 4	−1.9	−2.6
Deceleration between Point 4 and Point 5	0.1	−0.6*

Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.

Results for Passenger Vehicle Data Collected during Night

Table 4-16 shows the results from the ANOVA analyses for passenger vehicle data collected at night. Again, at all five spot speed data collection locations the speeds were significantly different between the before and after data collection periods. Just as in the day data analysis, the average speed at the control point is a little higher during the after data collection period. The average speed at point 2 dropped from 65.5 mph in the before study to 64.5 mph in the after study. The average speed at point 3 and point 4 also dropped between the before and after study periods by 0.8 mph and 0.9 mph, respectively. The largest reduction in speed was seen at point 5, downstream of the treatment Speed Limit sign. The speed at point 5 was reduced from 63.0 mph in the before study to 61.5 mph in the after study, a difference of 1.5 mph.

Similar results were seen for 85th percentile speeds for passenger vehicles at night. The 85th percentile speed at the control point was 2 mph faster in the after study than in the before study. At point 5, however, the 85th percentile speed is 3 mph less in the after study than it was in the before study. No significant differences were detected for variance data. Figure 4-20 is a graphical representation of the average and 85th percentile speeds for both the before and after data.

Table 4-16. Results for FM 36 Approaching Milano, Nighttime Passenger Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	68.2	69.2*	1
	85th Speed (mph)	73	75	2
	Std. Dev. (mph)	5.6	5.9	0.3
	Sample Size	120	63	NA
Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph) [1]	65.5	64.5*	−1
	85th Speed (mph)	71	70	−1
	Std. Dev. (mph)	5.3	5.3	0
	Sample Size	120	63	NA
Halfway between Threshold and Sign	Mean Speed (mph) [1]	64.9	64.1*	−0.8
	85th Speed (mph)	70	69	−1
	Std. Dev. (mph)	5.4	5.5	0.1
	Sample Size	120	63	NA
At Speed Limit Sign Treatment Sign	Mean Speed (mph) [1]	62.8	61.9*	−0.9
	85th Speed (mph)	69	68	−1
	Std. Dev. (mph)	5.6	5.4	−0.2
	Sample Size	120	63	NA
Downstream of Sign	Mean Speed (mph) [1]	63.0	61.5*	−1.5
	85th Speed (mph)	70	67	−3
	Std. Dev. (mph)	5.9	4.9	−1
	Sample Size	120	63	NA

[1] Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

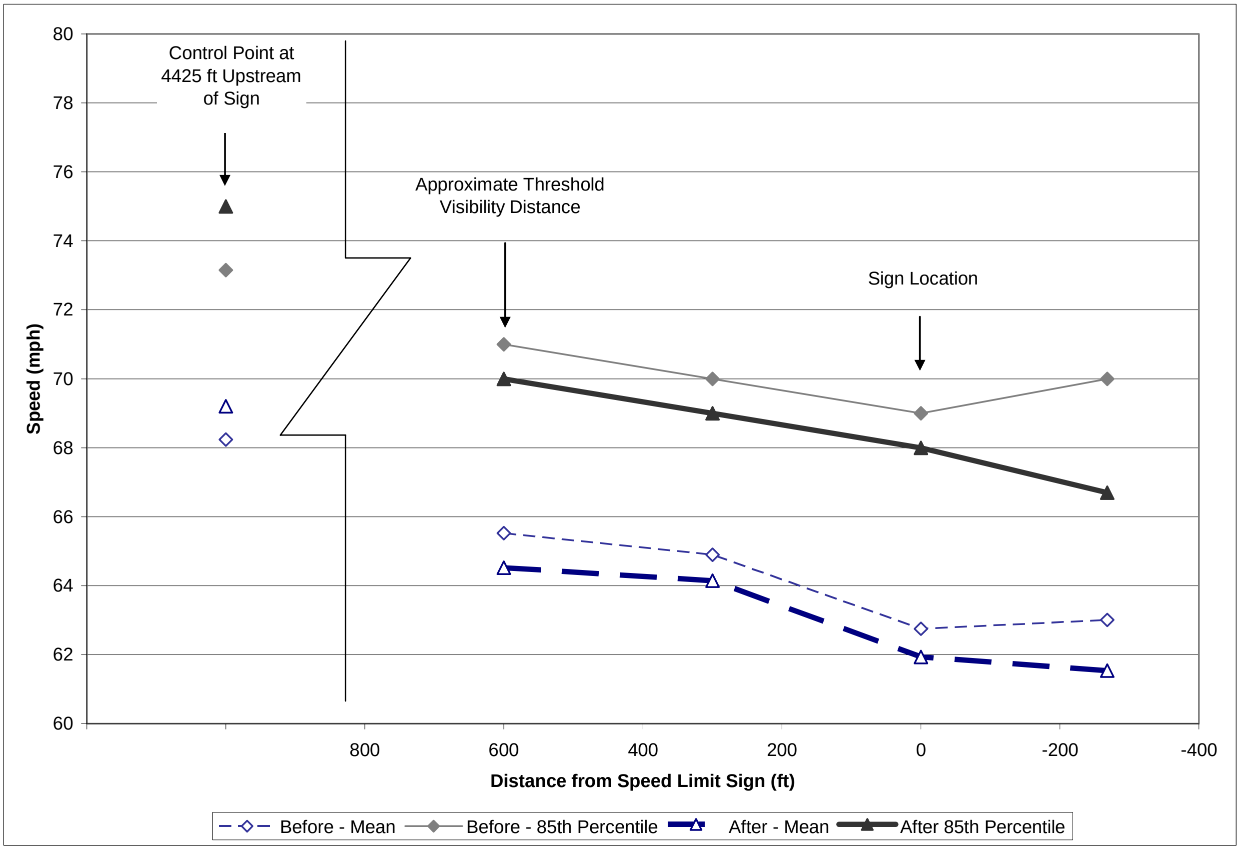

Figure 4-20. FM 36, Milano—Mean and 85th Percentile Speeds before and after Red Border Installation, Passenger Vehicles, Night Data Only.

Results for Heavy Vehicle Data Collected during Daylight

Only heavy vehicle data collected during daylight was analyzed for this site because during the after study only a very small number of heavy vehicle speeds were collected. The sample size at night for heavy vehicles during the after study was only eight vehicles. So ANOVA analyses performed on the heavy vehicle day data only will be reported. Table 4-17 shows the results from the ANOVA analyses and the 85th percentile calculations. The only location where a significant difference was found was at the control point. The average speed in the after study was 70.0 mph, and the average speed in the before study was 67.6 mph, a difference of 2.4 mph. The fact that no significant difference was found between the before and after average speeds at points 2 through 5 is probably because the control point speed was entered as a covariate in the analysis. Even though the difference is about 2 mph at each point, because the upstream control point speed was also about 2 mph higher in the after study the difference was not found to be statistically significant. Figure 4-21 shows a graphical representation of the average and 85th percentile speeds for heavy vehicle data collected during daylight in Milano.

Table 4-17. Results for FM 36 Approaching Milano, Daytime Heavy Vehicles.

Location	Measure of Effectiveness	Before	After	After-Before
Control Point: 7500 ft Upstream from Sign	Mean Speed (mph)	67.6	70.0*	2.4
	85th Speed (mph)	73	74	1.0
	Std. Dev. (mph)	4.7	4.3	−0.4
	Sample Size	157	116	NA
Approximate Threshold Distance (Where Sign Is Legible)	Mean Speed (mph) [1]	63.6	65.6	2.0
	85th Speed (mph)	68	70	2.0
	Std. Dev. (mph)	5.1	4.6	−0.5
	Sample Size	157	116	NA
Halfway between Threshold and Sign	Mean Speed (mph) [1]	63.6	65.4	1.8
	85th Speed (mph)	68	70	2.0
	Std. Dev. (mph)	5.1	4.8	−0.3
	Sample Size	157	116	NA
At Speed Limit Sign Treatment Sign	Mean Speed (mph) [1]	62.1	63.9	1.8
	85th Speed (mph)	66	69	3.0
	Std. Dev. (mph)	4.8	4.8	0.0
	Sample Size	157	116	NA
Downstream of Sign	Mean Speed (mph)[1]	62.3	63.8	1.5
	85th Speed (mph)	66	70	4.0
	Std. Dev. (mph)	5.1	5.3	0.2
	Sample Size	157	116	NA

[1]Control point speed was included in the analysis as a covariate.
Negative numbers indicate deceleration, and positive numbers indicate acceleration.
* indicates the before and after values are significantly different a 95 percent confidence level.
85th percentile speeds were not tested for significant difference.

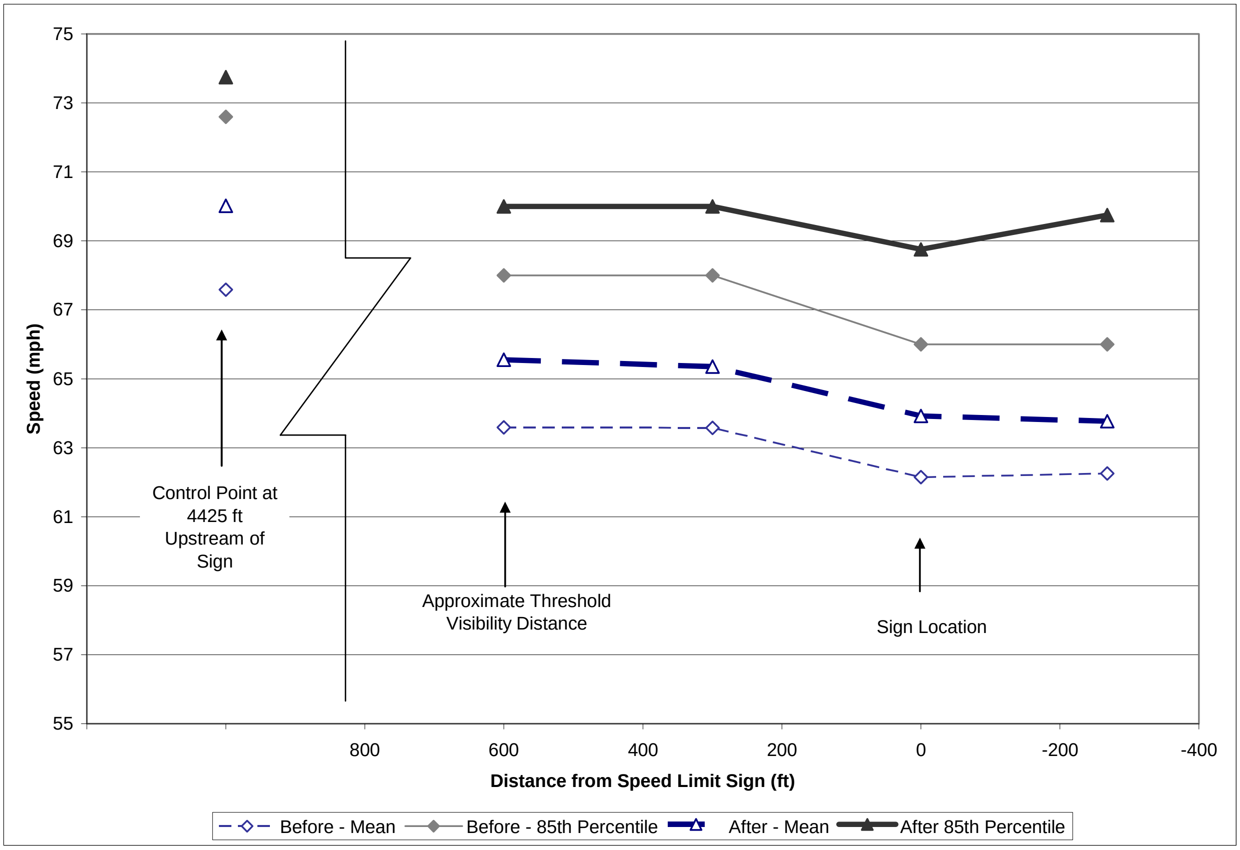

Figure 4-21. FM 36, Milano—Mean and 85th Percentile Speeds before and after Red Border Installation, Heavy Vehicles, Day Data Only.

Percent of Vehicles Exceeding Specific Speed Thresholds

Again, binomial proportions tests were used to test whether there was a significant difference between the percent of vehicles exceeding certain speed thresholds in the before study compared to the percent exceeding those thresholds in the after study. Table 4-18 shows the results for this analysis for the percent exceeding 70, 60, and 55 mph. At Milano, the results from this statistical test indicate that the red border had little effect on the faster speeding vehicles. The percent of passenger vehicles during the daytime exceeding 70 mph at the control point was higher in the after study than in the before study. At point 5, the percent of vehicles exceeding 70 mph dropped from 26.6 in the before study to 19.8 in the after study, a difference of 6.8 percent. No statistically significant reductions in the percent of vehicles exceeding 60 mph and 55 mph were observed, though at point 5 a small (but not statistically significant) reduction was seen for both the percent exceeding 60 and 55 mph.

Table 4-18. Percent Exceeding Specific Speed Thresholds in Milano.

