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Increasing Speed Limit Compliance in Reduced-Speed School Zones

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INCREASING SPEED LIMIT COMPLIANCE IN

REDUCED-SPEED SCHOOL ZONES

by

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ABSTRACT

INCREASING SPEED LIMIT COMPLIANCE IN

REDUCED-SPEED SCHOOL ZONES

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Master of Science

Reduced-speed school zones greatly improve the safety of young children commuting to and from school and provide larger gaps in traffic for children to cross the street. The main focus of this study was to determine effective methods for increasing speed compliance in reduced-speed school zones. This objective was accomplished through an in-depth literature review, a public opinion survey of Utah drivers, and an evaluation of the effects of speed monitoring displays (SMDs) in school zones.

The main focus of the literature review was to determine how to increase and maintain speed limit compliance within school zones. Information about the following topics with respect to school zones was researched and compiled: traffic control devices, SMDs, law enforcement, and other speed influences.

A public survey was developed and implemented to evaluate the feelings and concerns of Utah drivers with respect to school-zone safety and school-zone traffic

control devices. The survey was conducted in various locations throughout the state of Utah and proved to be an effective tool. The majority of those surveyed felt there was a need to improve school-zone safety in Utah.

An evaluation of SMDs in four school zones throughout the state was performed. The results concluded that the SMDs analyzed in this study proved to increase speed compliance in most cases. In some cases, the SMDs maintained their effectiveness at increasing speed compliance over time; on the other hand, others lost some of their effectiveness over time, possibly due to higher percentages of commuter traffic. For the most part, speed compliance increased as manifested by the decrease in mean speed, standard deviation, 10 mph pace range, and the percentage of vehicles exceeding the 20 mph school-zone speed limit.

In summary, the results of this study suggest that a combination of effective traffic control devices, public education, and appropriate law enforcement are all necessary to improve speed-limit compliance in school zones.

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Chapter 1 Introduction

For years, traffic engineers and other roadway officials have provided young children with safe havens for crossing the street on their way to and from school. These safe havens are referred to as school zones and consist of a wide variety of traffic control devices, such as signage, flashing beacons, crossing guards, etc. School zones are used to increase drivers' awareness of the presence of children crossing the street. At times, traffic engineers must reduce vehicular speeds in these zones to provide safe and adequate gaps in traffic for children to cross the street. Some methods for reducing speeds in school zones are more effective than others. Traffic engineers face the challenge of identifying methods that will be most effective at increasing and maintaining speed compliance in reduced-speed school zones.

This report discusses the effectiveness of different procedures for reducing speeds in school zones. An in-depth literature review was performed to determine what has been done and what is the most effective. A public survey was conducted among Utah drivers to identify their opinions and views about current traffic control devices in school zones, as well as to assess their attitudes and feelings toward specific school-zone traffic control devices. By understanding drivers' attitudes and opinions, traffic engineers can appropriately decide which devices should be used to produce the most efficient result. In addition, speed monitoring displays (SMDs) were installed in four reduced-speed school zones in Utah to evaluate the effectiveness of these dynamic signs at improving speed compliance. Speed data collected before and after the signs were installed were analyzed and compared. This report discusses and explains the results of the literature search, public survey, and evaluation of SMDs in school zones.

1.1 Goals and Objectives

This study was commissioned by the Utah Department of Transportation (UDOT) to gain more information about the effectiveness of school-zone traffic control devices used by UDOT for increasing speed limit compliance in reduced-speed school zones. Since young children generally lack experience in dealing with traffic, they require safer areas for crossing the street. The main goal of this study was to enhance the safety of children commuting to and from school by increasing speed compliance in school zones.

The first objective of this study was to compile and evaluate past techniques for improving speed compliance in school zones through an extensive literature search. The next objective was to prepare and execute a public opinion survey about current school-zone traffic control devices in order to evaluate and better understand drivers' opinions and attitudes. The third objective of this study was to evaluate the effects of SMDs in school zones with respect to drivers' speeds.

1.2 Methodology

This research project consisted of three main components aimed at meeting the objectives identified in the previous section. The first component was an in-depth literature search on increasing speed compliance in reduced-speed school zones. The second involved the execution of a public opinion survey with respect to school-zone safety and speed compliance. Last, the project entailed an evaluation of SMDs in four school zones in the State of Utah. From the findings of these three components, a set of recommendations was developed with regards to school-zone safety and efficiency. The methodologies for each of these three components are discussed in the following subsections.

1.2.1 Literature Review

The main focus of the literature review was determining methodologies available to increase and maintain speed compliance within school zones. The use of different school-zone traffic control devices, such as flashing beacons, pavement markings, traffic signals, speed limits, crossing guards, and others were researched. An extensive search on the use and effectiveness of SMDs in school zones was also performed. Other speed influences were explored as well, such as law enforcement, increased fines, and traffic calming techniques. The literature review section discusses the factors found to influence drivers' speeds in school zones and other findings that relate to school-zone speed compliance.

1.2.2 Public Survey

A public opinion survey was designed and executed to determine the attitudes and behaviors of Utah drivers with respect to school-zone safety and speed compliance. The survey consisted of 20 questions and was given to 762 drivers. The questions on the survey were specifically designed to determine drivers' opinions about the necessity of improving the safety and efficiency of school zones, the general speed compliance in school zones, any apparent speed influences, and the effectiveness of SMDs. An additional analysis of the data was performed to find apparent relationships between the responses of two different questions. These relationships were found using a Chi-square test to evaluate how the actual frequency of responses differed from what was expected. By understanding the attitudes and behaviors of drivers, traffic engineers can provide the public with safer and more efficient transportation facilities.

1.2.3 Field Study

A field evaluation of SMDs purchased by UDOT was performed to determine if these signs would improve both short-term and long-term speed compliance in school zones. Four school zones were chosen by UDOT officials in which to install the new SMDs. The initial intent was to collect speed data before, one to two weeks after, and again five to six months after the signs were installed. Unfortunately, that schedule was not strictly enforceable due to problems with the SMDs not working properly. Regardless of these difficulties, speed data were collected in all four locations once the SMDs were functioning correctly. Speed data were collected using road tubes provided by UDOT. Data were collected for approximately four days (Monday through Thursday) for each condition (before, short-term, and long-term). Only speeds collected when the school zones were active were analyzed. From the data, statistics such as the mean speed, standard deviation, 85^{th} percentile speed, percent exceeding the school-zone speed limit, 10 mph pace, and percent in the 10 mph pace were computed. The mean speeds measured before and after the SMDs were installed were compared using a normal approximation test to find statistically significant differences between the two conditions. The distributions of speeds were also plotted and compared to observe any apparent differences. The results of the analysis can help UDOT and other transportation officials decide whether or not to use or continue using these new SMDs.

Chapter 2 Literature Review

For many years, reduced-speed school zones have been used to protect and improve the safety of children walking to and from school. Since young children tend to lack proper experience in dealing with traffic, a need exists to provide them with safer areas for crossing the street. A school zone can be used to offer this safer environment for kids to travel to and from school. When vehicular speeds are reduced in these zones, children can more accurately judge appropriate gaps in traffic that are suitable for crossing the street. In addition, drivers can stop quicker, as well as be more observant of their surroundings. Reducing speeds provides more gaps in traffic that are safe for crossing the street. In addition, if an accident were to occur in a school zone, the severity of that accident would be reduced as a result of lower speeds. One study suggests that a fatal pedestrian accident is six times less likely to happen if the vehicle's impact speed is 23 mph (10 percent chance of fatality) as opposed to 28 mph (60 percent chance of fatality) (Anderson et al. 1997). Reducing vehicular speeds in school zones enables children to commute safely to and from school. The main focus of this literature review was to examine methodologies available to increase and maintain speed compliance within school zones. To accomplish this purpose, the following subtopics are discussed:

- Traffic Control in School Zones
- Speed Monitoring Displays in School Zones
- Enforcement in School Zones
- Other Speed Influences

Each of these topics will be discussed further in the sections that follow.

2.1 Traffic Control in School Zones

The use of reduced-speed school zones is not a new concept. For years, these reduced-speed zones have been used to improve safety for young children. A number of traffic control devices have been used to slow vehicles down and thereby provide adequate gaps in traffic for students to safely cross the street. Some of these controls have been found to be more effective than others; however, the effectiveness of any traffic control device is conditional on the location where the device is implemented. Specific findings regarding the use of traffic control devices such as flashing beacons, pavement markings, traffic signals, different speed limits, crossing guards, and signage are discussed in the subsections that follow.

2.1.1 Flashing Beacons

Flashing beacons have been used for many years to make drivers more aware of a reduced speed limit in school zones. Many studies have reported that flashing beacons reduce speeds in school zones (Zegeer et al. 1976, Reiss and Robertson 1976, Hawkins 1993, Aggarwal and Mortensen 1993, Saibel et al. 1999). However, a few instances have been reported where flashing beacons were not very effective at reducing speeds (Burritt et al. 1990, Sparks and Cynecki 1990). Flashing beacons make drivers more aware of school zones and remind them to reduce their speed to assure children's safety.

Zegeer, Havens, and Deen (1976) reported that speed reductions caused by flashers were statistically significant at the 95 percent level at 84 percent of the locations studied. The average speed reduction was 3.6 mph. The authors of this study also mentioned a drop of about 5 mph in the 85th percentile speed for all 48 locations; however, they observed that the 85th percentile speed for all the locations was still about 19 mph over the 25 mph speed limit. A lack of sight distance between the motorists and the flashers may have been the cause for the ineffectiveness of the signs at five of the locations. Other possible reasons for the ineffectiveness of the flashers in that study included signalized or stop-sign intersections adjacent to or between the flashers, excessively long flashing times, and a recent history of inappropriate flashing (Zegeer et al. 1976). For the most part, the flashers were effective at reducing speeds, but they may have been more effective with a combination of other traffic control devices such as more law enforcement.

Reiss and Robertson (1976) found a statistically significant decrease in the mean speed when the flashers were on as opposed to when they were off. The researchers randomly collected speed data with a radar gun. Once the speed was recorded for each vehicle, a police officer stopped each car downstream of the school zone to collect the drivers' opinions about the effectiveness of the flashing beacons. Reiss and Robertson concluded that drivers were generally not observant of the school advance warning and crosswalk signs. In fact, the majority of the drivers only noticed the active school-zone sign with flashing beacons. Still, only 59 percent of those surveyed noticed the sign with the flashing beacons. Unfortunately, having noticed the flashing beacons did not always modify the drivers' behavior (Reiss and Robertson 1976).

Burritt, Buchanan, and Kalivoda (1990) discussed a study to evaluate the effectiveness of flashing beacons in two school zones along a state highway. Prior to this study, the Arizona Department of Transportation (ADOT) had never installed flashers in school zones along state highways. ADOT's standard at the time was to install flashers on arterial streets within Tucson, but not on state highways. ADOT performed a study in 1987 to see if flashers should be installed in the two previously mentioned school zones along a state highway. The study recommended that flashers should not be installed (this study was not discussed in detail). Despite this recommendation, the flashers were installed and evaluated to determine their effectiveness at reducing speeds. Unexpectedly, a statistically significant increase in the average speed was observed after the flashers were installed; however, the basis for the increase was not discussed. The researchers measured 4.2 and 1.9 mph increases in the average speed at the two locations analyzed. The results of this study concluded that flashing beacons were not an enhancement to school-zone safety and could actually make conditions worse (Burritt et al. 1990).

Sparks and Cynecki (1990) published a literature search of their own about the effectiveness of flashing beacons. They concluded from their search that flashers were ineffective at reducing vehicular speeds. They suggested "the longer the flasher operates, the more it becomes part of the scenery and eventually loses any effectiveness" (Sparks and Cynecki 1990, p. 35). Their study was somewhat biased since they did not cite any studies in which flashers were found to be effective. However, the search did bring to light the importance of avoiding overuse of flashers and maintaining uniformity to improve the effectiveness of flashers in school zones (Sparks and Cynecki 1990).

Hawkins (1993) discussed the results of a study performed in Iowa school zones along multilane roadways. Due to the functional classifications of the roadways, speeding through these zones was a problem. The approach speed limit to these school zones was 35 mph. Spot speed studies were conducted at seven locations before and after the flashing beacons were installed. Flashing beacons with oversized speed limit signs were tested and proved to significantly reduce vehicle speeds even a year after installation. These speed reductions were considered to be marginal (after one year, an 8.8 percent reduction of 2.8 mph in the afternoon and a 5.6 percent reduction of 1.7 mph in the morning). The author also suggested the need for enhanced police enforcement, public awareness, and public acceptance of the signs (Hawkins 1993). These three factors could have contributed to the effectiveness of the signs in this particular study.

Aggarwal and Mortensen (1993) found advance school flashers to be effective at reducing speeds in a brand new school zone in northern California. Flashers were placed on a roadway where the normal posted speed limit was 40 mph. The results of the study showed that flashers were effective in reducing vehicular speeds when the flashing beacons were on as opposed to when they were off. The authors discovered that the average speed was reduced from 38 mph to 31 mph; this was much closer to their goal of 25 mph. The total speed reductions may or may not be completely attributed to the flashers since multiple enhancements were added at the same time as the flashers (i.e., standard signing, pavement markings, and crossing guards). An analysis comparing speeds before and after the signs were installed may have produced more meaningful results, as opposed to comparing speeds when the signs were on to speeds when the signs were off. The flashers coupled with crossing guards and other school-zone pavement markings proved to reduce speeds and to make drivers more aware of the need to slow down in school zones.

Saibel, Salzberg, Doane, and Moffat (1999) reported on a study performed by the Washington Traffic Safety Commission (WTSC) to verify types of school-zone signs that were most effective at causing speed limit compliance. Researchers conducted spot speed studies at 40 different school zones and concluded that if the approach speed limit was about 35 mph (30 to 40 mph), then the most efficient sign was the "when flashing" one. The percent of vehicles exceeding 35 mph is presented in Table 2-1 for the different school-zone signs examined in the study. The study also concluded that the type of sign had no significant effect on speeds for school zones with an approach speed limit of 25 mph. Researchers suggested that reduced-speed school zones with an approach speed limit of 35 mph should be equipped with flashing beacons (Saibel et al. 1999).

Flashing beacons are commonly used in reduced-speed school zones on state routes in Utah. Although flashers may not be 100 percent effective at reducing speeds, they do improve driver awareness and provide safer environments for young students to cross the street. The general consensus of these studies is that proper use of flashers (avoiding excessive flashing periods, demonstrating uniformity, and providing adequate enforcement) increases their effectiveness. For the most part, flashing beacons have proven to be an excellent addition to traffic control devices in school zones.

Table 2-1: Percent of Vehicles Exceeding 35 mph for Different Sign Types for School Zones with an Approach Speed Limit of 35 mph

Type of Sign	When Flashing	When Children Are Present	When Flagged
Percent Exceeding 35 mph	3.43%	29.93%	22.96%

(Source: Saibel et al. 1999)

2.1.2 Pavement Markings

UDOT produced a publication entitled *Traffic Controls for School Zones* (UDOT 2003). This document is based on the most recent edition of the Manual of Uniform Traffic Control Devices (MUTCD 2003) and discusses the current standards and recommendations for traffic control devices in UDOT school zones. This document includes a section about school-zone pavement markings. Typical pavement markings found in school zones include crosswalks, stop bars or yield lines, curb markings, large letters and/or symbols, and lane markings. All of these markings can be useful for enhancing the visibility of a school zone.

