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16. Abstract

Dynamic speed display signs (DSDS), devices that detect and display a vehicle's current speed back to the driver, have been shown to have a significant speed-reducing effect in temporary applications such as work zones or neighborhood speed watch programs. In this report, researchers examined the effectiveness of DSDS installed permanently in several locations that were experiencing speed-related problems. Seven sites were evaluated, including a school speed zone, two transition speed zones in advance of a school speed zone, two sharp horizontal curves, and two approaches to signalized intersections on high-speed roadways. Data were collected before the DSDS were installed, about one week after installation to determine initial effects of the signs upon vehicle speeds, and again about four months after installation to determine how well the initial speed reductions were maintained. Researchers analyzed average speeds, 85th percentile speeds, percent of the sample exceeding the speed limit and standard deviations of the samples. Also, least square regression analyses between the speed of a vehicle upstream of the DSDS and that vehicle's speed measured again at the DSDS were performed to determine whether the sign affected higher speed vehicles more than lower speed vehicles.

Overall, average speeds were reduced by 9 miles per hour at the school speed zone. Elsewhere, the effect of the DSDS was less dramatic, with average speeds reduced by 5 mph or less, depending on the location tested. As expected, the influence of a DSDS was found to differ depending on how fast a motorist approached the DSDS. Those motorists traveling faster than the posted speed did appear to reduce their speed more significantly in response to the DSDS than did motorists traveling at or below the posted speed limit. The results of this project suggest that DSDS can be effective at reducing speeds in permanent applications if appropriate site conditions apply.

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EVALUATION OF DYNAMIC SPEED DISPLAY SIGNS (DSDS)

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

INTRODUCTION

STATEMENT OF THE PROBLEM

According to National Highway Traffic Safety Administration data, excessive speed is a contributing factor to a large number of accidents (as many as 21 percent) in the U.S. and in Texas each year (*1*). Many of these accidents occur at problem locations where, for one reason or another, some motorists fail to properly adjust their speed. Over the years, transportation agencies have tried many different approaches to reduce vehicle speeds at such problem locations. These efforts have ranged from increased targeted enforcement activities, to roadway design alterations, to the installation of traffic control devices designed to encourage a reduction in speed by increasing the driver's awareness of his or her speed. It is generally agreed that enforcement presence is one of the most effective methods available to reduce speeds at locations where speeding behavior is problematic. Unfortunately, the biggest drawback to the use of enforcement is manpower availability. Therefore, the need often exists to supplement available enforcement presence to address a speed-related problem at permanent locations such as hazardous curves, school zones, signalized intersections, etc.

Because it is sometimes difficult to obtain and maintain the intensity of law enforcement presence necessary to reduce speeds at a location, considerable interest exists in new technologies that have the potential for reducing the speeds of vehicles and thus improving safety at these locations. One technology that appears to offer the potential for reducing vehicles' speeds is termed dynamic speed display signs (DSDS). These devices are also known as driver feedback signs or simply speed display signs. DSDS detect and indicate to approaching drivers their current travel speed. DSDS have proven to be very effective at temporary installations in reducing the speed of vehicles entering work zones. However, most tests have been limited to a few weeks duration. It is not known whether DSDS installed in a more permanent manner at a location can achieve similar speed-reducing effects, can achieve them under different types of roadway and hazard conditions (i.e., school zones, sharp horizontal curves, high-speed signalized intersection approaches, etc.), and can maintain that effect over long periods of time. The remainder of this report documents research performed by the Texas Transportation Institute (TTI) for TxDOT to investigate these questions.

BACKGROUND

Previous Studies of Speed Display Technologies

In recent years, changeable message sign (CMS) and speed radar detection technology have been combined in a dynamic feedback process in an attempt to present messages targeted specifically at those motorists exceeding a speed threshold at a location. Tests conducted at work zones in Virginia suggested that this type of system could generate significant reductions in speeds and speed variance (*2*). Furthermore, researchers found that the effect was maintained over a significant (several months) amount of time in this work zone application (*3*). In these tests, the CMS presented warning messages only to high-speed drivers as shown below:

- EXCESSIVE SPEED SLOW DOWN
- HIGH SPEED SLOW DOWN
- REDUCE SPEED IN WORK ZONE
- YOU ARE SPEEDING SLOW DOWN

Eventually, CMS and speed detection technology were further simplified together to provide drivers an indication of their current speed as a DSDS. These first DSDS were combined into self-contained portable trailer units and deployed in residential neighborhoods as part of speed control programs (*4*). The success experienced in these applications led transportation agencies to consider their use in work zone locations as well. Figure 1 illustrates a typical system used in some Texas work zones.

Figure 1. Example of a Portable Dynamic Speed Display System for Work Zones.

Studies have consistently shown these devices to be quite effective in reducing vehicle speeds in high-speed work zone applications. In one study, researchers were able to reduce the average speed of vehicles entering a work zone on rural interstate highways by 4 to 5 mph (*5*). Perhaps more importantly, the number of drivers exceeding the posted advisory speed limit through the work zone was reduced by 20 to 40 percent (*6*). In studies conducted in Texas work zones, this technology resulted in 2 to 9 mph reductions in average automobile speeds and 2 to 10 mph reductions in average truck speeds. Furthermore, the percentage of vehicles exceeding the posted work zone speed limit was reduced 15 to 20 percent (*6*). However, in both instances, the duration of the DSDS deployment was only a few days.

The success of DSDS in temporary applications has now generated interest in its potential use in treating more permanent situations (school speed zones, sharp horizontal curves, high-speed signalized intersection approaches, etc.). Unfortunately, efforts to evaluate this type of technology in permanent locations have been much more limited. In one instance, a truck warning system, utilizing changeable message signs that presented advisory speed information in addition to a vehicle's current speed, was installed at five sharp horizontal curve locations in hilly terrain in northern California (*7*). An evaluation of these sites revealed an initial speed-reducing effect. However, over time, the effect of the signs began to diminish. A companion motorist survey performed in the same time period supported the speed study findings. Specifically, researchers in that study found that the percent of motorists who indicated that they had slowed down in response to the signs decreased substantially over a one-year period immediately following the installation of the signs (*7*). These results, although limited in scope, do point to one of the key concerns about using DSDS in a permanent application; namely, will such devices be capable of maintaining their effectiveness over time?

Other Permanent DSDS Applications

As an initial effort on this project, TTI researchers attempted to identify other jurisdictions and locations where DSDS technology had been deployed in a permanent manner to address an excessive speed problem. Researchers contacted several different manufacturers of this type of technology to obtain customer lists and then attempted to contact those customers to obtain any data that had been collected on the effectiveness of the signs.

Overall, researchers identified a total of 19 different jurisdictions in 8 states that had deployed some brand of DSDS technology. Researchers found that most installations had occurred in the past few years and most were at school speed zones. Unfortunately, essentially all of the installations had been done by local agencies. Generally speaking, local agencies do not have the financial resources to collect data before and after installation to assess the impact of the DSDS. Anecdotal comments received from agency officials indicated that most were pleased with the devices and felt that the signs had successfully reduced speeds. However, researchers hypothesized that that some of the perceived "success" of the signs may have been simply the result of fewer citizen complaints about speeds on that roadway. In turn, citizen complaints about those locations may have decreased simply because it was perceived that the agency had purchased and installed devices to "fix" the speeding problem.

Prior to the initiation of this research project, TxDOT had installed DSDS at a couple of high-speed rural highway intersections. Speed data collected with mechanical traffic counters at the DSDS before and shortly after installation found that speeds at the two sites were not affected in a similar manner. At one location, average speeds were affected by only 1 or 2 mph, whereas speeds were 5 to 6 mph slower after DSDS installation at the second site. Clearly, certain site-specific factors had a significant influence on how drivers responded to the DSDS at each site.

PROJECT OBJECTIVES

The objectives of the research project documented in this report were two-fold:

1. determine and compare the short-term (i.e., few weeks) and long-term (several months) effectiveness of DSDS installed within and in advance of school speed zones, on approaches to high-speed signalized intersections, and on approaches to sharp horizontal curves; and
2. develop implementation guidelines for the use of DSDS to address traffic speed concerns at permanent locations.

This report describes the methods and results of studies performed at several different DSDS installations in four TxDOT districts. Implementation guidelines developed based on this research are included as an appendix in this report.

PROJECT METHODOLOGY

ANALYSIS APPROACH

To evaluate the effectiveness of DSDS in permanent applications, researchers collected field data during three study periods for each test site:

1. before the DSDS was installed,
2. immediately after (zero to three weeks) the DSDS was installed, and
3. several (two to four) months after DSDS installation.

The before study was performed to establish normal speed trends at each site. Following the installation of a DSDS, the first after study was conducted as a means of determining how the sign initially affected traffic. The second after study was performed to determine if any initial speed reductions observed immediately after DSDS installation were maintained over time.

At each site, researchers identified both a control location and a test location at which to measure speeds. The control location was selected upstream and beyond the influence of the anticipated DSDS installation and was to be approximately 2000 to 3000 feet upstream of the DSDS, once installed. The test location was then positioned adjacent to the spot where the DSDS would be installed.

Researchers hypothesized that the DSDS would not have a uniform effect upon all motorists approaching each test location. Instead, researchers envisioned that those approaching the DSDS at speeds much higher than the posted speed limit would react more strongly to the sign than those approaching at or below the posted speed limit. Therefore, researchers adopted a data collection method that tracked specific vehicles. As a specific vehicle approached, data collection personnel at the control location took a speed measurement and then described the vehicle on a walkie-talkie to the second data collection person stationed at the test location. When that vehicle arrived at the test location, its speed was measured again. This approach allowed researchers to correlate initial approach speeds to speeds at the DSDS and thus assess how the sign impacted motorists' speed-changing behavior.

In addition to the speed data, researchers also used video cameras placed on tripods positioned to view the rear of vehicles approaching the DSDS. These video data were then reviewed to determine if the DSDS led to an increase in the frequency or severity of erratic maneuvers at each test site. Although many hours of video data were collected and analyzed, researchers found that the DSDS created no erratic maneuvers of any kind at any of the study sites. Therefore, this report presents only speed data results.

Researchers also contacted enforcement officials at each site to ensure that enforcement levels did not change from study to study. For the most part, the respective enforcement agencies cooperated with this request. However, as will be discussed, enforcement levels were somewhat higher (or possibly perceived to be so) at a few of the test sites, which appeared to significantly affect the effectiveness of the DSDS in reducing speeds.

DESCRIPTION OF THE DSDS EVALUATED

The DSDS utilized for this research project was a fairly recent off-the-shelf product that a vendor offered to loan to TxDOT for evaluation purposes. This particular device combines a black-on-white rectangular sign with a “YOUR SPEED” message over two light-emitting diode (LED)/flip-disk (with strong yellow-green reflective sheeting attached to the flip disks) CMS characters (see Figure 2). The LED pixels outline the character and provide adequate visibility at night. The sign houses a K-band radar antenna aimed at approaching vehicles. As a speed is detected, the CMS characters switch and display that speed to the approaching motorist. If no vehicle is detected, the DSDS returns to a no-display status (the characters show no speed). The CMS characters approximate the size of numerals on a regulatory speed limit sign (i.e., at least 10 inches on a 24 by 36 inch sign; at least 16 inches on a 36 by 48 inch sign). Sizes of the DSDS units utilized depended on the appropriate size of regulatory speed limit signs required at each of the study sites.

Figure 2. Example of a Permanently Installed Self-Contained DSDS Unit.

The radar antenna was calibrated to detect vehicles up to 500 feet in advance of the DSDS. The radar signal broadcasts in a 12-degree cone perpendicular to the face of the sign. The vendor literature for the DSDS indicated that the sign was capable of displaying characters between 5 and 99 mph, although thresholds could be set to limit how large a speed indication the sign would allow (to avoid motorists attempting to “max out” the speed indication). It should be noted, however, that TTI researchers did see instances where the sign displayed “00” for short periods of time. These indications appeared to occur when traffic volumes were fairly high, suggesting that the radar signal logic may have been confused by a large numbers of vehicles within the detection zone at one time.

SITE SELECTION AND DESCRIPTION

TxDOT project monitoring committee members for this research identified a total of seven locations state-wide to install DSDS for testing purposes. The sites were selected to encompass a range of roadway and speed conditions for which DSDS could possibly be used.

Overall, panel members selected the following situations for study:

- one school speed zone (active only during portions of the school day),
- two advance warning areas for school zones,
- two high-speed signalized intersection approaches, and
- two approaches to sharp horizontal curves.

The following paragraphs provide a description of each of the sites, their physical characteristics, and the speed characteristics before the DSDS sign was installed.

Site 1: School Speed Zone, FM 471, Forney

The first site evaluated was a school speed zone located in Forney, Texas. The speed zone was installed at the local high school on farm-to-market (FM) Road 741. FM 741 is a two-lane rural/suburban highway with no paved shoulders and a normal speed limit of 55 mph. At the high school, the roadway widens slightly to allow a left-turn bay for student and faculty entrances onto campus. The roadway serves a large number of commuters who travel northbound in the morning en route to their employers located about 20 miles away in Dallas. During school speed zone time periods, the limit drops to 35 mph. A flashing beacon attached atop the school speed zone sign flashes during the time periods that the reduced speed zone is in force (generally 7:30 – 8:20 AM and 3:35 – 4:10 PM each day school is in session). Generally speaking, vehicle speeds normally average about 50 mph all the way through the area. During the hours of the school speed zone, average speeds at the beginning of the zone do decrease to about 45 mph but are still significantly above the 35 mph posted speed limit.

Combined with the large numbers of turning vehicles into and out of campus (and the typical aggressive driving behavior associated with teenage drivers), the speeds on FM 471 during the school speed zone times were considered too high to be safe, and a mechanism for bringing speed more in line with the school speed zone limit was desired. Consequently, the DSDS installed at this location was connected directly to the power provided for the flashing beacon so that the sign would be active only during the school speed zone hours. This approach proved to be somewhat problematic in that the DSDS often lost power at the end of the school speed zone time while still displaying a speed indication. When this occurred, that speed was "frozen" on the sign until the next time that power was restored to the DSDS. The end result was that the sign often appeared to not be functioning properly. During one of the data collection studies, a local resident even questioned one of the TTI researchers about why the sign did not work properly. The possible implications that this type of operation may have had upon speeds at that site are discussed in more detail in the "Study Results" section.

Figure 3 provides a schematic illustration of this study site showing the location of the DSDS, other traffic control devices, and the data collection locations selected. The control point at this site (labeled point 1) was located about 2200 feet in advance of the school speed limit sign (the eventual location of the DSDS). The second data collection point was located at the school area sign (S1-1) in the before study and at the DSDS sign (375 feet downstream) in both after studies. A third data collection point initially identified was ultimately not used because of the congestion that developed at that location each day due to turning vehicles.

Researchers collected data during three different time periods at this site: morning peak (7:00 – 9:00 AM), midday off-peak (11:00 AM – 1:00 PM), and afternoon peak (3:00 – 5:00 PM). Thus, the morning and afternoon peak data collection periods encompassed the hours that the school speed zone was active each day.

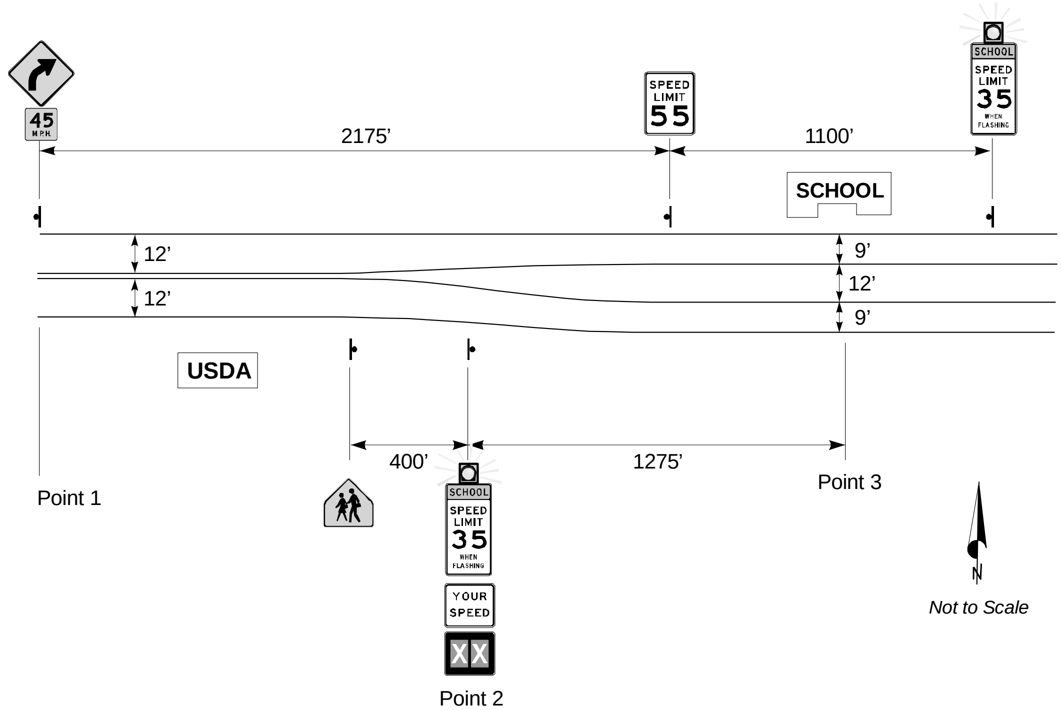

Figure 3. Schematic Layout of Site 1.

Sites 2 and 3: Advance School Zone Areas, FM 89 North and Southbound, Abilene

To test the effectiveness of DSDS in a different type of school zone application, two sites were selected on FM 89 (also known as Buffalo Gap Road) in Abilene, Texas. At these sites, the DSDS signs were placed in advance of a school zone in both directions in an attempt to slow vehicles down prior to reaching the zone. Since the DSDS were installed in conjunction with the normal 45 mph speed limit sign, they were set to operate continuously and thus have a speed-reducing influence even when the school speed zone was not active.

Figures 4 and 5 illustrate the layouts at these sites. In this area, motorists travel northbound from a more rural environment (speed limit 55 mph, low driveway densities and adjacent land use development) into an environment that is more suburban/urban in nature. The reverse is true for motorists traveling southbound. These differences by direction are reflected in slightly different travel speeds by motorists. Whereas motorists traveling northbound into town typically averaged about 55 mph upstream and at the 45 mph speed limit sign, motorists traveling southbound averaged between 45 and 50 mph upstream and at the 45 mph speed limit sign.

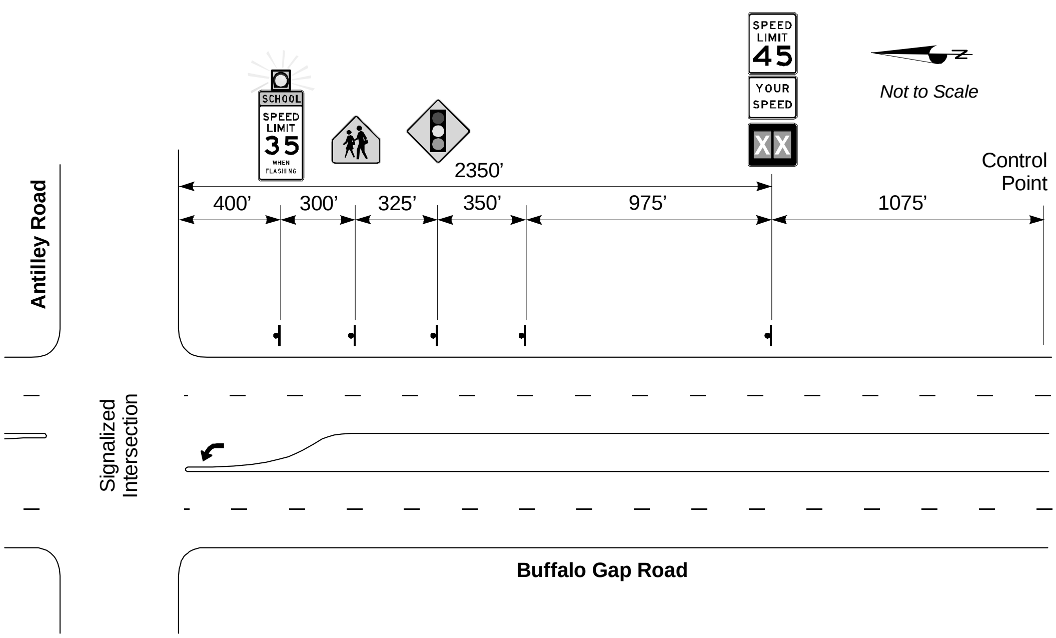

Figure 4. Schematic Layout of Site 2.

In the northbound direction, the DSDS was placed about 1950 feet upstream of a school speed limit sign and approximately 2350 feet upstream of an intersection. In the southbound direction the DSDS was placed about 1125 feet upstream of a school speed limit sign and about 1725 feet upstream of an intersection. In both directions, the control data collection point was placed about 1000 to 1100 feet upstream of the DSDS and the second data collection point was positioned immediately adjacent to the DSDS.