Condition	Point	Percent Exceeding 70 mph		Percent Exceeding 60 mph		Percent Exceeding 55 mph	
		Before	After	Before	After	Before	After
Passenger Day	1	54.8	65.7*	95.6	99.2*	100	100
	2	39.9	38.7	90.3	94.5*	96.4	98.9
	3	34.9	34.9	88.9	90.1	97.0	98.4
	4	22.7	19.0	83.1	79.9	94.7	96.4
	5	26.6	19.8*	79.5	77.2	95.0	93.4
Passenger Night	1	29.2	34.9	92.5	93.7	100	98.4
	2	16.7	11.1	82.5	77.8	96.7	95.2
	3	11.7	12.7	79.2	76.2	95.0	93.7
	4	6.7	6.3	65.0	58.7	89.2	90.5
	5	7.5	3.2	63.3	54.0	90.0	90.5
Heavy Vehicles Day	1	25.5	48.3*	94.3	97.4	98.1	99.1
	2	8.3	12.9	70.7	87.1	95.5	97.4
	3	7.0	14.7*	74.5	83.6	96.8	97.4
	4	4.5	9.5	63.7	76.7	90.4	94.8
	5	7.6	7.8	65.0	72.4	88.5	93.1

* indicates the before and after values are significantly different a 95 percent confidence level.

No statistically significant reductions were found for passenger vehicle data collected at night. At point 5, there were small reductions in the percent of vehicles exceeding 70 and 60 mph. This result may be considered somewhat important because the percent of vehicles exceeding 70 and 60 mph at the control point are higher in the after study.

For heavy vehicle data collected during daylight, there were no locations where the percent exceeding the various thresholds was significantly lowered in the after study. It is hard to draw any conclusions from the heavy vehicle data exceeding 70 mph because the percent of vehicles exceeding the speed limit at the control point is substantially higher in the after data collection period. Overall it seems that the red border had a greater effect on those vehicles driving faster than 70 mph for both passenger and heavy vehicles.

Site 4—US 79 Southbound Traffic Approaching Franklin

Equipment failures on two different occasions left researchers with data at counter 5 only for both the before and after study. An ANOVA analysis was performed on the data; however, no upstream variable was available to be entered as a covariate. Table 4-19 shows the results from the ANOVA analysis and the 85th percentile speeds. The results indicate that average and 85th percentile speeds were actually much greater in the after study than in the before study. There are several possible reasons for this, with the most likely reason being that the equipment was again not functioning properly. Another explanation could be that the sample in the before study was just much slower than usual. With data from only one counter it is hard to validate these results, especially with no similar results at any other sites. The data from this site were regarded as bad data and not used to draw any conclusions about the performance of the red border.

Table 4-19. Results for US 79 Approaching Franklin.

Location	Measure of Effectiveness	Before	After	After-Before
Passenger Vehicles: Downstream of Sign	Mean Speed (mph)[1]	53.6	61.9*	8.2
	85th Speed (mph)	59	68	9
	Std. Dev. (mph)	4.9	5.9*	0.9
	Sample Size	2665	2552	NA
Heavy Vehicles: Downstream of Sign	Mean Speed (mph)[1]	52.9	61.7*	8.8
	85th Speed (mph)	57	67	10
	Std. Dev. (mph)	3.7	5.3*	1.6
	Sample Size	195	585	NA

[1]Control point speed was included in the analysis as a covariate.
* indicates the before and after values are significantly different a 95 percent confidence level.
85 percentile speeds were not tested for significant difference.

SUMMARY AND CONCLUSIONS

This study examined the effectiveness of installing a red border around a Speed Limit sign in locations where the speed limit decreased by at least 10 mph. Four sites were examined. At three of the sites, several positive results were identified. Some of the positive benefits attributed to the red border included:

- **A decrease in the percent of vehicles exceeding speed thresholds, especially downstream of the Speed Limit sign**—At Site 1, at point 5, there was a 3.7 percent reduction in the percent of passenger vehicles during daylight exceeding 70 mph and a 4.1 percent reduction in the percent of passenger vehicles during daylight exceeding 60 mph. For heavy vehicle data collected during the day at Site 1, there was a 9.1 percent reduction in the percent of vehicles exceeding 70 mph and a 16.8 percent reduction in vehicles exceeding 60 mph. At Site 2, reductions of about 3 percent were seen for the percent of daytime passenger vehicles exceeding 55, 60, and 65 mph; however, the reductions were not significant. At point 4, significant reductions between 3 and 5 percent were observed. At Site 3, a significant reduction of about 6.8 percent in the percent of vehicles exceeding 70 mph was observed at point 5 for daytime passenger vehicle data. Reductions in the percent of vehicles exceeding 70 and 60 mph were also observed at point 5 for nighttime passenger vehicle data, but the difference was not significant.
- **A reduction in average speed between 0.5 and 2.0 mph at the Speed Limit sign and downstream of the Speed Limit sign**—At Site 1, despite faster speeds at the control point for passenger vehicles during the after study, a decrease in the average speed of 0.8 mph was seen at point 5 for passenger vehicles collected during daylight, and a decrease in average speed of 1.9 mph was seen at point 5 for passenger vehicles collected at night. At Site 2, the largest reduction in average speed was seen at point 4, the Speed Limit sign for passenger vehicles during daylight. The average speed was reduced by about 1 mph at point 4, and by about 0.5 mph at point 5. At night passenger vehicles reduced their average speed by about 0.5 mph at both points 4 and 5. At Site 3, passenger vehicles reduced their average speeds by 0.3 and 0.9 mph at points 4 and 5, respectively. At night passenger vehicle's average speed was reduced by 0.9 mph at the Speed Limit sign and 1.5 mph downstream of the sign.
- **A reduction in 85th percentile speed of 1 to 3 mph downstream of the treatment Speed Limit sign**—At Site 1, the 85th percentile speed for passenger vehicles during daylight dropped by 1 mph at point 4 and 2 mph at point 5. The 85th percentile speed for passenger vehicles during nighttime dropped by 1 mph at

point 5. At Site 2, the 85th percentile speed dropped by 1 mph at point 5, and the 85th percentile speed for passenger vehicles at night dropped by 1 mph at points 2, 3, 4, and 5. At Site 3, the 85th percentile speed dropped by 1 mph at point 4 and by 3 mph at point 5.

RECOMMENDATIONS

The red border Speed Limit sign showed promising results at three of the four tested sites. At the present time, researchers recommend that the red border be used for emphasis at problem locations where the speed limit is dropping at least 10 mph. The researchers plan to conduct additional evaluations of this treatment as a future activity on this project.

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4. Permise en ligne (License on Line). The Code. http://www.permisenligne.com/. Accessed September 9, 2004.

CHAPTER 5:
WORK ZONE SIGN SUPPORT CRASH TEST

INTRODUCTION

The crashworthiness of work zone sign supports is a significant issue and one that can have an important impact on the safety of work zones. The Texas Department of Transportation (TxDOT) and the traffic control industry are on a continuous quest to identify sign support systems for work zone applications that are cost-effective to build, install, and maintain. To facilitate improvements in work zone safety, Project 0-4701 was modified during the first year to add a work zone sign support crash test to the project activities. The crash test was conducted on July 27, 2004, at the Texas A&M Riverside Campus to evaluate the impact performance of a new intermediate/long-term temporary sign support system.

TEST ARTICLE

The system was fabricated from perforated square steel tubing and had a 4×4 ft diamond-shaped plywood sign substrate mounted at a height of 7 ft above the ground surface. The sign panel was attached to two 1¾×1¾ inch perforated steel tube uprights. The uprights were inserted into 2×2 inch × 3 ft long vertical sleeves that were welded on their inside and outside edges to the tops of 2×2 inch × 5 ft long skids. The welds were designed to fracture and release the sleeves from the uprights in a frontal impact. A 2×2 inch cross brace was bolted to the back sides of the sleeves just above the skids. The bolts connecting the brace to the sleeves limited the insertion depth of the uprights into the sleeves to 1 inch above the top of the skids. Photographs of the test installation are shown in Figure 5-1.

TEST CONDITIONS

All crash test and data analysis procedures were in accordance with the guidelines presented in *National Cooperative Highway Research Program (NCHRP) Report 350*. Appendix 5-A presents brief descriptions of these procedures. Additionally, the FHWA Windshield Damage Classification Criteria was followed in assessing damage to the windshield.

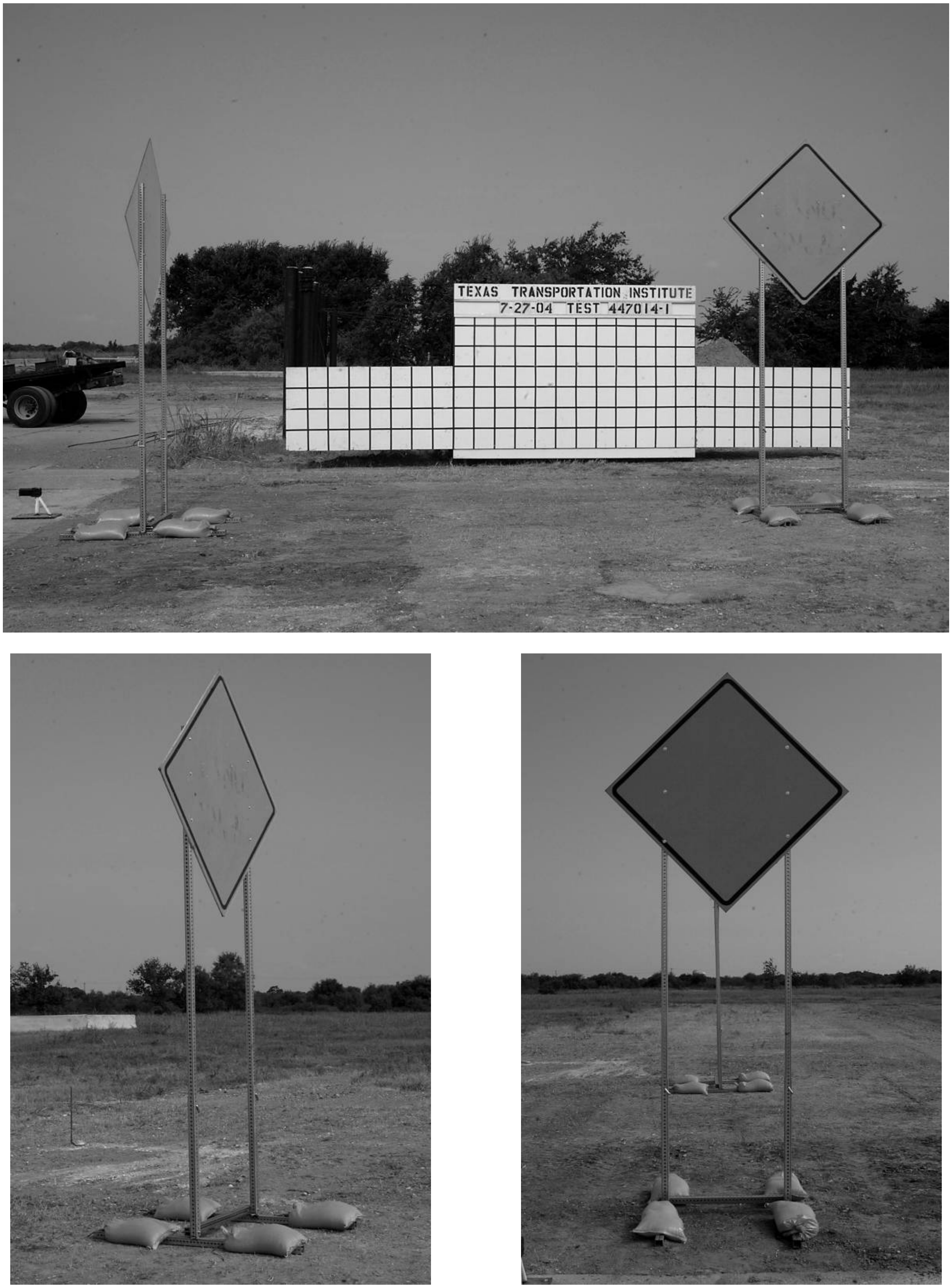


Figure 5-1. Sign Supports Used for Test.

The test followed the impact conditions of test designation 3-71 of *NCHRP Report 350*. This test involves an 820 kg (1800 lb) passenger car impacting the device at a speed of 100 km/h (62 mph). This is considered to be the critical test for work zone sign supports due to the increased propensity for occupant compartment intrusion at higher speeds. A 50th percentile male anthropomorphic dummy was placed in the driver's position and restrained with standard equipment lap and shoulder belts, thus increasing the test weight of the vehicle to 950 kg.

FHWA requires the impact performance of temporary work zone sign supports to be evaluated for two different orientations. In addition to the common scenario involving the car impacting the device head-on (i.e., 0 degrees), an impact with the device turned 90 degrees is also required. This test condition accounts for the common field practice of rotating a device out of view of traffic until it is needed again and/or picked up and moved by the work zone personnel. In order to reduce testing costs, FHWA permits the evaluation of both the 0 and 90 degree orientations using two separate devices impacted in sequence in a single crash test. This approach was used to evaluate the perforated steel tube sign support system. Two separate sign support systems were offset 15 ft (6 m) from one another and placed at different orientations with respect to the path of the vehicle. The first support was oriented perpendicular to the vehicle path for a head-on impact at 0 degrees. The second support, placed behind the first sign support, was oriented parallel to the vehicle path for an end-on impact at 90 degrees. The supports were placed on soil because that represents a more critical condition than if they were placed on a paved surface.