UDOT has reserved longitudinal crosswalk markings for school crosswalks and reduced-speed school zones (UDOT 2003). Setting this standard preserves the uniformity of traffic control devices in UDOT school zones. With regards to crosswalk markings, the Oregon Department of Transportation (ODOT) discourages the use of colored and/or textured crosswalks. ODOT claims that textured crosswalks tend to be less visible and require more maintenance. ODOT also suggests that these crosswalks sometimes become considerably rough and can cause pedestrians to trip and fall in the middle of the street (ODOT 2005). The standardization of crosswalk pavement markings in school zones further distinguishes these crossings as school zones.

According to the MUTCD, stop and yield lines are used in school zones to indicate the point where a yield or a stop is intended or required. The use of these markings provides another warning to drivers of the presence of a school zone. Stop and yield lines are not required traffic control devices for school zones but can be used to more effectively attract drivers' attention than without them (MUTCD 2003).

According to MUTCD and UDOT guidelines, when parking regulations are in place, the use of a sign along with curb markings should be used in areas where snow and ice accumulation can cover the painted curb (MUTCD 2003, UDOT 2003). Restricting parking near school crossings provides better sight distance for both pedestrians and drivers. The absence of parked vehicles also provides better visibility of the school-zone signage.

Pavement markings play an important role in controlling traffic in school zones. If properly implemented, pavement markings can make school zones more recognizable to drivers and thereby improve safety. Unfortunately, these markings can lose their effectiveness fairly rapidly. For example, they can be covered by snow or might not be as visible when wet. Another limitation is that they must be repainted often since they tend to fade due to traffic and weather. When functioning properly, however, pavement markings make school zones more visible and therefore effectively improve safety.

2.1.3 Traffic Signals

Sometimes the public feels that installing traffic signals is the best thing to do to enhance safety. The solution is not always that simple. The truth is that traffic signals may actually make some situations worse. Lee and Bullock (2003) prepared a study for the Indiana Department of Transportation to analyze crash data at seven traffic signals in or near school zones “that were installed where the warrants were justified by only a slim margin” (p. 3). The results of the study showed no benefit for installing traffic signals in school zones when the warrants defined in the MUTCD have not been met. The authors concluded that for intersections not meeting the warrants, signals should not be installed. In fact, the researchers did not find one significant safety improvement after installing the signals at any of the seven intersections in or near school zones. Lee and Bullock suggested that speeds in school zones could be reduced through two methods, driver awareness and enforcement. The authors also suggested that cities and county school districts should prevent future schools from being built on major streets in order to improve pedestrian safety. Unless warranted and deemed necessary, traffic signals should not be installed in school zones to improve safety (Lee and Bullock 2003).

2.1.4 Speed Limits

Reduced-speed school zones with higher approach speed limits require more traffic control devices than do school zones with lower approach speed limits to assure speed limit compliance. Saibel, Salzberg, Doane, and Moffat (1999) found that the speed of vehicles in reduced-speed school zones (20 mph speed limit) was much greater on roads with approach speed limits of 35 mph than they were on roads with a normal speed limit of 25 mph. Greater effort must be put forth in order to guarantee better speed compliance for reduced-speed school zones with high approach speed limits (Saibel et al. 1999).

Speed compliance can also be achieved through better signage and regular law enforcement. In a Nebraska study, McCoy and Heimann (1990) concluded that, on roads with a speed limit of 35 mph or higher, the most effective reduced speed limit within school zones was 25 mph. The researchers found that the 85th percentile speeds in school zones with an approach speed limit of 35 mph were actually lower with a school-zone speed limit of 25 mph as opposed to speed limits of 20 and 15 mph (McCoy and Heimann 1990). However, nearly all of the reduced-speed school zones with 25 mph speed limits included signs with flashing beacons, while none of the reduced-speed school zones with speed limits of 20 and 15 mph operated with flashing beacons. For this reason, the conclusion that a reduced speed limit of 25 mph is the most effective speed limit may not be appropriate. The reason that the 85th percentile speed for these school zones was lower may be accredited to the flashing beacons or other unknown variables. Proper signage and regular enforcement should be used to increase speed compliance in school zones. Uniformity of reduced school-zone speed limits may also improve drivers' observance of the speed limit.

2.1.5 Crossing Guards

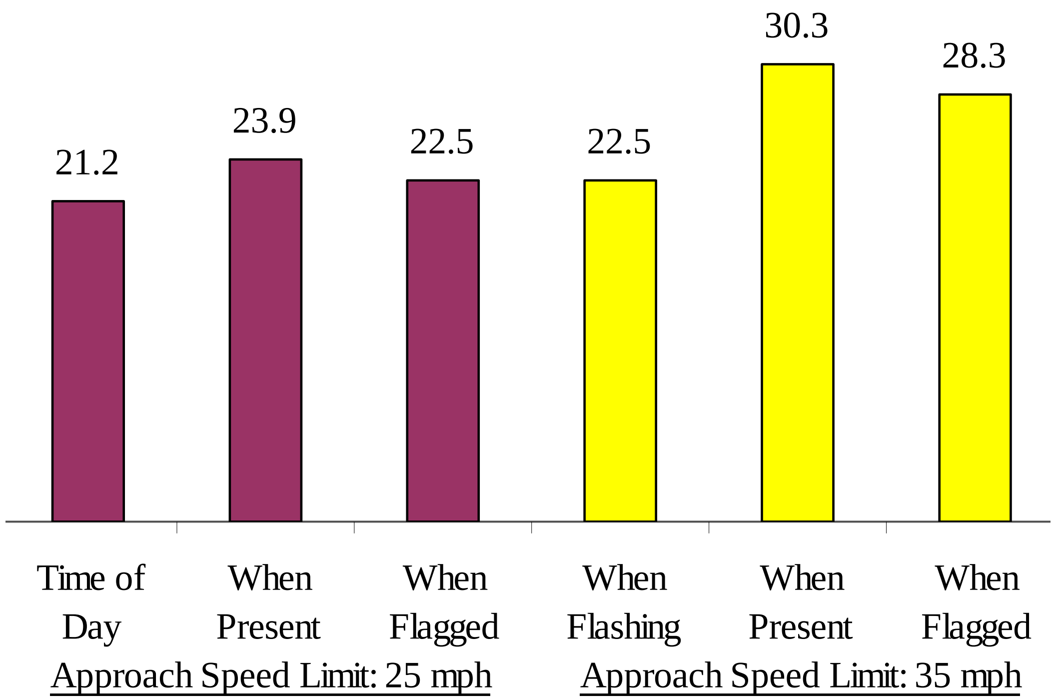
Although somewhat costly compared to other traffic control devices, crossing guards have been shown to aid in reducing speeds in school zones. These generous individuals assist students by choosing appropriate gaps in traffic to stop vehicles so children can safely cross the street. Crossing guards should teach the young children safe crossing techniques and pedestrian safety (UDOT 2003). A study performed by Zegeer, Havens, and Deen (1976) found that the presence of crossing guards contributed to about a 9 mph drop in speeds at five different school zones. At the same locations without the presence of crossing guards, the average speed reduction was only 2.7 mph (Zegeer et al. 1976). McCoy, Mohaddes, and Haden (1981) also reported a speed reduction due to crossing guards. They observed that the presence of crossing guards reduced vehicular speeds by about 2 to 5 mph (McCoy et al. 1981). Crossing guards definitely aid in reducing speeds and protecting children from accidents.

2.1.6 Signage

Just like any traffic control device, signs should demonstrate uniformity to simplify the task of driving and to help drivers recognize and understand the warnings that are being presented. For this reason, traffic engineers must determine which signs are the most effective at demanding drivers' attention.

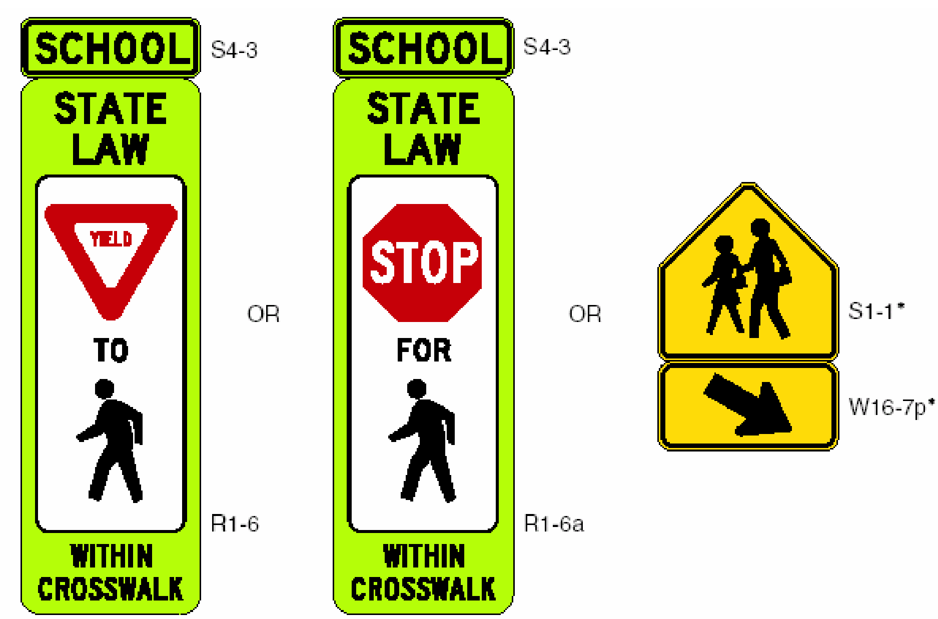
As mentioned previously, a study by Saibel, Salzberg, Doane, and Moffat (1999) helped verify what types of school-zone signs were most effective. Spot speed studies were conducted at 40 different school zones in the state of Washington. The study concluded that if the approach speed limit of the road was 25 mph, then the type of school-zone sign had no significant effect on vehicle speeds. On the other hand, the study also found that if the approach speed limit was about 35 mph (30 to 40 mph), then the most efficient sign was the "when flashing" one. The average speeds for school zones with different signs and approach speeds are illustrated in Figure 2-1. The type of sign used should depend on the approach speed limit of the school zone (Saibel et al. 1999).

The use of in-street signs as presented in Figure 2-2 can also make school zones more noticeable to drivers. The use of these signs should conform to the guidelines and standards outlined in the MUTCD. These signs are not required but can be used to make school zones more noticeable (MUTCD 2003).



(Source: Saibel et al. 1999)

Figure 2-1: Average Speed in School Zones vs. Sign Type and Approach Speed Limit



*Reduced Size – (Source: UDOT 2003)

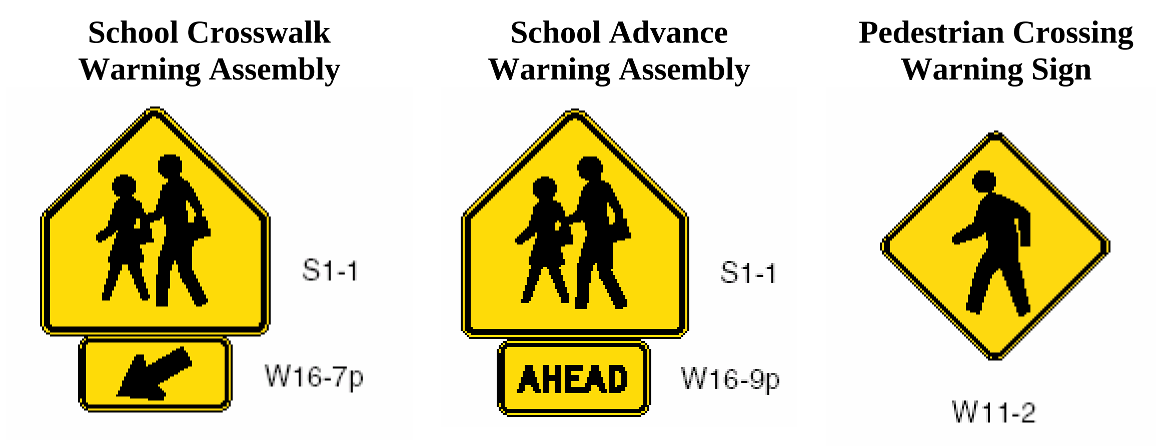
Figure 2-2: In-Street Signs for School-Zone Crosswalks

Redmon (2003) summarized a study that was performed using focus groups to assess the attitudes of both drivers and pedestrians. When using focus groups, researchers cannot generally guarantee any kind of statistically significant result; however, focus groups can be useful to assess attitudes and behaviors. Researchers found that those in the focus group of drivers felt that signs in the middle of the street were effective at making drivers, in general, more aware of the law to yield or stop for pedestrians (Redmon 2003). Kamyab (2003) assessed the effects of in-street signs at a rural pedestrian crossing (not in a school zone) and found that in-street signs were effective at reducing average speeds by about 5 mph and increasing speed compliance by about 24 percentage points (Kamyab 2003). When wisely implemented, in-street signs can compel drivers to slow down in school zones; however, engineers should be concerned that these signs could become dangerous projectiles if hit by approaching vehicles.

Another method of making school-zone signage more visible to drivers is the use of the newer fluorescent yellow-green (FYG) background on all school-zone signs. UDOT has reserved the FYG background for school-zone signs (UDOT 2003). The purpose behind doing this is to maintain uniformity of the signs while making school zones more visible to passing drivers. A group of researchers in Canada performed a study of the effects of the FYG background at pedestrian crossings. They concluded that FYG pedestrian signage did not produce any detectable safety benefit. The researchers did not discover significant changes in the mean percentage of motor-vehicle and pedestrian conflicts, nor in the mean percentage of drivers yielding to pedestrians when comparing signs made with the FYG background to signs made with the traditional white background (pedestrian signs in Canada are regulatory signs, hence the white background) (Van Houten et al. 2002).

One problem with the current school-zone signage is that it is very similar to the current pedestrian crossing signs. Even though they are different shapes and have different figures as illustrated in Figure 2-3, drivers often confuse the two signs. Ford and Picha (2000) found that teenage drivers had difficulty distinguishing between school advance warning signs and pedestrian crossing signs; they also confused school crossing signs for pedestrian crossing signs (Ford and Picha 2000). Perhaps the need exists to make school-zone signs more unique to maintain consistency and efficiency.

In summary, effective traffic control devices in school zones are essential to providing safe and appropriate gaps in traffic for children to cross the street. Controlling traffic and reducing vehicular speeds widens gaps in traffic and improves safety. The effectiveness of traffic control devices depends on location and individual circumstances; therefore, traffic engineers must use their best judgment to assign suitable traffic control devices in school zones while still maintaining uniformity. Flashing beacons have



(Source: MUTCD 2003)

Figure 2-3: Comparison of School-Zone Signs and Pedestrian Signs

proven to be effective in many instances to reduce speeds and make drivers more aware of their surroundings. Although pavement markings are limited by weather conditions and require frequent maintenance, they also alert drivers of the presence of school zones. When not warranted by the MUTCD, traffic signals in school zones can actually decrease safety. Compliance to reduced-speed zones can be met through proper signage and the presence of crossing guards. School zones demand appropriate traffic control devices and enforcement to provide safe and effective crossing for young students.