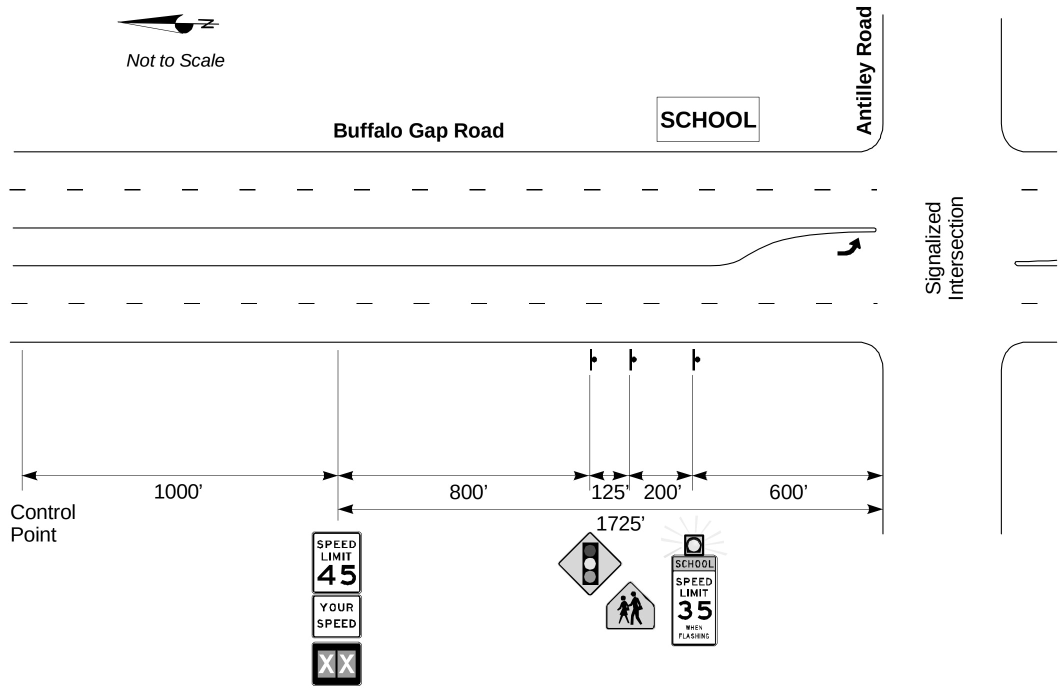

Figure 5. Schematic Layout of Site 3.

Sites 4 and 5: Sharp Horizontal Curve, US 277/183/283 North and Southbound, Seymour

A fairly sharp curve (ball banked at about 20 mph) on US 183/283/277 in Seymour, Texas, served as the location of the next two sites where DSDS effectiveness was tested. This location had been experiencing problems with large trucks entering the curve at too great of a speed and overturning. Despite the application of a multitude of warning devices approaching and within the curve from both directions, the problem of trucks overturning continued. On average, speeds approaching this curve from both directions are quite moderate, only averaging between 35 and 37 mph at the beginning of the curve. The posted regulatory speed limit within the curve is only 30 mph, while 20 mph advisory speed plaques and a 90-degree curve warning sign is located on a mast arm over the travel lanes. It should be noted that the 20 mph advisory speed limits were even slower (10 mph) when researchers conducted the before studies for these sites. The change in advisory speed limit made it more difficult to ascertain the influence that the DSDS may have had at these sites. Figure 6 presents the schematic layout of these sites.

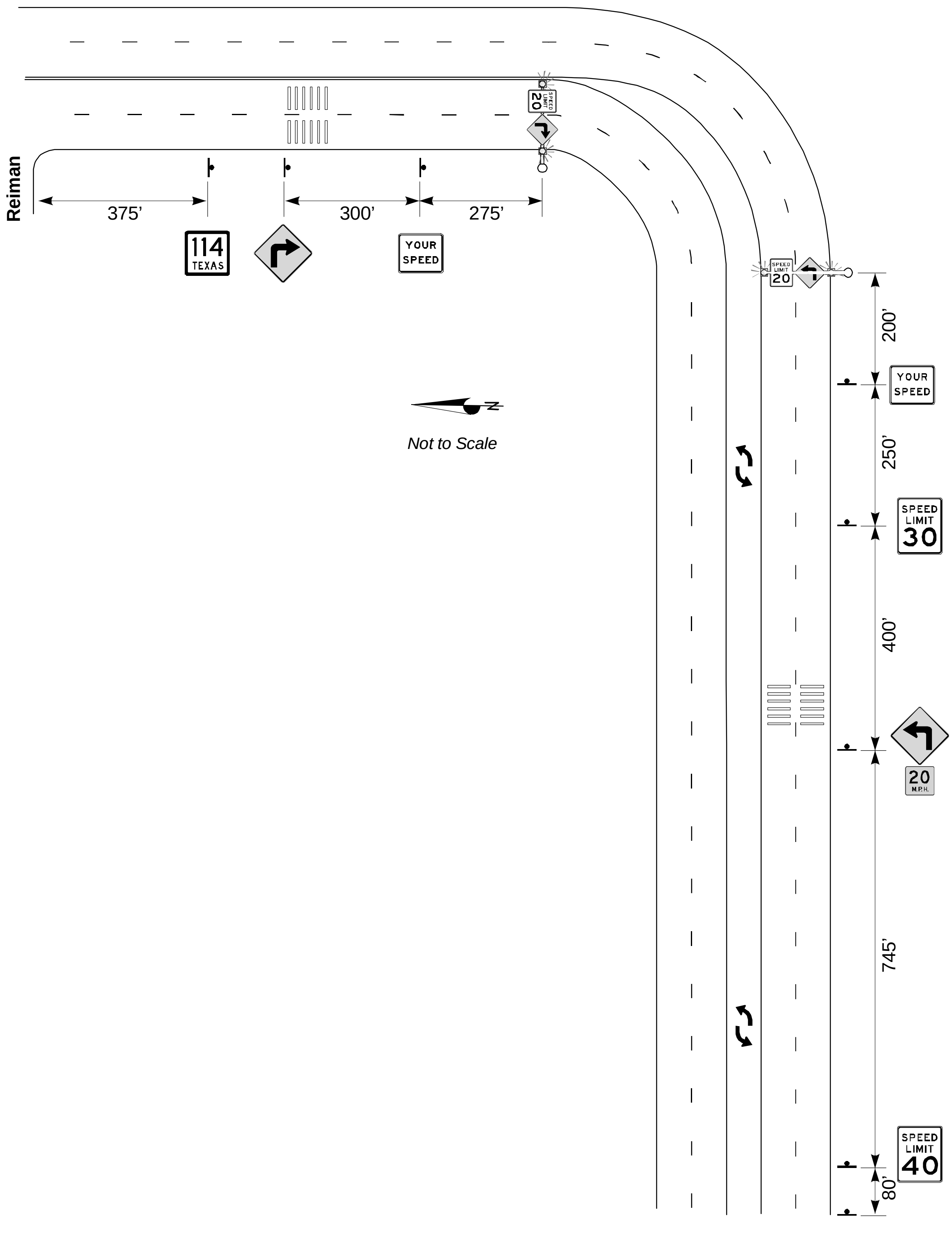

Figure 6. Schematic Layout of Sites 4 and 5.

Sites 6 and 7: High-Speed Signalized Intersections, US 59 at Loop 390 Southbound and US 59 at SR 43 Northbound, Marshall

The final two test sites for DSDS evaluation were located on the approaches of two signalized intersections on high-speed, multi-lane highway approaches. Test site 6, US 59 at Loop 390 southbound, is the first signalized intersection encountered as southbound motorists reach the town of Marshall. These motorists have been traveling in a rural environment (70 mph speed limit) prior to reaching this location. Although the southbound approach to the intersection has a good amount of sight distance, problems associated with speeding at this location (increased crashes, red-light running, etc.) still occur. Researchers hoped that installing the DSDS would alert motorists to the situation and to the need to slow down to comply with the 55 mph speed zone that begins about 1350 feet upstream of the intersection (see Figure 7). Prior to the installation of the DSDS, average speeds at the 55 mph speed limit signs were approximately 58 mph, with 85th percentile speeds nearly 65 mph.

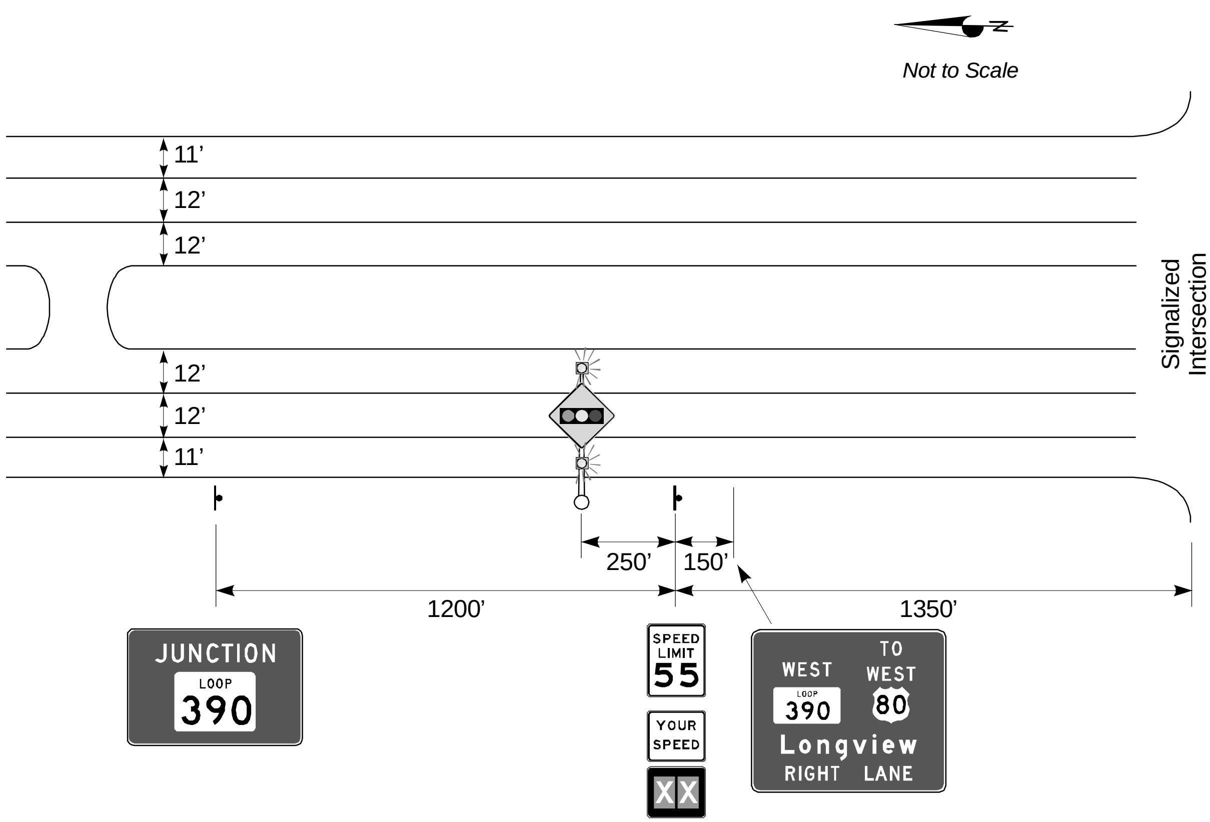

Figure 7. Schematic Layout of Site 6.

Site 7, US 59 at State Road (SR) 43 northbound, represents a different condition for motorists approaching this signalized intersection. At this location, motorists are traveling away from the town of Marshall toward a rural area (and actually have not yet reached the intersection with Loop 390 referred to above). Speed-related problems at this intersection appear due more to the fact that sight distance on the approach is restricted below that required to provided decision sight distance for an urban/suburban stop condition (approximately 1175 feet for vehicles approaching at 55 mph) (*8*). Figure 8 presents a schematic layout of this site. At the 45 mph speed limit sign prior to the installation of the DSDS, average speeds were slightly greater than 45 mph, with the 85th percentile speed equal to 50 mph.

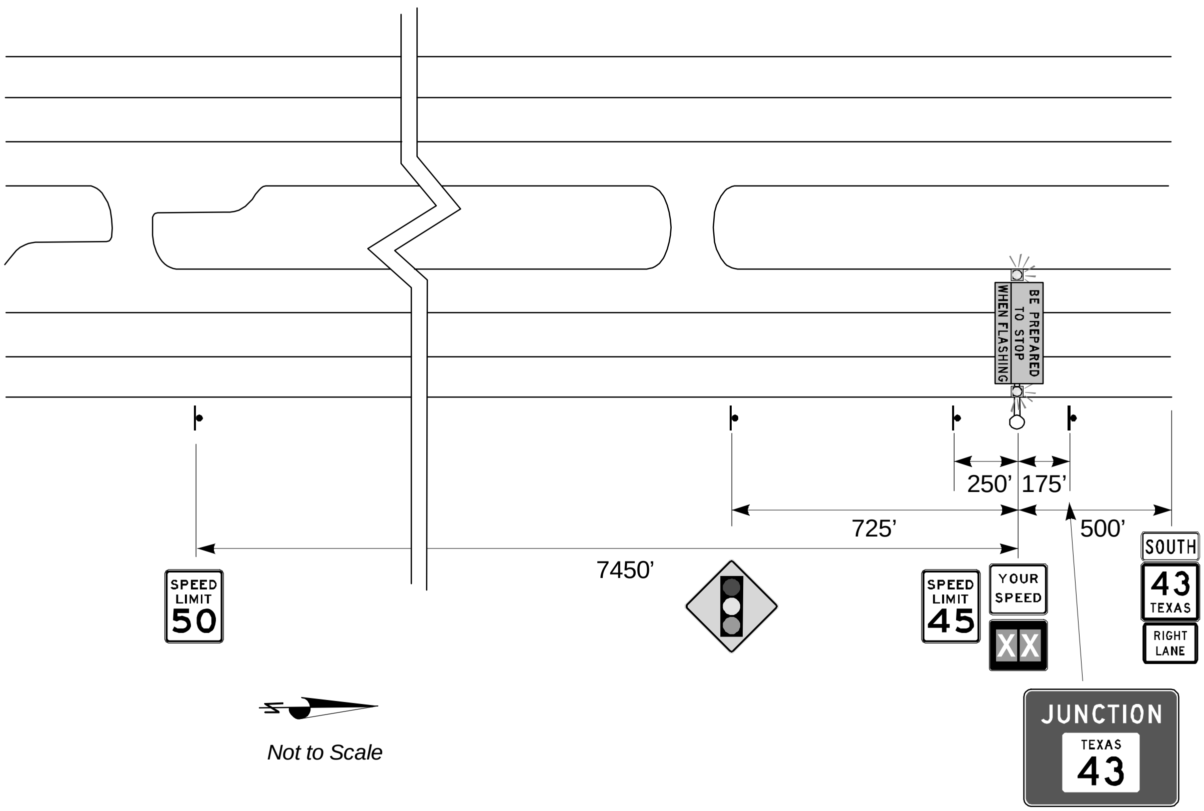

Figure 8. Schematic Layout of Site 7.

DATA COLLECTION

As stated previously, researchers utilized a before-after-after study design for this project. Vehicle speed and erratic maneuver data were collected during each study period. The primary erratic maneuvers that researchers looked for included severe braking in direct response to the DSDS (or to a sudden deceleration of a vehicle in front that had slowed because of the sign) or last-second swerving or lane changes to avoid slowed vehicles. Speed measurements were taken far enough upstream at each site so that drivers were not yet affected by the DSDS and again at the DSDS. Erratic maneuvers were recorded using an 8 mm video camera mounted on a tripod and positioned to record the rear of vehicles approaching the DSDS over a distance of approximately 500 feet upstream of the sign.

Speed data at both data collection points were obtained using hand-held lidar guns. Data collection personnel positioned themselves in unmarked vehicles in parking lots, driveways, or if necessary on the shoulder of the facility as unobtrusively as possible. Researchers recorded only free-flowing vehicle speeds and also recorded the distance at which each speed reading was taken to ensure that the data were collected within a reasonable range at the data collection point. Researchers attempted to sample both passenger vehicles and large trucks in the approximate proportion of each in the overall traffic stream. At six of the seven sites, researchers at the control point identified the specific vehicle they had just measured (generally by vehicle type and color) by walkie-talkie to the data collector at the second (DSDS) point so that the speed of that same vehicle could be measured again. In this way, researchers could also assess how vehicles altered their speeds as they approached the DSDS location. A total of 13,584 speed measurements were taken by researchers at the seven sites over the three studies (before, first after, and second after).

Data were generally collected over multiple time periods over a two-day period at each site for each study. The time periods consisted of a morning peak period, a midday off-peak period, an evening time period, and a night period. At site 1, the morning and evening periods encompassed the times when the school speed zone (and the DSDS) was active, as well as times when the DSDS was not active. At the remaining sites, the DSDS remained active continuously. Table 1 presents the week when the before data were collected at each site, when the DSDS was activated, when the first after study was conducted, and when the second after study was conducted. Researchers strived to conduct the first after study one to two weeks after the DSDS was activated and the second after study about four months after DSDS activation.

Table 1. Dates of Data Collection at the Test Sites.

Site	Week of Before Study	Week of DSDS Activation	Week of 1st After Study	Week of 2nd After Study
1	December 8, 2002	January 13, 2003	January 20, 2003	May 5, 2003
2	March 3, 2003	March 10, 2003	March 17, 2003	May 12, 2003
3	March 3, 2003	March 17, 2003	March 17, 2003	July 7, 2003
4	November 18, 2002	February 17, 2003	February 24, 2003	June 9, 2003
5	November 18, 2002	February 17, 2003	February 24, 2003	June 9, 2003
6	December 16, 2002	February 10, 2003	February 17, 2003	June 2, 2003
7	December 16, 2002	February 10, 2003	February 17, 2003	June 2, 2003

DATA REDUCTION AND ANALYSIS

Upon returning to the office, researchers entered vehicle speed and description data into spreadsheets for further analysis. Student personnel counted vehicles and reduced the video data to develop rates of erratic maneuvers for each study at each site. As noted previously, however, this activity did not yield any erratic maneuvers at any of the study sites during any of the studies. Consequently, only the speed data were useful for analysis.

Once the speed data were reduced, researchers generated simple spot speed descriptive statistics at both the control point and at the DSDS data collection point. These included average (or mean) speeds, standard deviation, 85^{th} percentile speed, and the percent of vehicles exceeding the posted speed limit at that point. Statistical comparisons between studies were then performed as appropriate. Researchers aimed for an overall 95^{th} percentile level of confidence to test for statistical significance. Since multiple comparisons were made with each set of study data, this meant that individual tests had to be performed at a higher (98.75 percentile) level of confidence.

In addition to the spot speed statistical comparisons, researchers also utilized regression analysis to compare speeds of matched vehicles. Vehicle speed at the upstream control point was compared against the speed of the same vehicle at the DSDS location. Least-square regression lines were computed for each study (before, first after, second after) and tested for significant differences between them. This procedure allowed researchers to determine whether the effect of the DSDS differed as a function of the approach speed of the vehicle. Researchers hypothesized that the sign could cause those vehicles approaching at higher speeds to slow more substantially than those approaching at slower speeds. By comparing the slopes of the regression lines between studies, researchers could test this hypothesis directly.

PROJECT RESULTS

SITE 1: FM 741 WESTBOUND, FORNEY

As Figure 3 illustrated, the DSDS sign at this site was located beside the school speed limit (35 mph) sign. The DSDS was connected to the beacon that flashed when the school speed limit was active. Thus, the sign was only "active" between 7:30 AM – 8:20 AM and 3:35 PM – 4:10 PM on school days. Data were collected during three different times of day and separated into two categories: data collected when the sign was active and data collected when the sign was not active. The spot speeds collected at the control point and at the DSDS were analyzed to determine the average speed, the 85th percentile speed, the proportion of the sample exceeding the speed limit, and the standard deviation of the sample. Table 2 shows the results for this analysis.

Table 2. Summary of Speed Statistics for Westbound Traffic on FM 741 at Site 1.

	Control Point			DSDS		
	Speed Limit = 55 mph			Speed Limit = 35 mph		
DSDS ON	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	49.3	48.8	50.1	44.5	35.3^A	35.7^A
Standard Deviation (mph)	6.1	5.7	5.7	5.5	5.9	5.8
Percent Exceeding Speed Limit (mph)	15.6	12.9	17.2	95.3	34.1^A	43.9^A
85th Percentile Speed (mph)*	56	54	56	50	40	42
DSDS OFF	Speed Limit = 55 mph			Speed Limit = 55 mph		
Average Speed (mph)	50.8	49.6^A	51.0^B	51.9	48.3^A	49.0^A
Standard Deviation (mph)	5.8	6.2	5.9	5.9	6.8	6.8
Percent Exceeding Speed Limit (mph)	21.7	16.3^A	22.4^B	26.2	14.6^A	16.6^A
85th Percentile Speed (mph)*	57	56	57	57	55	56

A: Significantly different from the before study
B: Significantly different from the 1st after study
* Not tested for statistical significance
sample sizes DSDS on: before, 254; 1st after, 215; 2nd after, 219
sample sizes DSDS off: before, 443; 1st after, 535; 2nd after, 464

DSDS ON – Speed Statistics

Table 2 shows that average speeds at the control point when the DSDS was active were not significantly different between the three study periods. Meanwhile, the average speed at the DSDS dropped substantially from 44.5 mph in the before study to 35.3 mph shortly after the sign was installed, suggesting that the DSDS was responsible for an initial 9.2 mph decrease in average speed at the beginning of the school speed zone. For the second after study conducted four months after DSDS installation, the average speed was 35.7 mph, still 8.8 mph below the average recorded at that location in the before study. At this site, it does appear that installing the DSDS resulted in a significant decrease in average speeds that was maintained over a 16 week period.