TEST VEHICLE

A 1997 Geo Metro, shown in Figures 5-2 and 5-3, was used for the crash test. Test inertia weight of the vehicle was 1,918 lb (871 kg), and gross static mass was 2,092 lb (950 kg). The height to the lower edge of the vehicle's front bumper was 15.7 inches (400 mm), and the height to the upper edge of the front bumper was 20.7 inches (525 mm). The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

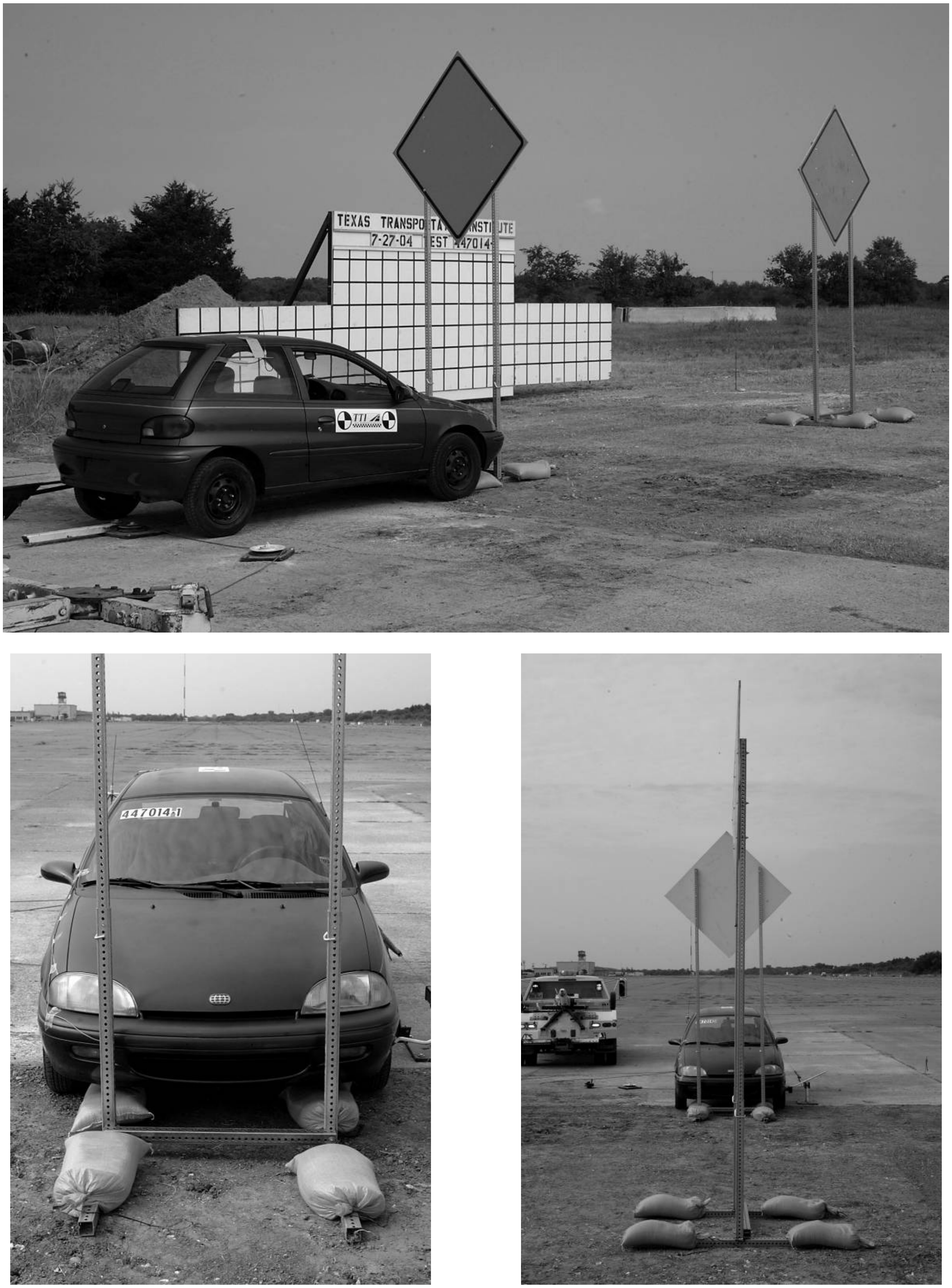


Figure 5-2. Vehicle and Support Geometrics before Test.

Figure 5-3. Vehicle before Test.

TEST DESCRIPTION

The 1997 Geo Metro, traveling at a speed of 63.0 mph (101.4 km/h), impacted the first support head-on at 0 degrees. Upon impact with the first support, both uprights deformed around the front of the vehicle and subsequently released from the skids through fracture of the welds. The sign panel and its supports rotated toward the vehicle and contacted the roof. As the vehicle traveled forward, the panel and supports carried up and over the vehicle. The vehicle then impacted the second sign support system end-on at 90 degrees. Upon impact with the second support, the leg on the impact side of the support began to deform and pulled the sign panel downward towards the vehicle. The corner of the sign panel contacted the windshield just below the roof edge, shattering the windshield and deforming the roof.

TEST ARTICLE DAMAGE

As shown in Figure 5-4, the upper section of the first support remained intact after separating from its base. The second support separated into several pieces.

TEST VEHICLE DAMAGE

The vehicle sustained damage to the front bumper, hood, windshield, and roof, as shown in Figure 5-5. Maximum exterior crush to the front of the vehicle was 9.4 inches (240 mm). Maximum occupant compartment deformation was 8 inches (203 mm) in the windshield area just to the passenger's side of centerline of the vehicle.

OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle's center of gravity, were digitized for evaluation of occupant risk parameters. In the longitudinal direction, the occupant impact velocity was 10.8 ft/s (3.3 m/s) at 0.302 seconds, the highest 0.010 second occupant ridedown acceleration was 4.9 g's from 0.321 to 0.331 seconds, and the maximum 0.050 second average acceleration was −3.9 g's between 0.001 and 0.051 seconds. In the lateral direction, the occupant impact velocity was 2.0 ft/s (0.6 m/s) at 0.302 seconds, the highest 0.010 second occupant ridedown acceleration was 9.7 g's from 0.396 to 0.406 seconds, and the maximum 0.050 second average was 2.9 g's between 0.355 and 0.405 seconds. These data and other pertinent information from the test are summarized in Table 5-1.

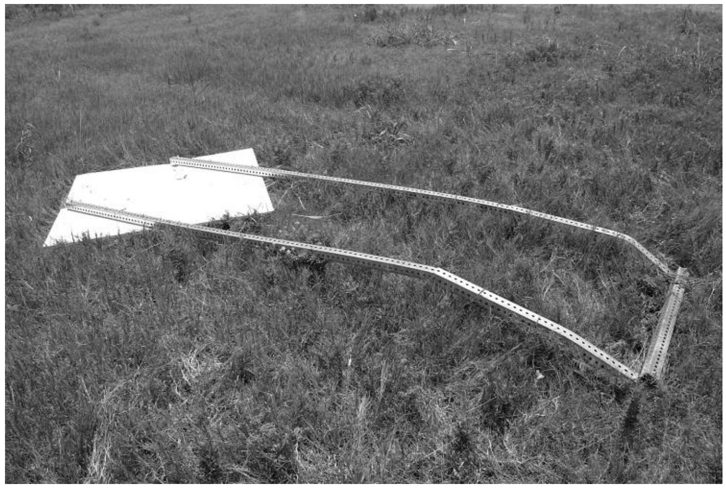
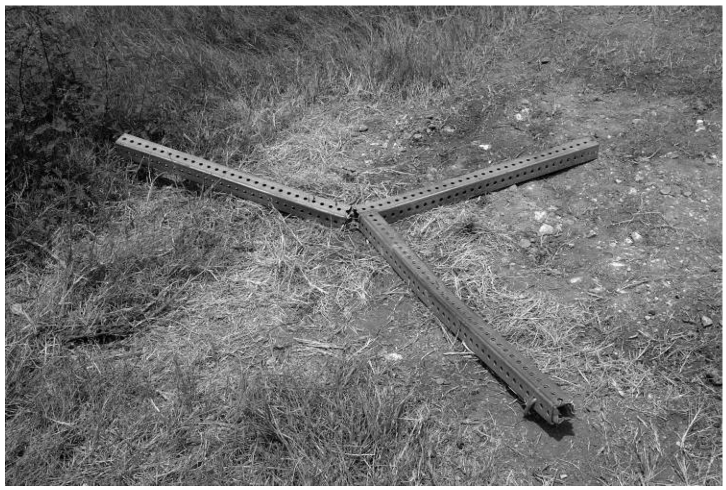
First Support	
Second Support	 

Figure 5-4. Supports after Test.

Figure 5-5. Vehicle after Test.

Table 5-1. Summary of Crash Test Results.

General Information Test Agency ..... Texas Transportation Institute Test No. .... 447014-1 Date .... 07/27/2004 **Test Article** Type .... Dual Support Sign Name .... Sign Support Installation Height .... 2.1 m (7 ft) Material of Key Element .... **Soil Type** .... Standard Soil **Test Vehicle** Designation .... 820C Model .... 1997 Geo Metro Mass Curb .... 1,725 lb (783 kg) Test Inertial .... 1,918 lb (871 kg) Dummy .... 174 lb (79 kg) Gross Static .... 2,092 lb (950 kg) **Impact Conditions** Speed .... 63.0 mph (101.4 km/h) Angle .... 0 deg and 90 deg	**Occupant Risk Values** Impact Velocity Longitudinal Direction... 10.8 ft/s (3.3 m/s) Lateral Direction .... 2.0 ft/s (0.6 m/s) Ridedown Accelerations Longitudinal Direction .... 4.9 g's Lateral Direction .... 9.7 g's Max.0.050 Second Average Longitudinal Direction .... −3.9 g's Lateral Direction .... 2.9 g's **Vehicle Damage** Max. Exterior Crush .... 9.4 inches (240 mm) Max. Occupant Compartment Deformation .... 8 inches (203 mm)

CONCLUSIONS

The sign support did not meet the occupant risk requirements of *NCHRP Report 350* or FHWA's "Windshield Damage Criteria for Category II Work Zone Traffic Control Devices." According to the FHWA criteria:

"It is desirable that the maximum permanent deflection of the windshield not exceed 55 mm (2 inches). A maximum permanent deflection exceeding 75 mm (3 inches) shall be considered a failure."

The maximum deformation into the occupant compartment of the test vehicle was 8 inches (203 mm).

CHAPTER 6:
RETROREFLECTIVE SIGNAL BACKPLATES

INTRODUCTION

In February 2004, the Federal Highway Administration (FHWA) issued an interim approval for the use of retroreflective borders on traffic signal backplates (*1*). The approval is based on a 1998 project sponsored by the Insurance Corporation of British Columbia (ICBC) and the National Committee on Uniform Traffic Control (NCUTC) (*2*). The project studied the use of a microprismatic retroreflective border on signal head backplates. The goal was to frame the signal head, thereby enhancing the visibility of the signal to the motorist and improving the nighttime safety of the intersection. Six intersections were used for the study. A 3 inch (75 mm) wide yellow border was added to each backplate. The researchers used nighttime rear-end accidents as a measure of the effectiveness of the retroreflective border. Over a three year period, the researchers found a significant reduction in the number of rear-end collisions (70 percent) in addition to a significant reduction in the total number of intersection accidents (52 percent) as indicated in Table 6-1.

Table 6-1. Total Night Accidents by Primary Accident Type.

Primary Accident Type	Before Period	After Period		
		1st Year	2nd Year	3rd Year
Intersection 90	1	3	0	1
Left Turn	3	1	1	0
Right Turn	1	1	0	0
Rear End	**7**	**2**	**3**	**0**
Overtaking	0	1	0	0
Off Road	0	1	1	1
Unknown	2	5	0	1
Total	**14**	**14**	**5**	**3**

Based on the results, the researchers recommended that yellow retroreflective borders be applied to all signal backplates in British Columbia. In addition, the researchers recommended further research using fluorescent yellow retroreflective borders.

Based on a series of sample pictures of retroreflective borders, one of which is shown in Figure 6-1, it was determined that a 2.5 inch fluorescent yellow microprismatic border would be used for the evaluation. The border would be placed along the outside edge of the signal backplate, outlining the backplate. On an 8 inch backplate, this would leave a black space of approximately 5.5 inches.