2.2 Speed Monitoring Displays in School Zones

Another method for reducing speeds and making drivers more aware of school zones is the use of SMDs. SMDs are signs that use radar to measure and display the speeds of approaching vehicles. As drivers view their speed displayed on a sign, they become more aware of their speed and their surroundings. SMDs attract attention to the roadways' surroundings by portraying the notion of possible danger ahead. Drivers decrease their speed due to a perceived risk of enforcement and due to their increased awareness of their actual speed. A number of studies have reported that SMDs enhance school-zone safety and efficacy. These studies are discussed in more detail in the paragraphs that follow.

Rose and Ullman (2003) evaluated the effectiveness of SMDs in and near school zones, as well as at other locations where speed was an issue. In a rural school zone for example, an SMD was placed next to the school-zone speed limit sign. The approach speed limit to the school zone was 55 mph. Speed data were collected 2200 feet upstream of the SMD (a control point) and at the SMD both before and after the SMD was installed. Immediately after the sign was installed, the SMD proved to reduce the average speed from 44.5 to 35.3 mph, the percentage of vehicles exceeding the school-zone speed limit (35 mph) from 95.3 percent to 34.1 percent, and the 85th percentile speed from 50 to 40 mph. These statistics were all measured directly adjacent to the SMD. Even after 4 months, the SMD proved to be effective at maintaining lower speeds. The average speed next to the SMD was measured to be 35.7 mph, the percent of vehicles exceeding the speed limit was 43.9 percent, and the 85th percentile speed was 42 mph (Rose and Ullman 2003). The results of the study indicate that the SMD was successful at increasing and maintaining speed compliance.

Rose and Ullman (2003) also evaluated the effectiveness of two SMDs located in advance of a reduced-speed school zone (35 mph). For the northbound direction, the sign was located about 1950 feet upstream of the school zone. For the southbound traffic, the sign was placed about 1100 feet upstream of the school zone. The school zone was located at a signalized intersection. The signs were placed in advance of the school zone in an attempt to slow vehicles down before they reached the zone. The signs were located where the speed limit was 45 mph and operated continuously since they were not located directly in the school zone. Speeds were measured directly adjacent to the SMDs. For the northbound direction, the average speed before the signs were installed was 55.2 mph. Immediately after the signs were installed, the average speed was 51.8 mph. After 4 months, the average speed was still found to be less than the initial average speed; however, the average speed was measured to be 2 mph more than the average speed immediately after the signs were installed. For the southbound direction, the average speed before the sign was installed was measured to be 47.7 mph. Immediately after the installation and about 4 months later, the average speeds were 45.1 and 46.3 mph, respectively (Rose and Ullman 2003). Unfortunately, data were not collected in the school zones to determine if the signs had any significant effect on speeds in the school zone. Less of a reduction in speed was measured in this scenario compared to when the SMDs were located in the school zone and only operated when the school zone was activated. In summary, SMDs may be more efficient when located in the vicinity of a school zone rather than in advance of one. The results of this study may also suggest that SMDs should be activated only during necessary time periods to avoid overuse.

An evaluation of SMDs in school zones conducted by the City of Garden Grove, California, also found SMDs to be effective at reducing speeds in school zones. Four signalized school zones were equipped with SMDs that were mounted on either the signal mast arm (suspended over the street) or on the signal pole. Each school zone was outfitted with an SR4R School-25 mph-when children are present sign that was located adjacent to the SMD. The SMDs were activated for two hours before and two hours after school. Researchers collected speed data before and after the SMDs were installed. Speed data were collected before and two to three months after the installation of the signs. The resulting 85th percentile speeds determined by the researchers are summarized in Table 2-2. Not only were the SMDs effective at reducing speeds, but they were also very well accepted by the public, including the local police department, schools, and parent organizations (Garden Grove 2003).

Casey and Lund (1993) discussed the effectiveness of SMDs on vehicular speeds in multiple locations. As part of this study, SMDs were tested at a number of sites, including five reduced-speed school zones (25 mph speed limit). Speeds were measured

Table 2-2: 85th Percentile Speeds for Different School Zones with SMDs Installed

Location (Street Name)	ADT	No. of Lanes	Speed Limit	Before	After	Percent Change
Springdale	11,800	4	35	42.7	33.8	20.8%
Orangewood	9,200	2	35	33.4	30.9	7.5%
Trask	29,200	4	35	44	34.2	22.3%
Buaro	8,000	2	25	26.9	25.4	5.6%

(Source: Garden Grove 2003)

using undetectable radar. The SMDs proved effective at significantly reducing vehicular speeds in school zones. Within the school zones studied, the signs were found to reduce the average speed by about 14 percent when the baseline average speed was 10 mph over the speed limit and by about 7 percent when the baseline average speed was about 5 mph over the speed limit. The average speeds measured before and after the SMDs were installed for the five different school zones were approximately 35 to 30 mph, 30 to 28 mph, 35 to 30 mph, 28 to 26.5 mph, and 32 to 27 mph (Casey and Lund 1993). The results of this study suggest that SMDs are effective at lowering speeds within school zones.

Bloch (1998) evaluated the effectiveness of using photo-radar and SMDs to lower speeds. SMDs and photo-radar separately proved to reduce speeds by about 4 to 5 mph. The effectiveness of the SMDs increased with law enforcement. All of these methods were especially effective on excessive speeds traveling 10 mph or more over the legal speed limit. The effects of the devices did not last very long after they were removed. As part of the research project, a cost-effectiveness study was performed and found that the use of SMDs without law enforcement was by far the most cost-effective method to reduce speeds (Bloch 1998).

Pesti and McCoy (2001) tested the effectiveness of SMDs in a series of work zones along I-80 in Nebraska. As part of the study, three SMDs were placed within a 2.7-mile strip of roadway that consisted of two work zones and were evaluated for a 5-week period. The SMDs proved to be effective at reducing the mean speed (3 to 4 mph reduction) and the 85th percentile speed (2 to 7 mph reduction). The signs were effective during the entire study and even had some residual effects after the signs were removed. The authors noted that the results may not have been the same in areas that have higher percentages of commuter traffic, assuming that commuters might become more accustomed to the signs (Pesti and McCoy 2001).

In summary, SMDs are an effective and efficient tool for reducing speeds in school zones. These signs give drivers a perceived sense of law enforcement. They also make drivers more aware of their surroundings and how fast they are actually traveling. Although little has been done to determine if SMDs maintain their effectiveness over a long period of time, SMDs have proven to reduce vehicular speeds in school zones for short periods of time.

2.3 Speed Enforcement in School Zones

Enforcement of traffic laws is essential to ensure obedience to such laws. Unfortunately, people sometimes fail to understand the purpose of traffic laws. For this reason, these laws are broken. Credible law enforcement must be used to provide drivers with a reason to slow down. Zegeer, Havens, and Deen (1976) found that "regular speed enforcement in school zones by police agencies caused average reductions of 8.4 mph at seven locations" (p. 39). The perceived risk of receiving a citation undoubtedly increases speed compliance in school zones.

2.3.1 Law Enforcement

Proper law enforcement is a necessity for maintaining speed compliance in school zones. Redmon (2003) summarized a study conducted for the Federal Highway Administration (FHWA) to assess general attitudes of drivers and pedestrians. Focus groups were used to obtain an understanding of the differing opinions between drivers and pedestrians. The researcher found that the drivers in the focus groups felt that they would slow down due to the presence of a police officer. Redmon also noted that "unfortunately, drivers were influenced more by the thought of getting a ticket than by endangering a life" (2003, p. 29). The drivers in the focus groups also felt that reminders were necessary for drivers to remember the laws with respect to pedestrians in the roadway. They thought that drivers should be reminded of the laws regarding pedestrians upon renewing their licenses (Redmon 2003). Regular police enforcement seems to have a great impact on drivers' attitudes toward speeding.

Law enforcement is expensive compared to other traffic control devices. Fortunately, once law enforcement officials have established their presence and credibility in a school zone, these officials need not patrol that zone as frequently. McCoy, Mohaddes, and Haden (1981) concluded that school speed zones were only effective when drivers sensed a need for caution and when the credibility of enforcement was perceived. They found that once law enforcement had established credibility, less enforcement was necessary to maintain compliance. They also concluded that the desired reduction in speeds at school crossings could not be achieved without credible law enforcement (McCoy et al. 1981). Law enforcement is crucial for maintaining and promoting compliance with school-zone speed limits.

2.3.2 Fines

Jones, Griffith, and Haas (2002) conducted a study for ODOT and the FHWA to measure the effectiveness of using double fines in reduced-speed zones. The study examined the use of double fines in areas such as work zones, school zones, and other safety corridors. Double fines have been used in Oregon school zones since 1997; however, the use of double-fine warning signs is rare. Since signs indicating the enforcement of double fines were rarely used in school zones prior to this study, drivers did not commonly notice them when the signs were present. When the signs were noticed, they were effective at influencing drivers to change their speed. The authors noted that “awareness of the applicability of double fines in school zones elevates the perception of the risk of traffic fines, traffic citations, and higher insurance rates” (Jones et al. 2002, p. 34). Drivers will reduce their speed in school zones if they are aware that they will be issued double fines for speeding in such zones. Since most people work hard for their money, they would prefer to hold on to it, as opposed to paying excessive fines. Educating the public about the risk of increased fines for speeding in school zones can improve speed limit compliance and therefore enhance safety in school zones.

2.4 Other Speed Influences

In addition to school-zone traffic control devices and law enforcement, other factors can influence drivers’ speeds, including traffic calming enhancements and the presence of pedestrians. Surely, anything that gives drivers a reason or perceived reason to slow down will reduce speeds. McCoy and Heimann suggested that speeds in school zones are influenced more by the normal speed limits and speed characteristics of the streets than by the school speed limits (McCoy and Heimann 1990). Changing geometric alignments, lane narrowing, speed humps, and other physical changes to roadways can cause vehicles to slow down. Drivers must perceive a reason for slowing down in school zones, or they will most likely not slow down. By using multiple methods to slow vehicles, traffic engineers can influence a greater percentage of drivers and thereby improve the safety and efficiency of school zones.

2.4.1 Other Enhancements

Physical changes to a roadway can give drivers a reason to slow down; however, the implementation of such changes can cause speed reduction during other time periods as well. The building of a school on or near busy streets should be avoided to limit pedestrian-vehicle conflicts and to minimize the need to slow vehicles.

Other traffic calming techniques can be used to slow vehicles. Schrader (1999) evaluated the effectiveness of other less common school-zone traffic control devices. Schrader tested the effectiveness of five different school-zone traffic control devices at five different school zones. The devices included fiber optic signs, spanwire-mounted flashing beacons, post-mounted flashing beacons, transverse lavender stripes, and large painted legends. Schrader found that all of these devices caused at least a slight reduction in the 85^{th} percentile speed; however, only one caused a statistically significant reduction. That one traffic control device was the fiber optic sign. The fiber optic sign was blank when the school zone was not active, but displayed the school-zone speed limit of 20 mph when the school zone was active (Schrader 1999). Perhaps each of the devices tested in this study would have been more effective in different school zones. Traffic engineers must be creative and consider many factors when attempting to slow traffic.

2.4.2 Presence of Pedestrians

Two particular studies have found that the presence of pedestrians reduces speeds in school zones (McCoy et al. 1981, Zegeer et al. 1976). When drivers see the presence of pedestrians, they become more aware of a possible conflict and therefore reduce their speed. Providing adequate sight distance between pedestrians and drivers is very important in order to increase safety. Pedestrians, especially child-pedestrians, should be taught to make themselves more visible to oncoming traffic in order to reduce the risk of unnecessary conflicts.

2.5 Chapter Summary

In summary, traffic engineers should use multiple forms of traffic control devices to guarantee better speed compliance. Traffic engineers should work together with law enforcement officers to increase speed compliance and therefore improve the safety and efficiency of school zones. Uniformity of traffic control devices, effective and noticeable traffic control devices, education, and proper law enforcement are all necessary to assure drivers are compliant with reduced school-zone speed limits.

Chapter 3 Public Opinion Survey

Traffic engineers must interpret drivers' feelings and reactions toward traffic control devices to guarantee desired safety and order. In this research, a public survey was written and implemented to evaluate the feelings and concerns of Utah drivers with respect to school-zone safety and traffic control devices. Questions in the survey were designed to decipher drivers' opinions and views about school-zone safety in general. The survey was also designed to determine how well Utah drivers feel they comply with the school-zone speed limit. Possible school-zone safety enhancements were also considered and evaluated. The results were analyzed and compared to formulate possible changes or enhancements that should take place in UDOT school zones. The survey was implemented in various locations throughout the state of Utah. The study focused on how to improve and maintain speed limit compliance in school zones.

This chapter describes the questionnaire used to survey Utah drivers. The data collection procedures and analyses are discussed, and the results of the survey are presented, including an analysis to find statistically significant relationships between drivers' responses. A summary of the findings from the public survey is located at the end of the chapter.

3.1 Description of Questionnaire

The questionnaire was designed to evaluate the attitudes and opinions of Utah drivers toward school-zone traffic control devices and child-pedestrian safety. The survey attempts to depict drivers' opinions about children's abilities to safely cross the street. The survey also endeavors to determine speed compliance in school zones based on drivers' opinions. Drivers' views about their own speed compliance in school zones are later compared to the actual speed data collected and presented in Chapter 4. Some of the questions in the survey were intended to establish the most significant factors influencing speeds within school zones. Drivers were asked to rank various school-zone traffic control devices based on how they influence their speed. In addition, a few of the questions were specifically related to SMDs. An attempt was made to determine drivers' attitudes toward improving school zones through better signage, enforcement, and traffic control devices. The questionnaire form consisted of two sides as shown in Figure 3-1 and Figure 3-2.

Public Survey: School Zone Safety

This is a **completely anonymous** survey conducted by BYU students to determine drivers' opinions of school zone safety measures. There are 20 short questions that take just a few minutes to answer. Completing this survey is voluntary. Please answer each question honestly. Participants must be at least 18 years old, or have parental consent.