Comparison of the 85th percentile speed statistics indicated similarly impressive effects of the DSDS. The 85th percentile speed dropped from 50 mph in the before study to 40 mph in the first after study and was still down around 42 mph in the second after study. Similarly, the percent exceeding the school zone speed limit dropped dramatically from 95.3 percent in the before study to only 34.1 percent in the first after study. A slightly higher value, 43.9 percent, was then recorded in the second after study, but was not found to be statistically different from the first after study. This again suggested that the effect of the DSDS was maintained over this four-month duration.

In addition to the effects on speed reductions, researchers were also concerned with the effect of the DSDS on the dispersion of speeds at the beginning of the school zone, as several other studies have shown a correlation between higher speed variance and higher crash rates. As Table 2 illustrates, researchers found no statistically significant differences in the standard deviation in speeds between any of the three studies.

DSDS OFF – Spot Speed Statistics

Table 2 also shows that even when the DSDS was off during the non-school zone time periods, the signs appeared to have a small effect on average speeds. However, researchers found interpretation of the data during the DSDS-off condition to be slightly more complicated, due to some differences detected in speeds at the upstream control point. Whereas the speeds at the control point when the DSDS was off were statistically the same for the before and second after studies, the average during the first after study was slightly lower (by about 1 mph). A similar trend is evident in the percent of vehicles exceeding the posted speed limit at that control point. Researchers could not identify any specific weather or other reasons that would help explain why speeds at the control point were lower in the first after study. Consequently, researchers emphasized the comparison of speeds at the DSDS between the before and second after study.

With respect to speeds at the DSDS when the sign was off, researchers did find a rather surprising speed-reducing “halo” effect. As the table indicates, the average speed in the before study was 51.9 mph but dropped to 49.0 mph in the second after study. Similarly, the proportion of drivers exceeding the speed limit dropped from 26.2 percent in the before study to 16.6 percent in the second after study. Although researchers could not determine a true cause of these speed reductions, they hypothesized that speeds may have dropped because the DSDS usually did not show a blank screen when the sign turned off. Rather, the sign typically showed the speed of the last vehicle to pass through the area when power to the sign was turned off at the end of the school speed zone period. At other times, the sign showed “00” when the power to the DSDS was terminated for that time period. Consequently, the display of an unusual speed (that was generally much lower than the speeds of vehicles approaching during the DSDS-off condition) may have confused drivers, or at least caught their attention and resulted in a slightly lower speed past the DSDS even when it was not on.

Researchers found no significant differences between the standard deviations for the three studies. Thus, even when the sign displayed an incorrect speed to approaching motorists, it did not appear to cause significant variability in speeds. Finally, the 85th percentile speed also dropped about 1 mph between the before and second after study, consistent with the change observed in the average speeds.

DSDS ON – Regression Analysis

Least-squares regression lines for each study period were calculated using samples that had been tracked through the site (i.e., a spot speed was obtained at the control point and at the DSDS point for each sample vehicle). The intent of this analysis was to determine if faster vehicles and slower vehicles reacted in the same magnitude to the sign. Figure 9 is a graph of the three regression lines calculated from the data collected while the DSDS was active.

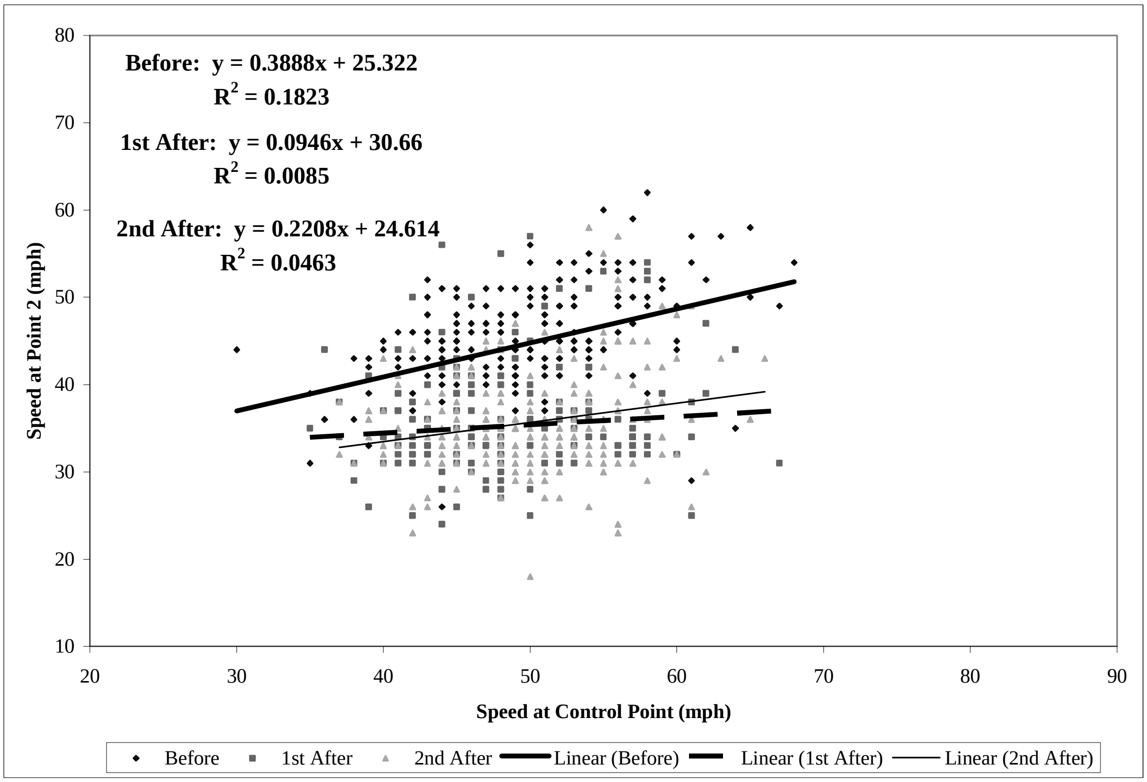

Figure 9. Regression Lines for Data Collected in Forney while the DSDS was ON.

The key item of interest in this phase of the analysis was whether or not the slopes of the regression lines were different. Statistical calculations to answer this question are included in Appendix A. First, researchers performed an F test to see if the three regression lines were the same. Then, if the regression lines were statistically significant, they performed a T-test to determine whether the slopes of the regression lines were the same. As might be expected through visual inspection, the regression lines shown in Figure 9 for the before and first after studies were found to be statistically different. However, no statistical difference could be detected between the slopes of the second after study regression line and either of the other studies. The similarity between the slope of the before study and that of the second after study implies that all vehicles were affected equally by the installation of the DSDS at this location. In other words, the amount by which vehicles slowed down at the DSDS data collection point was fairly similar regardless of how fast the vehicles were initially traveling at the control point. It should be noted that, even in the before study, higher speed vehicles were already slowing down more than slower vehicles as they approached the school speed zone (as evidenced by the low 0.3889 regression coefficient). Consequently, the potential for the DSDS to further reduce this coefficient was rather limited. Another possible explanation of these results is that the installation of the DSDS created a perception among drivers that this school zone had become a "problem" area. Given that school zones in general receive higher levels of enforcement and that essentially all vehicles were exceeding the posted speed limit in the before condition, the installation of the DSDS may have suggested a greater potential for enforcement presence and caused a significant reduction in speeds across the entire range of values.

DSDS OFF – Regression Analysis

Regression lines for each study period were again calculated and are presented in Figure 10 and summarized in Appendix A. Even though the DSDS was not active, the regression lines for both the after studies were statistically different from those computed for the before study. The slopes for the first and second after regression lines were not significantly different from each other. The flatter slope in both after study regression lines (i.e., the regression coefficients are much smaller than for the before study) indicates that faster vehicles slowed down more dramatically than vehicles who were approaching at lower speeds when they saw the DSDS. Whereas the effect of the DSDS would be estimated (based on the difference in speeds predicted by each regression line) to be a 3.7 mph reduction for vehicles approaching at 55 mph, it would be 9.2 mph for vehicles approaching at 65 mph.

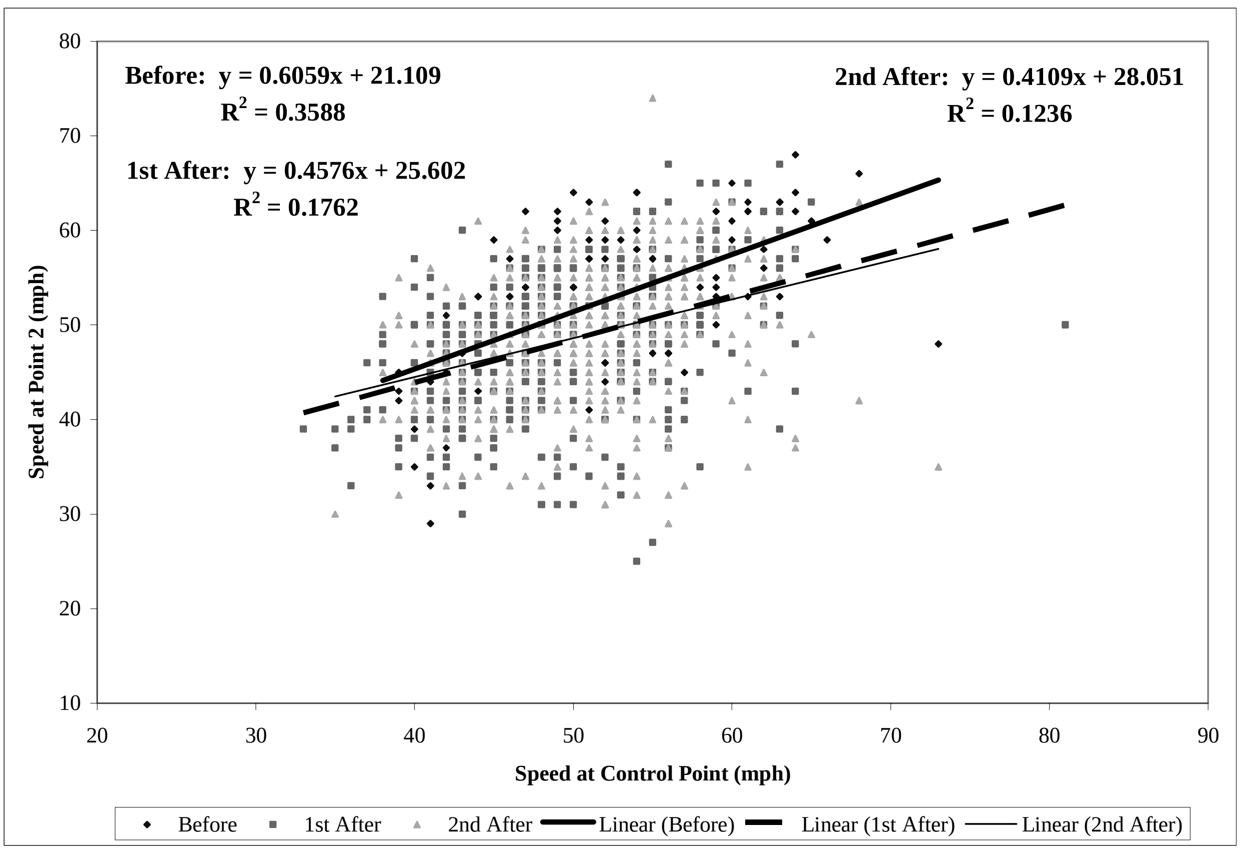

Figure 10. Regression Lines for Data Collected in Forney while the DSDS was OFF.

SITE 2: FM 89 (BUFFALO GAP ROAD) NORTHBOUND, ABILENE

Day Data – Spot Speed Statistics

Table 3 shows the analysis results of the spot speeds collected at the control point and at the DSDS for site 2. The average speeds at the control point are not significantly different between the before and first after study, but are slightly higher in the second after study. Consequently, the differences observed in the data collected at the DSDS for the second after study should be interpreted in light of the slightly higher approach speeds that were recorded.

At the DSDS sign, average vehicle speeds were reduced by 3.4 mph in the first after study. By the second after study, the apparent reduction in speed had diminished to only 1.4 mph (from 55.2 mph down to 53.8 mph). However, considering that the upstream (control point) average speed during the second after study was somewhat higher, the extent to which the DSDS effect had diminished is debatable. Meanwhile, the proportion of vehicles exceeding the speed limit at this site was extremely high at the DSDS in the before study, with 97 percent of the sampled vehicles exceeding the speed limit. This proportion dropped somewhat to 85.6 percent in the first after study, but returned to 90.9 percent in the second after study. The 85th percentile speeds also showed similar trends to the average speed data. Again, the fact that approach speeds in the second after study were slightly higher may partially explain the slight rise in these measures between the first and second after studies. Finally, no significant differences were evident in the standard deviation across studies, suggesting there was no increase in speed variability attributable to the sign.

Table 3. Summary of Speed Statistics for Northbound Traffic on FM 89.

Day	Control Point			At DSDS		
	Speed Limit = 55 mph			Speed Limit = 45 mph		
	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	55.7	55.6	56.8 AB	55.2	51.8 A	53.8 AB
Standard Deviation (mph)	5.2	4.4	5.9	5.6	6.1	6.3
Percent Exceeding Speed Limit (mph)	49.6	45.9	53.9 B	97.0	85.6 A	90.9 AB
85th Percentile Speed (mph)*	61	60	63	61	58	61
Night	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	52.3	54.1	53.4	52.0	50.1	51.2
Standard Deviation (mph)	5.7	5.6	5.8	5.8	6.3	5.7
Percent Exceeding Speed Limit (mph)	28.9	34.2	34.3	86.7	79.7	87.9
85th Percentile Speed (mph)*	58	59	59	58	56	57

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes day: before, 847; 1st after, 534; 2nd after, 790
sample sizes night: before, 173; 1st after, 79; 2nd after, 99

Night Data – Spot Speed Statistics

The bottom half of Table 3 shows speed statistics calculated from data collected after dark. As would be expected, the speeds at the control point collected at night are a little slower than the speeds collected during the day. The sample sizes for night data were much smaller than those for day data; thus, the data are not as sensitive to differences in averages between studies. Researchers found no significant differences for average speed, proportion of sample exceeding the speed limit, or standard deviation at either the control point or at the DSDS data collection point.

Day Data – Regression Analysis

Regression lines for the speeds at the control point and at the DSDS were calculated for each study period for all day data. Figure 11 is a graph of the data and regression lines for each study period. The analyses verified that the slope for the before study regression line is steeper than the other two regression lines. However, the slopes of the regression lines for the first and second after studies do not differ statistically, although visually some additional "flattening" of the regression line is evident. These results indicate that motorists approaching the DSDS at a high speed slowed down more significantly than did motorists approaching at slower speeds.

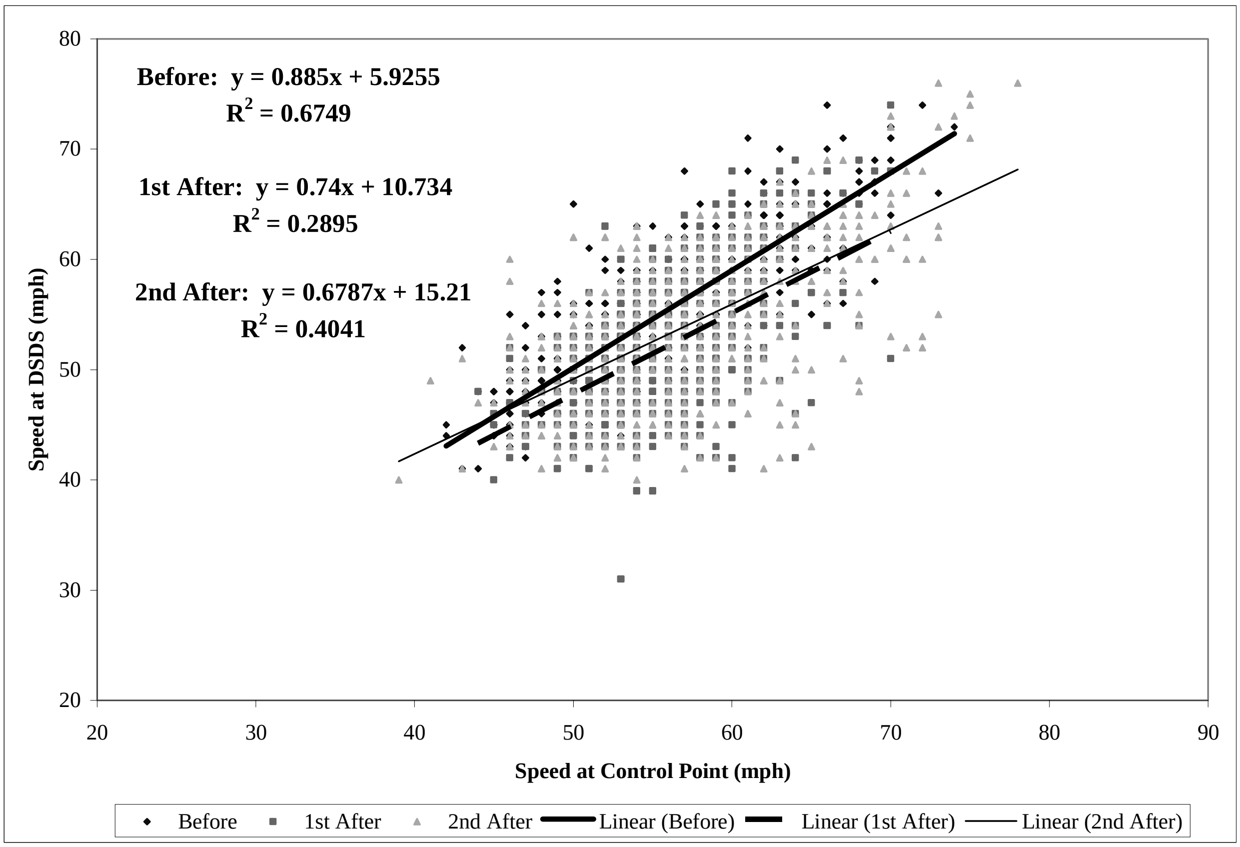

Figure 11. Regression Lines for FM 89 Northbound Day Data.

The practical significance of the differences in regression slopes is illustrated in Table 4 below, which shows the speeds at the DSDS sign predicted using the three regression equations. For motorists approaching at 55 mph, the differences in predicted speeds at the DSDS are only 2 to 3 mph. However, for motorists approaching at 65 mph, the speeds in the two after studies are 4 to 5 mph lower than in the before study. Unfortunately, even though the effect of the DSDS appears to be more significant on higher speed vehicles, the influence is still not enough to bring a majority of them into compliance or near compliance with the posted speed limit at the DSDS.

Table 4. Difference in Daytime Predicted Speeds at DSDS, FM 89 Northbound.

	Speed At Control Point	
Study	**55 mph**	**65 mph**
Before	54.6	63.5
1st After	51.4	58.8
2nd After	52.5	59.3

Night Data – Regression Analysis

Regression lines for vehicle speeds collected at night at this site for each study period are illustrated in Figure 12.

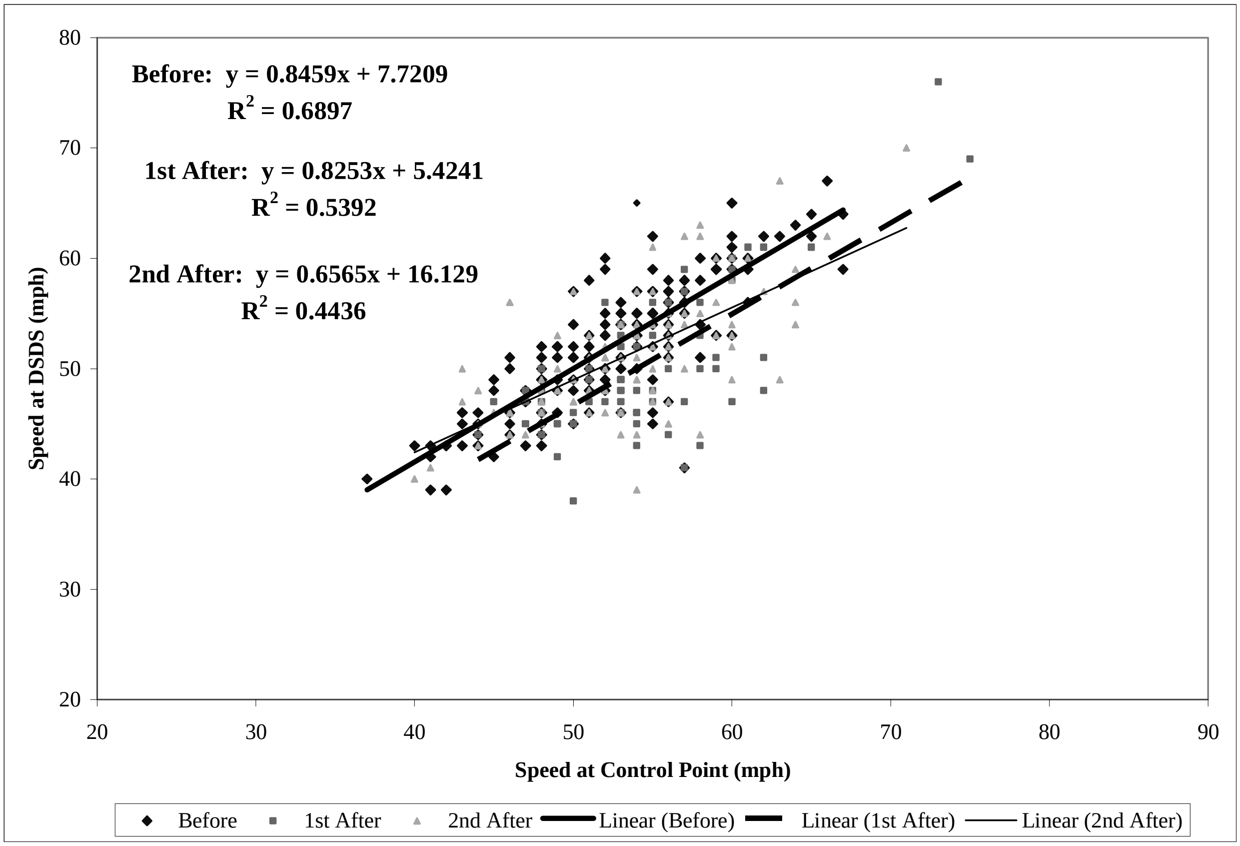

Figure 12. Regression Lines for FM 89 Northbound Night Data.