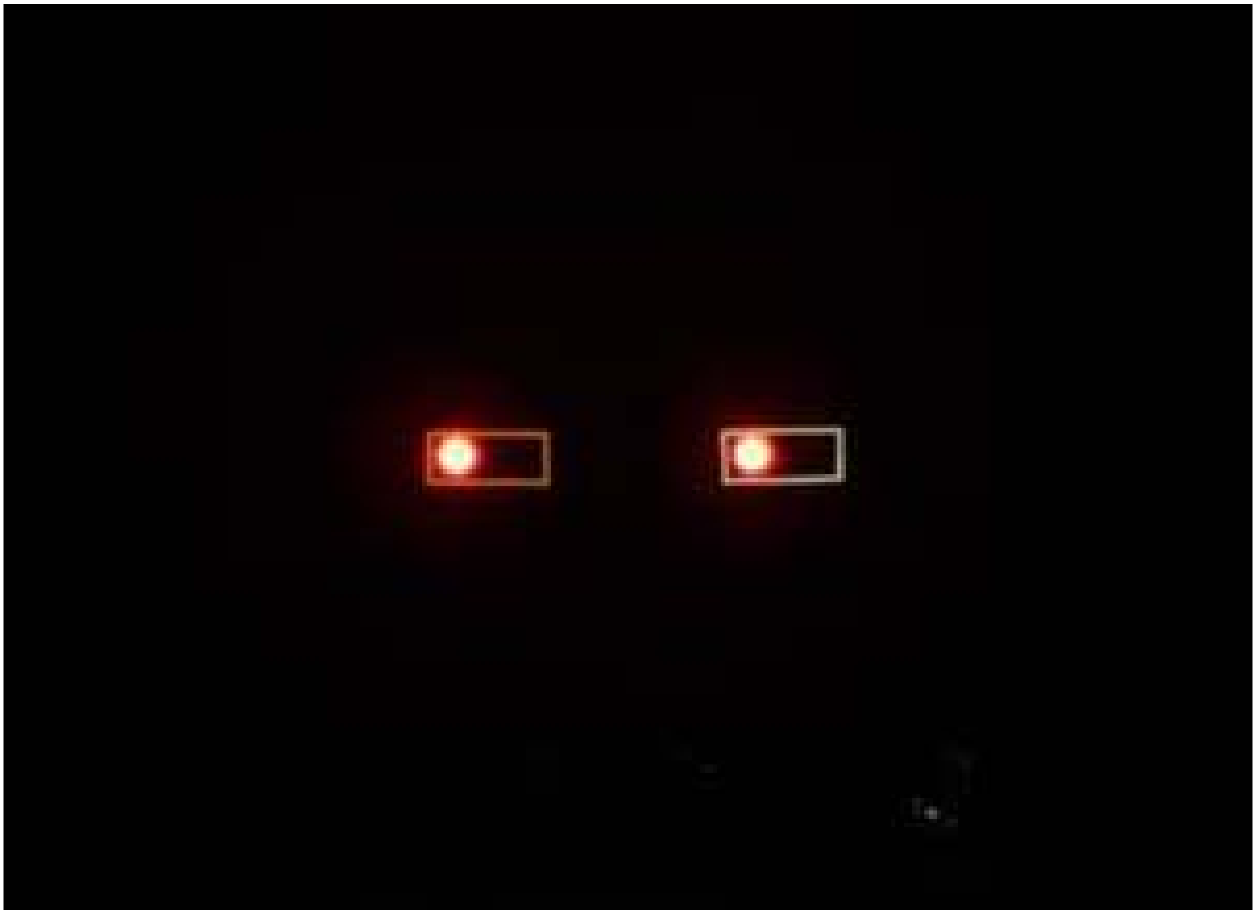


Figure 6-1. Sample Image of Retroreflective Backplate Borders.

FIELD EVALUATION

This project was a short-duration study determining the possible benefits of using retroreflective borders on traffic signal backplates. A 2002 project by Bonneson et al. studied various engineering countermeasures that could be used to reduce red-light running (3). In this project, Bonneson et al. used signal backplates as a countermeasure to red-light running (compared to signals without backplates). In order to provide more depth to this limited study, the researchers chose the intersection employed by Bonneson to determine the benefits of the retroreflective borders. In addition, the data collection methods and measures of effectiveness used were identical to those used in Bonneson's project (hereinafter referred to as Project 0-4027). The measures of effectiveness are red-light running (RLR) per 1000 vehicles and RLR per 10,000 vehicle-cycles.

The intersection chosen for this study is located at SH 44 and FM 2292 Southbound in Corpus Christi, Texas. It is a three-leg intersection consisting of four lanes with a left-turn lane on the main lanes and two lanes with a left-turn lane on the minor road. The speed limit at the intersection is 45 mph. The leg of the intersection used in this study was the westbound (WB) through lanes of SH 44. The westbound direction has three signal heads. The two signal heads for the through lanes have backplates, while the left-turn signal head does not have a backplate. Figure 6-2 illustrates the study location.

Figure 6-2. Intersection of SH 44 and FM 2292 Southbound.

Field data collection was performed using a video camera recorder. The camera was set up near the intersection such that the westbound signal indications and the stop bar were visible at the same time. Data were collected for a period of six hours over two successive nights from 5 pm to 11 pm. The before period was collected in May of 2004. Following the completion of the before data collection, the retroreflective border was added to the backplates.

The border strips were applied in four pieces. A TxDOT sign crew used an aerial bucket truck to reach the signal and applied the border by hand. The signal and backplate were not removed to apply the border. Figure 6-3 is a nighttime photograph of the signal with the border applied. The after data was collected in June of 2004. Approximately four full calendar weeks passed between the before and after data collection times.

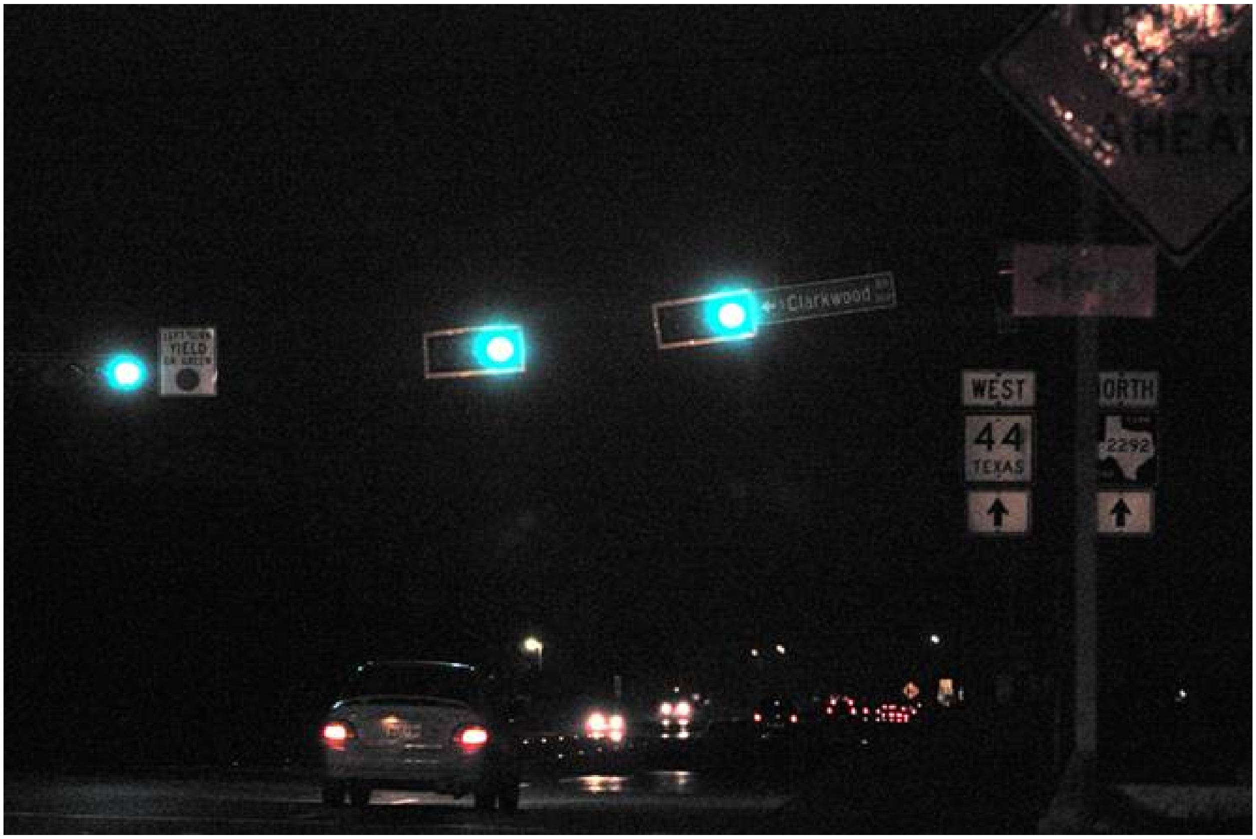


Figure 6-3. Study Site Image during "After" Period.

The collected video data were then analyzed. The reviewers logged the following information on a per cycle basis:

- start of yellow phase,
- total number of vehicles,
- total number of heavy vehicles,
- number of RLR vehicles,
- number of yellow-light running (YLR) vehicles, and
- start of green phase.

RESULTS AND DISCUSSION

Analysis of the video data produced the results shown in Table 6-2. Data were collected for 12 hours over 2 days (6 hours per day) for the before and after periods. The values in Table 6-2 represent 6 hour averages for each period. Included in Table 6-2 is the after data collected on the 0-4027 project. These data are from an identical condition to the before data collected for retroreflective border analysis (black signal backplates). YLR was not available for the project 0-4027 data.

Table 6-2. Average Observations Summary.

Project	Site	Study Period	Cycles	Vehicles		
				Observed	RLR	YLR
0-4701	SH 44 WB	Before	182	3098	25	80
		After	197	3461	36	97
0-4027	SH 44 WB	After	148	3899	10	-

Further data reduction produced the RLR and YLR rates shown in Table 6-3. Again, the rates from Project 0-4027 are included. According to Bonneson et al., the typical intersection experiences between 3.0 to 5.0 red-light runners per 1000 vehicles and approximately 1 red-light runner per 10,000 vehicle-cycles *(3)*.

Table 6-3. RLR and YLR Rates.

Project	Site	Study Period	RLR Rate			
			RLR per 1000 veh	RLR per 10,000 veh-cyc	YLR per 1000 veh	YLR per 10,000 veh-cyc
0-4701	SH 44 WB	Before	8.1	2.7	2.7	8.5
		After	10.3	3.1	3.1	8.5
0-4027	SH 44 WB	After	2.6	1.0	-	-

Comparison of the RLR rates of the 0-4701 "before" data to the 4027 "after" data shows an increase of 211 percent in the number of RLR per 1000 vehicles and similarly a 170 percent increase in the number of RLR per 10,000 vehicle-cycles. Comparing the 0-4701 "before" and "after" data also shows an increase in RLR: 27.1 percent for RLR per 1000 vehicles and 14.8 percent for RLR per 10,000 vehicle-cycles.

A procedure to measure the effectiveness of the retroreflective backplate border is the "log-odds ratio" test. This test compares the ratio of the RLR and YLR of before and after periods for a control site. In this instance, the control site is the eastbound approach of SH 44. The ratio of the two ratios (control and treatment) represents the relative change due to the treatment with respect to the control site. To determine if the relative change is significant, a z-statistic is computed. This statistic is used to identify the probability of incorrectly rejecting the null hypothesis (i.e., that there is no change). The results of the log-odds ratio test are shown in Tables 6-4 and 6-5.

Table 6-4. Results of Log-Odds Ratio Test for RLR.

Project Before/After	RLR Frequency		After/Before Ratio (R)	Relative Change (RC)	Z-Statistic (p-value)
	"Before" Study	"After" Study			
0-4027/0-4701	10	25	2.3	127.3	0.562 (0.575)
Control	-	-	1		
0-4701/0-4701	25	36	1.4	44.0	0.253 (0.803)
Control	1	1	1		

Table 6-5. Results of Log-Odds Ratio Test for YLR.

Project Before/After	RLR Frequency		After/Before Ratio (R)	Relative Change (RC)	Z-Statistic (p-value)
	"Before" Study	"After" Study			
0-4701/0-4701	80	97	1.2	21.3	0.253 (0.803)
Control	40	40	1		

The log-odds ratio test indicates a positive relative change of 127.3 percent between the 0-4027 "after" period and the 0-4701 "before" period. This indicates an increase in the number of red-light runners between study periods for the same treatment. Note that this test has to assume no change in the control site as control site data were not available. The test also shows that RLR increased approximately 44 percent between the "before" and "after" periods of the 0-4701 project. In this instance the control site did not experience any change in the number of red-light runners.

The log-odds ratio test for the YLR data also shows an increase (21.3 percent) in the number of yellow-light runners at the project site. Again, the control site showed no increase in YLR events.

CONCLUSIONS

The results from this research effort would appear to indicate that the use of retroreflective borders on signal backplates increases the amount of red-light and yellow-light running. The comparison to the Project 0-4027 data shows a significant increase in the number of RLR events. Note, however, that the Project 0-4027 data were collected during daylight hours, during the middle of the day. The data were collected during the evening hours and covered the majority of the typical rush hour period. In addition, only one intersection was selected for study. The results do show a steady increase in the number of RLR events over time, which may indicate that an unaccounted factor exists that is affecting the rate of red- and yellow-light running.

RECOMMENDATIONS

The analysis associated with this effort did not indicate a benefit from the retroreflective border for a signal backplate. As mentioned previously, this traffic control device application has been issued as an interim approval by the FHWA and is expected to be added to the *Manual on Uniform Traffic Control Devices* (MUTCD) in a future revision. Therefore, the researchers recommend that TxDOT wait until FHWA has revised the national MUTCD to address the use of signal backplates with a retroreflective border and implement the practice accordingly.