1.) Gender: **Male** **Female**
Age: **16-17** **18-25** **26-35** **36-50** **Over 50**

2.) How often do you drive a motor-vehicle? *(Check one)*
a.) About everyday **c.) Just a few times a month**
b.) A few times a week **d.) Rarely**

3.) If you do ***not*** have school-age children, go to question 5. If you do, how do they most commonly get to and from school? *(Check any that apply)*
a.) They walk or ride their bike alone **d.) They ride the school bus**
b.) They walk, but are escorted by an adult **e.) They are driven by another person**
c.) They ride public transit **f.) They drive themselves**

4.) What type of schools do your children attend? *(Check any that apply)*
a.) Preschool **c.) Junior High/Middle School**
b.) Elementary School **d.) High School**

5.) There is need for more child pedestrian education in schools. *(Circle one)*
Strongly Agree **Agree** **Somewhat Agree** **No Opinion** **Somewhat Disagree** **Disagree** **Strongly Disagree**

6.) The majority of young students understand how to safely cross the street. *(Circle one)*
Strongly Agree **Agree** **Somewhat Agree** **No Opinion** **Somewhat Disagree** **Disagree** **Strongly Disagree**

7.) In your opinion, how important is it that vehicles slow down in school zones? *(Circle one)*
Extremely Important **Important** **Somewhat Important** **Not Important** **No Opinion**

8.) What is the uniform speed limit for reduced speed school zones in Utah? *(Check one)*
a.) 15 mph **c.) 25 mph**
b.) 20 mph **d.) 30 mph**

9.) The majority of people comply with the school zone speed limit. *(Circle one)*
Strongly Agree **Agree** **Somewhat Agree** **No Opinion** **Somewhat Disagree** **Disagree** **Strongly Disagree**

10.)How often do you drive through a school zone during the reduced speed times? *(Check one)*
a.) More than twice in a day **c.) A few times a week** **e.) Never**
b.) About once or twice a day **d.) Rarely**

11.)I obey the speed limit in school zones... *(Circle one)*
Always **Most of the time** **About 75% of the time** **About half the time** **About 25% of the time** **Rarely** **Never**

12.)When you speed in school zones, approximately how much over the speed limit are you traveling? *(Check one)*
a.) 0 – 5 mph **c.) 10 – 15 mph** **e.) over 20 mph**
b.) 5 – 10 mph **d.) 15 – 20 mph**

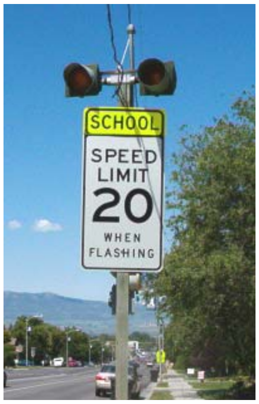
13.)If you have sped through a school zone before, what was the main reason for speeding? *(Check one)*
a.) You were not aware it was a school zone until it was too late.
b.) You were in a hurry or late for something (for example, work or school).
c.) You felt it was unnecessary to slow down due to absence of children.
d.) You felt it was inconvenient to slow down, even when children were present.

e.) Other ____

(Continue on Back)

Figure 3-1: Front Side of Public Survey

14.)Rank the following factors from 1 through 5 (1 being the most influential) that influence your speed while driving through a school zone.



_____ **Flashing Beacons above Speed Limit Sign *(Left)***

_____ **Presence of children**

_____ **Presence of Law Enforcement**

_____ **Presence of Crossing Guard**

_____ **Police operated portable electronic signs that display drivers' speed *(Right)***

15.)How helpful are the electronic signs *(above right)* that display vehicle speeds at informing you of your speed while driving? *(Check one)*

a.) Very helpful **c.) Sometimes helpful** **e.) Never helpful; I always know how fast I am going**
b.) Helpful **d.) Rarely helpful**

16.)The electronic signs that display vehicle speeds are effective at making me aware that there might be danger ahead. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

17.)The electronic signs that display vehicle speeds are effective at causing me to slow down. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

18.)The new florescent yellow-green school zone signs help increase the awareness of the presence of school zones in comparison to the old yellow signs. *(Circle one)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

19.)Were you aware that there are increased fines for speeding in school zones? *(Circle one)*

Yes **No**

20.)It is important and/or necessary to improve school zones (for instance, better signs, more traffic control devices, more law enforcement, etc.). *(Circle one and briefly explain)*

Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree

What can be done? ____

____

Thank you for your time and for completing this survey!

If you have any questions about this survey, you may contact Dr. M. Saito at (801) 422-6326. If you have any questions regarding your rights as a participant in research projects, you may contact Dr. Renea Beckstrand, IRB Chair, BYU, 422 SWKT, Provo, UT 84602, (801) 422-3873, renea_beckstrand@byu.edu.

Figure 3-2: Back Side of Public Survey

3.2 Data Collection and Analysis

Once the survey was written, the data collection began. Several students were hired to assist in collecting data. The survey was administered in four general areas throughout the state of Utah as described in Section 3.2.1. The areas were in the immediate vicinity of the four school zones that would have the new SMDs added to them for evaluation in this research. Surveys were collected at public libraries and gas stations at these four areas. After completing the survey, those surveyed were offered a small compensation for their time (e.g., candy, soft drinks, etc.). The total number of surveys collected was 762. A wide variety of people were surveyed in the study as discussed in Section 3.2.2.

3.2.1 Survey Locations

As mentioned earlier, surveys were collected in four general areas of the state consistent with the locations of the new SMDs: Logan, Salt Lake City, Provo/Pleasant Grove (combined), and Goshen/Santaquin (combined). In Logan, surveys were collected as people entered and exited the Logan City Public Library and as people purchased gasoline at the Chevron Gas Station on the corner of Main Street and 400 North. In Salt Lake City, the second area where surveys were collected, questionnaires were handed out at the Salt Lake City Main Public Library (400 South and 200 East) and at a Chevron Gas Station on the corner of 900 South and State Street. The third general area where surveys were collected was in the Cities of Provo and Pleasant Grove. These two cities were combined for analysis purposes since they are in close proximity to one another and are very similar in nature. Data in this area were collected at both the Provo and Pleasant Grove Public Libraries and at a Chevron Gas Station on the corner of University Avenue and 3700 North in Provo. The last general area where surveys were gathered was in the Cities of Goshen and Santaquin. These two cities were also combined for analysis purposes since they are in close proximity to one another and are both located in a rural setting. In Goshen, surveys were collected as parents picked up their children from the Goshen Elementary/Middle School. In Santaquin, questionnaires were handed out as people purchased gasoline at the Conoco Gas Station in the middle of town. A map of the survey locations is provided in Figure 3-3.

Figure 3-3: Map of Survey Locations

3.2.2 Demographic Information

Of the 762 people surveyed, 335 people (44 percent) were male, 358 people (47 percent) were female, and 69 people (9 percent) did not specify. Of those surveyed, 280 people (37 percent) were between the ages of 16 and 25, 206 people (27 percent) were between the ages of 26 and 35, 160 people (21 percent) were between the ages of 36 and 50, and 91 people (12 percent) were over the age of 50. The remaining 25 people (3 percent) did not specify their age group. The survey was translated into Spanish in an attempt to determine any differences between the Spanish population and the English population. However, only 24 of the Spanish surveys were completed.

Of those surveyed, 603 people (79 percent) indicated that they drive a motor vehicle everyday, 54 people (7 percent) only drive a few times a week, 26 people (3 percent) said they only drive a few times a month, while 79 people (10 percent) said they rarely drive. Although the ratio of those who indicated that they rarely drive seems to be more than would be expected, this high percentage is most likely attributed to a high number of transit riders surveyed at the Salt Lake City Public Library. The results of the survey concluded that 274 people (36 percent) had school-aged children, and 488 people (64 percent) did not.

3.3 Drivers' Opinions

As mentioned earlier, the survey was designed to evaluate the driving public's opinions about school-zone safety. Questions related to child pedestrians' abilities to safely cross the street were evaluated to establish a need for school zones. Also, speed compliance was measured based on drivers' opinions. Factors influencing speeds in school zones were compared to determine the most effective traffic control devices for school zones. An effort was also made to determine drivers' opinions about SMDs in school zones. The main purpose of the survey, however, was to find out exactly what the public thinks about improving school zones to provide students with a safe commute to and from school. The results of the survey are discussed in more detail in the subsections that follow. All of the statistics presented in these subsections exclude missing responses; hence, the total number of responses in the tables may not add up to 762.

3.3.1 Children's Abilities to Cross the Street

Drivers were asked whether they agreed or disagreed with two different statements with respect to how they felt about children's abilities to safely cross the street (questions 5 and 6). Table 3-1 shows the number of people for each possible response to these two statements. The results for the first statement indicate that drivers sense a need to further educate young children in pedestrian safety (87 percent in the "agree" side). The results for the second statement were more widely distributed (65 percent in the "agree" side); however they still show that drivers are not very confident about young students' abilities to safely cross the street. This suggests a need for more pedestrian

Table 3-1: Drivers' Feelings about Children's Abilities to Cross the Street

5.) There is need for more child pedestrian education in schools.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
269 (35.5%)	306 (40.4%)	86 (11.3%)	77 (10.2%)	10 (1.3%)	4 (0.5%)	6 (0.8%)
6.) The majority of young students understand how to safely cross the street.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
33 (4.4%)	161 (21.2%)	299 (39.4%)	35 (4.6%)	136 (17.9%)	75 (9.9%)	19 (2.6%)

education for young students. Parents, crossing guards, and teachers can and should provide this education to these children.

3.3.2 School-Zone Speed Limit Compliance

Of those surveyed, 663 people (87 percent) ranked the importance of slowing down in school zones (question 7) as “extremely important.” Another 84 people (11 percent) felt slowing down in school zones was “important.” Not a single person expressed that slowing down in school zones was “not important.” The majority of those surveyed (70.6 percent) were aware of Utah’s uniform speed limit for reduced-speed school zones (question 8) as summarized in Table 3-2. Still, almost 30 percent answered incorrectly. Perhaps drivers should be reminded of the school-zone speed limit, as well as other traffic safety laws, every time they renew their license. The use of a uniform speed limit for reduced-speed school zones may be the reason why the majority answered correctly. Uniformity eases the task of driving for all and can be a cause of higher speed limit compliance.

Utah drivers seem to be very compliant with school-zone speed limits. The results of three questions from the survey (questions 9, 11, and 12) related to school-zone speed limit compliance are summarized in Table 3-3. When those surveyed were asked if the majority of people comply with the school-zone speed limit, a variety of responses

Table 3-2: Drivers' Knowledge of Uniform Speed Limit for Reduced-Speed School Zones in Utah

8.) What is the uniform speed limit for reduced-speed school zones in Utah?			
15 mph	*20 mph	25 mph	30 mph
161 (21.2%)	537 (70.6%)	60 (7.9%)	3 (0.3%)

**Correct Answer*

Table 3-3: Survey Results on Speed Compliance in School Zones

9.) The majority of people comply with the school-zone speed limit.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
21 (2.8%)	146 (19.3%)	259 (34.2%)	23 (3.0%)	155 (20.4%)	113 (14.9%)	41 (5.4%)
11.) I obey the speed limit in school zones…						
Always	Most of the time	About 75% of the time	About half the time	About 25% of the time	Rarely	Never
493 (65.0%)	200 (26.4%)	38 (5.0%)	17 (2.2%)	5 (0.7%)	5 (0.7%)	1 (0.1%)
12.) When you speed in school zones, approximately how much over the speed limit are you traveling?						
	0-5 mph	5-10 mph	10-15 mph	15-20 mph	Over 20 mph	
	628 (83.4%)	81 (10.8%)	27 (3.6%)	13 (1.7%)	4 (0.5%)	

were observed (only 56.3 percent in the “agree” side). However, when asked how they as individuals obey the school-zone speed limit, most people claimed to be very compliant (91.4 percent responded with “always” or “most of the time”). Very few actually admitted to speeding in school zones. These results are later compared to the actual speed limit compliance found in the four school zones discussed in Chapter 4.

3.3.3 Speed Influences

Another purpose of the survey was to determine what traffic control devices and/or other factors have the most significant influence on drivers’ speeds. When asked, “If you have sped through a school zone before, what was the main reason for speeding?” in question 13, 446 respondents (59 percent) chose the response, “You were not aware it was a school zone until it was too late.” Whether this is the fault of the driver for simply not paying attention or the result of insufficient traffic control and warning devices is unclear. Perhaps both are to blame.

The second most popular reason for speeding in a school zone was that drivers "felt it was unnecessary to slow down due to the absence of children." This response was selected by 72 people (9.4 percent). These drivers could be deterred from speeding by avoiding excessive reduced-speed time periods. In other words, a minimum time should be used when speeds are to be reduced to maximize roadway capacity and maintain the effectiveness of the school-zone traffic control devices.

Another 66 people (8.7 percent) said their reason for speeding in a school zone was because they "were in a hurry or late for something." Traffic engineers can do little to solve this problem. Law enforcement is most likely the best solution to cause these drivers to slow down in school zones.

The last reason for speeding in a school zone was that people "felt it was inconvenient to slow down, even when children were present." Fortunately, only 10 people out of 762 (1.3 percent) chose this answer. The attitude these drivers have is extremely selfish and therefore makes slowing these drivers down very difficult for traffic engineers alone. Stricter fines and penalties for these drivers may cause them to increase their compliance with school-zone speed limits.

Another 105 people (13.8 percent) simply left this question blank for not having sped in a school zone before. The remaining 63 people (8.3 percent) marked "other" and stated that they do not speed in school zones, or they gave some other reason for speeding. Of the few other reasons for speeding mentioned by drivers, none stood out as significant enough to document. Since the most common reason for speeding in school zones is that drivers are not aware of the reduced-speed zone, more noticeable traffic control devices should be used to attract drivers' attention.

Drivers were also asked to rank five different factors that influence their speed while driving through a school zone (question 14). The five factors included flashing beacons, the presence of children, the presence of law enforcement, the presence of a crossing guard, and SMDs. Those surveyed were asked to rank these factors from one to five, with one being the most influential and five being the least influential. For each factor, the number of drivers was counted for each specific rank (one through five), and the average ranking was then calculated. The results of the analysis are summarized in Table 3-4. Only the surveys that properly ranked the factors from one to five were evaluated to avoid an unbalanced ranking of each factor. Five hundred and seventy-four people ranked the five factors as anticipated. The results after disregarding those who failed to follow the correct procedure when ranking the five factors were actually very similar to the results of summing the rankings for each factor before disregarding some of the surveys (the lowest sum being the most influential).

As noted in Table 3-4, the most dominant factor influencing drivers' speeds is the presence of children. Hence, a need definitely exists to maintain adequate sight distance between drivers and pedestrians to ensure that drivers are aware of the presence of children. Prohibited parking in school zones helps establish appropriate sight distance. Traffic engineers must provide adequate sight distance between pedestrians and drivers to assure safety and to reduce vehicular speeds.

The second most influential factor is the use of flashing beacons above the school-zone speed limit sign. As mentioned earlier, flashers are effective at attracting attention to the presence of a school zone since they are only active when drivers should be more cautious. Flashing beacons are necessary for reduced-speed school zones.

Drivers ranked the presence of law enforcement as the third most influential factor out of the five according to the average ranking. However, the most common rank given to the presence of law enforcement was fourth. Similarly, the ranking of the presence of crossing guards resulted in the fourth most significant factor according to the average ranking; however, the most common rank it received was third.

Surprisingly, SMDs were ranked as the least effective of the five factors. Drivers may have ranked the SMDs as the least effective since they have rarely been used in Utah school zones. Nevertheless, drivers feel that SMDs influence their speed and make them more aware of their speed and of their surroundings. Since SMDs were ranked the lowest and still prove to be effective, all five of the factors have great potential to significantly reduce speeds in school zones.

Table 3-4: Drivers' Rankings of Factors Influencing Speed in School Zones

Flashing Beacons Above Speed Limit Sign						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	176	141	90	86	81	2.57
Presence of Children						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	244	163	89	44	34	2.06
Presence of Law Enforcement						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	89	132	90	155	108	3.11
Presence of Crossing Guard						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	32	100	234	141	67	3.19
Police Operated Portable Electronic Signs that Display Drivers' Speeds (SMDs)						
Rank	1	2	3	4	5	Average Ranking
No. of Drivers	33	38	71	148	284	4.07

Increasing driver awareness can help to reduce vehicle speeds in school zones. Recently UDOT has reserved the FYG sign background for school-zone signs to help set them apart from other signs and to maintain uniformity. As part of the public survey, drivers were asked if the new FYG school-zone signs help increase the awareness of school zones compared to the old yellow signs (question 18). The results to this question are summarized in Table 3-5. As noted in the table, 599 of 762 people (78.6 percent) agreed that the new signs were more effective at making school zones more visible to drivers than the traditional yellow signs.