Researchers found that the before study and first after study regression line slopes were statistically similar, suggesting that the initial effect of the DSDS was to shift all approaching vehicle speeds slightly downward. In contrast, the slope for the second after regression line was statistically different from the slopes of the other two regression lines. Furthermore, the slope was significantly smaller in the second after study, implying that vehicles with higher approach speeds were more affected by the presence of the DSDS than were vehicles with lower approach speeds. Researchers interpreted these results as indicating a possible initial "novelty effect" to the sign at night whereby all motorists slowed down slightly when they saw the sign. Then, over time, motorists became familiar with the DSDS presence, such that only those higher speed motorists were influenced to slow down by the DSDS. This is illustrated in Table 5, which shows speeds predicted at the DSDS sign using the three night data regression equations for an approach speed of 55 mph (motorist traveling 10 mph over the speed limit) and 65 mph (a motorist exceeding the speed limit by 20 mph).

Table 5. Difference in Nightime Predicted Speeds at DSDS, FM 89 Northbound.

Study	Speed At Control Point	
	55 mph	65 mph
Before	54.2	62.7
1st After	50.8	59.1
2nd After	52.2	58.8

The results in Table 5 are similar to the results in Table 4. A motorist approaching at 55 mph is predicted to drive only 2 mph slower at the DSDS than he would have traveled before the DSDS was installed. Conversely, the motorist approaching at 65 mph is predicted to drive 4 mph slower than he would have traveled before the DSDS was installed.

SITE 3: FM 89 (BUFFALO GAP ROAD) SOUTHBOUND, ABILENE

Day Data – Speed Statistics

Table 6 summarizes the spot speed statistics at the control point and DSDS data collection point for site 3. The sample size at this location was also quite large. Average speeds at the control point were not statistically different for any of the three study periods for data collected during the daylight time periods. At the DSDS, average speeds dropped 2.6 mph in the first after study, but were only 1.4 mph lower in the second after study. Similar trends were seen for the proportion exceeding the speed limit. However, this statistic also differs by study at the control point, and so may not truly indicate substantial changes in behavior at the DSDS. The 85th percentile speed followed the general trends of the average speeds and percentage of vehicles exceeding the posted speed limit. Finally, the standard deviations were not statistically different, indicating that the sign did not affect the variability of speeds during any of the studies.

Night Data – Spot Speed Statistics

The sample size at night at site 3 was much smaller than in the daytime. The average speeds at the control point were the same for the first two studies, but different for the second after study, similar to the results calculated at the DSDS. Consequently, it was not possible to conclude that the DSDS had a significant effect upon average speeds at this location. Both the 85th percentile speeds and the proportion of vehicles speeding showed similar trends. In each case speeds or proportions at both the control point and the DSDS were not statistically different for the before and first after studies, but were lower at both the control point and the DSDS during the second after study. Regardless of the reasons for the differences detected, it is apparent that the DSDS had little or no effect upon these statistical measures at night.

Table 6. Summary of Speed Statistics for Southbound Traffic on Buffalo Gap Road.

	Control Point			**At DSDS**		
	Speed Limit = 45 mph			Speed Limit = 45 mph		
Day	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	48.2	48.7	47.6	47.7	45.1^A	46.3^AB
Standard Deviation (mph)	4.7	4.2	4.5	5.1	4.1	4.5
Percent Exceeding Speed Limit (mph)	69.1	76.1^A	64.8^B	62.5	39.6^A	52.1^AB
85th Percentile Speed (mph)*	53	53	52	53	49	51
Night	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	47.4	47.9	45.9^AB	46.6	45.6	44.5^A
Standard Deviation (mph)	4.4	4.1	4.6	4.6	4.4	4.5
Percent Exceeding Speed Limit (mph)	62.9	74.5	46.8^AB	57.3	43.6	33.1^AB
85th Percentile Speed (mph)*	52	52	50	51	50	48

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes day: before, 1120; 1st after, 536; 2nd after, 940
sample sizes night: before, 267; 1st after, 94; 2nd after, 154

Day Data – Regression Analysis

Regression lines based on the data collected at this site for each study period during the day are presented in Figure 13. Although the spot speed data implied very little differences between studies, the results of the regression analyses suggested that the DSDS did indeed have some effect. As Figure 13 illustrates, the trend line for the first after study had a considerably smaller slope than that in the before study, indicating that the DSDS had more speed reducing effect on vehicles approaching the DSDS at higher speeds. However, the trend in the second after study suggested that the relationship between approach speed and speed at the DSDS was returning to the before study trend.

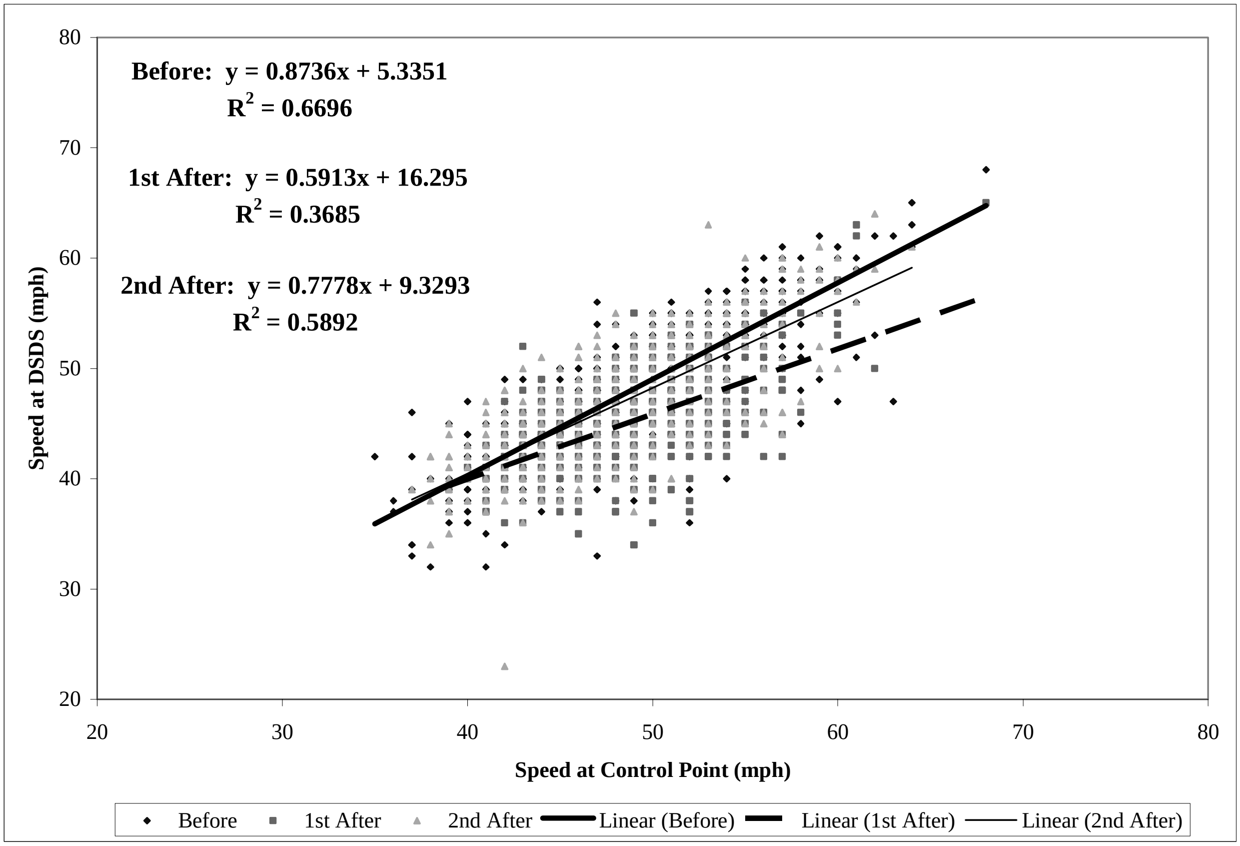

Figure 13. Regression Lines for FM 89 Southbound Day Data.

As Table 7 illustrates, comparison of the speeds predicted by the regression equations also emphasize a slight incremental effect of the DSDS at higher approach speeds. Motorists approaching the DSDS at 45 mph are predicted to travel 1.7 mph slower at the DSDS in the first after study (as compared to the before study). However, in the second after study, a motorist approaching at 45 mph is predicted to travel just over 44 mph at the DSDS, essentially identical to that predicted based on the before study data. Considering a faster traveling vehicle, though, implies that some speed reduction is predicted for both after studies. As compared to the before study regression equation, a motorist approaching at 55 mph is expected to travel at 48.8 mph in the first after study and at 52.1 mph in the second after study. These are 4.6 and 1.3 mph less than the speed predicted using the regression equations. In other words, a small speed reducing effect was still evident in the second after study for those motorists approaching at higher speeds.

Table 7. Difference in Daytime Predicted Speeds at DSDS, FM 89 Southbound.

	Speed at Control Point	
Study	**45 mph**	**55 mph**
Before	44.6	53.4
1st After	42.9	48.8
2nd After	44.3	52.1

Night Data – Regression Analysis

Regression lines based on the data collected at this site for each study period during the day are presented in Figure 14. Statistical comparisons of the data imply that there were statistically significant differences in the relationship between speeds at the control point and at the DSDS, even though little difference was evident in the spot speed statistics at both locations across the three study periods. In comparison to the trend line for the before data, the trend line for the first after data suggests a slight shift downward across the entire speed range observed at the control point. However, in the second after study, a difference in the trend line is only evident at higher speed values for the control point. This once again implies a slightly greater effect of the DSDS upon those vehicles approaching at higher speeds.

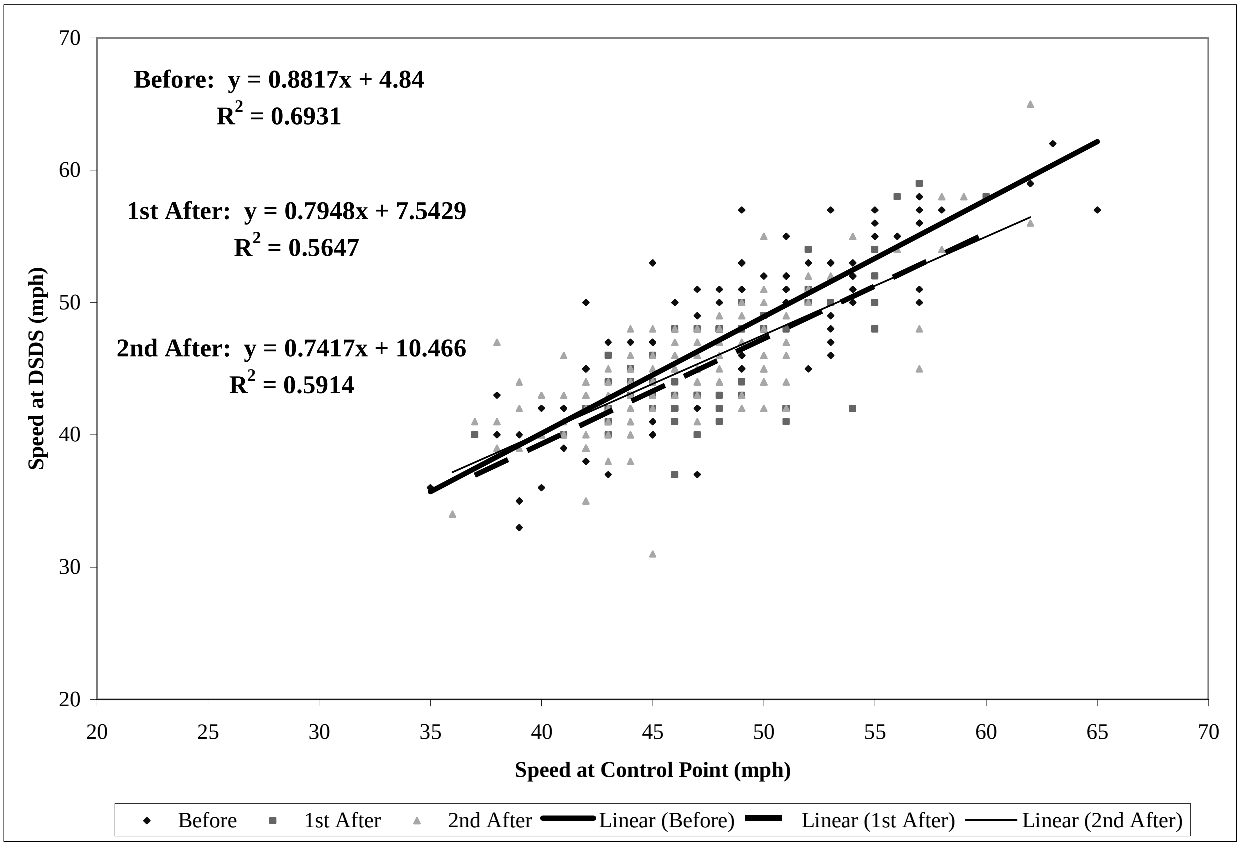

Figure 14. Regression Lines for FM 89 Southbound Night Data.

The extent of this incremental effect is demonstrated in Table 8. Speeds predicted from the regression equations for vehicles approaching at 45 mph indicate a 1.2 mph drop in the first after study, diminishing to only a 0.7 mph difference in the second after study. In contrast, speeds predicted for vehicles approaching at 55 mph illustrate a 2.0 mph drop in the first after study, which is then retained until the second after study as well. Although the changes are indeed fairly small, the trends do imply that the DSDS was able to retain some speed reducing effect for vehicles who were approaching the DSDS at higher speeds (i.e., speeds 55 mph or greater) over the four-month period of the study.

Table 8. Difference in Nighttime Predicted Speeds at DSDS, FM 89 Southbound.

	Speed at Control Point	
Study	**45 mph**	**55 mph**
Before	44.5	53.3
1st After	43.3	51.3
2nd After	43.8	51.3

SITE 4: US 277 NORTHBOUND SEYMOUR

As Figure 6 illustrated, the DSDS at this site was located near the beginning of a sharp horizontal curve. The speed limit at the DSDS was 30 mph and the curve had a 10 mph advisory speed in the before study and a 20 mph advisory speed in the after studies. The speed limit upstream of the DSDS at the control point was 40 mph, but upstream of the control point the speed limit was even higher (55 mph). This roadway serves a significant amount of heavy vehicle traffic at this location. In fact, the major reason for installing a DSDS at this site was to slow heavy vehicle traffic down and reduce the frequency of truck overturns. The site had a history of several severe accidents involving heavy vehicles. The sign is operational at all times. Since the influence of the DSDS upon heavy vehicles was of special interest at this location, the daytime data at this site were divided into passenger vehicles and heavy vehicles. A number of difficulties during data collection activities at night limited the amount of data that could be collected, and so the night sample was not subdivided by vehicle type. Table 9 shows a summary of speed statistics for the three data categories.

Table 9. Summary of Speed Statistics for Northbound Traffic on US 277.

Day Traffic	Control Point Speed Limit = 40 mph			At DSDS Speed Limit = 30 mph		
Passenger Vehicles	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	46.4	43.3A	45.6	37.1	33.6A	37.1B
Standard Deviation (mph)	6.1	6.2	6.0	5.2	5.8	5.1
Percent Exceeding Speed Limit (mph)	84.3	67.2A	79.1B	91.9	65.7A	92.1B
85th Percentile Speed (mph)*	53	49	52	42	40	42
Heavy Vehicles	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	43.0	42.7	42.9	30.0	30.6	35.2AB
Standard Deviation (mph)	4.3	4.5	5.0	4.6	4.3	4.6
Percent Exceeding Speed Limit (mph)	74.5	77.6	67.0	73.6	44.9A	85.1B
85th Percentile Speed (mph)*	47	47	47	38	36	40
Night Traffic – All	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	41.8	39.6	42.6	34.1	29.3	35.6
Standard Deviation (mph)	6.1	6.2	6.3	5.1	5.0	4.3
Percent Exceeding Speed Limit (mph)	57.3	42.1	61.3	79.2	39.5AB	90.3
85th Percentile Speed (mph)*	49	46	50	40	35	39

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes Day passenger vehicle data: before, 458; 1st after, 204; 2nd after, 940
sample sizes Day heavy vehicle data: before, 110; 1st after, 49; 2nd after, 94
sample sizes Night data: before, 96; 1st after, 38 2nd after, 31

Day Data Passenger Vehicles – Spot Speed Statistics

Table 9 shows that passenger vehicle average speeds at the control point were statistically the same for the before and second after study, but not in the first after study. Speeds in general in the first after study were lower at both the control and the DSDS, due to weather or some other factor, such that it is not appropriate to conclude that the DSDS was responsible for the reductions in average speeds and percent exceeding the speed limit. The first after study at this site was shorter than intended due to snow that came later in the week. Consequently, researchers emphasized the comparison of speeds at the DSDS between the before and second after study.

With respect to passenger vehicle speeds at the DSDS during daylight, researchers found average speeds during the second after study to be 37.1 mph, the same as the average in the before condition. The proportion of vehicles exceeding the speed limit also remained about the same. Reductions were seen in average speed, 85th percentile speed, and proportion exceeding the speed limit during the first after study, but these reductions cannot be completely attributed to the new sign. Researchers hypothesize that weather conditions (there was a chance for snow in the forecast during the first after study) or other characteristics were responsible for the slower speeds in that study. Based on these data, the DSDS at this site did not seem to provide any speed reduction benefit specifically for passenger vehicles.

In addition to the effects on speed reductions, researchers examined the effect of the DSDS on the dispersion speeds. As Table 9 also illustrates, researchers found no statistically significant differences in the standard deviation between any of the three studies.

Day Data Heavy Vehicles – Spot Speed Statistics

Table 9 shows that average heavy vehicle speeds collected during daylight at the control point were not significantly different between the three study periods. At the DSDS, average speeds were 30.0 mph in the before study and 30.6 mph in the first after study. The difference was not statistically significant. Heavy vehicle average speeds then increased from 30.6 mph in the first after study to 35.2 mph in the second after study. As indicated in Table 9, the average speed in the second after study was significantly different from both before and first after average speeds. The increase in speed might, in part, be attributable to the change in the posted advisory speed. Recall that in the before study, the advisory speed was posted at 10 mph. In both after studies, the advisory speed was posted at 20 mph. Although one would expect the effect of increasing the advisory speed (if indeed that advisory speed did influence speeds) to occur in both after studies, the adverse weather conditions mentioned previously may have prevented researchers from detecting any increase in average speed in the heavy vehicles in the first after study.

The proportion of heavy vehicles exceeding the speed limit at the control point was not statistically different during the three study periods. At the DSDS the proportion exceeding the speed limit dropped significantly from 73.6 percent in the before study to 44.9 percent in the first after study. However, this effect also diminished over time. The proportion of heavy vehicles exceeding the speed limit in the second after study had risen to 85.1 percent. Again, researchers do not know the extent to which the lower proportion in the first after study is attributable to adverse weather conditions or to the effect of the newly installed DSDS. The 85^{th} percentile speed showed similar trends at this site. An initial drop in 85^{th} percentile speed was seen at the DSDS in the first after study (38 mph in before study to 36 mph in the first after study), but the 85^{th} percentile speed was higher in the second after study than it was before the sign was placed. There was no significant difference in the standard deviation at either the control point or the DSDS, indicating that the DSDS did not have an effect on the variability of speeds at this location.

Night Data – Spot Speed Statistics

Sample sizes collected at night at this site were not large enough (due to data collection equipment and procedure difficulties) to allow separate analyses of passenger and heavy vehicles. Thus, heavy vehicles and passenger vehicles were analyzed together. There were no significant differences in average speeds at either the control or the DSDS data collection points, but trends similar to those observed in the day results were again seen. The average speed at the DSDS is slightly less in the first after study and then returns to approximately the before installation average speed in the second after study. The proportion of vehicles exceeding the speed limit at the DSDS was significantly reduced from 79.2 percent before the DSDS was activated to 39.5 percent during the first after study, but then returned to previous levels in the second after study. There was no significant difference found in the standard deviation at either the control point or the DSDS.

Day Data Passenger Vehicles – Regression Analysis

Regression lines based on the data collected at this site for passenger vehicles during the daytime for each study period are presented in Figure 15. The slopes of the before and first after regression lines are not significantly different from each other, but the slope of the second after regression line is significantly lower than the other two studies (see Appendix A for summaries of the statistical analyses). From a practical standpoint, however, the flatter slope seen in the second after regression line still suggests only minimal effects upon speeds. In fact, for vehicles approaching at speeds less than 50 mph, the second after regression line predicts that a vehicle will be going the same speed, if not faster, at the DSDS than before the sign was activated.