REFERENCES

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3. Bonneson, J., K. Zimmerman, and M. Brewer. Engineering Countermeasures to Reduce Red-Light-Running. Report 4027-2. Texas Transportation Institute, College Station, Texas, August 2002.

CHAPTER 7:
LOCATING NO-PASSING ZONES

INTRODUCTION

Accurate placement of no-passing zones is important for motorist safety, efficiency, and liability (*1*). The Uniform Vehicle Code, Section 11-307, provides that "(t)he (State highway commission) and local authorities are hereby authorized to determine those portions of any highway under their respective jurisdictions where overtaking and passing or driving on the left side of the roadway would be especially hazardous and may by appropriate signs or markings on the roadway indicate the beginning and end of such zones" (*2*). No-passing zones are required at horizontal and vertical curves where the passing sight distance is less than the minimum necessary for safe passing. The American Association of State Highway Transportation Officials (AASHTO) bases the passing sight distance equation on a single vehicle passing a single vehicle. It is the sum of four distances (*3*):

- distance traveled during the perception-reaction time and during the initial acceleration to the point of reaching the left lane,
- distance traveled within the left lane,
- distance between the passing vehicle after it has returned to the right lane and an oncoming vehicle, and
- distance traveled by the oncoming vehicle for two-thirds of the time the passing vehicle traveled in the left lane.

However, the *Manual on Uniform Traffic Control Devices* (MUTCD) provides minimum passing sight distances based on the 85th percentile, posted, or statutory speed limit of the roadway (*4*). The MUTCD describes the passing sight distance on a vertical curve as "the distance at which an object 3.5 ft above the pavement surface can be seen from a point 3.5 ft above the surface." Figure 7-1 presents the vertical passing sight distance concept as shown in the MUTCD. On a horizontal curve, the passing sight distance is measured along the centerline of the roadway between two points at a height of 3.5 ft above the pavement. These two points are on a line tangent to any obstruction that cuts off or limits the view on the inside of the horizontal curve. Figure 7-2 presents the horizontal curve passing sight distance concept as shown in the MUTCD.

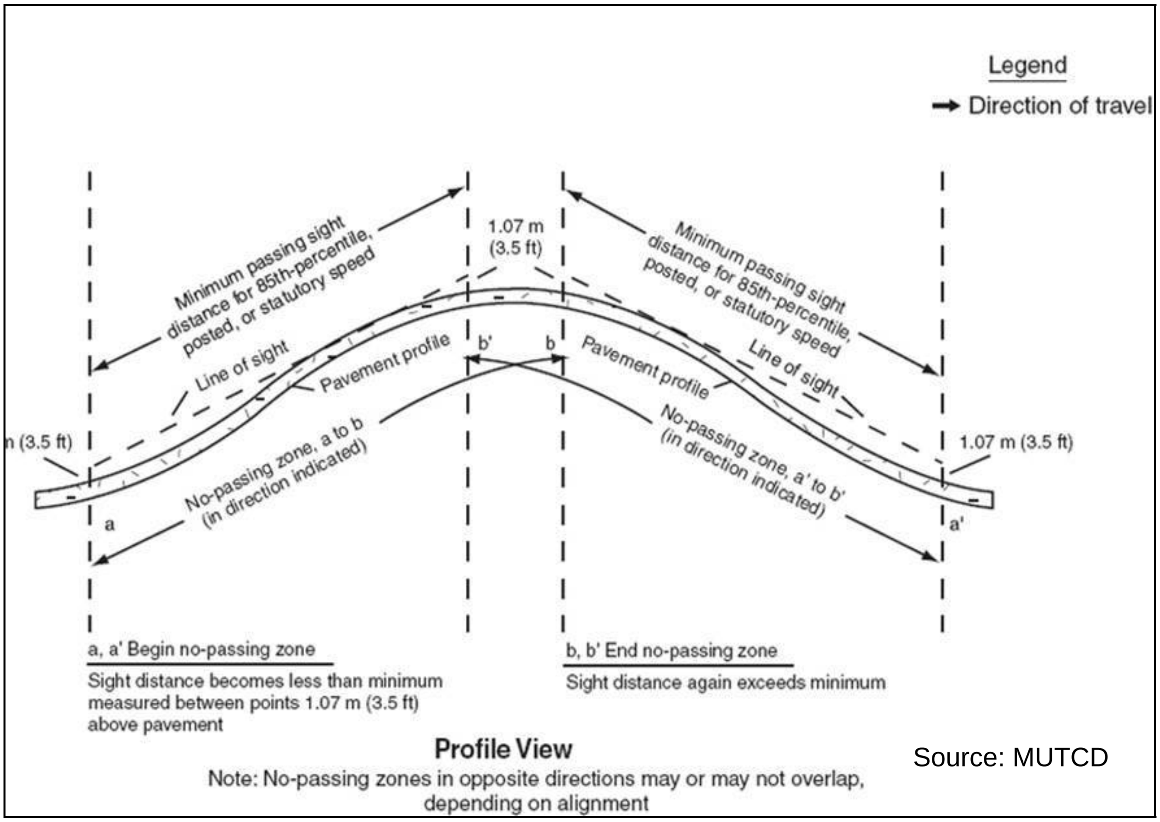


Figure 7-1. Locating No-Passing Zones on a Vertical Curve.

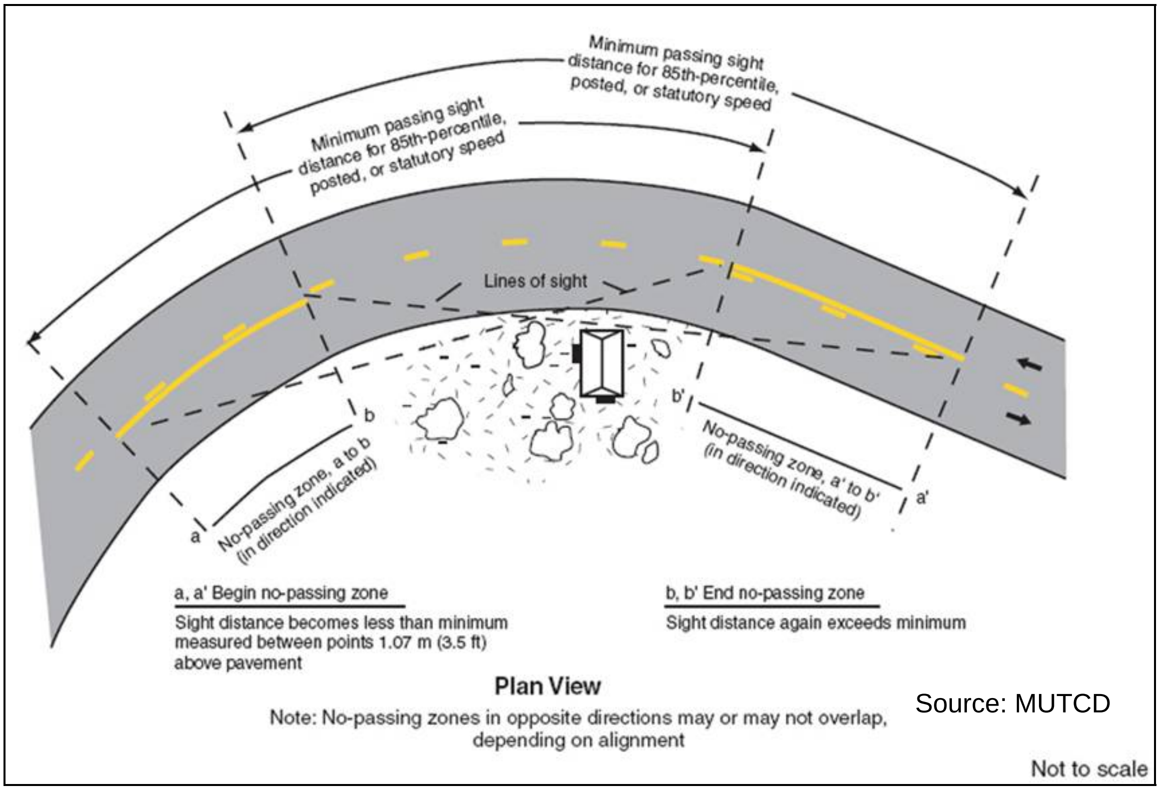


Figure 7-2. Locating No-Passing Zones on a Horizontal Curve.

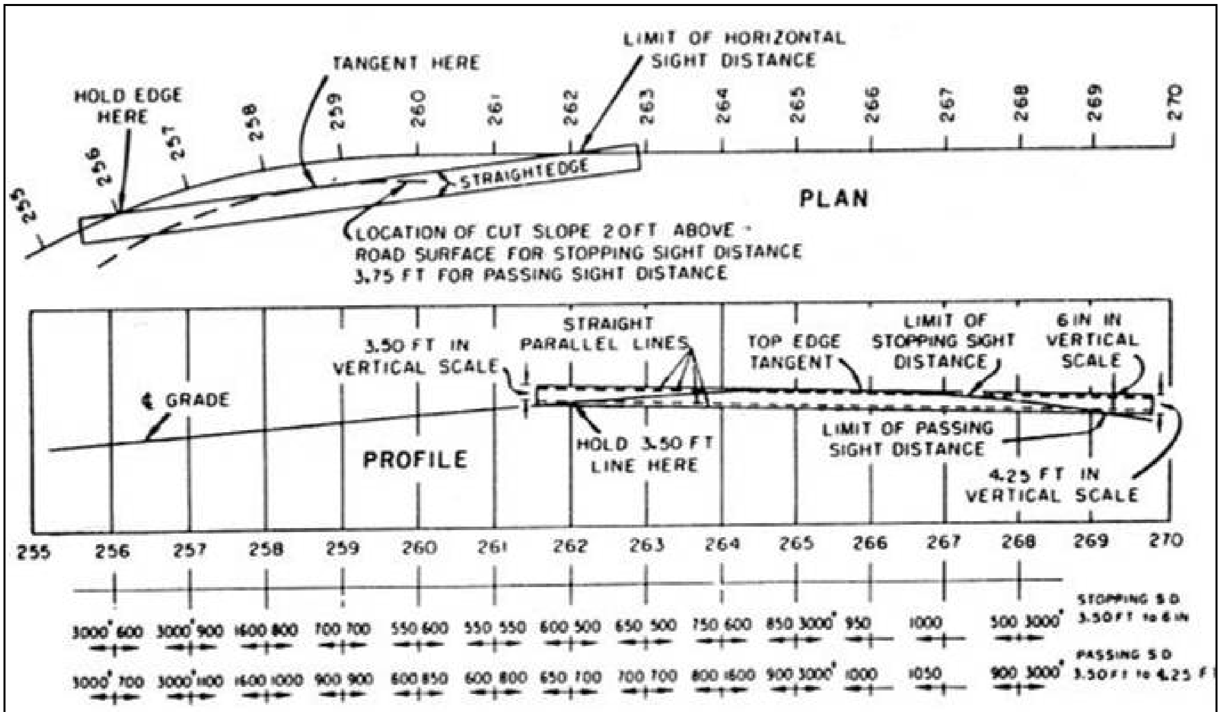
The *Traffic Control Devices Handbook* describes over 10 methods of locating no-passing zones on horizontal and vertical curves (*5*). The methods range from completely manual to completely automated systems. Several methods are improvements or variations on more manual methods. The various methods used to mark no-passing zones are discussed in the following section.

METHODS FOR LOCATING NO-PASSING ZONES

The following sections describe several different methods that can be used to locate the beginning and end of no-passing zones.

Plans Review Method

A no-passing zone can be established using available construction plans. This method is described in the AASHTO publication, *A Policy on Geometric Design of Highways and Streets* (*3*). The technique is design to be employed during the design of the facility. Sight distance is scaled from the plans at each reference point (station or mile marker) and recorded. Sight distance for both the horizontal and vertical is measured and in both directions from the reference point. Figure 7-3 illustrates the method of scaling sight distance from construction plans. Measurement of the horizontal sight distance is performed using a straightedge. The edge of the straightedge is placed along the centerline of the roadway at a station point and rotated such that the same edge is tangent to any horizontal obstruction shown on the plans (cut section, tree, etc.). The point at which the centerline and straightedge intersect, past the obstruction, marks the available sight distance. Vertical sight distance is measured using a transparent strip marked with a line representing the object height (3.5 ft). This line is marked parallel to the long edge of the strip. The object height line is set at a station point, and the strip is rotated such that the upper edge is tangent to the vertical curve. The point at which the object height line intersects the vertical curve represents the available sight distance. The reference points between which the available sight distance is less than the minimum required sight distance are used to locate the start and end of the no-passing zones.



Source: AASHTO Policy on Geometric Design of Highways and Streets

Figure 7-3. AASHTO Method for Scaling and Recording Sight Distance on Plans.

Eyeball Method

The eyeball method is considered the most inexpensive and quickest method. It requires one vehicle and two crewmembers to complete. An accuracy of 50 to 100 ft can be achieved with an experienced crew. This method works very well in horizontal applications and for sharp crest vertical curves. However, longer vertical curves require more time to complete and can be more difficult (5). The method begins with the driver and observer driving toward a horizontal or vertical curve. The observer estimates where the no-passing zone should begin based on the sight distance restrictions and then verifies the location by measuring (using the odometer of the vehicle or other device) the distance from the estimated point to the point where an approaching vehicle would appear.