As noted in the literature review, increased fines have proven to be effective at reducing speeds. Utah currently penalizes drivers who speed in school zones with larger fines than given for speeding on other sections of roadway. Of those surveyed, 168 drivers (22 percent) were not aware of increased fines for speeding in Utah school zones (question 19). These results suggest a need to educate Utah drivers about increased fines for speeding in school zones. As the perceived risk of increased fines and more severe penalties is increased, speed conformity is enhanced, and safety is improved.

Both improving traffic control devices and increasing law enforcement enhance the safety and utility of school zones due to the reduction of vehicular speeds. Traffic

Table 3-5: Effectiveness of Fluorescent Yellow-Green Background for School-Zone Signs

18.) The new fluorescent yellow-green school-zone signs help increase the awareness of the presence of school zones in comparison to the old yellow signs.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
176 (23.6%)	288 (38.6%)	135 (18.1%)	124 (16.6%)	13 (1.7%)	4 (0.5%)	7 (0.9%)

control devices should be extremely visible to drivers. This enhanced visibility improves drivers' awareness, decreases speeds, and augments safety. Law enforcement also gives drivers more reason to decrease their speed in school zones. The combination of law enforcement and traffic control devices reduces speeds and supplements safety.

3.3.4 Effectiveness of Speed Monitoring Displays

As documented earlier in the literature review portion of this report, SMDs have proven to increase drivers' awareness of school zones and to reduce speeds. Various questions (questions 15, 16, and 17) in the survey were designed to verify the public's opinion about the effectiveness of these signs. The results associated with these questions are summarized in Table 3-6. According to those surveyed, SMDs are very effective at increasing drivers' awareness of their surroundings and of their speed. The results also provide evidence that SMDs are effective at reducing speeds. SMDs caution drivers to reduce their speed in school zones by increasing their awareness.

Table 3-6: The Effectiveness of Speed Monitoring Displays

15.) How helpful are SMDs at informing you of your speed while driving?						
Very Helpful	Helpful	Sometimes Helpful	Rarely Helpful	Never Helpful; I always know how fast I am going		
335 (44.8%)	175 (23.4%)	132 (17.7%)	62 (8.3%)	43 (5.8%)		
16.) SMDs are effective at making me aware that there might be danger ahead.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
177 (23.6%)	240 (32.0%)	130 (17.3%)	67 (8.9%)	61 (8.1%)	52 (6.9%)	23 (3.2%)
17.) SMDs are effective at causing me to slow down.						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
195 (26.0%)	301 (40.1%)	136 (18.1%)	27 (3.6%)	36 (4.8%)	37 (4.8%)	19 (2.5%)

3.3.5 Need to Improve School Zones in Utah

The last question in the survey (question 20) asked drivers about their feelings with respect to the importance and/or necessity of improving school zones in Utah through better signage, more traffic control devices, and increased law enforcement. The results for this question are summarized in Table 3-7. Of those surveyed, 670 Utah drivers (89.8 percent in the "agree" side) sensed a need for such improvements.

In summary, the majority of Utah drivers sensed the importance of protecting young children from accidents. The drivers surveyed believed that a need exists to better educate young children about proper pedestrian safety. For the most part, drivers claimed to be very compliant with the reduced school-zone speed limit. Flashing beacons, the presence of children, the presence of law enforcement, the presence of a crossing guard, and SMDs all proved to be effective tools at reducing speeds within school zones. Educating the public, providing better traffic control devices, and increasing law enforcement will reduce speeds and provide children with a safer commute to and from school.

Table 3-7: The Need to Improve School Zones in Utah

20.) It is important and/or necessary to improve school zones (for instance, better signs, more traffic control devices, more law enforcement, etc.)						
Strongly Agree	Agree	Somewhat Agree	No Opinion	Somewhat Disagree	Disagree	Strongly Disagree
268 (35.9%)	291 (39.0%)	111 (14.9%)	44 (5.9%)	20 (2.7%)	10 (1.3%)	2 (0.3%)

3.4 Statistically Significant Relationships between Drivers' Responses

Survey-question responses were compared and analyzed using a Chi-square test. The Chi-square test is useful to find out if there is a relationship between drivers' responses to two different questions. For example, the test shows if there is a difference in the way a parent answered a particular question compared to a non-parent. The test does not point out what that relationship is; it simply suggests that substantial evidence of a relationship exists by comparing the actual frequency observed to an expected frequency. Personnel in the BYU Center for Statistical Consultation and Collaborative Research assisted in performing the analysis using SAS statistical analysis software. The results of the analyses are provided in Appendix A. As shown in Appendix A, some questions were modified by combining responses or simply eliminating them from the analysis to more fully meet the requirements or assumptions needed for the test to be accurate (e.g., the expected values in each cell needs to be greater than or equal to five). For example, when comparing speed compliance (question 11) to other questions, the last few possible choices (i.e., "about half the time," "about 25 percent of the time," "rarely," and "never") were combined into one category ("50% or less") to better satisfy the assumptions made for the Chi-square test. Since very few people circled those responses, the expected values were not sufficient to meet the Chi-square test assumption. Other questions were similarly modified to more accurately depict relationships between questions.

After approximately 100 Chi-square tests comparing different questions were performed, a variety of relationships were found. Due to the large number of tests performed, a Bonferroni test was implemented to avoid making false conclusions. More information about the Bonferroni test can be found on the internet (Wolfram Research 1999). This test suggested that a *p*-value less than or equal to 0.0005 would produce a more reliable result than the traditional *p*-value of 0.05. Using a *p*-value of 0.0005 or smaller would minimize the chances of obtaining a false positive (i.e., the chance that an insignificant relationship may be called significant). Given this criterion, relationships were encountered between speed compliance and other survey questions, between drivers' ages and a few of the drivers' opinions, and between the location where the surveys were collected and a few of the drivers' responses. A few other relationships were found as well. The results of these comparisons are discussed in further detail in the subsections that follow. The results of these comparisons allow professionals to focus their efforts on specific groups of people to improve the safety and efficiency of school zones. These comparisons also allow for more profound and in-depth conclusions compared to simply considering rough percentages.

3.4.1 Relationships with Speed Compliance in School Zones

From the Chi-square analysis, three of the survey questions were found to have significant relationships with speed compliance (question 11). Those relationships with speed compliance included having or not having school-aged children (question 3), age (question 1), and the frequency of driving through a school zone (question 10). Another relationship between the extent of exceeding the speed limit (question 12) and the reason for speeding (question 13) was also found. These comparisons provide some possible reasoning and conclusions for why certain people speed in school zones.

The first relationship encountered was speed compliance with having school-aged children. The results of this comparison are summarized in Table A-1 of Appendix A.

From the analysis, an observation was made that those who have children are more likely to "always" obey the speed limit than those who do not have children. Of those who do not have children, more people than expected were observed to have chosen a speed compliance of "most of the time" or "75% of the time." The exact opposite was observed for those who have children. Having children caused respondents to describe their compliance with school-zone speed limits as more compliant compared to those who did not have children.

The way people described their compliance with school-zone speed limits was also dependent on people's ages. The result of this comparison is summarized in Table A-2 of Appendix A. Those between the ages of 16 and 25 years old were more prone to describing their compliance as "most of the time" or "75% of the time" instead of "always" compared to the older age groups. Still, about 52 percent of this age group (16 to 25 years old) said they "always" obey the school-zone speed limit; however, compared to the other age groups, this was considerably less. The percentage of those who chose "always" when describing their compliance was observed to increase with increasing age.

A relationship between the frequency of driving through a school zone and the admittance to school-zone speed limit compliance was also observed (Table A-3 of Appendix A). A discovery was made that the percentage of those who rarely drive through a school zone who admitted to "always" obeying the speed limit was lower than expected, and the other responses (i.e., "most of the time," "75% of the time," or "50% of the time") were somewhat higher than expected. Since the main reason for speeding among all drivers was that they were simply unaware of the school zone, drivers who rarely drive through school zones may have more reason to slow down if the school zones are more visible (i.e., better signs, pavement markings, traffic control devices, etc.). These drivers perhaps require more visible and noticeable school zones since they rarely come across such an area and are not as familiar with them. Drivers who commonly drive through school zones seem to be more compliant than those who do not.

The last variable exhibiting a relationship with speed compliance was the drivers' reason for speeding through school zones (question 13). The results of this comparison are summarized in Table A-4 of Appendix A. The extent of exceeding the school-zone speed limit (question 12) differed among drivers based on their reason for speeding (question 13). Unfortunately, all of the assumptions for the Chi-square test were not met. In other words, the relationship between the extent of exceeding the school-zone speed limit and the reason for speeding may or may not be statistically significant due to the fact that the expected values in a third of the cells were less than five (Table A-4 of Appendix A). Nevertheless, the data still suggest that drivers are more likely to exceed the speed limit by 10 mph or more if they chose reason (c) ("You felt it was unnecessary to slow down due to the absence of children") or reason (d) ("You felt it was inconvenient to slow down, even when children were present"). Even though only 10 people (1.3 percent) chose reason (d), five of those 10 said they have traveled 10 mph or more over the speed limit in school zones, which is a much higher percentage compared to the other reasons for speeding. Perhaps the only way to reduce these excessive speeds, if any, is to increase law enforcement.

From these comparisons, a few conclusions and recommendations can be made to increase speed compliance in school zones. First, if any effort is made to educate and inform the public of the need for and importance of slowing down in school zones, the focus should be placed on younger age groups and on those who do not regularly drive through school zones since these groups are more prone to speeding in school zones. However, efforts should not be solely devoted to these groups alone. Other factors that can increase speed compliance in school zones include more visible signage, pavement markings, and traffic control devices with an increase of law enforcement. The combination of education, traffic engineering, and law enforcement together can effectively improve school-zone speed limit compliance.

3.4.2 Responses Varying by Age

Three additional relationships were found between the ages of those surveyed and the responses to other questions. Responses concerning the importance of slowing down in school zones (question 7) (Table A-5 of Appendix A), the helpfulness of SMDs at informing drivers of their speed (question 15) (Table A-6 of Appendix A), and the effectiveness of SMDs at making drivers aware of possible danger ahead (question 16) (Table A-7 of Appendix A) all varied with the age of the respondents.

For those 16 to 25 years old, more people than expected chose “important” or “somewhat important” compared to “extremely important” with respect to slowing down in school zones. Only 80 percent of the respondents from 16 to 25 years old thought it was “extremely important.” In comparison, nearly 93 percent of the rest of the age groups felt that slowing down in school zones was “extremely important.” Once again this comparison suggests more of a need to educate and inform drivers between the ages of 16 and 25 years old.

The helpfulness of SMDs at informing drivers of their speed and the effectiveness of SMDs at making drivers aware of possible danger tended to increase with age. This again suggests that more effort may be needed to slow down younger drivers. These comparisons tend to imply that the effectiveness of SMDs increases with the age of the driver. Despite this difference in age groups, SMDs still prove to effectively influence drivers' awareness, as demonstrated by the overall results of the survey.

Obviously, age influences drivers' attitudes. Even though a distinct difference exists among the age groups, difficulty may be encountered when attempting to pinpoint each group to cause them to slow down. However, if any emphasis is placed on a particular age group to reduce speeds, that emphasis should be focused on younger drivers.

3.4.3 Answers Varying by Location

Two particular differences were found in the way drivers responded to the survey questions based on the location where the survey was collected. As mentioned earlier, the survey locations were divided into four main groups: Logan, Salt Lake City, Provo/Pleasant Grove, and Goshen/Santaquin. The two differences between locations included knowledge of Utah's uniform speed limit for reduced-speed school zones (question 8) (Table A-8 of Appendix A) and obedience to the school-zone speed limit (question 11) (Table A-9 of Appendix A).

The Goshen/Santaquin area had the highest percentage of respondents who were aware of the uniform speed limit for reduced-speed school zones in Utah (95 percent). Logan was the next highest, with 75 percent awareness. The Provo/Pleasant Grove and Salt Lake areas had 70 percent and 62 percent, respectively. Perhaps the reason the percentage is so high in the Goshen/Santaquin area is that most of the respondents surveyed were parents picking up their children from school and had just driven through a school zone. Regardless of the location, of those who did not know the speed limit, most guessed the lower 15 mph response.

Speed compliance also seemed to vary by location. Again, the Goshen/Santaquin area seemed to be the most compliant, with 82 percent saying they “always” obey the school-zone speed limit. The Salt Lake, Logan, and Provo/Pleasant Grove areas had 75, 64, and 57 percent, respectively, of those surveyed say they are “always” compliant. The reason why those surveyed in the Goshen/Santaquin area claimed to be the most compliant may have resulted from the large number of parents surveyed. Two relationships found depended on the location the surveys were collected, namely knowledge of the uniform school-zone speed limit and how people described their compliance to school-zone speed limits.

3.4.4 Other Relationships

Two other interesting relationships were found to be significant based on both the Chi-square test and a Fisher’s exact test. More information about the Fisher’s exact test can be found on the internet (Wolfram Research 1999). The first was that, of the 24 Spanish individuals that were surveyed, not one of them was unaware of increased fines for speeding in school zones. Of the English individuals surveyed, only 76 percent knew of the increased fines (Table A-10 of Appendix A). The other relationship found was that women tended to respond more toward “extremely important” as opposed to “important” or “somewhat important” with respect to slowing down in school zones in comparison to men. Of those surveyed, 83 percent of the men compared to 93 percent of the women said slowing down in school zones was “extremely important.” As noted, regardless of gender, the majority felt that slowing down in school zones was very important (Table A-11 of Appendix A).

3.5 Chapter Summary

The results of the public survey indicate that a need exists to improve school zones in the State of Utah. Necessary improvements include education, more effective traffic control devices, and increased law enforcement. Education should focus on the need for slowing down in school zones, as well as informing the public of increased fines for speeding in school zones. Education should be focused at all groups of people but should have particular emphasis on younger drivers. Perhaps more effort can also be placed on educating young students about how to safely cross the street as well. Traffic control devices such as flashing beacons, crossing guards, SMDs, etc. are all effective at increasing speed compliance in school zones. Increasing the visibility of school zones with the use of more noticeable traffic control devices can also improve speed limit compliance. Without the help of law enforcement, however, sufficient compliance cannot be achieved. Although most drivers do not require such enforcement, many drivers do need such enforcement as a reason to slow down in school zones. The combination of education, traffic engineering, and law enforcement is the best way to ensure safe and effective school zones throughout the State of Utah.

Chapter 4 Field Evaluation of Speed Monitoring Displays

An in-depth evaluation of the effects of SMDs on vehicular speeds was performed in four different school zones in the State of Utah. All four school zones had reasonably high approach speed limits (35 mph) compared to the reduced school-zone speed limit of 20 mph. UDOT traffic and safety engineers collaborated and decided which four school zones would be assessed in the study. For each location, speed data were collected using road tubes. The initial intent was to collect data before, one to two weeks after, and then again five to six months after the signs were installed. Unfortunately, due to problems with the functionality of the SMDs, some of the data collection had to be delayed or eliminated. Regardless of these difficulties, sufficient data were collected to perform valuable comparisons. The results of the comparisons varied between locations. For the most part, SMDs were effective at improving drivers' compliance with the reduced-speed school-zone speed limit.