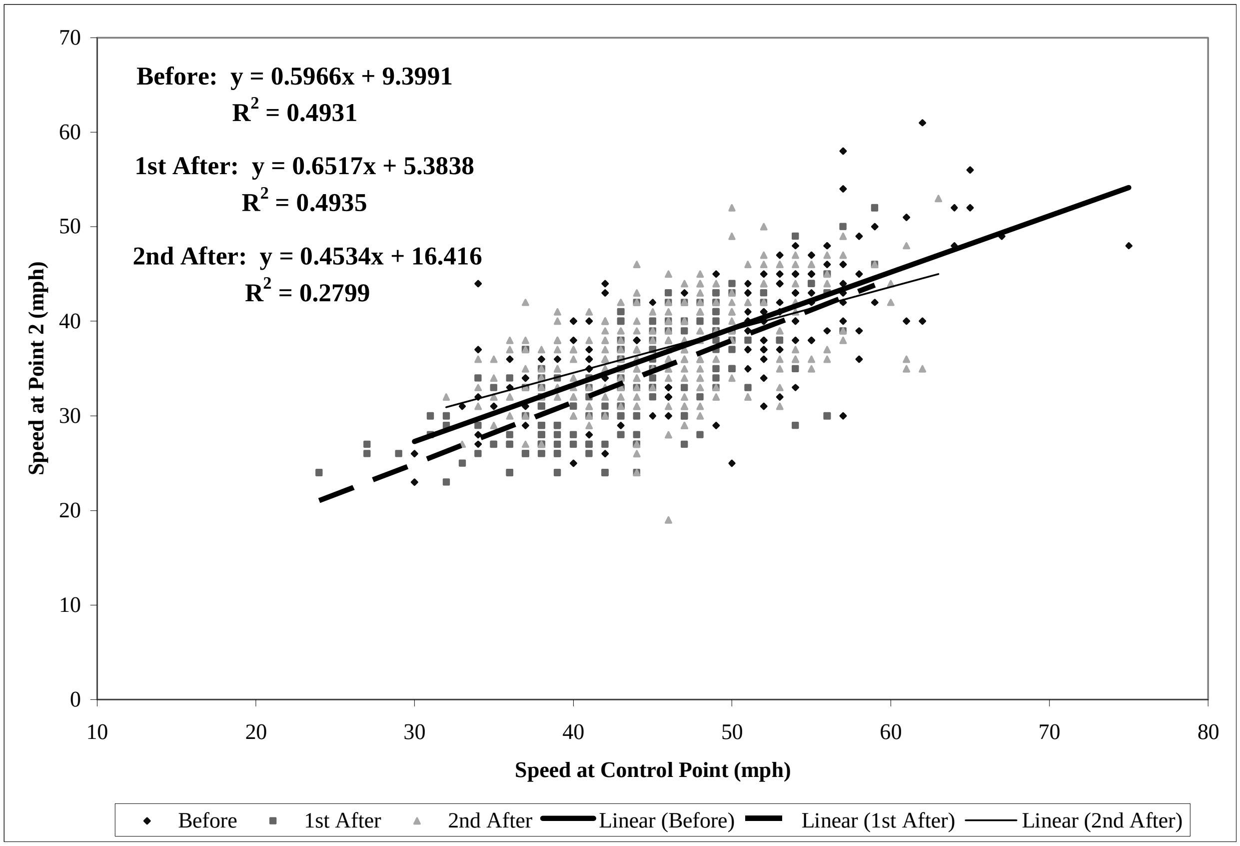

Figure 15. US 277 Northbound Passenger Vehicle Day Traffic.

Further illustrations of the effects of the DSDS are highlighted in Table 10. Speeds predicted by the regression lines show that the effect during the first after study is small. In fact, the reduction predicted by the regression analysis implies that faster vehicles actually slowed down less than slower vehicles. During the second after study, the slope of the regression line was such that the effect of the DSDS was slightly greater at higher approach speeds than at lower speeds. However, for vehicles approaching at 60 mph (20 mph over the speed limit), the regression analysis suggests that the DSDS was responsible for only a 1.6 mph speed reduction (from 45.2 mph before to 43.6 mph in the second after study).

Table 10. Difference in Daytime Passenger Vehicle Predicted Speeds at DSDS, US 277 Northbound.

Study	**Speed at Control Point**		
	40 mph	**50 mph**	**60 mph**
Before	33.3	39.2	45.2
1st After	31.5	38.0	44.5
2nd After	34.6	39.1	43.6

Day Data Heavy Vehicles – Regression Analysis

Figure 16 shows the three regression lines developed from the heavy vehicle data collected during the daytime. Although the three regression lines were significantly different (see Appendix A), the actual slopes of the three regression lines were not significantly different between studies. Researchers believe that once again it is the combination of impending adverse weather conditions during the first after study, along with a change in the advisory speed posted at the site between the before and after studies, that were responsible for changes in heavy truck speeds. It is evident that the DSDS did not have a clear and consistent effect on heavy vehicles at this site.

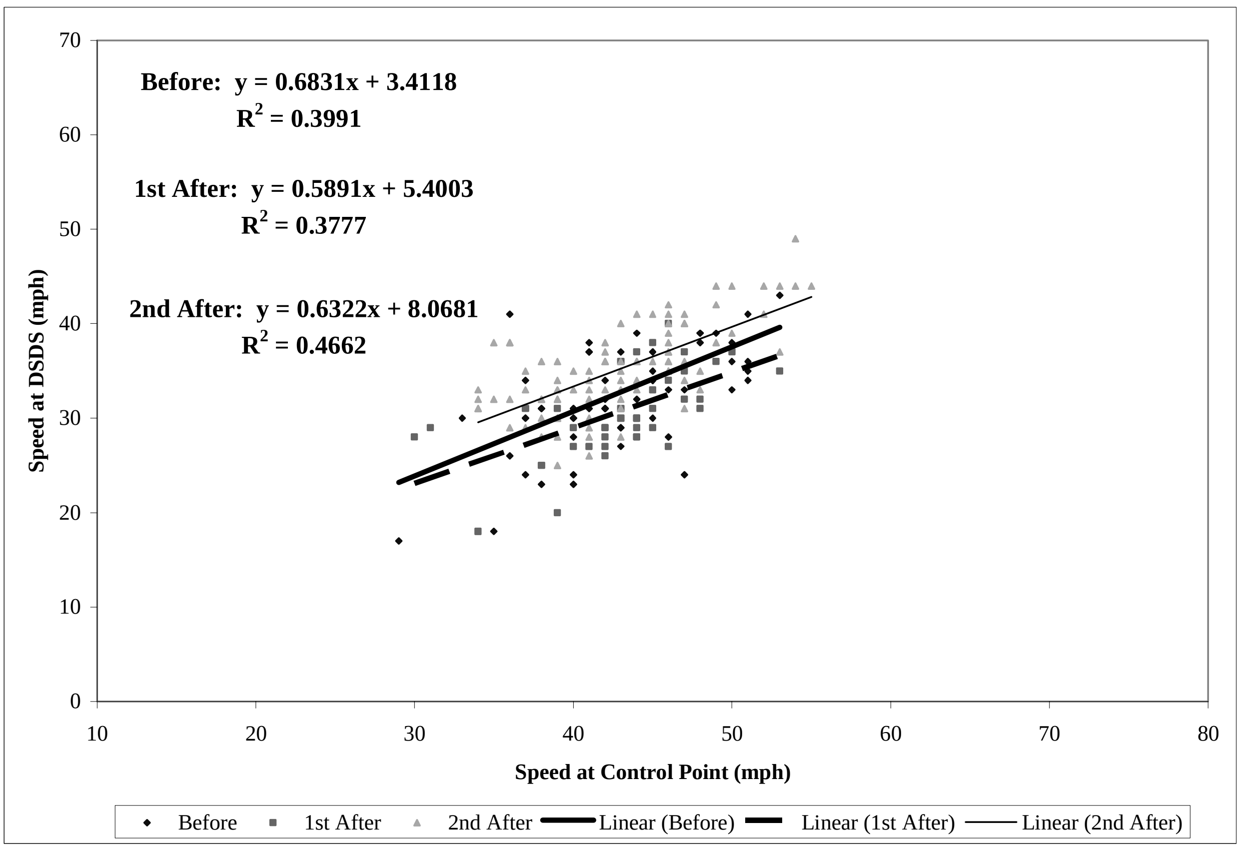

Figure 16. US 277 Northbound Heavy Vehicles Day Traffic.

Night Data All Vehicles – Regression Analysis

Regression lines based on the data collected at this site at night for each study period are shown in Figure 17. As noted previously, researchers combined the data for passenger and heavy vehicles during this time period due to the smaller sample size available from this site. No significant differences were detected between the slopes for the three lines in this analysis. A small overall shift down in the first regression line (relative to the before study regression line) is consistent with the lower average speed values seen in Table 9. Meanwhile, the second after study regression line is essentially identical to that calculated for the before study.

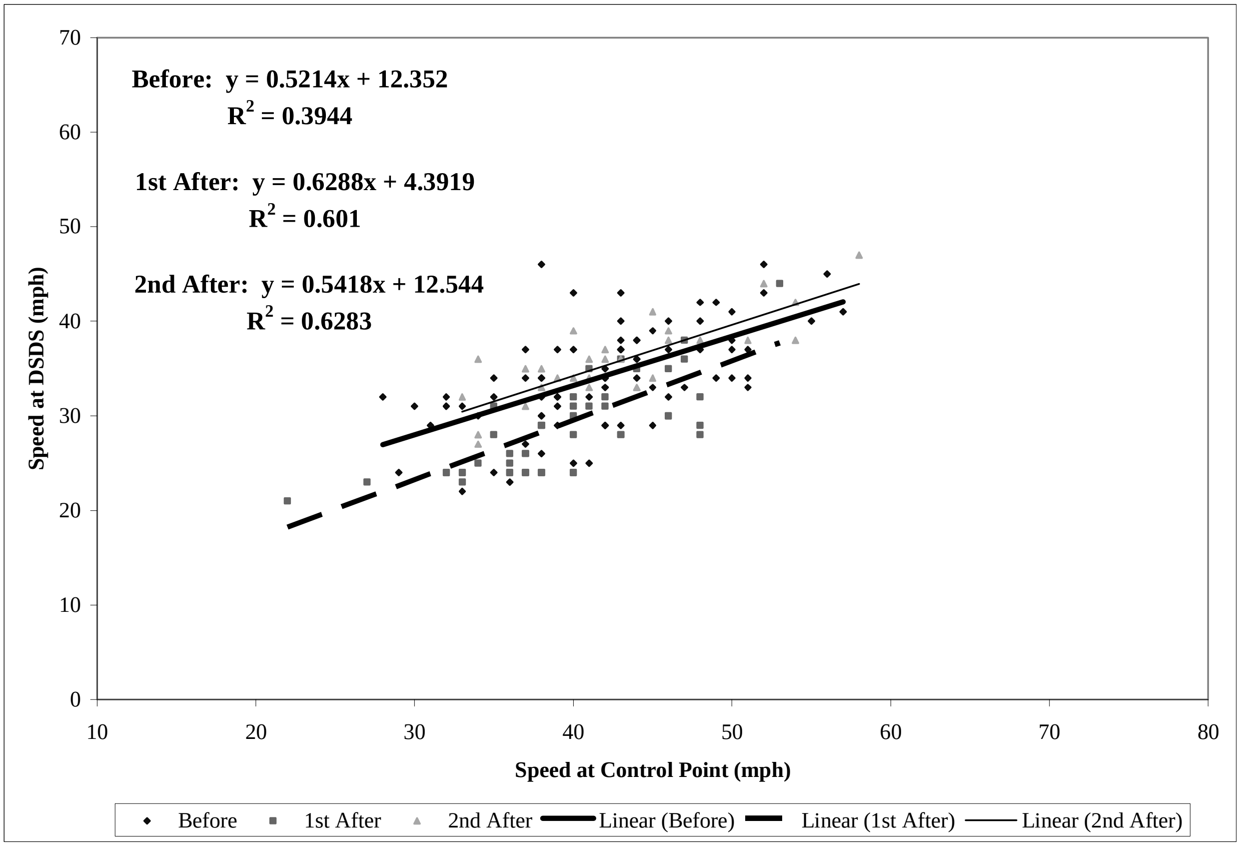

Figure 17. US 277 Northbound All Vehicles Night Traffic.

SITE 5: US 277 SOUTHBOUND, SEYMOUR

As Figure 6 illustrated, the DSDS at site 5 was located on the other side of the site 4 curve. The speed limit at the DSDS was 30 mph and the curve had a 10 mph advisory speed in the before study and a 20 mph advisory speed in the after studies. The speed limit upstream of the DSDS at the control point was 30 mph. Vehicles traveling southbound on US 277 drove through a slower commercial area before reaching the curve on the way out of town. Heavy vehicle traffic in this direction was also high, and the major purpose of installing a DSDS at this site was to slow heavy vehicle traffic down before they entered the curve. As mentioned previously, the site had a history of several severe accidents involving heavy vehicles. The sign is operational at all times. The data at this site were split into three categories: passenger vehicles during daylight, heavy vehicles during daylight, and all vehicles at night. The night sample size was too small to divide into two categories. Table 11 shows a summary of the speed statistics for this site.

Table 11. Summary of Speed Statistics for Southbound Traffic on US 277.

	Control Point			**At DSDS**		
Day Traffic	Speed Limit = 30 mph			Speed Limit = 30 mph		
Passenger Vehicles	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	33.5	33.7	32.5B	35.3	33.2A	32.9A
Standard Deviation (mph)	4.0	4.1	4.6	3.6	5.2	4.6
Percent Exceeding Speed Limit (mph)	74.3	75.7	69.0	82.6	70.4A	68.2A
85th Percentile Speed (mph)*	38	38	38	41	38	38
Heavy Vehicles	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	32.0	32.4	33.1	31.5	29.2	32.8B
Standard Deviation (mph)	3.8	4.1	4.6	3.5	5.2	4.6
Percent Exceeding Speed Limit (mph)	69.1	63.4	70.6	63.0	39.0A	72.1B
85th Percentile Speed (mph)*	36	36	37	35	34	37
Night Traffic – All	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	31.0	33.4	31.6	31.8	32.8	32.7
Standard Deviation (mph)	4.0	4.9	4.2	5.0	6.1	4.9
Percent Exceeding Speed Limit (mph)	51.4	69.6	55.0	54.2	65.2	65.0
85th Percentile Speed (mph)*	36	37	36	37	37	37

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes Day passenger vehicle data: before, 362; 1st after, 362; 2nd after, 242
sample sizes Day heavy vehicle data: before, 81; 1st after, 41; 2nd after, 68
sample sizes Night data: before, 72; 1st after, 23; 2nd after, 40

Day Data Passenger Vehicles – Spot Speed Statistics

Table 11 shows that the average speed at the control point was the same during the before and first after study, but was about 1 mph slower in the second after study. Consequently, researchers interpreted the differences in the data collected at the DSDS for the second after study in light of the slightly lower approach speeds recorded. The data samples were large, and thus the data are sensitive to small differences. The average speed data at the DSDS indicates a small initial drop in speed from 35.3 mph in the before study to 33.2 mph in the first after study (about a 2 mph drop). During the second after study the average speed at the DSDS was 32.9 mph, which was about 0.5 mph faster than the speed at the control point. There were no significant differences between the speed at the DSDS during the first after and second after studies. However, the fact that passenger vehicles sped up between the control point and the DSDS in the second after study and not in the first after study leads researchers to question whether the DSDS actually retained its effect over time. There were no significant differences between the proportion of vehicles speeding in any of the three studies at the control point thus, the reduction in the proportion of passenger vehicles exceeding the speed limit in both after studies can likely be attributed to the activation of the DSDS. The 85th percentile speeds were the same at the control point, and a reduction of 3 mph was observed at the DSDS in both after studies. There were no statistical differences found between the standard deviations at either point during any of the three study periods.

Day Data Heavy Vehicles – Spot Speed Statistics

The average speeds at the control point for heavy vehicles during daylight were not significantly different between any of the study periods. In addition, there was no significant difference in average speeds at the DSDS between the before and first after study. However, a statistically significant increase in the average speed at the DSDS occurred between the first and second after studies. The average speed at the DSDS in the second after study was not significantly different from the average speed at the DSDS in the before study. Considering the average speeds between the before and second after studies, then, the DSDS did not seem to have any affect on the average speeds of heavy vehicles. The proportion of vehicles speeding was reduced from 63 percent in the before study to 39 percent in the first after study. However, the reduction in the percent of vehicles speeding was not maintained over time, as this measure returned to 72 percent by the second after study. As already suggested, prediction of adverse weather during the week of the first after study, or a combination of the "novelty effect" of the sign and the weather, may have contributed to the reductions in speed that were detected in that study. The 85^{th} percentile speed followed similar trends to those seen in the percent of vehicles speeding. An initial drop was observed but was not maintained over time. There was no significant difference observed in the standard deviation of the speed data between the three study periods at either of the two points.

Night Data All Vehicles – Spot Speed Statistics

The sample sizes for the data collected at night at this site were fairly small, and thus only large differences would be significant. No significant differences were found for any of the spot speed statistics measures of effectiveness. This serves as further evidence that the sign had little to no effect at this site.

Day Data Passenger Vehicles – Regression Analysis

Since very few effects were evident in the spot speed analyses for this site, researchers were unsure exactly what magnitudes of impacts might be detected through the use of regression analysis. Regression lines based on the passenger vehicle data collected at this site for each study period are presented in Figure 18. The three regression lines were statistically different; however, the slopes of the regression lines (an indication that the DSDS effect was not identical over all speed ranges sampled) were not significantly different. The regression line from the first after study data seems to be shifted slightly downward, implying a 1 to 2 mph reduction in speed at the DSDS across the entire range of approach speeds examined. Meanwhile, the second after regression line is slightly but not significantly flatter than the other two lines. The regression analysis for this data confirmed earlier impressions that the DSDS maintained about a 1 to 2 mph reduction in speed at the DSDS.

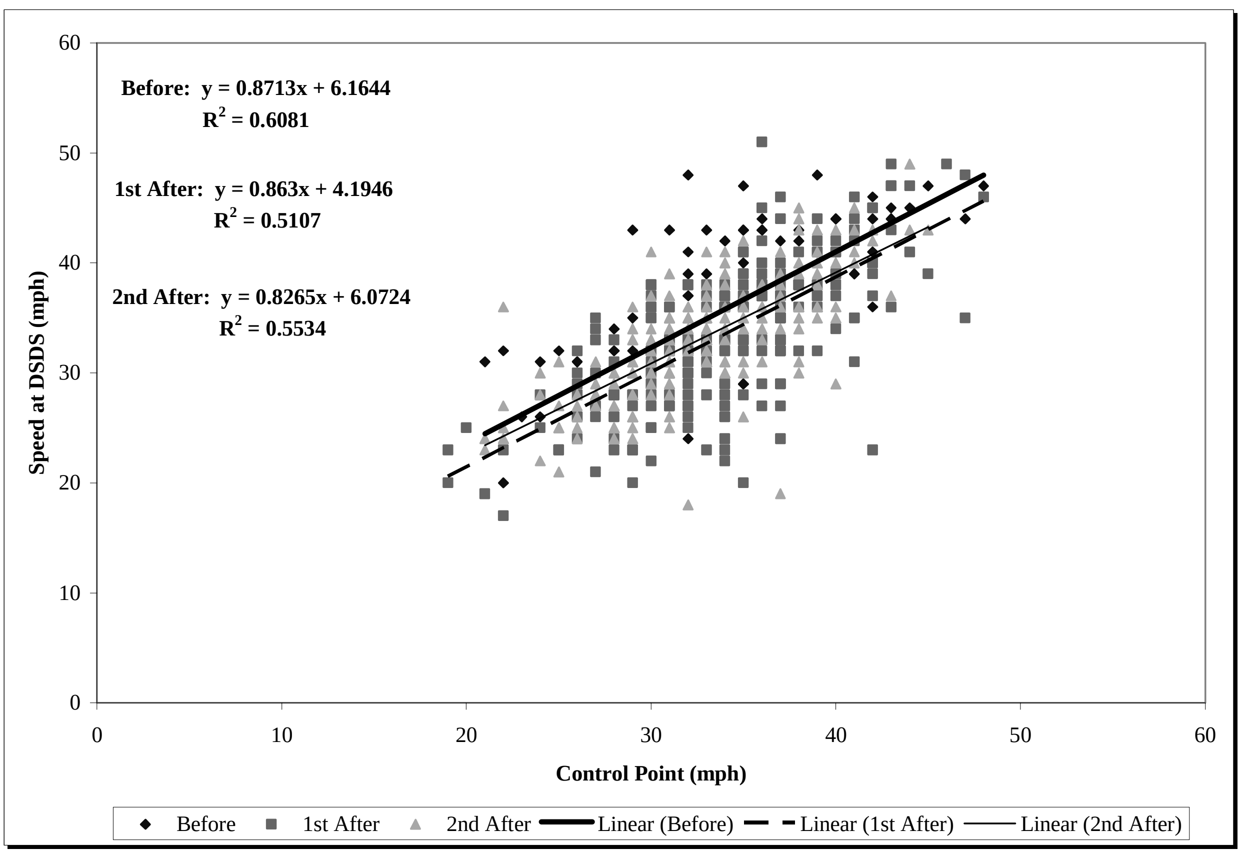

Figure 18. Regression Lines for US 277 Passenger Vehicle Day Data.