Speed and Distance Method

This method uses the equation of distance equals the speed multiplied by time. An observer records the time it takes for a receding vehicle to disappear from view (starting at the point the vehicle passes the observer). The vehicle's average speed is also recorded. The average speed is calculated from the vehicle's speed when it passes the observer and the vehicle's speed at the point at which the vehicle disappears from view. The distance is calculated. The speed and distance method relies on the eyeball method for approximating the location where the no-passing zone should begin. The speed and distance method is used to further refine this location and can be more accurate than the walking method (*1*).

Walking Methods

Walking methods are also considered an accurate method for locating no-passing zones (*1*, *5*). It does however take more time to complete than other methods. This method requires a two-person crew and a length of chain or rope equal in length to the minimum passing site distance for the roadway. The crew walks along the centerline of the road (toward the curve) with the length of rope or chain stretched between them. The lead crewmember carries a target on a range pole set at the driver eye height. The beginning of the no-passing zone is marked by the trailing crewmember when the lead target is no longer visible. The end of the no-passing zone is marked by the lead crewmember when the trailing crewmember can see the lead target again. The procedure is repeated to mark the no-passing zone in the opposing flow direction. If both crewmembers carry targets, the zones can be located in both directions at one time.

The New Jersey cone method uses several traffic cones set up along the roadway at intervals of 100 ft through the horizontal or vertical curve. This method is very time and labor intensive. A two person crew and a truck or trailer are required. Using the cones as reference points, the crew determines the point at which a vehicle just disappears around a curve or hill and interpolates the distance. Through a trial and error process, they locate the no-passing zones (*5*).

An improvement on the New Jersey cone method is the rangefinder method. This method requires one operator and a rangefinder. The operator uses the rangefinder to determine at what point the sight distance falls below the minimum passing sight distance. The range finder can be either an optical type or a laser type (LIDAR). The operator measures the distance at which a vehicle just disappears around a curve or hill. The initial point is determined using the eyeball method, and the final measurement point is interpolated by the operator. To increase the speed of this method, operators can take measurements at 100 ft intervals although this does sacrifice accuracy. The cost of a LIDAR instrument is around $3000 to $4000. This cost can be offset by using an optical rangefinder, which costs $300 to $1000. The rangefinder method can be more accurate than just the walking method in properly locating no-passing zones (*1*).

Single-Vehicle Method

The single-vehicle method uses one vehicle and an operator. The vehicle is equipped with a distance measuring instrument (DMI). The operator drives slowly through the horizontal or vertical curve. When the operator reaches a point at which the vista or view opens up and there is sufficient length in the roadway to pass safely, this point represents the end of the no-passing zone in the direction of travel. From this point, the operator reverses direction and travels the minimum passing site distance. This point represents the beginning of the no-passing zone in the new direction of travel (original opposing flow direction). Repeating the procedure starting in the original opposing flow direction locates the remaining points. The single-vehicle method is considered to be similar in accuracy to the walking method; however, it does result in a more conservative estimate (*1*).

Multivehicle Methods

There are several vehicle methods available to locate no-passing zones. While the methods vary in equipment, the basic procedures follow that of the walking method.

The towed-target method uses one vehicle and one operator. A target is towed behind the vehicle at a distance equal to the minimum passing sight distance for the roadway. The operator drives toward the curve, at the point where the target is no longer visible to the driver. A mark is made on the roadway indicating the beginning of the no-passing zone. The operator resumes driving. At the point where the target is visible again, a mark is made indicating the end of the no-passing zone. This method is repeated to mark the opposing flow no-passing zone.

The two-vehicle method uses two vehicles and two crew members (*6*). The two vehicles are driven along the roadway (at low speed) separated by a distance equal to that of the minimum passing sight distance. This distance is maintained by the drivers communicating through two-way handheld radios. The drivers can use a cable stretched between the vehicles, the vehicle odometers, or DMIs. The lead vehicle is equipped with a target (height of 3.5 ft). The vehicles proceed along the roadway, maintaining the separation distance. When the target of the lead vehicle disappears from view, both vehicles stop and the crewmembers mark the centerline. The trailing vehicle mark represents the beginning of the no-passing zone in the direction of travel. The lead vehicle mark represents the end of the no-passing zone in the opposing direction of travel. The vehicles proceed along the roadway. When the lead vehicle target appears, both vehicles stop and the crewmembers again mark the centerline. The trailing vehicle mark represents the end of the no-passing zone in the direction of travel, and the lead vehicle mark represents the beginning of the no-passing zone in the opposing flow direction. The two-vehicle method is less accurate than the walking method (*1*).

A further enhancement of the two-vehicle method is a system supplied by Nu-Metrics. This system is called the "Range Tracker System" (*7*). It employs two vehicles equipped with DMIs, a laptop computer, two wireless modems, and a target. This system requires three crewmembers. Two crewmembers drive the lead and trailing vehicles, while the third operates the laptop computer. It is an all-in-one system that measures the separation distance between the two vehicles, loss and return of target visibility, time, and distance traveled. In addition, the system allows the operator to log roadside features or other events. The system also provides a printout, giving locating information. The system, however, is very expensive and does require two trips to locate and then mark the no-passing zones. The tradeoff for cost is high accuracy.

Videolog or Photolog Method

Videolog and photolog systems are integrated into very specialized data collection vehicles (*5*). Videologs and photologs are pictorial images of the roadway and the roadside that are embedded with geographical references such as global positioning system coordinates. These methods are considered highly accurate; however, the accuracy is offset by the increased cost. Because the location of the no-passing markings is performed after data collection, this method also requires two trips to a site, one to collect the videolog or photolog data and the second to mark the location of the no-passing zones.

SURVEY OF STATE DOT MARKING PRACTICES

A survey of state department of transportation (DOT) organizations is summarized in Table 7-1. The survey was an informal question and response survey using an email list server.

Table 7-1. Results from DOT Survey of No-Passing Zone Marking Methods.

State	Method
Wyoming	Range tracking system
Alabama	Two-vehicle method
Missouri	Range tracking system
Pennsylvania	Two-vehicle method
Nevada	Range tracking system
West Virginia	Single-vehicle method
Maine	Two-vehicle method
New Hampshire	Eyeball method
Kansas	Rope method
Indiana	Range tracking system

Wyoming reported using a range tracking system similar to that described by the *Traffic Control Devices Handbook*. The Nevada DOT response stated that Nevada uses a two-vehicle method. However, it goes on to state that each vehicle is equipped with DMIs and a laptop that can receive data from each DMI. This system is similar to the range tracking system described previously. Missouri and Indiana specifically use a system developed by Nu-Metrics. Nu-Metrics calls this system the Range Tracker System. The Nu-Metrics system also operates similar to the description of a range tracking system. Pennsylvania uses the two-vehicle system with DMIs in each vehicle and 3.5 ft targets on each vehicle. Alabama described their method as a "hodgepodge" of the two-vehicle, eyeball, and towed-target methods. Maine also uses the two-vehicle system to mark no-passing zones; however, this method is used only if a set of plans for the roadway section is unavailable.

CONCLUSIONS

A review of current practices for locating no-passing zones indicates that the one-vehicle method, using a digital DMI, would be the best balance of accuracy, cost, and speed for locating no-passing zones. This method would be best applied when locating no-passing zones after maintenance activities that cover or remove existing markings. In the interests of worker safety, the method should be modified to add a second crewmember as a passenger. The method requires driving at less than the posted speed and pulls the driver's attention away from the road. A second crewmember would be able to perform the task of locating where the view opens while the driver concentrates on driving. In instances when accurate construction plans are available (such as reconstruction or realignment of a roadway), the plans review method should be employed. Using an instrumented vehicle to locate no-passing zones should be reviewed periodically because these systems offer highly accurate locating directions and speed.

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CHAPTER 8: SUMMARY AND RECOMMENDATIONS

As described in Chapter 1, this research project was funded to address numerous, small-scale research efforts related to traffic control devices. In the first year of the project, six different evaluations were completed.

SUMMARY OF ACTIVITIES

The six evaluations considered various aspects related to the operational impacts of traffic control device improvements. The following sections provide a brief description of the key issues and types of assessments associated with each of the evaluations.

Evaluate the Effectiveness of Dual Logos

This evaluation assessed the impact of using dual logo panels on the ability of drivers to identify the type of services describe in a specific service sign. In this evaluation, which is described in Chapter 2, researchers used a timed survey presented on a laptop computer. Participants were shown numerous images of specific service signs, some of which had dual logo sign panels. Participants were asked to indicate whether a specific business was shown on the sign, and the sign was presented for only a brief interval of time. Over 200 subjects took part in the survey.

The results indicate that, while single logos were correctly recognized more often than dual logos, the difference in correct response rate between single and dual logos diminished with longer time exposures. The researchers also found that the ability to recognize a logo is more dependent on driver familiarity with the logo than on whether the business is located in a dual or single panel. Based on these findings, the researchers could not identify a strong reason to prohibit the use of dual logo panels. However, the researchers recommend that dual logo panels not be used unless all available space on the sign is already used by single logos. Furthermore, if implemented, the use of dual logos should be limited to no more than two dual logo panels per sign.

Assess the Impacts of Rear-Facing School Speed Limit Beacons

In this evaluation, rear-facing beacons were installed in four school speed limit zones. Vehicle speeds were measured before and after installation of the beacons. The results indicate that, at the sites selected for evaluation, the beacons did reduce the speeds of vehicles at some of the study sites. It should be noted that the sites selected for study were ones where drivers might have a tendency to forget that they were in a school speed limit zone and where the rear-facing beacons might provide an effective means of reminding them. These school speed limit zones have traffic control (traffic signal or Stop sign) located within the zone (drivers accelerating from the stop condition speed up to the normal speed instead of accelerating to the lower school speed limit) or long school speed limit zones.

Evaluate the Impacts of Improving Speed Limit Sign Conspicuity

The results of this evaluation indicate some promise to the benefits of improving the conspicuity of the red border speed limit treatment. Researchers found a decrease in the percent of vehicles exceeding speed thresholds especially downstream of the Speed Limit sign at three of the four study sites. Due to the significance associated with changing the design of the Speed Limit sign, the researchers plan to conduct additional evaluations of this treatment.

Crash-Test a Sign Support Structure

A new sign support system was evaluated as part of this project to determine if it would meet the appropriate crash test criteria for work zone applications. The crash test was conducted at 60 mph using a small car. The work zone sign support system did not pass the crash test. As a result, the sign support system cannot be used in practice until revisions are made to the design and it passes a new crash test evaluation.

Evaluate the Benefits of Retroreflective Signal Backplates

Applying a retroreflective border to traffic signal backplates was found to improve safety in a Canadian study. As part of this project, researchers evaluated the impact of a retroreflective signal backplate border on red-light and yellow-light running at one intersection in the evening and nighttime hours. The results actually found an increase in red-light and yellow-light running at the intersection.

Develop Improved Methods for Locating No-Passing Zones

TxDOT personnel are sometimes challenged to identify the starting and ending points of no-passing zones on two-lane highways. This activity describes several different methods that can be used to identify the starting and ending points of these zones.

IMPLEMENTATION RECOMMENDATIONS

The implementation status of the individual evaluations is described in the following sections.

Evaluate the Effectiveness of Dual Logos

Based on the findings for this evaluation, the Texas Department of Transportation (TxDOT) has requested that the Federal Highway Administration (FHWA) revise the *Manual on Uniform Traffic Control Devices* (MUTCD) to allow the use of dual logo panels. No further evaluations are expected to be conducted on this issue as part of this research project.

Assess the Impacts of Rear-Facing School Speed Limit Beacons

Because of the beneficial effects found in the evaluation, TxDOT plans to develop guidelines for the use of rear-facing school speed limit beacons. No further evaluations are expected to be conducted on this issue as part of this research project.

Evaluate the Impacts of Improving Speed Limit Sign Conspicuity

Although the evaluation identified beneficial impacts associated with the red border Speed Limit sign, the results are not sufficiently conclusive to support a change to the MUTCD at this time. Additional evaluations of this treatment will be conducted during the second year of this research project.

Crash-Test a Sign Support Structure

Due to the failure of the sign support in the crash test, the design cannot be implemented at this time. The sign support will be redesigned, and additional crash tests will be conducted as part of efforts outside the scope of this research project.

Evaluate the Benefits of Retroreflective Signal Backplates

The results of the evaluation did not identify a benefit to using a retroreflective treatment on signal backplates. Because this issue has already been addressed in an MUTCD interim approval, the researchers recommend that TxDOT defer to the FHWA for implementation guidance on this practice.

Develop Improved Methods for Locating No-Passing Zones

This activity was different from the others in the research project in that it was a synthesis of available information rather than an evaluation of a specific traffic control device treatment. The information gathered from this synthesis will be distributed to TxDOT districts as appropriate to assist them in defining the most appropriate means of marking no-passing zones.

APPENDIX 1-A:
DUAL LOGO SURVEY QUESTIONS

The images in this appendix present the critical elements of the driver survey. The first eight pages present all of the graphic images used through the first survey question. The remaining pages of this appendix present only the graphic associated with each of the questions. The question number and business name defined in the question have been added to each of these images in the upper left corner. This information did not appear in the graphic that was presented to drivers.