Both a description of the SMDs used in this study and a description of each of the locations where these SMDs were implemented are provided in the following sections. In addition, the procedure and methodologies for the spot speed study are discussed. The results of the spot speed study for each location are summarized in the following sections as well. Finally, the results of the spot speed studies are evaluated, and conclusions and recommendations with regards to the SMDs are presented.

4.1 Description of Speed Monitoring Display

The SMDs used in this experiment were purchased by UDOT. The signs were all pole-mounted as shown in Figure 4-1 and displayed vehicles' speeds as illustrated Figure 4-2. The dimensions of the signs are 36 in. by 48 in., and the dimensions of the variable

(Photo taken by Kelly Ash 2004)

Figure 4-1: SMD Just After Installation

(Source: Salt Lake Tribune 2004)

Figure 4-2: SMD in Action at Salt Lake City School Zone

speed display area are 24 in. by 30 in. Vehicle speeds are displayed with FYG (same color as school-zone signs) sliding disks that slide in and out depending on the number. The signs were programmed to function only during the school-zone times. The signs were also programmed so that small LED lights in the numbers would flash to attract drivers' attention if a speed of more than 5 mph over the school-zone speed limit was measured (25 mph or more). Most of the signs purchased came equipped with solar panels, which were used at all of the locations in the study except for the Goshen site. Unfortunately, most of the solar powered signs experienced difficulties from time to time due to insufficient power for proper functionality. These difficulties hindered some of the data collection efforts; however, sufficient data were collected to evaluate the SMDs. The SMDs were all installed on the shoulder of the road between the crosswalk and the school-zone speed-limit sign (measuring from the crosswalk, approximately 60 percent of the distance from the crosswalk to the school-zone speed-limit sign). These SMDs helped increase the visibility of the school zones due to their dynamic nature.

4.2 Description of Study Sites

A detailed description of each school zone analyzed is provided in the following subsections.

4.2.1 SR-89 (400 North) at 400 East in Logan, Utah

The first school zone studied is located at the intersection of 400 North (SR-89) and 400 East in Logan, Utah. The school zone protects children crossing 400 North to commute to and from Adams Elementary School, which is located one block north of the school zone. The roadway (400 North) has four lanes and a two-way left-turn lane

(TWLTL) with a downward slope on the westbound approach. The road also has sufficient shoulder widths to allow cars to park on both sides of the street. Even though the street is very busy, houses line its shoulders. The approach speed limit to the school zone is 35 mph.

For both the eastbound and westbound traffic, a School Advance Warning Assembly, which consists of signs S1-1 and W16-9p according to the MUTCD, is installed as illustrated in Figure 4-3 for the westbound approach and Figure 4-4 for the eastbound approach. The word "SCHOOL" is painted across both lanes of traffic where these signs are located as shown in Figure 4-3.

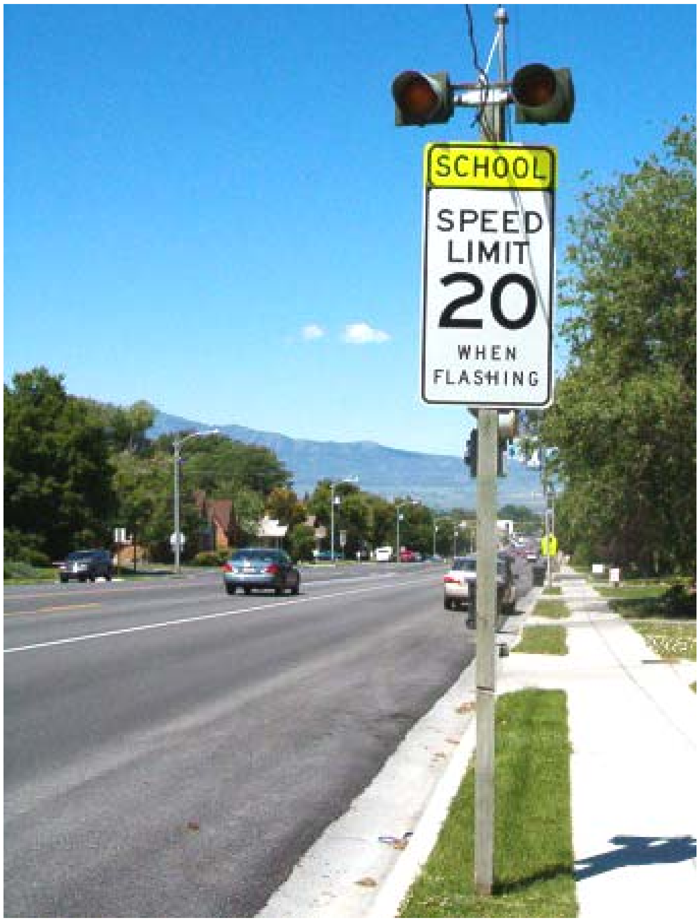
(Photo taken by Kelly Ash 2004)

Figure 4-3: School Advance Warning Assembly for Westbound SR-89 in Logan

(Photo taken by Kelly Ash 2004)

Figure 4-4: School Advance Warning Assembly for Eastbound SR-89 in Logan

Following the School Advance Warning Assembly on both sides of the street, a School Speed Limit Sign with two flashing beacons above it marks the beginning of the reduced-speed zone. This sign is S5-1 according to the MUTCD and can be seen in Figure 4-5. From the School Speed Limit Sign to the intersection, a solid white line separates the two traffic lanes in each direction to dissuade drivers from changing lanes within the school zone. The crosswalk for the school zone is located on the east side of the intersection and crosses 400 North. The crosswalk consists of large white rectangles with the long side painted parallel to the flow of traffic. At the crosswalk, for both directions of traffic, a School Crosswalk Warning Assembly denotes the presence of the crosswalk. According to the MUTCD, the School Crosswalk Warning Assembly consists of signs S1-1 and W16-7. The crosswalk and School Crosswalk Warning Assembly are illustrated in Figure 4-6. The school zone ends shortly after the crosswalk with an End School Zone sign. This is sign S5-2 according to the MUTCD.



(Photo taken by Kelly Ash 2004)

Figure 4-5: School-Zone Speed Limit Sign for Westbound SR-89 in Logan

(Photo taken by Kelly Ash 2004)

Figure 4-6: School Crosswalk Warning Assembly for Westbound SR-89 in Logan

4.2.2 SR-89 (State Street) at 1110 South in Salt Lake City, Utah

The next school zone studied is located on SR-89, or State Street, at about 1110 South in Salt Lake City, Utah. The school zone serves a number of young students that cross State Street to commute to and from Lincoln Elementary School. The school is located one block east of the school zone. In this area, State Street receives heavy volumes of traffic and consists of six lanes of traffic with a raised median on a flat grade. The road also has shoulder widths large enough for cars to park on both sides of the street. The street is lined with both residential and commercial land uses. The approach speed limit to the school zone is 35 mph.

For both the northbound and southbound traffic, a School Advance Warning Assembly warns drivers that they are approaching the school zone. Figure 4-7 shows the School Advance Warning Assembly for the southbound approach, which utilizes standard MUTCD signage.

(Photo taken by Kelly Ash 2004)

Figure 4-7: School Advance Warning Assembly for Southbound SR-89 in Salt Lake City

Pavement markings are also used to denote the presence of a school zone at this location. The word “SCHOOL” is painted twice across the three lanes of traffic in each direction just upstream from where the School Advance Warning Assemblies are located. Also, from the School Advance Warning Assembly to the stop bar of the intersection, solid white painted lines are used to separate the traffic lanes in order to discourage lane changes. These pavement markings help notify drivers of the school zone.

Following the School Advance Warning Assembly for both directions of traffic, two large School Speed Limit Signs (one in the median and one on the shoulder) mark the beginning of the reduced-speed zone. These signs display the 20 mph school-zone speed limit and state that the speed limit is in effect when the lights are flashing. For both northbound and southbound traffic, the School Speed Limit Signs located in the median have two flashing beacons above the sign. The signs on the shoulder have one flashing beacon above and another below the sign. The School Speed Limit Signs for the northbound approach can be seen in Figure 4-8.

For both directions of traffic, a School Crosswalk Warning Assembly helps distinguish the location of the crosswalk as illustrated Figure 4-9. The crosswalk itself consists of large white rectangles with the long side painted parallel to the flow of traffic and is located on the north side of the intersection. A stop bar is painted just before the crosswalk for both directions of traffic as illustrated in Figure 4-10. The school zone ends shortly after the crosswalk with an End School Zone sign.

(Photo taken by Kelly Ash 2004)

Figure 4-8: School-Zone Speed Limit Signs for Northbound SR-89 in Salt Lake City

(Photo taken by Kelly Ash 2004)

Figure 4-9: School Crosswalk Warning Assembly for Northbound SR-89 in Salt Lake City

(Photo taken by Kelly Ash 2004)

Figure 4-10: School-Zone Crosswalk Viewed from the West Side of SR-89 in Salt Lake City

4.2.3 SR-146 (100 East) at 1800 North in Pleasant Grove, Utah

The third school zone studied is located along SR-146 in Pleasant Grove, Utah. This school zone serves a large number of young students crossing 100 East (SR-146) at 1800 North to commute to and from Manila Elementary School. SR-146 is a two-lane highway with a TWLTL on the south side of the intersection and no median on the north side of the intersection. The approach speed limit to the school zone is 35 mph. The road has a slight downhill grade for the southbound approach. On the south side of the intersection, SR-146 is lined with sidewalks on both sides of the street. However, the north side of the intersection has soft shoulders. Both approaches to the school zone are equipped with a School Advance Warning Assembly; however, the assembly for the southbound traffic lacks the “AHEAD” sign. These signs are shown in Figure 4-11 for the southbound approach to the school zone and Figure 4-12 for the northbound approach to the school zone. Figure 4-12 also demonstrates how the word “SCHOOL” is painted across the approach lane. These pavement markings are located adjacent to the School Advanced Warning Assembly for both directions of traffic.

(Photo taken by Kelly Ash 2004)

Figure 4-11: School Advance Warning Assembly for Southbound SR-146 in Pleasant Grove

(Photo taken by Kelly Ash 2004)

Figure 4-12: School Advance Warning Assembly for Northbound SR-146 in Pleasant Grove

Both approaches are also equipped with a School Speed Limit Sign with two flashing beacons above each. As mentioned earlier, these signs denote that the school-zone speed limit is 20 mph when the beacons are flashing. Just like the other school zones studied, the crosswalk consists of large white rectangles with the long side painted parallel to the flow of traffic. For both directions of traffic, a School Crosswalk Warning Assembly helps show the location of the school zone crosswalk as shown in Figure 4-13 and Figure 4-14 for the northbound and southbound directions, respectively. Shortly following these signs, the school zone ends with an End School Zone sign. All of these traffic control devices are used to reduce vehicular speeds during the school-zone crossing times.

(Photo taken by Kelly Ash 2004)

Figure 4-13: School Crosswalk Warning Assembly for Southbound SR-146 in Pleasant Grove

(Photo taken by Kelly Ash 2004)

Figure 4-14: School Crosswalk Warning Assembly for Northbound SR-146 in Pleasant Grove

4.2.4 US-6 in Goshen, Utah

The last school zone evaluated in this study is located on US-6 at Reference Post (RP) 153.8 in Goshen, Utah. The school zone is located adjacent to the Goshen Elementary/Middle School, which is on the north side of the road. Going through Goshen, SR-6 is a two-lane level highway with a painted TWLTL and extremely wide shoulders as illustrated in Figure 4-15 for the eastbound approach to the school zone. Due to the width of the roadway, children must travel a significant distance to cross the street. Along the street, both residential and commercial establishments surround the school. The approach speed limit to the school zone is 35 mph.

For both the eastbound and westbound traffic, a School Advance Warning Assembly is present and in accordance with the MUTCD as at the other school zones discussed previously. The wide shoulders of the road and the School Advance Warning Assembly for the eastbound traffic are illustrated in Figure 4-15. For both directions of

(Photo taken by Kelly Ash 2004)

Figure 4-15: School Advance Warning Assembly for Eastbound US-6 in Goshen

traffic, the word "SCHOOL" is painted across the approach lane where the School Advance Warning Assemblies are located.

Following the School Advance Warning Assembly on both sides of the street, a School Speed Limit Sign with two flashing beacons above it marks the beginning of the reduced-speed school zone. Figure 4-16 shows a picture of this sign for the eastbound approach. Both the eastbound and westbound signs are mounted on two wooden poles and state that the speed limit is 20 mph when flashing. They also advise drivers that they are entering the school zone and that caution must be taken because children may be crossing the street.

The crosswalk for the school zone is located on the east side of the intersection and consists of large white rectangles with the long side painted parallel to the roadway. For both directions of traffic, a School Crosswalk Warning Assembly is present at the crosswalk as at the other school zones. The eastbound School Crosswalk Warning Assembly is shown in Figure 4-17. The school zone ends shortly after the crosswalk with an End School Zone sign.

(Photo taken by Kelly Ash 2004)

Figure 4-16: School-Zone Speed Limit Sign for Eastbound US-6 in Goshen

(Photo taken by Kelly Ash 2004)

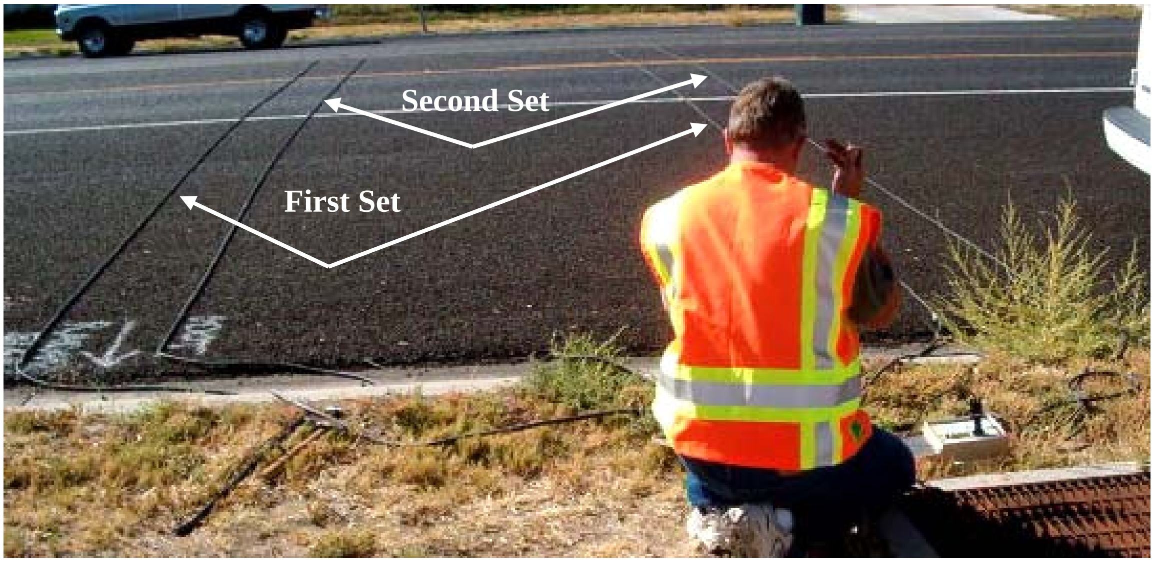
Figure 4-17: School Crosswalk Warning Assembly for Eastbound US-6 in Goshen

4.3 Spot Speed Study

Speed data were collected in each school zone using road tube counters. An attempt was made to collect speed data before, about two to four weeks after, and again about four to five months after the SMDs were installed and functioning properly. As mentioned previously, difficulties were encountered with maintaining this schedule for every location. In each case, the data were collected for approximately four days (Monday through Thursday) for each collection period. Only speeds during the school-zone times were analyzed. Standard statistics including the average speed, standard deviation, 85^{th} percentile, percent exceeding the school-zone speed limit, 10 mph pace, and percent within the 10 mph pace were all compiled and compared for each school zone. Results of the spot speed study are further discussed for each school zone in the following sections. The equipment and procedures associated with the spot speed study are discussed in the following subsections.