Day Data Heavy Vehicles – Regression Analysis

Table 11 indicated that the average speed for heavy vehicles was actually a little higher in the second after study than before the sign was activated. Regression lines for heavy vehicle data collected during the day were examined to determine if any incremental effects could be seen. The regression lines for heavy vehicle day data are presented in Figure 19. There was a significant difference between the three regression lines, but once again there was no significant difference between the slopes of the three lines. The regression analysis confirms the previous conclusion that the sign had little to no effect on heavy vehicles at this site. Any differences between the lines were more likely attributable to the change in advisory speed on the curve.

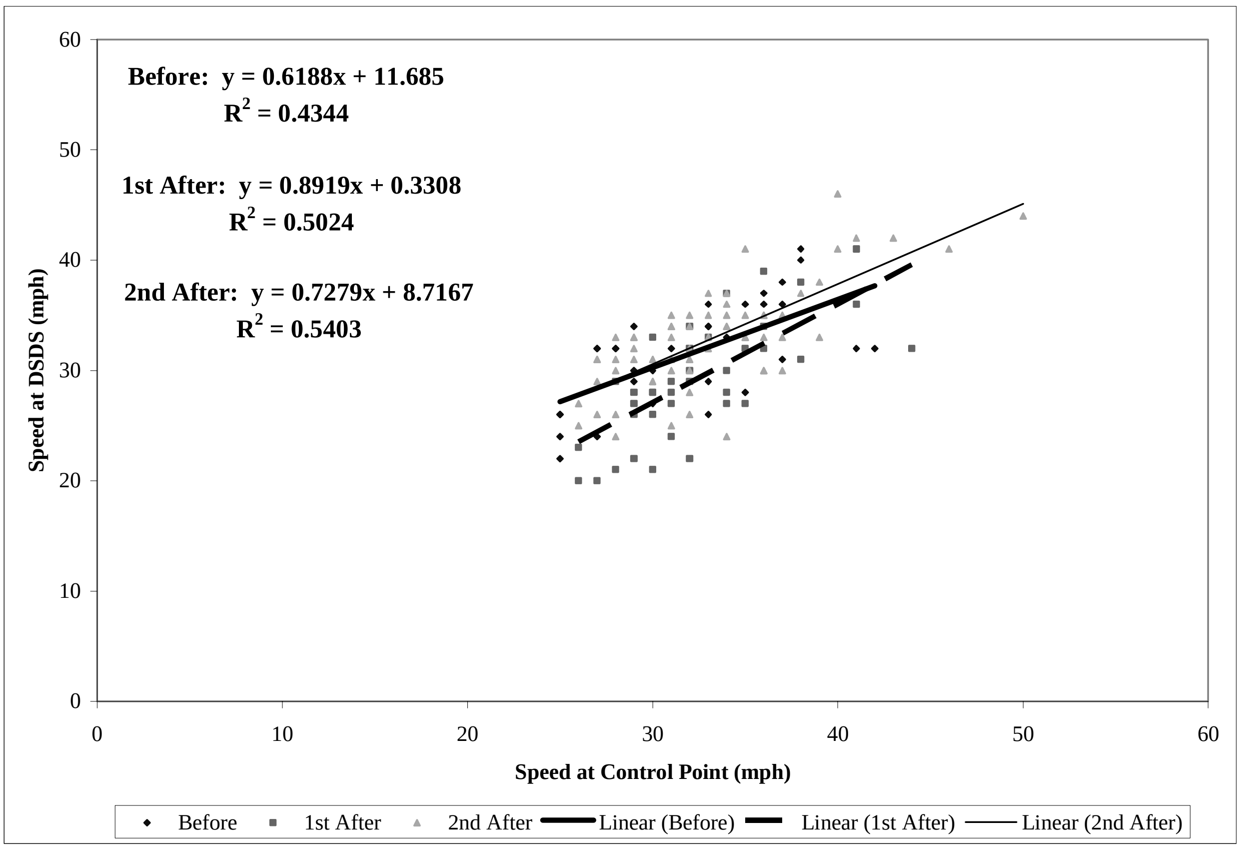

Figure 19. Regression Lines for US 277 Heavy Vehicle Day Data.

Night Data All Vehicles – Regression Analysis

There were no significant differences between the average speeds at the DSDS for the night data collected. Regression analysis was performed to see if any incremental differences in effect of the DSDS could be detected in the data. The regression lines based on the data collected at night at this site are presented in Figure 20. Once again, the lines were not significantly different. Indeed, the before and second after regression lines appear to be almost identical. The first after study data regression line is steeper, but not unduly so.

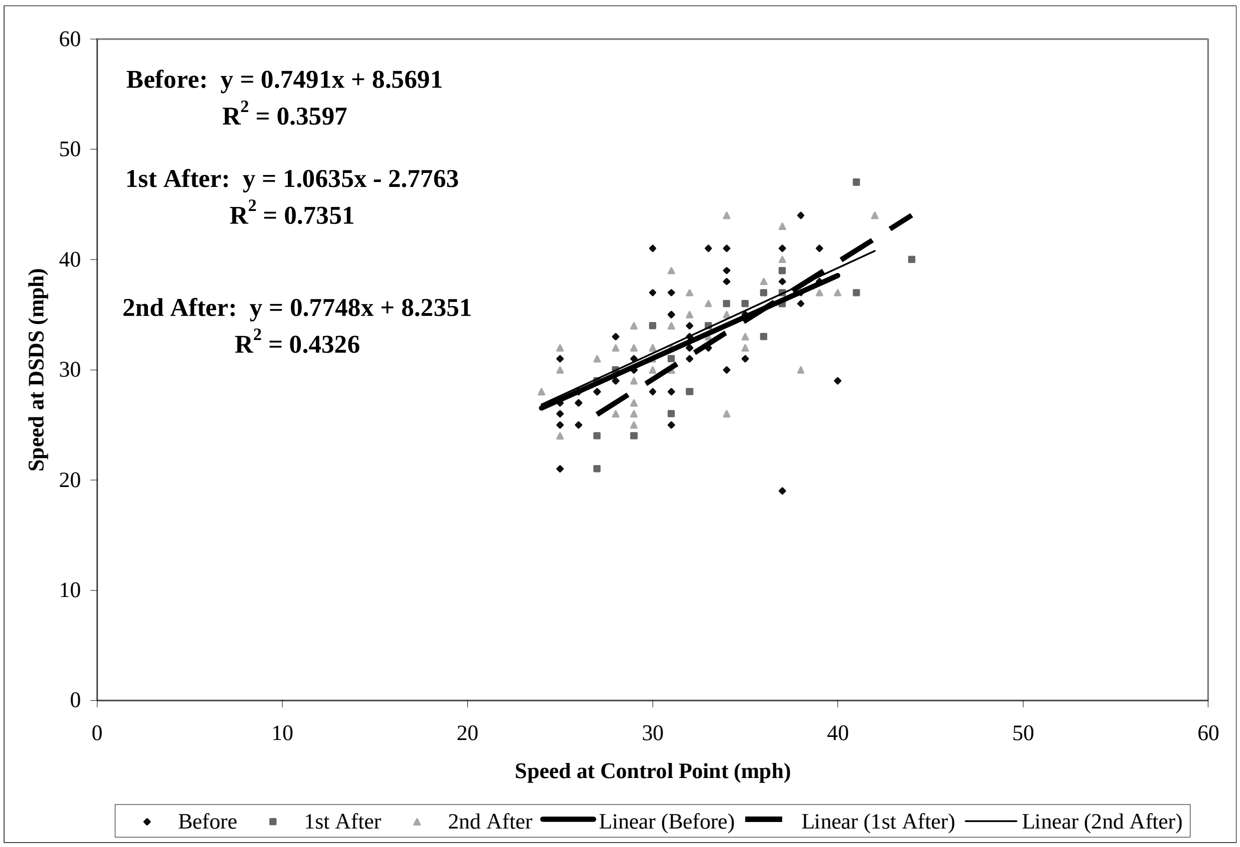

Figure 20. Regression Lines for US 277 Southbound Night Data.

SITE 6: US 59 AT LOOP 390 SOUTHBOUND, MARSHALL

As Figure 7 illustrates, the DSDS at this location is located about 1350 feet upstream of a high-speed intersection. There is clear sight distance to the intersection from the DSDS, and a mast arm with an intersection warning sign sits about 250 feet in advance of the DSDS. The speed limit drops from 70 mph to 55 mph at the DSDS. Researchers did not emphasize the collection of heavy vehicle speed data at this site. Although the overall sample does contain speeds of heavy trucks in the general proportion of their presence in the traffic stream, there were not enough heavy vehicle samples to warrant a separate analysis of their reactions to the DSDS. Therefore, the results described in this section represent those of the overall traffic stream.

Day Data – Spot Speed Statistics

Table 12 shows that average speeds at the control point collected during daylight were all significantly different between studies. The large sample size is probably the reason the before and first after averages are significantly different. However, the second after average speed was 2 mph faster than the before average and 3.5 mph faster than the first after average speed. These differences in average speeds at the control point make it difficult to draw any solid conclusions about the speeds at the DSDS. The average speeds at the DSDS do appear to drop about 3.5 mph between the before and first after study and then return approximately to the before value by the second after study. However, the difference between the speed at the control point and the DSDS in the before study is about 5 mph, and is actually about 7 mph in both after studies. This implies that some effect was maintained. Similar trends are observed in the percent exceeding the speed limit data. Consequently, researchers relied upon the regression analysis results to draw additional conclusions about DSDS effectiveness at this site.

Table 12. Summary of Speed Statistics for Southbound Traffic on US 59 at Loop 390.

	Control Point			**DSDS**		
	Speed Limit = 70 mph			Speed Limit = 55 mph		
Daytime Traffic	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	62.6	61.1[A]	64.6[AB]	57.5	54.1[A]	57.7[B]
Standard Deviation (mph)	5.6	5.6	5.1	6.3	6.1	5.9
Percent Exceeding Speed Limit (mph)	6.9	3.3[A]	9.6[B]	62.7	37.2[A]	63.4[B]
85th Percentile Speed (mph)*	68	67	70	64	60	64
Night	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	58.7	No Data	58.6	53.5	No Data	52.3
Standard Deviation (mph)	5.2	No Data	5.1	5.8	No Data	5.9
Percent Exceeding Speed Limit (mph)	1.1	No Data	2.2	37.9	No Data	31.3
85th Percentile Speed (mph)*	64	No Data	63	59	No Data	59

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes Day data: before, 913; 1st after, 455; 2nd after, 500
sample sizes Night data: before, 185 (control point), 175 (DSDS); 2nd after, 48 (control point), 46 (DSDS)

Night Data – Spot Speed Statistics

Table 12 shows that nighttime spot speed data were not obtained during the first after study at either the control or the DSDS data collection locations. A lack of overhead lighting at this location and the higher traffic volumes made it impossible to effectively track vehicles through the site. Researchers decided to utilize pneumatic tubes at each location in the first after study to facilitate collecting spot speeds, but due to equipment failure no data were available for this study period. Researchers then decided to simply collect spot speeds at each location in the second after study but not attempt to match vehicles for tracking purposes. Table 12 shows that there were no significant differences detected between studies in the night data.

Day Data – Regression Analysis

Regression lines based on the data collected at this site for each study period during the day are presented in Figure 21. Statistical comparisons of the regression lines indicate that the three lines are different. The slopes of the before and second after regression lines were also significantly different. Examination of the graph shows an incremental effect can be seen in the second after study, but the reduction in speed at the control point is small when a reduction exists at all.

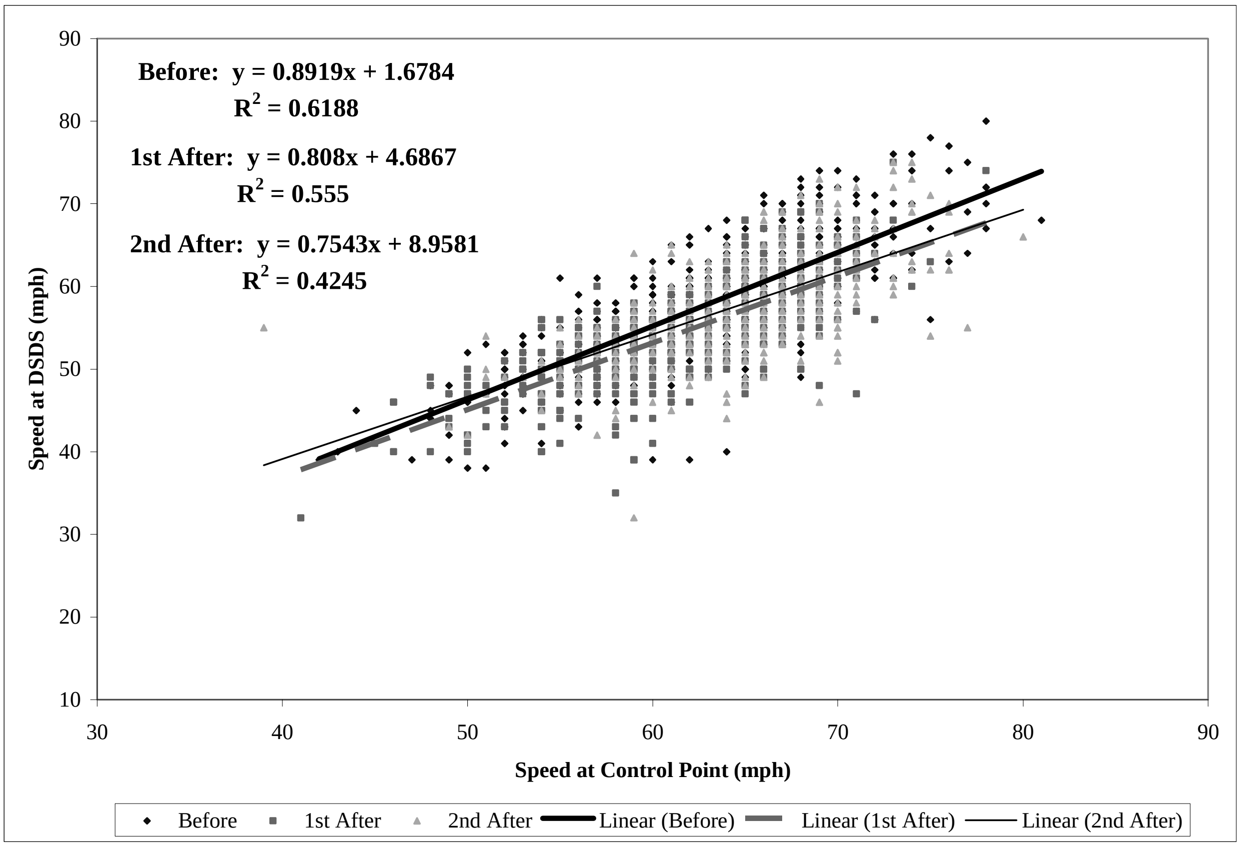

Figure 21. Regression Lines for US 59 at Loop 390 Southbound Day Data.

Further illustrations of the effects of the DSDS as determined through regression analysis are highlighted in Table 13. Speeds predicted by the regression lines show that the effects during both after studies are small. In fact, the reduction predicted by the regression analysis implies that the speeding vehicle slowed down by less than 1 mph more in the after studies than in the before study for those vehicles traveling as fast as 80 mph. It seems safe to conclude that the DSDS had little to no effect at this site.

Table 13. Difference in Daytime Predicted Speeds at DSDS, US 59 at Loop 390.

Study	Speed at Control Point	
	70 mph	80 mph
Before	64.1	73.0
1st After	61.3	69.3
2nd After	61.8	69.3

SITE 7: US 59 AT SR 43 NORTHBOUND, MARSHALL

Figure 8 illustrates the general layout of the site. The DSDS is located approximately 1275 feet upstream of an intersection at the crest of a vertical curve. The intersection is not visible until the driver passes the DSDS. A mast arm with two beacons that begin to flash when the signal is about to turn red is located 8 feet downstream of the DSDS. The speed limit at the control point is 50 mph and the speed limit at the DSDS is 45 mph. The daytime data were subdivided into motorists who approached the DSDS while the beacons were flashing and motorists who approached the DSDS while the beacons were not flashing (i.e., motorists who would probably need to stop for the signal and motorists who probably would not need to stop for the signal). There were not enough heavy vehicles sampled to subdivide the two categories by vehicle type.

Day Data Beacon Flashing – Spot Speed Statistics

Table 14 shows that average speeds at the control point while the beacon was flashing were not significantly different between the three study periods. Meanwhile, the average speed at the DSDS dropped from 45.3 mph in the before study to 41.7 mph in the first after study. For the second after study the average speed was 41.3 mph, suggesting the DSDS was responsible for a 3.5 to 4.0 mph decrease in average speed that was sustained over the four-month period that the DSDS was evaluated.

Comparison of the percent exceeding the speed limit indicated similarly impressive results. The percent exceeding the speed limit at the DSDS dropped from 50.6 percent in the before study to 22.8 percent in the first after study, and was still down at 22.3 percent by the second after study. Similar trends were observed when comparing the 85th percentile speeds. A 3 mph reduction in the 85th percentile speed was seen in the first after study and maintained until the second after study.

In addition to the effects on speed reductions, the standard deviation was calculated to determine if the DSDS had any effects on the dispersion of speeds. No significant differences were detected at either the control point or the DSDS, indicating that the DSDS did not affect the variability of speeds at this site.

Table 14. Summary Speed Statistics for Northbound Day Traffic on US 59 at SR 43.

	Control Point			**DSDS**		
Day Data	Speed Limit = 50 mph			Speed Limit = 45 mph		
Beacon Flashing	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	53.4	52.1	52.7	45.3	41.7A	41.3A
Standard Deviation (mph)	4.6	4.8	4.5	5.0	5.1	5.3
Percent Exceeding Speed Limit (mph)	72.9	63.0	65.1	50.6	22.8A	22.3A
85th Percentile Speed (mph)*	58	57	58	50	47	47
Beacon Not Flashing	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	53.5	52.8	52.4A	45.6	41.1A	42.1A
Standard Deviation (mph)	4.7	4.8	4.8	5.1	5.2	5.6
Percent Exceeding Speed Limit (mph)	73.6	66.7	67.7	46.9	21.4A	23.5A
85th Percentile Speed (mph)*	58	59	57	51	46	47
Night Data	Before	1st After	2nd After	Before	1st After	2nd After
Average Speed (mph)	51.1	50.9	51.0	44.4	40.0A	40.6A
Standard Deviation (mph)	4.1	4.6	3.4	5.0	5.0	4.6
Percent Exceeding Speed Limit (mph)	50.7	55.0	63.8	38.9	13.6A	10.6A
85th Percentile Speed (mph)*	55	56	54	49	45	44

A: Significantly different from the before study.
B: Significantly different from the 1st after study.
* Not tested for statistical significance
sample sizes Beacon Flashing data: before, 340; 1st after, 127; 2nd after, 238
sample sizes Beacon Not Flashing data: before, 580; 1st after, 147; 2nd after, 254
sample sizes Night data: before, 203; 1st after, 140; 2nd after, 47

Day Data Beacon Not Flashing – Spot Speed Statistics

Table 14 shows that average speeds at the control point were not significantly different between the before and first after study; however, the average speed during the second after study was slightly lower than the average speed during the before study (about 1 mph). The difference was probably detected because sample sizes for this data set were very large. At the DSDS, speeds dropped from 45.6 mph in the before study to 41.1 mph in the first after study (a reduction of 4.5 mph). The average speed in the second after study, 42.1 mph, was slightly higher than the average speed in the first after study. Because average speeds at the control point were slightly lower during the second after study it is difficult to say whether the reduction in speed was truly maintained. However, there was no significant difference between the proportion of vehicles speeding at the control point during the three different study periods, and the reduction at the DSDS was maintained over the four-month period. The percent exceeding the speed limit dropped from 46.9 percent in the before study to 21.4 percent in the first after study. The percent exceeding the speed limit rose slightly but not significantly in the second after study to 23.4 percent. Again, no significant differences in standard deviation were detected between the three study periods, indicating that the sign did not affect speed dispersion at this site.

Night Data – Spot Speed Statistics

Table 14 indicates that average speeds at the control point at night were not significantly different between the three study periods in the night data. Meanwhile, the average speed at the DSDS fell from 44.4 mph in the before study to 40.0 mph in the first after study. The average speed rose to 40.6 mph in the second after study, but was not significantly different than the first after study. This indicates that the DSDS was responsible for about a 4 mph reduction in average speed at night, similar to that observed in the daytime data. It should be noted that the average speed actually dropped below the speed limit with the installation of the DSDS at this location. The percent exceeding the speed limit showed equally impressive results. During the before study 38.6 percent of the sample exceeded the speed limit at the DSDS. This was significantly reduced to 13.6 percent in the first after study and the reduction was maintained over the four-month period. In addition, the 85th percentile speed also decreased from 49 mph in the before study to 45 mph in the first after study. This effect was also maintained over the four-month period. Again researchers detected no significant differences between the standard deviations for the three study periods.

Day Data Beacon Flashing – Regression Analysis

The regression lines based on the data collected when the flashing beacon was active for each study period during the day are presented in Figure 22. Statistical comparisons of the data imply that there were statistically significant differences in the relationship between speeds at the control point and speeds at the DSDS. In comparison to the trend line for the before data, the trend line for the first after data suggests a shift downward across the entire speed range observed. However, in the second after study, a difference in the trend line is significantly flatter than the other two lines, implying that the DSDS eventually influenced only those drivers traveling much faster than the posted speed limit at that site.