Texas Logo Signs
Survey on Their Effectiveness

Research conducted by the Texas Transportation Institute
Research sponsored by the Texas Department of Transportation

Texas Transportation Institute

Texas Department of Transportation

Logo Signs

- The purpose of this survey is to evaluate the effectiveness of logo signs

Logo Signs

- Logo signs are guide signs placed on interstates and other similar roads that let the motorist know about specific services offered at the next exit
- Food, Gas, Lodging, and Camping are typical services represented on these signs

Evaluation Process

- For this survey you will be shown pictures of logo signs and asked to identify whether a particular business is represented on the sign (Yes, No, Not Sure)

Survey Directions

- You will be presented with a question that will appear for a set length of time

Example:

Is the following business shown on the sign?

Pizza Hut

Survey Directions

- The question will automatically disappear and you will be presented with a picture of a logo sign. Different pictures will be displayed for different amounts of time.

In this example, the sign appears for 1 second

Survey Directions

- The next slide will appear automatically and the question will be restated
- You can state the answer as soon as you know it
- I will record your answer
- Answer slides are blue

Demographics

- Age (check one)
  - 18 to 25
  - 26 to 35
  - 36 to 45
  - 46 to 55
  - 55 to 65
  - 65 to 75
  - +75
- Zip code
- Do you drive on rural freeways?

Survey Directions

- The first question will be a practice question
- We will begin now...

Example 1

Is the following business shown on the sign?

Exxon

Answer Example 1

Was an

Exxon

in the sign?

YES NO NOT SURE

Questions?

Question 1

Is the following business shown on the sign?

Pizza Hut

Answer Question 1

Was a

Pizza Hut

logo on the sign?

YES NO NOT SURE


#1: Pizza Hut
GAS
FOOD
EXXON
CARROWS
RESTAURANTS
Applebee's
bp
A&W
Pizza Hut
Long John Silver's
Church's
NEXT RIGHT


#2: Hess
GAS - NEXT RIGHT
FINA
HESS
Jack's
PIZZA
FOOD - NEXT RIGHT
Pizza Hut
KFC
Applebee's
golden corral
Buffet & Grill


#3: Arby's
GAS
FOOD
Bob Evans
McDonald's
EXXON
Blimpie
Long John Silvers
Pizza Hut
Quizno's
SUBS
NEXT RIGHT


#4: Shell
GAS - NEXT RIGHT
76
Chevron
FOOD - NEXT RIGHT
Pizza Hut
TACO BELL
Bob Evans
POPEYES
PAPA JOHNS


#5: Burger King
GAS - NEXT RIGHT
FINA
BURGER KING
Shell
FOOD - NEXT RIGHT
Long John Silver's
KFC
Dairy Queen
Mister Donut


#6: Citgo
GAS
FOOD
Shell
Little Caesars
KFC
CITGO
TEXACO
BURGER KING
Blimpie
GRINGOS
NEXT RIGHT


#7: Chevron
GAS - NEXT RIGHT
SUBWAY
CONOCO
PHILLIPS 66
FOOD - NEXT RIGHT
SONIC
America's Drive-In
KFC
TACO BELL
SHONEY'S


#8: BP
GAS
FOOD
bp
SUBWAY
"TCBY"
Wendy's
Mobil
Love's
PIZZA
PAPA JOHNS
Rudy's
BAR-B-Q
NEXT RIGHT


#9: Blimpie
GAS
FOOD
PETRO
KFC
Blimpie
Mobil
TEXAS
Churchs
NEXT RIGHT


#10: Giant Burger
GAS - NEXT RIGHT
PETRO
Blimpie
Chevron
Shell
FOOD - NEXT RIGHT
Steak n Shake
EXXON
Captain D's


#11: McDonald's
GAS - NEXT RIGHT
Chevron
TEXACO
SONIC
EXXON
FOOD - NEXT RIGHT
KFC
A&W
BURGER KING
chili's


#12: KFC
GAS
FOOD
PHILLIPS 66
TacoTime
SONIC
KFC
Gulf
WENDY'S
McDonald's
EXXON
NEXT RIGHT


#13: In-N-Out
GAS - NEXT RIGHT
Chevron
AMOCO
FOOD - NEXT RIGHT
SHARKY'S
SEAFOODS
IN-N-OUT
SUBWAY
SUBWAY
SUBWAY
Dairy Queen

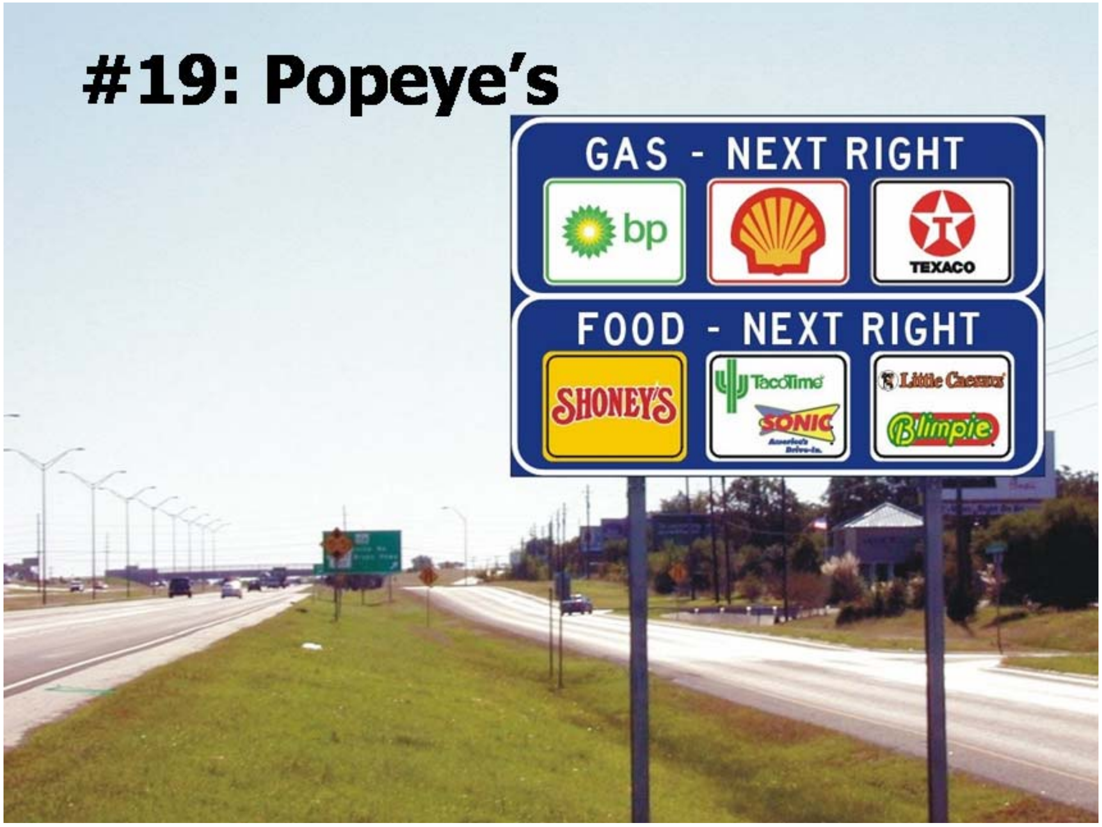

#14: Mapco Express
GAS
FOOD
Blimpie
KFC
TEXACO
POPEYES
SUBWAY
conoco
NEXT RIGHT


#15: Fina
GAS
FOOD
Shell
KFC
TEXACO
FINA
McDonald's
NEXT RIGHT


#16: Ultramar
GAS
FOOD
Ultramar
BONANZA
BURGER KING
TEXACO
Shell
TACO BELL
Quizno's SUBS
NEXT RIGHT


#17: Quizno's
GAS
FOOD
KFC
TEXACO
Blimpie
CONOCO
SUBWAY
NEXT RIGHT

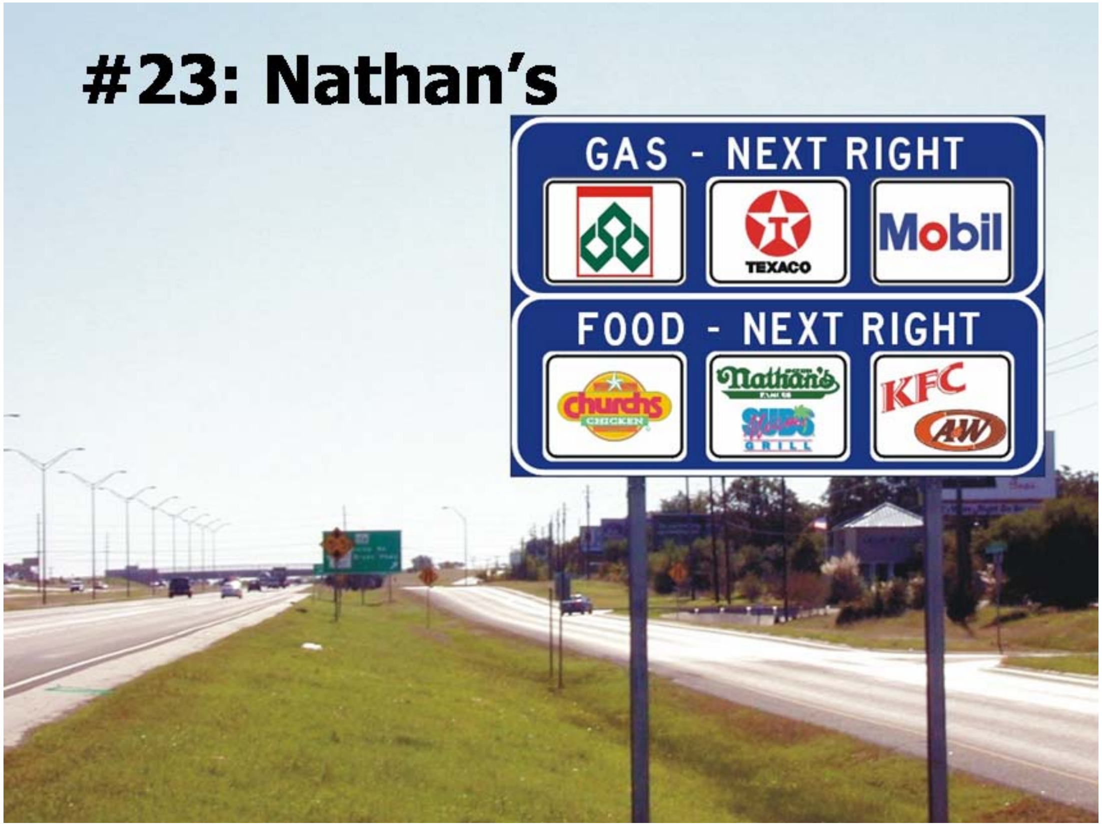

#18: KFC
GAS
FOOD
EXXON
BURGER KING
KFC
Pizza Hut
Shell
BENNIGAN'S
Rudy's
BAR-B-Q
NEXT RIGHT


#19: Popeye's
GAS - NEXT RIGHT
bp
TEXACO
FOOD - NEXT RIGHT
SHONEY'S
TacoTime
SONIC
Little Caesars
Blimpie


#20: A&W
GAS
FOOD
bp
T.G.I. FRIDAY'S
KFC
A&W
PETRO
Stopping Centers
SUBWAY
"TCBY"
CARROWS
RESTAURANTS
NEXT RIGHT


#21: Exxon
GAS - NEXT RIGHT
Shell
EXXON
PHILLIPS 66
FOOD - NEXT RIGHT
BURGER KING
Domino's Pizza
POPEYES
PAPA JOHNS
Pizza Hut


#22: Burritoville
GAS
FOOD
Shell
KFC
POPEYES
PAPA JOHNS
TEXACO
Blimpie
Little Caesars
GRINGOS
NEXT RIGHT


#23: Nathan's
GAS - NEXT RIGHT
Mobil
TEXACO
FOOD - NEXT RIGHT
churchs
CHICKEN
Nathan's
KFC
A&W