4.3.1 Equipment

Two counters and two sets of tubes were used to collect data for each direction of traffic. Two sets of counters were used to increase the probability that at least one good set of data would be obtained for each direction of traffic. Each set of tubes consisted of two road tubes laid out approximately 12 feet apart as illustrated in Figure 4-18 and Figure 4-19. The two tubes were connected to a counter that calculated the speed of each vehicle based on the fraction of time required for each vehicle to travel from the upstream tube to the downstream tube. The tubes were laid out where the new SMDs were to be located. After four days of collecting data, the equipment was dismantled, and the data were downloaded from the counters to be analyzed.



(Photo taken by Kelly Ash 2004)
Figure 4-18: Setting Up Tubes in Goshen


(Photo taken by Kelly Ash 2004)
Figure 4-19: Tube Configuration Shown at the Salt Lake City Site

4.3.2 Procedure

Once the speed data were collected and downloaded from the counters, the speeds to be analyzed were determined. Since the flashing beacons were not on timers and only came on when the crossing guards turned them on (i.e., not at an exact moment everyday), the researchers had to visually determine from the data when the reduced-speed school zones had become active.

Another issue in determining which speeds should be analyzed was that some of the speeds were abnormally high and obviously unrealistic. These abnormally high speeds recorded were most likely caused by vehicles in different lanes crossing the tubes at approximately the same time. The counters could not always distinguish between the two vehicles and therefore produced unrealistic results. In order to remove such outliers from the data, the researchers had to decide how to eliminate these excessive outliers from the data set. Given his observations during visits to the sites, the researchers decided to eliminate all speeds above 45 mph since that seemed like a realistic maximum speed for drivers that were completely oblivious to the presence of the school zone. Since the approach speed limit for all of the school zones was 35 mph, 10 mph over the approach speed limit was determined to be a reasonable and somewhat conservative maximum speed for a cut-off point.

After the abnormalities in the data set were removed, the results were compiled for each school-zone time period. The outcome of the analysis is described in the sections that follow.

4.4 Speed Results: SR-89 (400 North) at 400 East in Logan, Utah

Speed data were collected at the Logan site before and after the installation of the SMDs. Before the SMDs were installed, data were collected in the middle of September 2004, and the SMDs were installed shortly thereafter. Unfortunately, the SMDs were not functioning properly until about the middle of January 2005. Data were again collected at the end of March 2005. Once the SMDs were operating as designed, they proved to be very effective at increasing school-zone speed-limit compliance at this location. Perhaps these SMDs could have been more effective if the manufacturer had provided more technical support to aid in proper operation after the initial installation. As mentioned earlier, the main problem with the SMDs was related to the solar panels and the lack of power that they provided. The signs would function properly for a very short period of time; however, due to the lack of power they would suddenly stop working. The lack of power could be attributed to occasional snow and ice accumulations on the solar panels. Regardless of these difficulties, once the SMDs were functioning properly, they proved to be effective at increasing speed limit compliance in this school zone.

The results of the analyses are summarized in Table 4-1 for the westbound and eastbound approaches. For both directions of traffic and for both school-zone time periods, the SMDs were effective at reducing the mean speed, standard deviation, and 85th percentile speed. As recorded in the tables, speeds were initially higher for westbound traffic as a result of the downhill grade. The signs had a substantial impact on drivers traveling westbound. The mean speed decreased by about 3 mph, and the 85th percentile speed dropped by about 4 mph. The standard deviation decreased in all cases, suggesting a tighter distribution of speeds (i.e., fewer outliers). The percentage of vehicles exceeding the 20 mph speed limit decreased by about 39 percent, and the 10 mph pace decreased by about 3 mph. The percentage of vehicles in the pace increased as well, which also suggested an increase in compliance. The SMDs also had an impact on the vehicles traveling eastbound; however, due to the uphill grade and already compliant speeds, the changes were not quite as substantial as they were for the westbound traffic.

Table 4-1: Speed Results for SR-89 (400 North) at 400 East in Logan

Statistics	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Westbound Morning – 7:30 to 8:30 AM		
Mean (mph)	23.24	19.68[a]
Standard Deviation	4.59	3.30
85th Percentile (mph)	26.2	22.1
% Exceeding 20 mph	75.9%	35.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (91.1%)
Sample Size	809	1001
Westbound Afternoon – 2:15 to 3:15 PM		
Mean (mph)	22.99	19.97[a]
Standard Deviation	4.22	3.55
85th Percentile (mph)	26.0	22.5
% Exceeding 20 mph	77.0%	38.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (89.7%)
Sample Size	806	1383
Eastbound Morning – 7:30 to 8:30 AM		
Mean (mph)	19.86	18.70[a]
Standard Deviation	4.88	3.50
85th Percentile (mph)	23.3	20.7
% Exceeding 20 mph	32.2%	18.1%
10 mph Pace (% in Pace)	13 – 23 (84.3%)	13 – 23 (91.9%)
Sample Size	699	717
Eastbound Afternoon – 2:15 to 3:15 PM		
Mean (mph)	21.46	19.49[a]
Standard Deviation	5.98	3.51
85th Percentile (mph)	26.0	22.3
% Exceeding 20 mph	45.2%	31.5%
10 mph Pace (% in Pace)	14 – 24 (76.9%)	14 – 24 (90.7%)
Sample Size	863	1131

[a] *Difference was statistically significant from the "before" mean speed based on a normal approximation test at a 95 percent confidence level*

Appendix B shows the distribution of speeds for each time period and direction for this location. As summarized in Appendix B, the distribution of speeds for the westbound traffic (Figure B-1 and Figure B-2) suggests that all of the vehicles were influenced by the SMDs; however, of the vehicles traveling eastbound, only the faster vehicles were markedly impacted (Figure B-3 and Figure B-4). This analysis proves that the SMDs were extremely effective at increasing and maintaining school-zone speed-limit compliance at this Logan location.

4.5 Speed Results: SR-89 (State Street) at 1110 South in Salt Lake City, Utah

Speed data were also collected at the Salt Lake City location before and after the SMDs were installed. Data were collected before the SMDs were installed in the middle of September 2004. Similar to the Logan site, the SMDs did not function properly until about the middle of January 2005 for the same reasons. Data were also collected at the end of March 2005. UDOT placed an extra SMD on the median for northbound traffic in addition to the one on the shoulder to determine if an extra sign would have more influence on drivers' speeds. Unfortunately, the two SMDs did not function properly together, and therefore the SMD on the median was turned off. As summarized in Table 4-2, speeds were already very compliant with the school-zone speed limit at this location despite the functional classification of the roadway and expected high speeds. An observation was made that vehicles arrived at the school zone in platoons; therefore, drivers were less likely to speed due to the constraints of other vehicles around them. Since the speed limit compliance during the "before" condition was already excellent, little difference in speed compliance was observed after the SMDs were installed.

As observed in Table 4-2, the mean speed increased slightly (less than 1 mph) for the northbound traffic and decreased by about 1 to 2 mph for southbound traffic. The standard deviation remained fairly constant. The 85^{th} percentile speed decreased by about 1 to 2 mph for the southbound traffic and experienced minimal change for the northbound traffic. The percentage of vehicles exceeding the school-zone speed limit

Table 4-2: Speed Results for SR-89 (State Street) at 1110 South in Salt Lake City

Statistics	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Northbound Morning – 7:30 to 8:25 AM		
Mean (mph)	19.06	19.85[a]
Standard Deviation	3.23	3.70
85th Percentile (mph)	21.4	22.4
% Exceeding 20 mph	24.1%	37.0%
10 mph Pace (% in Pace)	14 – 24 (91.9%)	14 – 24 (90.7%)
Sample Size	1223	1069
Northbound Mid-day – 10:55 AM to 12:15 PM		
Mean (mph)	19.85	20.39[a]
Standard Deviation	4.14	4.29
85th Percentile (mph)	22.8	23.3
% Exceeding 20 mph	37.1%	42.0%
10 mph Pace (% in Pace)	14 – 24 (86.9%)	14 – 24 (85.6%)
Sample Size	2056	1796
Northbound Afternoon – 2:30 to 3:15 PM		
Mean (mph)	19.82	20.15
Standard Deviation	4.90	4.77
85th Percentile (mph)	23.2	22.9
% Exceeding 20 mph	35.7%	37.1%
10 mph Pace (% in Pace)	14 – 24 (81.9%)	14 – 24 (84.1%)
Sample Size	926	891
Southbound Morning – 7:30 to 8:25 AM		
Mean (mph)	19.83	18.94[a]
Standard Deviation	4.36	4.23
85th Percentile (mph)	22.7	21.3
% Exceeding 20 mph	40.4%	22.8%
10 mph Pace (% in Pace)	14 – 24 (86.0%)	13 – 23 (87.7%)
Sample Size	463	838
Southbound Mid-day – 10:55 AM to 12:15 PM		
Mean (mph)	20.61	18.84[a]
Standard Deviation	4.32	4.24
85th Percentile (mph)	23.6	21.5
% Exceeding 20 mph	47.1%	22.4%
10 mph Pace (% in Pace)	15 – 25 (85.2%)	13 – 23 (87.7%)
Sample Size	1994	2129
Southbound Afternoon – 2:30 to 3:15 PM		
Mean (mph)	19.95	18.65[a]
Standard Deviation	4.90	4.96
85th Percentile (mph)	23.5	21.8
% Exceeding 20 mph	39.7%	23.0%
10 mph Pace (% in Pace)	14 – 24 (78.6%)	12 – 22 (83.5%)
Sample Size	1409	1091

[a] *Difference was statistically significant from the "before" mean speed based on a normal approximation test at a 95 percent confidence level*

minimally increased for the northbound traffic but definitely decreased for the southbound traffic. The 10 mph pace remained essentially the same for northbound traffic but did decrease by about 2 mph for southbound traffic. As summarized in the speed distributions found in Appendix B (Figure B-5 through Figure B-10), the SMDs did not have a very significant effect on vehicles traveling at higher speeds. The SMD for the southbound approach seemed to reduce the speeds the vehicles already traveling near or at the school-zone speed limit as demonstrated in Figure B-8, Figure B-9, and Figure B-10 of Appendix B. For the most part, the signs were effective at slowing down vehicles. By no means did the SMDs degrade the safety of the school zone. Had the speed compliance been somewhat worse to begin with, greater effects caused by the SMDs may have been observed.

4.6 Speed Results: SR-146 (100 East) at 1800 North in Pleasant Grove, Utah

Speed data were also collected at the Pleasant Grove school zone to determine the effectiveness of SMDs at slowing down vehicles. Similar difficulties occurred with the southbound SMD at this location as occurred at the Logan and Salt Lake City locations. Data were collected before the SMDs were installed in the beginning of October 2004. The northbound SMD was functioning properly about the first week of November 2004, and the southbound SMD was functioning properly around the beginning of January 2005. Since the northbound SMD at this location was functioning properly within a month of installation, short-term data were collected for the northbound direction about the beginning of December 2004. Data were again collected for both directions of traffic around the end of March 2005. The results of the analysis seemed to vary for the two directions of traffic; the variance may have been caused by the dysfunction of the southbound SMD.

As summarized in Table 4-3, the results for the northbound morning traffic show that the SMD may have lost effectiveness over time. The short-term results show a significant decrease in the mean speed in the morning, but the long-term results show that

Table 4-3: Speed Results for SR-146 (100 East) at 1800 North in Pleasant Grove

Statistics	Before *(10/04/04 – 10/07/04)*	Short-term *(11/29/04 – 12/02/04)*	Long-term *(03/21/05 – 03/24/05)*
Northbound Morning – 8:15 to 8:50 AM			
Mean (mph)	19.88	18.81[a]	19.80[b]
Standard Deviation	4.44	4.16	3.78
85th Percentile (mph)	24.2	22.4	23.3
% Exceeding 20 mph	40.7%	27.4%	34.0%
10 mph Pace (% in Pace)	14 – 24 (77.4%)	13 – 23 (82.0%)	15 – 25 (86.6%)
Sample Size	513	678	777
Northbound Afternoon – 3:25 to 4:00 PM			
Mean (mph)	20.98	19.38[a]	19.25[a]
Standard Deviation	6.33	5.84	3.70
85th Percentile (mph)	26.7	24.2	22.1
% Exceeding 20 mph	45.9%	34.7%	32.9%
10 mph Pace (% in Pace)	13 – 23 (68.3%)	13 – 23 (71.3%)	13 – 23 (86.8%)
Sample Size	1052	926	856
Southbound Morning – 8:15 to 8:50 AM			
Mean (mph)	21.58	N/A	22.69[a]
Standard Deviation	4.92	N/A	4.09
85th Percentile (mph)	25.7	N/A	26.1
% Exceeding 20 mph	60.6%	N/A	76.0%
10 mph Pace (% in Pace)	16 – 26 (75.2%)	N/A	17 – 27 (83.0%)
Sample Size	926	N/A	317
Southbound Afternoon – 3:25 to 4:00 PM			
Mean (mph)	22.49	N/A	22.04
Standard Deviation	5.37	N/A	4.72
85th Percentile (mph)	27.0	N/A	25.2
% Exceeding 20 mph	67.6%	N/A	67.0%
10 mph Pace (% in Pace)	17 – 27 (71.3%)	N/A	15 – 25 (81.4%)
Sample Size	1061	N/A	194

[a] *Difference was statistically significant from the "before" mean speed based on a normal approximation test at a 95 percent confidence level*

[b] *Difference was statistically significant from the "short-term" mean speed based on a normal approximation test at a 95 percent confidence level*

the mean speed returned to approximately the same speed before the SMD was installed. The mean speed for the northbound vehicles in the afternoon continued to be less than the mean speed before the SMDs were installed. Perhaps the lack of long-term effectiveness for the morning time period was the result of more commuters along this route. The speed distributions for northbound traffic shown in Figures B-11 and B-12 of Appendix B demonstrate that the SMD had more influence on higher vehicular speeds in the afternoon than in the morning. This may also be the result of more commuter traffic on the road in the morning. The southbound SMD's lack of effectiveness may have been caused by the long time periods during which the SMD was not functioning properly. The SMD for the northbound traffic, however, appears to have influenced drivers' speeds and thereby improved the safety of the school zone.

4.7 Speed Results: US-6 in Goshen, Utah (RP 153.8)

Since the SMDs at the Goshen location were hard-wired instead of powered by solar panels, no apparent difficulties were encountered with the new SMDs at this location. For that reason, speed data were collected before, about three weeks after ("short-term"), and again about five months after ("long-term") the new SMDs were installed. Unfortunately, both sets of tubes used to collect data for the eastbound direction during the short-term collection period failed to collect sufficient data; therefore, as summarized in Table 4-4, this section was omitted for the eastbound analysis. The results obtained from the analysis of this site are provided in Table 4-4 for the eastbound approach and Table 4-5 for the westbound approach.