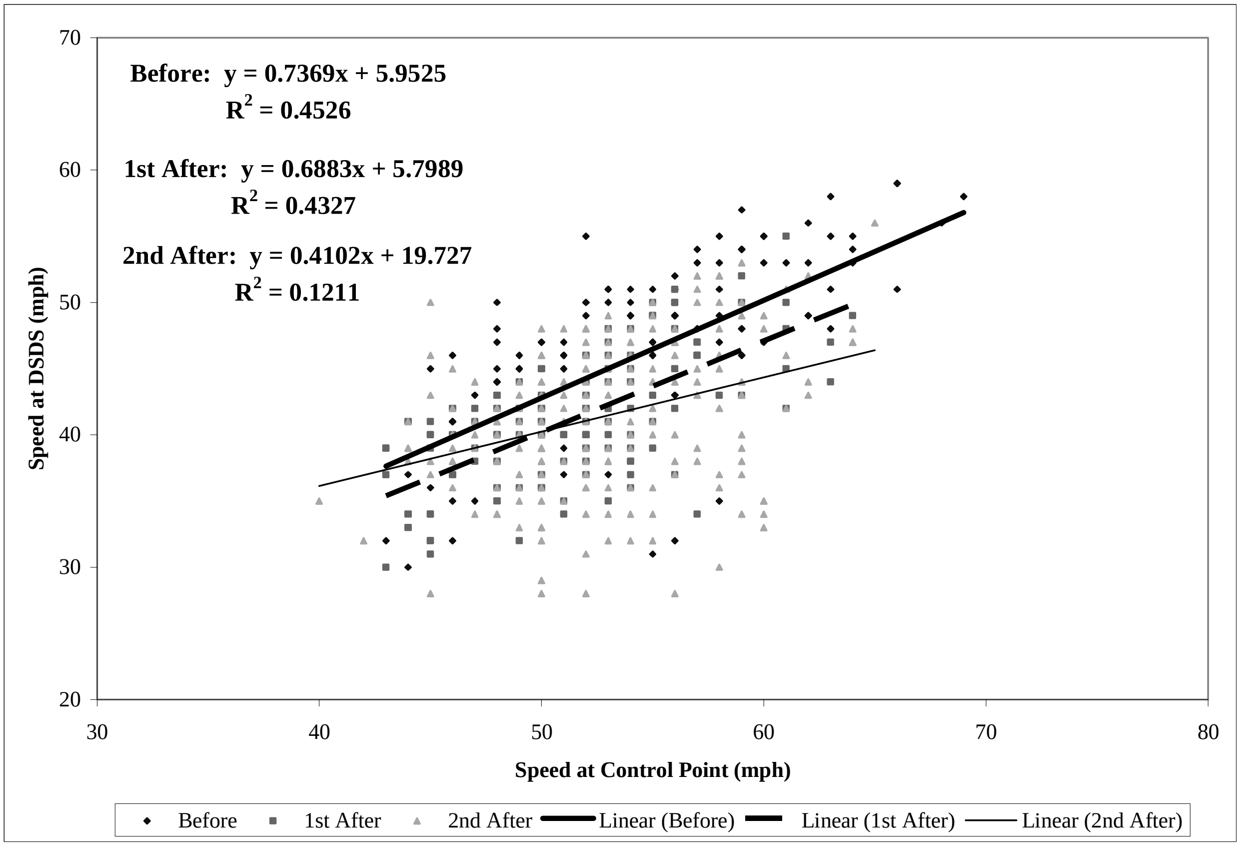

Figure 22. Regression Lines for Beacon Flashing Day Data on US 59 at SR 43.

Table 15 illustrates the magnitude of the incremental speed reductions predicted by the regression lines. A motorist traveling the speed limit at the control point (50 mph) is predicted to slow down to 42.8 mph in the before study, 40.2 mph in the first after study, and 40.2 mph in the second after study. Thus, the sign was responsible for a about a 2.5 mph reduction in speed for vehicles approaching at that speed. In comparison, a motorist traveling 60 mph at the control point is predicted to slow down to 50.2 mph in the before study and 47.1 mph in the first after study. This reduction in speed was about 3 mph. In the second after study the speeding vehicle is predicted to slow down even more, to 44.3 mph, a reduction in speed of almost 6 mph. In other words, the DSDS was responsible for a 2-3 mph reduction in the speeds during the first after study, but by the second after study most speeding vehicles are predicted to slow down to relatively close to the speed limit at the DSDS.

Table 15. Differences in Beacon Flashing Predicted Speeds at DSDS, US 59 at SR 43.

Study	Speed at Control Point	
	50 mph	**60 mph**
Before	42.8	50.2
1st After	40.2	47.1
2nd After	40.2	44.3

Day Data Beacon Not Flashing – Regression Analysis

The regression lines based on the data collected when the flashing beacon was not active during the day are presented in Figure 23 for each study period. As might be expected through visual inspection, the regression lines in Figure 23 were statistically different, and the slopes of the two after study regression lines were significantly flatter than the slope of the before regression line, indicating that faster vehicles slowed down more than slower vehicles in response to the DSDS. The second after regression line is shifted slightly above the first after regression line. The difference is not significant, but it does indicate a small speed adjustment took place between the first and second after periods.

Table 16 illustrates the magnitude of the incremental speed reductions predicted by the regression lines. A motorist traveling the speed limit at the control point (50 mph) is predicted to slow down to 43.3 mph in the before study, 40.0 mph in the first after study, and 41.0 mph in the second after study. Thus, the sign was responsible for a 2-3 mph reduction in speed for vehicles approaching at that speed. In comparison, a motorist traveling 60 mph at the control point is predicted to slow down to 49.9 mph in the before study, 44.9 mph in the first after study, and 45.6 mph in the second after study. In other words, the DSDS was responsible for a 4-5 mph reduction in the speeds of vehicles driving 10 mph over the speed limit at the control point.

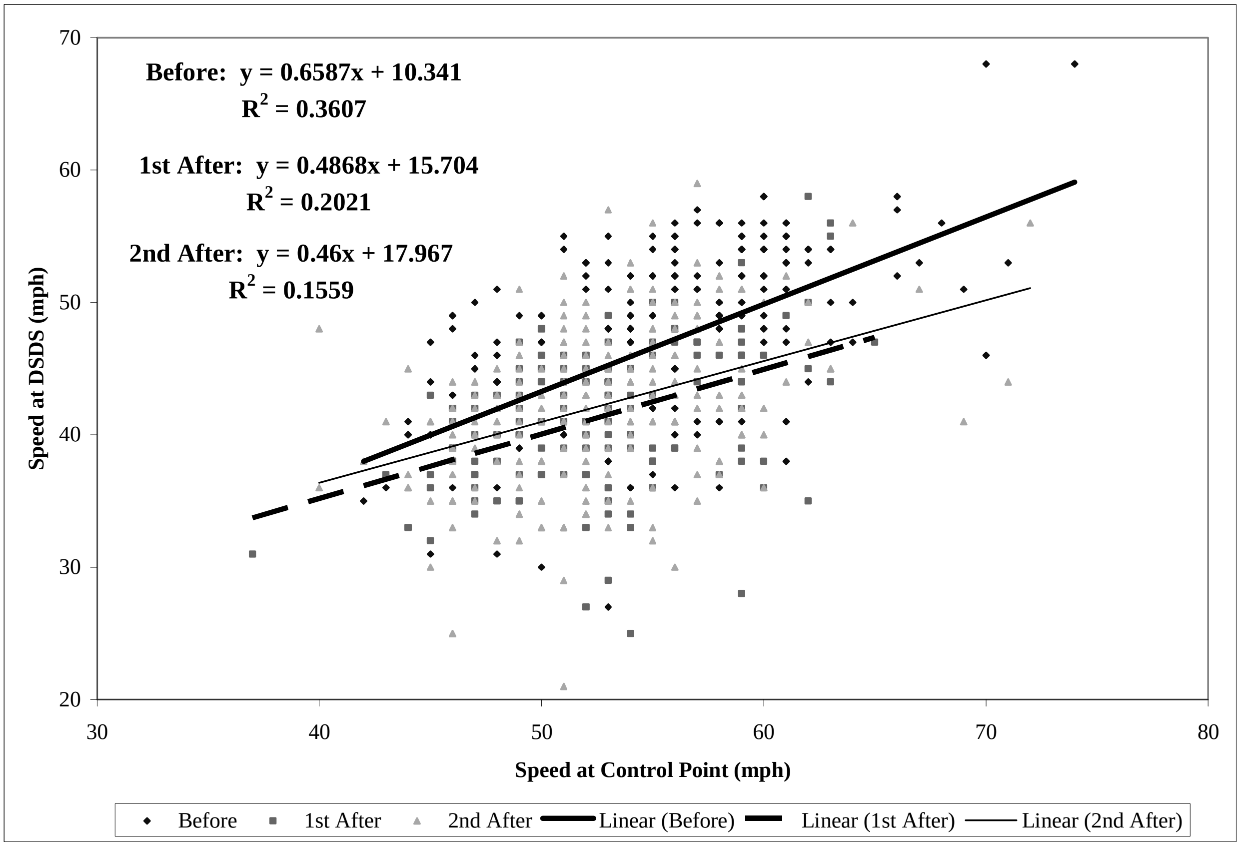

Figure 23. Regression Lines for Beacon Not Flashing Day Data on US 59 at SR 43.

Table 16. Differences in Beacon Not Flashing Predicted Speeds at DSDS, US 59 at SR 43.

	Speed at Control Point	
Study	**50 mph**	**60 mph**
Before	43.3	49.9
1st After	40.0	44.9
2nd After	41.0	45.6

Night Data – Regression Analysis

The regression lines based on the data collected at night for each study period are presented in Figure 24. As might be expected from visually examining the graph, the three regression lines were statistically different, but the slopes of the three regression lines were not significantly different. This indicates that all vehicles were affected fairly equally by the installation of the DSDS at night. Thus, no further conclusions can be drawn from the regression analysis, but the DSDS was shown to be effective at reducing average and 85th percentile speeds at night, as well as considerably reducing the percent speeding.

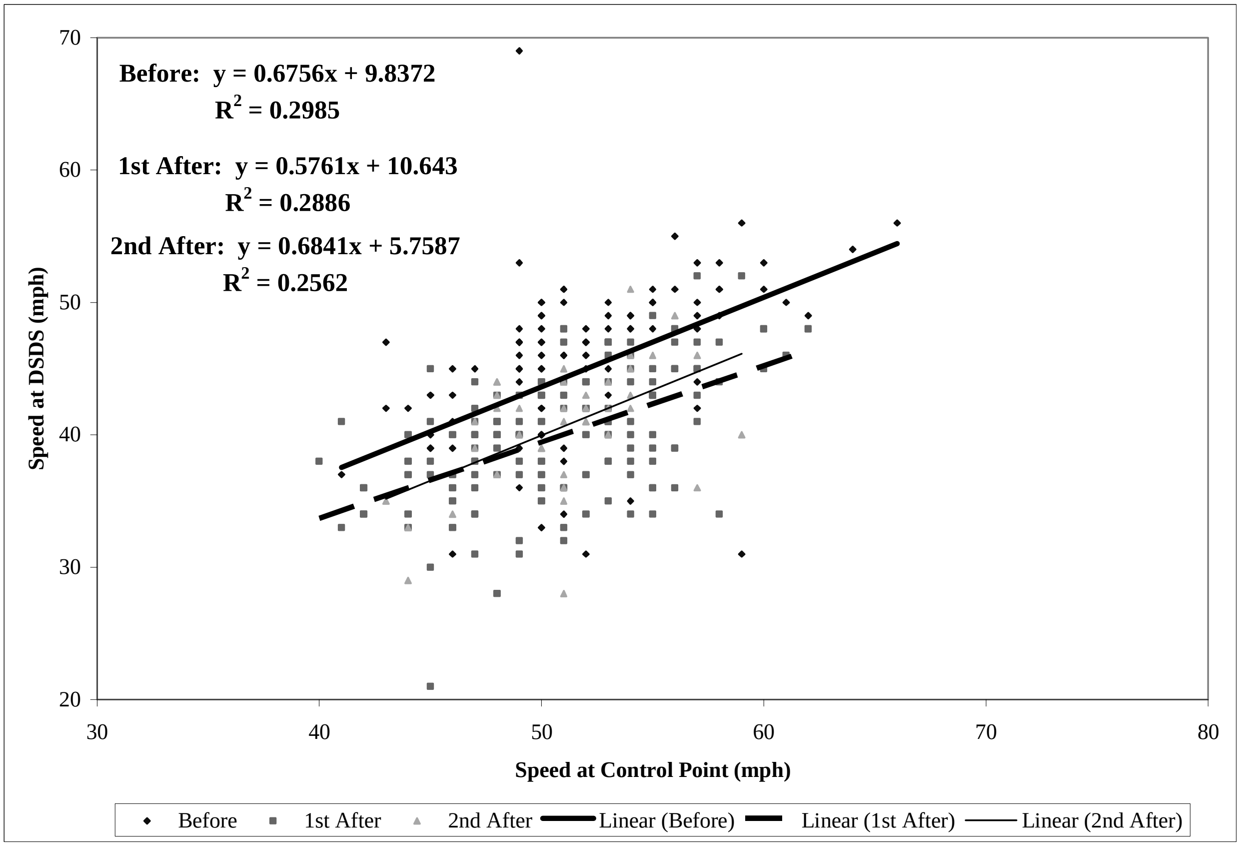

Figure 24. Regression Lines for Night Data on US 59 at SR 43.

SUMMARY

Table 17 summarizes the effects of the DSDS across the test locations examined in this project.

Table 17. Summary of Results by Site.

Site	Key Results
1 FM 741, Forney	▪ Average and 85th percentile speeds reduced 8 to 10 mph ▪ Percent exceeding school speed zone limit decreased 50 to 60 percent ▪ Reductions maintained over four-month study period ▪ Slightly greater effect on higher-speed vehicles
2 FM 89 NB, Abilene	▪ Average and 85th percentile speeds initially reduced 3 mph daytime, 2 mph nighttime ▪ Percent exceeding speed limit decreased 10 percent daytime, no significant change at night ▪ DSDS became slightly less effective over time ▪ Initially, DSDS affected all vehicle approach speeds. Over time, only those exceeding the posted speed limit reacted to the DSDS
3 FM 89 SB, Abilene	▪ Average and 85th percentile speeds initially reduced 2 to 4 mph daytime, no significant changes nighttime ▪ Percent exceeding speed limit initially decreased 20 percent daytime, no significant change nighttime ▪ DSDS became slightly less effective during daytime, slightly more at night ▪ Vehicles exceeding posted speed limit tended to react more significantly to the DSDS
4 US 277 NB, Seymour	▪ Average, 85th percentile, and percent exceeding speed limits for both passenger vehicles and trucks appeared unaffected by DSDS ▪ External influences (weather, change in advisory speed limit sign) made it difficult to isolate any influence of the DSDS
5 US 277 SB, Seymour	▪ Average, 85th percentile, and percent exceeding speed limits for both passenger vehicles and trucks appeared unaffected by DSDS ▪ External influences (weather, change in advisory speed limit sign) made it difficult to isolate any influence of the DSDS
6 US 59 at Loop 390 SB, Marshall	▪ Average and 85th percentile speeds initially reduced 3 to 4 mph daytime ▪ Percent exceeding speed limit decreased 25 percent daytime ▪ Speed reductions due to DSDS not sustained over time ▪ Trends imply only slight DSDS effect on vehicles exceeding posted speed limit
7 US 59 at SR 43 NB, Marshall	▪ Average and 85th percentile speeds reduced 3 to 4 mph daytime and nighttime ▪ Percent exceeding speed limit decreased 25 percent daytime and nighttime ▪ Speed reductions maintained over four-month period ▪ Vehicles exceeding posted speed limit tended to react more significantly to the DSDS. This incremental effect increased over time

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The results of the field studies at seven permanent DSDS installations indicate that such displays may have a significant and ongoing effect upon vehicle speeds, if certain conditions are present at the site. Some of these conditions are as follows:

- The perceived likelihood of an enforcement presence at a site appears to contribute to the speed reductions achieved by installing a DSDS. At the school speed zone (where enforcement activities tend to be higher) and at the approach to a signalized intersection on a high-speed roadway (where a significant enforcement presence was noted by researchers during all three field studies), average speeds decreased by 4 to 9 mph after the DSDS were installed. Furthermore, these reductions were maintained over the four-month period that the three studies (before, first after, and second after) were performed.
- DSDS may also be more effective at locations with sight distance less than that of decision sight distance to a hazard (such as a signalized intersection on a high-speed roadway). At one approach to a signalized intersection on a high-speed roadway, a DSDS installation had very little effect on speeds. This location had good decision sight distance to the intersection. A second signalized intersection where less than decision sight distance to the intersection was available, however, experienced a more significant (4 mph) reduction in average speeds when a DSDS was installed.
- DSDS may be more effective at locations on two-lane, two-way highways where only one travel lane exists per direction. This is because vehicles traveling in a single lane are more susceptible to changes in vehicle speeds in front of them. In other words, a DSDS that directly causes one motorist to slow down may also indirectly influence other motorists who are following some distance behind and who slow in response to the speed reduction of that initial motorist.

- DSDS may be more effective at locations where the sign supports an overall driver information system that conveys a clear and real need to reduce speeds at the location. Similarly, DSDS installation may be less effective at locations where there is already an overabundance of driver information that an approaching motorist needs to process.
- DSDS may be more effective when installed in conjunction with, and support of, regulatory speed limits (as compared to supporting advisory speed limits).

RECOMMENDATIONS

Based on the results of this project, the researchers recommend that DSDS be allowed for permanent installations to support school speed zones where approach speeds are substantially above the speed zone limit. Researchers also recommend that permanent DSDS installations be allowed if a preliminary assessment of factors shown in Table 18 indicates that a DSDS is likely to be effective in reducing speeds at the location. Furthermore, because of the limited sample size investigated in this study, a potential installation location may still be a viable candidate for DSDS even if it does not possess any of the site characteristics listed in Table 18. For those types of locations, however, before-after speed studies should be conducted to verify the effectiveness of the DSDS and to further add to the body of research knowledge concerning the use of this technology.

Table 18. Site Conditions that May Increase DSDS Effectiveness.

Factor	Effect on DSDS Effectiveness
Perceived level of enforcement	■ More effective if perception of regular enforcement (and threat of citation) exists at site
Sight Distance	■ More effective if sight distance to the condition being treated is less than decision sight distance
Number of travel lanes	■ More effective where only one lane exists per direction
Amount and type of other traffic control devices in area of DSDS	■ More effective with other information "indicators" of a need to reduce speed (school speed limit beacons, signal change warning beacons, etc.) ■ More effective if the DSDS is used to support a regulatory speed limit (as opposed to an advisory speed limit) ■ More effective if the overall information system at the location does not overwhelm the DSDS

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APPENDIX A:
REGRESSION ANALYSES RESULTS

Regression Results: School Speed Zone Flashers ON - Forney, Texas

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	25.322	0.389	5.015	1424.3	6387.6	7812.0	9421.8	256	254
1st After	30.660	0.095	5.858	63.3	7378.1	7441.4	7070.5	217	215
2nd After	24.614	0.221	5.679	342.6	7063.6	7406.2	7027.4	221	219
Combined	26.783	0.243	7.055	1404.3	34442.6	35846.9	113943.5	694	692

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	20829.3		688
SSE(R):	34442.6		692
F*	112.4	(calculated)	
F(0.95, 2, 688):	3.00	(from table)	

F*>F(0.95, 2, 688): Thus, regression lines are not equal.

Study	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	25.322	0.389	6387.6	1.06E-04	256	254
1st After	30.660	0.095	7378.1	1.41E-04	217	215
2nd After	24.614	0.221	7063.6	1.42E-04	221	219

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	13765.8	29.4	0.0852	0.112	0.477	2.143	Yes
Before/2nd After	13451.2	28.4	0.0841	-0.012	0.348	2.143	No
1st After/2nd After	14441.7	33.3	0.0972	-0.334	0.082	2.143	No

Regression Results: School Flashers/DSDS OFF - Forney, Texas

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP\text{-}CP_{avg})^2$	Count	df: n-2
Before	21.109	0.606	4.693	5435.0	9711.8	15146.8	14806.7	443	441
1st After	25.602	0.458	6.155	4318.5	20194.3	24512.8	20627.0	535	533
2nd After	28.051	0.411	6.419	2683.6	19036.3	21719.9	15893.9	464	462
Combined	24.615	0.496	6.010	12784.7	52006.6	64791.3	51942.2	1442	1440

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	48942.4		1436
SSE(R):	52006.6		1440
F*	22.5	(calculated)	
F(0.95, 2, 1436):	3.00	(from table)	

F*>F(0.95, 2, 1436): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP\text{-}CP_{avg})^2$	Count	df: n-2
Before	21.109	0.606	9711.8	6.75E-05	443	441
1st After	25.602	0.458	20194.3	4.85E-05	535	533
2nd After	28.051	0.411	19036.3	6.29E-05	464	462

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	29906.1	30.7	0.0597	0.020	0.276	2.143	Yes
Before/2nd After	28748.1	31.8	0.0644	0.057	0.333	2.143	Yes
1st After/2nd After	39230.7	39.4	0.0663	-0.095	0.189	2.143	No

Regression Results: FM 89 Daytime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	5.926	0.885	3.189	16618.9	9890.2	26509.1	22774.4	847	845
1st After	10.734	0.740	5.148	5746.3	14099.8	19846.1	10492.1	534	532
2nd After	15.210	0.679	4.833	12484.2	18408.0	30892.2	27101.4	790	788
Combined	11.302	0.759	4.588	34126.2	46826.6	80952.7	61078.0	2171	2169

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	42398.1		2165
SSE(R):	46826.6		2169
F*	56.5	(calculated)	
F(0.95, 2, 2165):	3.00	(from table)	

F*>F(0.95, 2, 2165): Thus, regression lines are not equal.

		Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	5.926	0.885	9890.2	4.39E-05	847	845
1st After	10.734	0.740	14099.8	9.53E-05	534	532
2nd After	15.210	0.679	18408.0	3.69E-05	790	788

Y-intercept

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	23990.1	17.4	0.0492	0.039	0.251	2.143	Yes
Before/2nd After	28298.2	17.3	0.0374	0.126	0.287	2.143	Yes
1st After/2nd After	32507.9	24.6	0.0571	-0.061	0.184	2.143	No

Regression Results: FM 89 Nighttime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	7.721	0.846	3.253	4021.5	1809.5	5830.9	5619.9	173	171
1st After	5.424	0.825	4.282	1651.9	1411.9	3063.8	2425.5	79	77
2nd After	16.129	0.657	4.307	1435.1	1799.7	3234.7	3329.6	99	97
Combined	11.190	0.757	4.045	6623.7	5710.9	12334.6	11560.9	351	349

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	5021.0		345
SSE(R):	5710.9		349
F*	11.9	(calculated)	
F(0.95, 2, 345):	3.00	(from table)	

F*>F(0.95, 2, 345): Thus, regression lines are not equal.

		Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	7.721	0.846	1809.5	1.78E-04	173	171
1st After	5.424	0.825	1411.9	4.12E-04	79	77
2nd After	16.129	0.657	1799.7	3.00E-04	99	97

Y-intercept

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	3221.3	13.0	0.0876	-0.168	0.209	2.156	No
Before/2nd After	3609.1	13.5	0.0803	0.017	0.361	2.143	Yes
1st After/2nd After	3211.6	18.5	0.1147	-0.079	0.417	2.163	No

Regression Results: FM 89 Daylight Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	5.335	0.874	2.913	19224.1	9487.1	28711.2	25188.9	1120	1118
1st After	16.295	0.591	3.224	3238.8	5550.7	8789.6	9264.1	536	534
2nd After	9.329	0.778	2.904	11344.0	7910.0	19254.0	18752.9	940	938
Combined	9.124	0.779	3.181	32519.6	26252.7	58772.3	53652.6	2596	2594

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	22947.9		2590
SSE(R):	26252.7		2594
F*	93.2	(calculated)	
F(0.95, 2, 2590):	3.00	(from table)	

F*>F(0.95, 2, 2590): Thus, regression lines are not equal.

		Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	5.335	0.874	9487.1	3.97E-05	1120	1118
1st After	16.295	0.591	5550.7	1.08E-04	536	534
2nd After	9.329	0.778	7910.0	5.33E-05	940	938

Y-intercept

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	15037.9	9.1	0.0367	0.204	0.361	2.143	Yes
Before/2nd After	17397.1	8.5	0.0281	0.036	0.156	2.143	Yes
1st After/2nd After	13460.8	9.1	0.0384	-0.269	-0.104	2.143	Yes

Regression Results: FM 89 Nighttime Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP\text{-}CP_{avg})^2$	Count	df: n-2
Before	4.840	0.882	2.565	3937.3	1743.2	5680.5	5065.2	267	265
1st After	7.543	0.795	2.902	1004.8	774.6	1779.4	1590.7	94	92
2nd After	10.466	0.742	2.861	1800.4	1244.1	3044.5	3272.7	154	152
Combined	7.015	0.825	2.783	6964.6	3972.2	10936.8	10240.8	515	513

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

			df
SSE(F):	3761.9		509
SSE(R):	3972.2		513
F*	7.1	(calculated)	
F(0.95, 2, 509):	3.00	(from table)	

F*>F(0.95, 2, 509): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP\text{-}CP_{avg})^2$	Count	df: n-2
Before	4.840	0.882	1743.2	1.97E-04	267	265
1st After	7.543	0.795	774.6	6.29E-04	94	92
2nd After	10.466	0.742	1244.1	3.06E-04	154	152

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	2517.8	7.1	0.0763	-0.077	0.250	2.143	No
Before/2nd After	2987.3	7.2	0.0600	0.011	0.269	2.143	Yes
1st After/2nd After	2018.7	8.3	0.0879	-0.135	0.241	2.143	No

Regression Results: US 277 Passenger Vehicles Daytime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	9.399	0.597	3.713	6116.0	6287.2	12403.2	17181.3	458	456
Shortly After	5.384	0.652	4.123	3346.1	3433.9	6779.9	7879.3	204	202
Long After	16.416	0.453	4.361	2039.6	5248.4	7287.9	9923.1	278	276
Combined	9.510	0.590	4.099	12620.9	15761.2	28382.1	36308.9	940	938

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	14969.4		934
SSE(R):	15761.2		938
F*	12.4	(calculated)	
F(0.95, 2, 934):	3.00	(from table)	

F*>F(0.95, 2, 934): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	9.399	0.597	6287.2	5.82E-05	458	456
Shortly After	5.384	0.652	3433.9	1.27E-04	204	202
Long After	16.416	0.453	5248.4	1.01E-04	278	276

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/Shortly After	9721.1	14.8	0.0523	-0.167	0.057	2.143	No
Before/Long After	11535.6	15.8	0.0501	0.036	0.251	2.143	Yes
Shortly After/Long After	8682.2	18.2	0.0643	0.060	0.336	2.143	Yes

Regression Results: US 277 Heavy Vehicles Daytime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	3.412	0.683	3.590	924.7	1392.3	2317.0	17181.3	110	108
Shortly After	5.400	0.589	3.468	343.0	565.1	908.1	7879.3	49	47
Long After	8.068	0.632	3.400	928.9	1063.7	1992.6	9923.1	94	92
Combined	5.577	0.645	3.858	2203.8	3735.0	5938.8	36308.9	253	251

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	3021.1		247
SSE(R):	3735.0		251
F*	14.6	(calculated)	
F(0.95, 2, 934):	3.00	(from table)	

F*>F(0.95, 2, 934): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	3.412	0.683	1392.3	5.82E-05	110	108
Shortly After	5.400	0.589	565.1	1.27E-04	49	47
Long After	8.068	0.632	1063.7	1.01E-04	94	92

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/Shortly After	1957.4	12.6	0.0483	-0.011	0.199	2.165	No
Before/Long After	2456.0	12.3	0.0442	-0.045	0.146	2.160	No
Shortly After/Long After	1628.8	11.7	0.0517	-0.155	0.069	2.167	No

Comparing Regression Lines for All Vehicles Night Traffic Traveling NB on US 183/283/277 in Seymour

Regression Results: US 277 All Vehicles Nighttime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	12.352	0.521	3.976	968.1	1486.4	2454.5	3561.5	96	94
1st After	4.392	0.629	3.199	554.9	368.5	923.4	1403.4	38	36
2nd After	12.544	0.542	2.682	352.7	208.7	561.4	1201.5	31	29
Combined	8.599	0.596	3.941	2257.7	2531.9	4789.6	6351.8	165	163

$$F^* = \frac{SSE(R)-SSE(F)}{4} \div \frac{SSE(F)}{n_1+n_2+n_3-6}$$

SSE(F):	2063.5		159
SSE(R):	2531.9		163
F*	9.0	(calculated)	
F(0.95, 2, 159):	3.06	(from table)	

F*>F(0.95, 2, 159): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	12.352	0.521	1486.4	2.81E-04	96	94
1st After	4.392	0.629	368.5	7.13E-04	38	36
2nd After	12.544	0.542	208.7	8.32E-04	31	29

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	1854.8	14.3	0.1190	-0.366	0.151	2.168	No
Before/2nd After	1695.0	13.8	0.1238	-0.289	0.248	2.169	No
1st After/2nd After	577.1	8.9	0.1171	-0.170	0.344	2.195	No

Regression Results: US 277 Passenger Vehicle Daytime Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	6.164	0.871	3.198	5715.0	3682.5	9397.5	7528.5	362	360
1st After	4.195	0.863	3.979	5948.5	5700.1	11648.6	7987.2	362	360
2nd After	6.072	0.826	3.425	3489.1	2815.7	6304.8	5108.2	242	240
Combined	5.381	0.858	3.694	15345.1	13153.0	28498.1	20851.7	966	964

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	12198.3		960
SSE(R):	13153.0		964
F*	18.8	(calculated)	
F(0.95, 2, 960):	3.00	(from table)	

F*>F(0.95, 2, 960): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	6.164	0.871	3682.5	1.33E-04	362	360
1st After	4.195	0.863	5700.1	1.25E-04	362	360
2nd After	6.072	0.826	2815.7	1.96E-04	242	240

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	9382.6	13.0	0.0580	-0.116	0.133	2.143	No
Before/2nd After	6498.2	10.8	0.0597	-0.083	0.173	2.143	No
1st After/2nd After	8515.8	14.2	0.0675	-0.108	0.164	2.143	No

Regression Results: US 277 Heavy Vehicles Daytime Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	11.685	0.619	2.668	581.6	617.3	1198.9	1127.8	81	79
1st After	0.331	0.892	3.700	340.5	337.2	677.8	677.8	41	39
2nd After	8.717	0.728	3.140	764.9	650.8	1415.7	1443.8	68	66
Combined	7.646	0.734	3.293	1768.8	2038.5	3807.4	3287.5	190	188

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	1605.3		184
SSE(R):	2038.5		188
F*	12.4	(calculated)	
F(0.95, 2, 184):	3.05	(from table)	

F*>F(0.95, 2, 184): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	11.685	0.619	617.3	8.87E-04	81	79
1st After	0.331	0.892	337.2	1.48E-03	41	39
2nd After	8.717	0.728	650.8	6.93E-04	68	66

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	954.5	8.1	0.1382	-0.573	0.027	2.171	No
Before/2nd After	1268.1	8.7	0.1175	-0.364	0.146	2.166	No
1st After/2nd After	988.0	9.4	0.1428	-0.147	0.420	2.176	No

Regression Results: US 277 All Vehicles Nighttime Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	(CP-CPavg)2	Count	df: n-2
Before	8.569	0.749	4.019	635.3	1130.6	1765.9	1132.0	72	70
1st After	-2.776	1.064	3.200	596.8	215.1	811.9	527.7	23	21
2nd After	8.235	0.775	3.775	412.9	541.5	954.4	687.8	40	38
Combined	6.662	0.809	3.835	1605.9	1956.0	3561.9	2450.8	135	133

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	1887.2		129
SSE(R):	1956.0		133
F*	1.2	(calculated)	
F(0.95, 2, 129):	3.06	(from table)	

F*<F(0.95, 2, 129): Thus, there is no significant difference between the three lines.

Regression Results: US 59 @ Loop 390 All Vehicles Daytime Data, SB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	1.678	0.892	3.921	22738.8	14006.8	36745.6	28587.1	913	911
1st After	4.687	0.808	4.086	9411.0	7546.8	16957.7	12764.7	455	453
2nd After	8.958	0.754	4.469	7336.3	9947.0	17283.3	12431.9	500	498
Combined	3.782	0.843	4.230	41808.1	33364.8	75172.8	59098.5	1867	1865

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	31500.6		1862
SSE(R):	33364.8		1865
F*	27.5	(calculated)	
F(0.95, 2, 1862):	3.06	(from Table)	

F*<F(0.95, 2, 1862): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	1.678	0.892	14006.8	3.50E-05	913	911
1st After	4.687	0.808	7546.8	7.83E-05	455	453
2nd After	8.958	0.754	9947.0	8.04E-05	500	498

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	21553.6	15.8	0.0423	-0.007	0.174	2.143	No
Before/2nd After	23953.8	17.0	0.0443	0.043	0.232	2.143	Yes
1st After/2nd After	17493.8	18.4	0.0540	-0.062	0.149	2.143	No

Regression Results: US 59 @ SR 43 All Vehicles Daytime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	9.488	0.672	3.983	10393.0	17166.0	27559.0	23031.4	1084	1082
1st After	11.922	0.564	4.348	2174.9	5577.4	7752.2	6848.2	297	295
2nd After	18.296	0.447	5.037	2188.7	12913.9	15102.6	10930.6	511	509
Combined	10.302	0.632	4.636	16500.5	40614.3	57114.8	41348.2	1892	1890

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	35657.3		1886
SSE(R):	40614.3		1890
F*	65.5	(calculated)	
F(0.95, 2, 1698):	3.00	(from table)	

F*>F(0.95, 2, 1698): Thus, regression lines are not equal.

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	9.488	0.672	17166.0	4.34E-05	1084	1082
1st After	11.922	0.564	5577.4	1.46E-04	297	295
2nd After	18.296	0.447	12913.9	9.15E-05	511	509

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	22743.4	16.5	0.0559	-0.012	0.228	2.143	No
Before/2nd After	30080.0	18.9	0.0505	0.116	0.333	2.143	Yes
1st After/2nd After	18491.3	23.0	0.0739	-0.042	0.224	2.143	No

Regression Results: US 59 @ SR 43 All Vehicles Nighttime Data, NB

	Y-intercept	Slope	Std Error	SSR	SSE	SSTO	$(CP-CP_{avg})^2$	Count	df: n-2
Before	9.837	0.676	4.228	352.6	3593.1	3945.7	3350.1	203	201
1st After	10.643	0.576	4.212	993.0	2447.9	3440.8	2991.4	140	138
2nd After	5.759	0.684	4.015	249.8	725.3	975.1	533.9	47	45
Combined	9.355	0.646	4.664	2875.7	8440.3	11316.0	6880.7	390	388

$$F^* = \frac{SSE(R) - SSE(F)}{4} \div \frac{SSE(F)}{n_1 + n_2 + n_3 - 6}$$

SSE(F):	6766.2		384
SSE(R):	8440.3		388
F*	23.8	(calculated)	
F(0.95, 2, 384):	3.00	(from table)	

F*>F(0.95, 2, 384): Thus, regression lines are not equal.

87

	Y-intercept	Slope	SSE	$1/(CP-CP_{avg})^2$	Count	df: n-2
Before	9.837	0.676	3593.1	2.98E-04	203	201
1st After	10.643	0.576	2447.9	3.34E-04	140	138
2nd After	5.759	0.684	725.3	1.87E-03	47	45

	SSE(F):	MSE(F):	Std. dev. (s)	$t(\alpha/4, n_1+n_2-4)$ CI lower limit (95%)	$t(\alpha/4, n_1+n_2-4)$ CI upper limit (95%)	t	Sig. Diff?
Before/1st After	6040.9	17.8	0.1062	-0.128	0.327	2.143	No
Before/2nd After	4318.3	17.6	0.1952	-0.429	0.412	2.156	No
1st After/2nd After	3173.1	17.3	0.1956	-0.531	0.315	2.162	No

APPENDIX B:
DSDS INSTALLATION GUIDELINES FOR PERMANENT APPLICATIONS

GUIDELINES FOR UTILIZING DYNAMIC SPEED DISPLAY SIGNS (DSDS) IN PERMANENT APPLICATIONS

DESCRIPTION

Dynamic speed display signs (DSDS), also termed driver feedback signs or speed display signs, measure the speed of an approaching vehicle and present that speed back to the motorist. Typically, a "your speed" or similar type of message is presented above or before the speed numbers. Figure B-1 depicts a common type of DSDS.

Figure B-1. A Typical DSDS Installation.

DSDS require a mechanism to measure the speed of individual vehicles from a distance far enough upstream to allow approaching drivers to detect the sign, recognize their current speed, and make adjustments if necessary. Currently, a common technology used is a radar transmitter/receiver that is built directly into the face of the DSDS. The DSDS unit is then self-contained and can be installed by a single work crew with a minimum amount of effort and impact upon traffic. However, DSDS that utilize inductive loop detectors in the pavement, video detection technology, or other methods of measuring speeds can also be used.

CONDITIONS INFLUENCING DSDS EFFECTIVENESS

DSDS can reduce vehicle speeds, especially those vehicles traveling faster than the posted speed limit, in a variety of applications. Studies have shown DSDS to be capable of reducing average speeds up to 9 mph at school speed zones and by as much as 2 to 4 mph at signalized intersection highway approaches, advance school zone areas, and low-speed horizontal curves. In most instances, DSDS can continue to reduce speeds even several months after installation.

Generally speaking, the amount of speed reduction likely to be achieved with the DSDS depends on the factors shown in Table B-1. DSDS tend to be more effective at locations where average speeds are 55 mph or less, where only one travel lane exists in one direction of travel, where the DSDS is located adjacent to a regulatory speed limit sign, and where there is a perception of a real enforcement presence and threat of citation such as exists at school speed zones.

Table B-1. Site Conditions that May Increase DSDS Effectiveness.

Factor	Effect on DSDS Effectiveness
Perceived level of enforcement	▪ More effective if perception of regular enforcement (and threat of citation) exists at site
Sight Distance	▪ More effective if sight distance to the condition being treated is less than decision sight distance
Existing operating speeds	▪ More effective if average speeds < 55 mph ▪ More effective if average speed is > 5 mph over the posted regulatory speed limit
Number of travel lanes	▪ More effective where only one lane exists per direction
Amount and type of other traffic control devices in area of DSDS	▪ More effective with other information "indicators" of a need to reduce speed (school speed limit beacons, signal change warning beacons, etc.) ▪ More effective if the DSDS is used to support a regulatory speed limit (as opposed to an advisory speed limit) ▪ More effective if the overall information system at the location does not overwhelm the DSDS

DSDS effectiveness is also influenced by the operating characteristics of the sign itself. The DSDS should be capable of clearing its display when no vehicle speeds are detected. Exercise care when using the sign in conjunction with time-of-day speed limits such as school speed zones. It is important to verify that the DSDS will return to a non-display condition once power to the sign is terminated.

DSDS effectiveness may also be influenced by the amount of traffic approaching the sign when installed on multi-lane roadways. If the DSDS is not properly designed, installed, and/or calibrated, the potential exists for the sign to display incorrect speeds or to change from speed to speed too quickly if traffic volumes are too high. Such improper operation can reduce the credibility of the device and ultimately its effectiveness. Once installed, operation of the DSDS should be manually observed during the highest volume time periods to ensure that it functions properly.

INSTALLATION OF DSDS

For a self-contained DSDS, the sign is installed adjacent to or over the traffic lane and aimed so that the speed detection zone is aligned horizontally as close as possible to the direction of vehicle travel, as depicted in Figure B-2. This alignment minimizes the amount of error in speed measurements taken by the detector. The goal should be to keep the angle α between the speed detector and the direction of travel to less than 10 degrees. Furthermore, the sign should be aligned vertically to ensure that approaching vehicles are detected far enough upstream to allow motorists to detect and recognize their current speed being displayed. This detection distance, X, depends on the approach speed of traffic as shown in Table B-2 for the DSDS positioned 2 feet laterally from the edge of the travel lanes. These distances should be increased by 25 feet for each additional 4 feet of lateral offset between the sign and the edge of the travel lanes. Large sign offsets will thus require fairly long detection zones upstream to ensure adequate driver viewing time for the displayed speed.

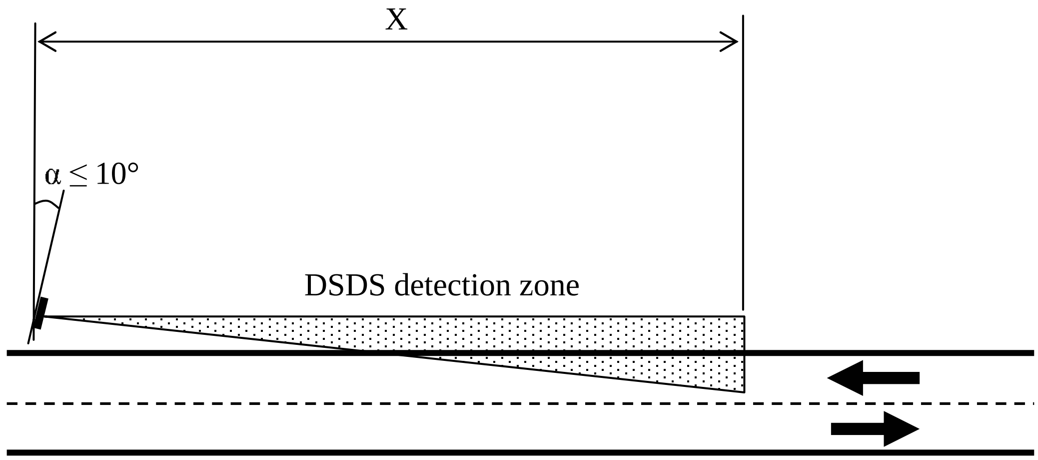

Figure B-2. DSDS Installation Characteristics.

Table B-2. Minimum DSDS Vehicle Detection Distances.

Approach Speed, Mph	Minimum Detection Distance X, Ft
40	225
45	250
50	275
55	300
60	325
65	350
70	375

Vertical and lateral clearances of the DSDS should meet or exceed those for warning and regulatory signs as per the Manual on Uniform Traffic Control Devices (MUTCD). The DSDS should be “anchored” to the desired speed of traffic at the site by installing it beneath, adjacent to, or just downstream of a speed limit sign (preferably a regulatory speed limit). Care should also be taken to minimize the number of other signs on the roadside that fall within the DSDS detection zone. The presence of such reflective surfaces can cause the DSDS to operate inconsistently.