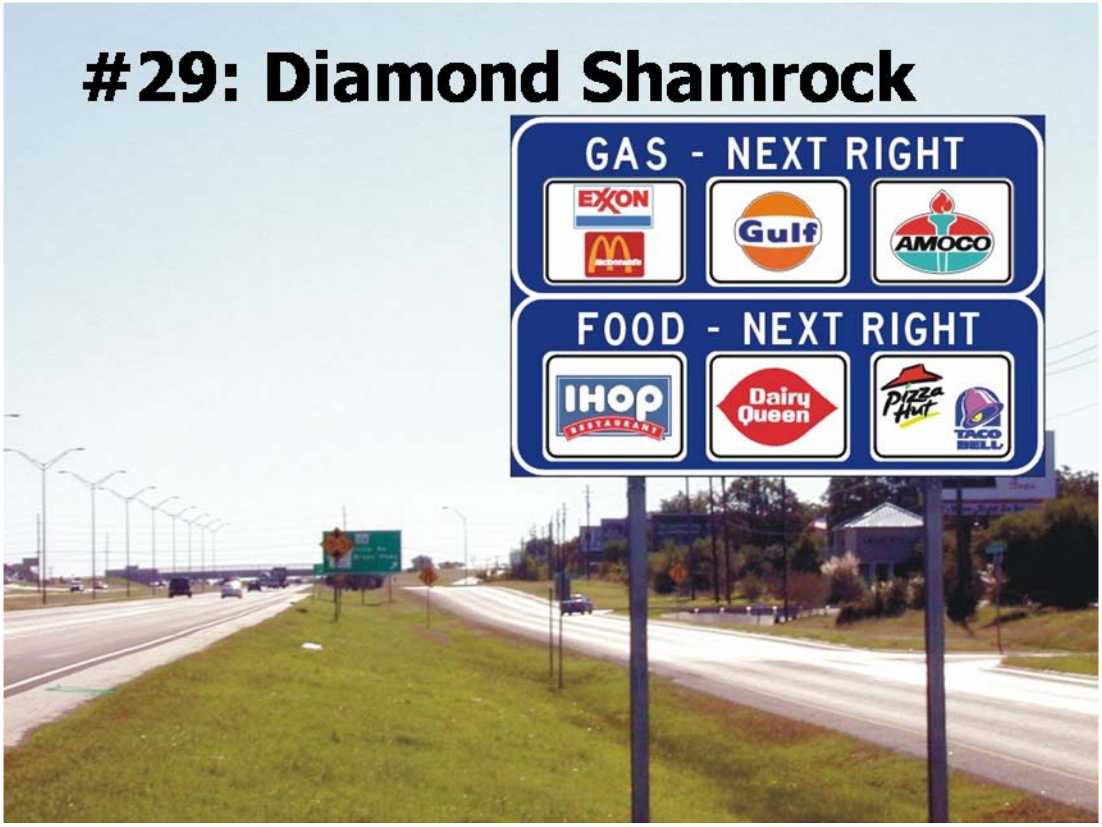

#24: Taco Bell
GAS
FOOD
WENDY'S
BURGER KING
TEXACO
Pizza Hut
TACO BELL
churchs
CHICKEN
PAPA JOHNS
NEXT RIGHT


#25: Mobil
GAS - NEXT RIGHT
CONOCO
TEXACO
PETRO
Stopping Centers
FOOD - NEXT RIGHT
ROCKFISH
McDonald's
Captain D's
Church's


#26: McDonald's
GAS
FOOD
CITGO
Chevron
McDonald's
IHOP
RESTAURANT
Popeyes
Captain D's
CHUCK E. CHEESE'S
NEXT RIGHT


#27: Texaco
GAS - NEXT RIGHT
FINA
conoco
popeyes
FOOD - NEXT RIGHT
KFC
golden corral
Buffet & Grill


#28: Pizza Hut
GAS
FOOD
BURGER KING
Pizza Hut
TACO BELL
TEXACO
Applebee's
NEXT RIGHT


#29: Diamond Shamrock
GAS - NEXT RIGHT
EXXON
Gulf
AMOCO
FOOD - NEXT RIGHT
IHOP
RESTAURANT
Dairy Queen
Pizza Hut
TACO BELL


#30: Green Burrito
GAS - NEXT RIGHT
FINA
Mobil
Wendy's
FOOD - NEXT RIGHT
Pizza Hut
Long John Silver's
KFC
GREEN BURRITO


#31: Flying J's
GAS
FOOD
CITGO
TEXAS
Blimpie
Mobil
Wendy's
churchs
KFC
NEXT RIGHT


#32: Mobil
GAS
FOOD
bp
Popeyes
Shakey's
CONOCO
CITGO
Mobil
Quizno's
SUBS
NEXT RIGHT


#33: Bob's
GAS
FOOD
CITGO
Blimpie
Dairy Queen
TEXACO
BURGER KING
POPEYES
McDonald's
NEXT RIGHT


#34: Del Taco
GAS - NEXT RIGHT
TEXACO
BURGER KING
Mobil
FOOD - NEXT RIGHT
Church's CHICKEN
DEL TACO
KFC
A&W


#35: Conoco
GAS
FOOD
CITGO
Red Lobster
NEXT RIGHT


#36: Total
GAS - NEXT RIGHT
TOTAL
Rally's
Mobil
FOOD - NEXT RIGHT
churchs
CHICKEN
PAPA JOHNS
KFC
A&W


#37: Taco Bell
GAS - NEXT RIGHT
bp
A&W
TEXACO
FOOD - NEXT RIGHT
SHONEY'S
TacoTime
Little Caesars
Blimpie


#38: Stage Deli
GAS - NEXT RIGHT
Chevron
Blimpie
CONOCO
CITGO
FOOD - NEXT RIGHT
SONIC
America's Drive-In
BURGER KING
STAGE DELI
FAST
PIZZA


#39: Souper Subs
GAS - NEXT RIGHT
Blimpie
TEXACO
BURGER KING
CITGO
FOOD - NEXT RIGHT
SHONEY'S
McDonald's
CHI-CHI'S


#40: White Castle
GAS - NEXT RIGHT
FINA
BURGER KING
Chevron
AMOCO
FOOD - NEXT RIGHT
Pizza Hut
SUBWAY
DEL TACO
White Castle

APPENDIX 1-B:
DUAL LOGO SURVEY RESULTS FOR INDIVIDUAL QUESTIONS

Table 1B-1 in this appendix presents a summary of the results for individual questions in both survey sets. This table also summarizes significant characteristics associated with each of the questions in the survey.

Table 1B-1. Summary of Individual Question Responses.

No.	Logo Design	Type of Logo	Business Asked about in Question	Logo Position	Layout	Time Exposure	Familiar	Correct Answer	Set A (0.8 and 1.3 sec)					Set B (1.3 and 1.8 sec)				
									% Correct	Sample Size	Y	N	U	% Correct	Sample Size	Y	N	U
1	S	Food	Pizza Hut	---	2/4	1.3	Y	Y	90%	132	119	12	1	96%	73	70	2	1
2	D	Gas/Food	Hess	First	3/3	1.3	N	Y	64%	132	84	27	21	77%	73	56	13	4
3	N	Food	Arby's	---	2/4	1.3	Y	N	89%	131	3	116	12	97%	73	1	71	1
4	S	Gas	Shell	---	3/3	0.8	Y	Y	95%	132	126	5	1	97%	73	71	2	0
5	D	Gas/Food	Burger King	Second	3/3	0.8	Y	Y	61%	132	80	30	22	84%	73	61	10	2
6	D	Food/Gas	Citgo	Second	2/4	1.3	Y	Y	45%	132	59	60	13	64%	73	47	19	7
7	N	Gas	Chevron	---	3/3	1.3	N	N	83%	132	7	109	16	83%	72	5	60	7
8	S	Gas	BP	---	2/4	0.8	N	Y	58%	132	77	33	22	67%	73	49	13	11
9	D	Food/Gas	Blimpie	First	2/4	1.3	Y	Y	74%	132	98	29	5	82%	73	60	12	1
10	N	Food	Giant Burger	---	3/3	1.3	N	N	65%	132	5	86	41	67%	73	1	49	23
11	N	Food	McDonald's	---	2/4	0.8	Y	N	83%	132	6	110	16	95%	73	3	69	1
12	S	Food	KFC	---	2/4	0.8	Y	Y	83%	132	109	9	14	84%	73	61	11	1
13	D	Food/Food	In-N-Out	Second	3/3	1.3	N	Y	43%	132	57	57	18	66%	73	48	21	4
14	N	Gas	Mapco Express	---	2/4	0.8	N	N	60%	132	5	79	48	84%	73	1	61	11
15	D	Food/Gas	Fina	Second	2/4	0.8	Y	Y	57%	132	75	39	18	71%	73	52	16	5
16	S	Gas	Ultramar	---	2/4	1.3	N	Y	36%	132	48	64	20	58%	73	42	24	7
17	N	Food	Quizno's	---	2/4	0.8	Y	N	62%	132	17	82	33	73%	73	4	53	16
18	D	Food/Food	KFC	First	2/4	0.8	Y	Y	92%	132	121	7	4	92%	73	67	4	2
19	N	Food	Popeye's	---	3/3	1.3	Y	N	87%	132	2	115	15	93%	73	5	68	0
20	D	Food/Food	A&W	Second	2/4	0.8	Y	Y	73%	132	97	22	13	71%	73	52	18	3
21	S	Gas	Exxon	---	3/3	1.3	Y	Y	93%	132	123	6	3	96%	73	70	3	0

No.	Logo Design	Type of Logo	Business Asked about in Question	Logo Position	Layout	Time Exposure	Familiar	Correct Answer	Set A (0.8 and 1.3 sec)					Set B (1.3 and 1.8 sec)				
									% Correct	Sample Size	Y	N	U	% Correct	Sample Size	Y	N	U
22	N	Food	Burritoville	---	2/4	1.3	N	N	67%	132	11	88	33	81%	73	1	59	13
23	D	Food/Food	Nathan’s	First	3/3	0.8	N	Y	48%	132	64	36	32	70%	73	51	13	9
24	D	Food/Food	Taco Bell	Second	2/4	1.3	Y	Y	56%	132	74	43	15	74%	73	54	14	5
25	N	Gas	Mobil	---	3/3	0.8	Y	N	59%	132	4	78	50	64%	73	5	47	21
26	D	Food/Gas	McDonald’s	First	2/4	0.8	Y	Y	70%	132	92	32	8	75%	73	55	13	5
27	N	Gas	Texaco	---	3/3	1.3	Y	N	76%	132	17	100	15	88%	73	4	64	5
28	D	Food/Food	Pizza Hut	First	2/4	1.3	Y	Y	93%	132	123	7	2	93%	73	68	3	2
29	N	Gas	Diamond Shamrock	---	3/3	0.8	N	N	66%	132	10	87	34	75%	73	2	55	16
30	S	Food	Green Burrito	---	3/3	0.8	N	Y	61%	132	81	28	23	88%	73	64	7	2
31	N	Gas	Flying J’s	---	2/4	1.3	N	N	83%	132	5	109	18	89%	73	0	65	8
32	D	Food/Gas	Mobil	Second	2/4	1.3	Y	Y	93%	132	123	9	0	99%	73	72	1	0
33	N	Food	Bob’s	---	2/4	0.8	N	N	62%	131	4	81	46	86%	73	0	63	10
34	S	Food	Del Taco	---	3/3	1.3	N	Y	80%	132	105	21	6	90%	73	66	7	0
35	N	Gas	Conoco	---	3/3	0.8	N	N	53%	132	10	70	52	67%	73	7	49	17
36	D	Gas/Food	Total	First	3/3	0.8	N	Y	62%	130	80	19	30	85%	73	62	8	3
37	N	Food	Taco Bell	---	3/3	1.3	Y	N	86%	131	5	113	13	93%	73	2	68	3
38	D	Food/Food	Stage Deli	First	3/3	1.3	N	Y	66%	131	86	33	11	82%	72	59	8	5
39	N	Food	Souper Subs	---	3/3	0.8	N	N	50%	132	8	66	58	77%	73	3	56	14
40	D	Food/Food	White Castle	Second	3/3	0.8	N	Y	49%	131	64	37	30	70%	73	51	13	9

APPENDIX 5-A:
CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were performed in accordance with guidelines presented in *NCHRP Report 350*. The following sections provide a brief description of these procedures.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

The test vehicles were instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity (c.g.) to measure longitudinal, lateral, and vertical acceleration levels; and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. These accelerometers were ENDEVCO® Model 2262CA, piezoresistive accelerometers with a ±100 g range.

The accelerometers are a strain gage type with a linear millivolt output proportional to acceleration. Angular rate transducers are solid state, gas flow units designed for high-"g" service. Signal conditioners and amplifiers in the test vehicle increase the low-level signals to a ±2.5 volt maximum level. The signal conditioners also provide the capability of a resistive calibration (R-cal) or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15-channel, constant-bandwidth, Inter-Range Instrumentation Group (IRIG), FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals from the test vehicle are recorded before the test and immediately afterward. A crystal-controlled time reference signal is simultaneously recorded with the data. Wooden dowels actuate pressure-sensitive switches on the bumper of the impacting vehicle prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produces an "event" mark on the data record to establish the instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, is received and demultiplexed onto separate tracks of a 28 track, IRIG tape recorder. After the test, the data are played back from the tape machine and digitized. A proprietary software program (WinDigit) converts the analog data from each transducer into engineering units using the R-cal and pre-zero values at 10,000 samples per second per channel. WinDigit also provides SAE J211 class 180 phaseless digital filtering and vehicle impact velocity.

All accelerometers are calibrated annually according to Society of Automotive Engineers (SAE) J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations are made any time data are suspect.

The Test Risk Assessment Program (TRAP) uses the data from WinDigit to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10 ms average ridedown acceleration. WinDigit calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50 ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60 Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP. TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001 second intervals and then plots: yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate systems being initial impact.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the vehicle. The dummy was not instrumented.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included three high-speed cameras: one placed behind the installation at an angle and two placed to have a field of view perpendicular to each of the two barricades/vehicle path. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked motion analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A BetaCam, a VHS-format video camera and recorder, and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

TEST VEHICLE PROPULSION AND GUIDANCE

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A two-to-one speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.