The results of the eastbound data collection actually show an increase in speeds, although fairly minor (1 to 2 mph) as outlined in Table 4-4. Reasons for the increase are unknown. The mid-day school-zone time period (kindergarten crossing) shows essentially no change in speed compliance; however, the rest of the time periods do show a significant decline in speed compliance compared to conditions before the SMDs were installed. The speed distributions shown in Figures B-15 and B-16 of Appendix B show

Table 4-4: Speed Results for Eastbound US-6 in Goshen

Statistics	Before *(09/27/04 – 09/30/04)*	After *(03/21/05 – 03/24/05)*
Eastbound Morning – 8:10 to 9:00 AM		
Mean (mph)	19.75	21.66[a]
Standard Deviation	4.69	3.18
85th Percentile (mph)	23.4	24.4
% Exceeding 20 mph	38.2%	63.9%
10 mph Pace (% in Pace)	15 – 25 (81.9%)	16 – 26 (88.2%)
Sample Size	144	119
Eastbound Mid-day – 11:15 to 11:45 AM and 12:10 to 12:45 PM		
Mean (mph)	22.17	21.88
Standard Deviation	5.53	3.81
85th Percentile (mph)	27.0	24.9
% Exceeding 20 mph	55.6%	63.1%
10 mph Pace (% in Pace)	15 – 25 (76.3%)	16 – 26 (87.7%)
Sample Size	169	260
Eastbound Afternoon – 2:45 to 3:20 PM		
Mean (mph)	19.72	22.05[a]
Standard Deviation	4.48	5.27
85th Percentile (mph)	23.5	24.9
% Exceeding 20 mph	38.9%	63.8%
10 mph Pace (% in Pace)	14 – 24 (79.0%)	16 – 26 (83.5%)
Sample Size	167	127
Eastbound Late-Afternoon – 3:45 to 5:00 PM		
Mean (mph)	22.02	23.12[a]
Standard Deviation	5.33	5.54
85th Percentile (mph)	27.3	26.4
% Exceeding 20 mph	53.7%	68.2%
10 mph Pace (% in Pace)	15 – 25 (74.6%)	16 – 26 (80.5%)
Sample Size	335	236

[a] *Difference was statistically significant from the "before" mean speed based on a normal approximation test at a 95 percent confidence level*

that during the morning and mid-day time periods, the SMDs had a noticeable influence in reducing excessive speeds through the school zone despite the increase in the mean speeds for these time periods. Regardless of the increase in the mean speeds, drivers traveling through this school zone were still very compliant with the reduced-speed school-zone speed limit. The SMD may have been more effective if the shoulders of the road had not been so wide. Even with the slight increase in the mean speeds, the SMDs showed no sign of decreasing safety during the morning and mid-day hours; in fact, the signs did increase safety during these times by reducing the number of vehicles traveling at excessive speeds (>25 mph) as observed from the distribution of speeds in Appendix B. On the other hand, a substantial reduction in excessive speeds was not observed during the afternoon time periods.

The results of the westbound analysis in Goshen were different than the results of the eastbound analysis as reported in Table 4-5. The morning and afternoon results showed no change in the mean speed, while the mean speed for the mid-day late-afternoon analyses reported a decrease in mean speed; however, the decrease in the mean speed for the late-afternoon analysis was not maintained through the long-term analysis.

The loss in effectiveness that the SMD exhibited during the late-afternoon hour for the westbound traffic may have been caused by an increase in commuter traffic. By no means did the SMD for the westbound traffic decrease the safety of the school zone. As suggested earlier, the SMDs at the Goshen location may have been more effective with narrower shoulders that would have increased the visibility of the signs.

Table 4-5: Speed Results for Westbound US-6 in Goshen

Statistics	Before *(09/27/04 – 09/30/04)*	Short-term *(11/29/04 – 12/02/04)*	Long-term *(03/21/05 – 03/24/05)*
Westbound Morning – 8:10 to 9:00 AM			
Mean (mph)	22.09	21.86	21.77
Standard Deviation	6.36	5.93	4.56
85th Percentile (mph)	28.3	27.8	27.3
% Exceeding 20 mph	55.2%	47.2%	50.9%
10 mph Pace (% in Pace)	14 – 24 (68.0%)	15 – 25 (70.8%)	16 – 26 (76.9%)
Sample Size	125	161	108
Westbound Mid-day – 11:15 to 11:45 AM and 12:10 to 12:45 PM			
Mean (mph)	23.99	21.56[a]	22.17[a]
Standard Deviation	5.47	4.66	5.29
85th Percentile (mph)	29.4	26.5	27.5
% Exceeding 20 mph	71.9%	52.7%	52.1%
10 mph Pace (% in Pace)	16 – 26 (74.0%)	16 – 26 (76.1%)	15 – 25 (73.6%)
Sample Size	146	222	140
Westbound Afternoon – 2:45 to 3:20 PM			
Mean (mph)	20.96	20.68	20.79
Standard Deviation	4.94	4.81	5.04
85th Percentile (mph)	25.3	24.3	25.8
% Exceeding 20 mph	47.2%	43.8%	40.8%
10 mph Pace (% in Pace)	15 – 25 (76.4%)	14 – 24 (81.3%)	15 – 25 (74.8%)
Sample Size	229	267	103
Westbound Late-Afternoon – 3:45 to 5:00 PM			
Mean (mph)	21.61	20.73[a]	21.49
Standard Deviation	5.09	4.60	4.75
85th Percentile (mph)	25.9	24.8	26.3
% Exceeding 20 mph	53.2%	43.3%	50.0%
10 mph Pace (% in Pace)	16 – 26 (77.3%)	14 – 24 (81.3%)	16 – 26 (79.3%)
Sample Size	295	374	92

[a] *Difference was statistically significant from the "before" mean speed based on a normal approximation test at a 95 percent confidence level*

4.8 Chapter Summary

In summary, the SMDs analyzed in this study proved to increase speed compliance in most cases. In only a few cases and for unknown reasons did the speeds increase after the new SMDs were installed. In some cases where multiple evaluations were completed (i.e., before, short-term, and long-term), the SMDs maintained their effectiveness at increasing speed compliance; on the other hand, some exhibited decreasing efficacy through time, possibly due to higher percentages of commuter traffic. As observed in the distribution of speeds at essentially every location, excessive speeds were reduced. In all cases, the safety of the school zone was not degraded by the installation of these signs. For the most part, the SMDs instead helped improve school-zone safety by decreasing speeds and increasing speed compliance as manifested by the decrease in mean speed, standard deviation, 10 mph pace range, and the percentage of vehicles exceeding the 20 mph school-zone speed limit.

Chapter 5 Conclusions and Recommendations

5.1 Summary

School zones are necessary to increase the safety and security of young children crossing the street to and from school; however, each school zone does not provide the same level of efficiency and safety. School-zone traffic control devices must warn drivers of the presence of children crossing the street. School zones can also be used to create safe and appropriate gaps in traffic for children to cross as a result of reducing vehicular speeds. The purpose of this study was to determine the most efficient ways to increase and maintain speed compliance in reduced-speed school zones. The major tasks of this study included the following:

- Literature Review
- Public Opinion Survey
- Field Evaluation of SMDs

5.2 Findings

The major findings for each of the three main tasks of the study are discussed in the following subsections.

5.2.1 Literature Review

The first task of this study was to perform an in-depth literature review specifically on how to increase speed compliance in school zones. As part of the literature review, a number of different traffic control devices and methods for reducing speeds in school zones were researched to determine their effectiveness. As a result of the extensive literature review, a conclusion was reached that a combination of factors must be present in order for drivers to be more compliant with the school-zone speed limit. Those factors include uniformity of traffic control devices, effective and noticeable traffic control devices, both pedestrian and driver education and awareness, and proper law enforcement.

5.2.2 Public Opinion Survey

Another task of this study was to perform a public opinion survey among Utah drivers. The results of the public opinion survey indicate that Utah drivers feel that a need exists to improve school zones in the State of Utah. Necessary improvements should include education, more effective traffic control devices, and increased law enforcement. Traffic control devices such as flashing beacons, crossing guards, SMDs, and FYG school-zone signs all effectively influence the majority of Utah drivers to slow down in school zones. Since the main reason for speeding in school zones among Utah drivers was that they did not notice the school zone, increasing the visibility of school zones with the use of more noticeable traffic control devices is anticipated to improve speed-limit compliance. Without the help of law enforcement, sufficient compliance is not expected to be achieved.

5.2.3 Field Evaluation of SMDs

The effectiveness of SMDs at increasing speed limit compliance in four school zones in the state was analyzed. The SMDs analyzed in this study proved to increase speed compliance in most cases. In some cases where multiple evaluations were completed (i.e., before, short-term, and long-term), the SMDs maintained their effectiveness at increasing speed compliance; on the other hand, some locations were characterized by reductions in the SMDs' effectiveness over time, possibly due to higher percentages of commuter traffic. As observed in the distribution of speeds at essentially every location, excessive speeds were reduced as a result of using the SMDs. Even in cases where speeds increased, the increase was minimal; therefore, the safety of the school zone was not degraded by the installation of these SMDs. For the most part, these SMDs helped improve school-zone safety by decreasing speeds and increasing speed compliance as manifested by the decrease in mean speed, standard deviation, 10 mph pace range, and the percentage of vehicles exceeding the 20 mph school-zone speed limit.

5.3 Recommendations

The combination of education, traffic engineering, and law enforcement is recommended as an effective combination to ensure safe and efficient school zones throughout the State of Utah. It is recommended that UDOT and other transportation agencies continually strive to improve school-zone safety. School-zone safety can be enhanced through better and more noticeable traffic control devices, increased public education, and appropriate law enforcement. As mentioned earlier, SMDs can be effective traffic control devices in school zones since they increase speed compliance in the majority of instances. SMDs should be used in school zones with excessive speeds and other areas where high speeds may result in unsafe conditions. Since the results of the field study differed by location, further research should be conducted to investigate other factors and conditions that contribute to and influence the effectiveness of SMDs. By effectively reducing speeds in school zones, engineers and other transportation professionals will improve both the safety and efficiency of those school zones.

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Appendix A. Public Survey Results

Table A-1: Speed Compliance vs. Having Kids

11.) I obey the speed limit in school zones… *(Circle one)*

Always | Most of the time | About 75% of the time | About half the time | About 25% of the time | Rarely | Never

vs.

Having kids derived from question 3.

Speed Compliance (Question 11)	Have Kids? (Question 3)		
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**DO NOT Have Kids**	**Have Kids**	**Total**
Always	281 312.43 3.1615 37.02 57.00 58.42	212 180.57 5.47 27.93 43.00 76.26	493 64.95
Most of Time	146 126.75 2.925 19.24 73.00 30.35	54 73.254 5.0608 7.11 27.00 19.42	200 26.35
~ 75% of Time	32 24.082 2.6036 4.22 84.21 6.65	6 13.918 4.5048 0.79 15.79 2.16	38 5.01
~50% or less	22 17.744 1.0206 2.90 78.57 4.57	6 10.256 1.7659 0.79 21.43 2.16	28 3.69
Total	481 63.37	278 36.63	759 100.00
Frequency Missing = 3			

Statistic	DF	Value	Prob
Chi-Square	3	26.5122	<.0001
Likelihood Ratio Chi-Square	3	27.9346	<.0001
Mantel-Haenszel Chi-Square	1	22.7451	<.0001
Phi Coefficient		0.1869	
Contingency Coefficient		0.1837	
Cramer's V		0.1869	

Table A-2: Speed Compliance vs. Age

11.) I obey the speed limit in school zones… *(Circle one)*

Always | Most of the time | About 75% of the time | About half the time | About 25% of the time | Rarely | Never

vs.

Age derived from question 1.

Speed Compliance (Question 11)	**Age (Question 1)**				**Total**
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**16-25**	**26-35**	**35-50**	**Over 50**	
Always	145 181.96 7.508 19.75 30.40 51.79	139 133.22 0.2506 18.94 29.14 67.80	120 103.98 2.4688 16.35 25.16 75.00	73 57.838 3.9747 9.95 15.30 82.02	477 64.99
Most of Time	99 74.005 8.4416 13.49 51.03 35.36	48 54.183 0.7055 6.54 24.74 23.41	35 42.289 1.2563 4.77 18.04 21.88	12 23.523 5.6448 1.63 6.19 13.48	194 26.43
~ 75% of Time	21 13.351 4.3815 2.86 60.00 7.50	8 9.7752 0.3224 1.09 22.86 3.90	3 7.6294 2.8091 0.41 8.57 1.88	3 4.2439 0.3646 0.41 8.57 3.37	35 4.77
~50% or less	15 10.681 1.7462 2.04 53.57 5.36	10 7.8202 0.6076 1.36 35.71 4.88	2 6.1035 2.7589 0.27 7.14 1.25	1 3.3951 1.6896 0.14 3.57 1.12	28 3.81
Total	280 38.15	205 27.93	160 21.80	89 12.13	734 100.00
Frequency Missing = 28					

Statistic	**DF**	**Value**	**Prob**
Chi-Square	9	44.9303	<.0001
Likelihood Ratio Chi-Square	9	47.2575	<.0001
Mantel-Haenszel Chi-Square	1	34.0987	<.0001
Phi Coefficient		0.2474	
Contingency Coefficient		0.2402	
Cramer's V		0.1428	

Table A-3: Speed Compliance vs. Frequency of Driving through a School Zone

11.) I obey the speed limit in school zones… *(Circle one)*

Always — Most of the time — About 75% of the time — About half the time — About 25% of the time — Rarely — Never

vs.

10.) How often do you drive through a school zone during the reduced-speed times?

a.) More than twice in a day
b.) About once or twice a day
c.) A few times a week
d.) Rarely
e.) Never

Speed Compliance (Question 11)	**Frequency of Driving through a School Zone (Question 10)**				
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**More than 2 times a day**	**About 1 or 2 times a day**	**A few times a week**	**Rarely**	**Total**
Always	84 68.521 3.4965 11.62 18.14 78.50	109 102.46 0.4172 15.08 23.54 68.13	184 180.59 0.0644 25.45 39.74 65.25	86 111.43 5.8025 11.89 18.57 49.43	463 64.04
Most of Time	19 29.007 3.4522 2.63 9.69 17.76	41 43.375 0.13 5.67 20.92 25.63	72 76.448 0.2588 9.96 36.73 25.53	64 47.17 6.0047 8.85 32.65 36.78	196 27.11
~ 75% of Time	2 5.4758 2.2063 0.28 5.41 1.87	5 8.1881 1.2413 0.69 13.51 3.13	18 14.432 0.8824 2.49 48.65 6.38	12 8.9046 1.076 1.66 32.43 6.90	37 5.12
~50% or less	2 3.9959 0.9969 0.28 7.41 1.87	5 5.9751 0.1591 0.69 18.52 3.13	8 10.531 0.6083 1.11 29.63 2.84	12 6.4979 4.6588 1.66 44.44 6.90	27 3.73
Total	107 14.80	160 22.13	282 39.00	174 24.07	723 100.00
Frequency Missing = 39					

Statistic	**DF**	**Value**	**Prob**
Chi-Square	9	31.4556	0.0002
Likelihood Ratio Chi-Square	9	31.6902	0.0002
Mantel-Haenszel Chi-Square	1	23.1206	<.0001
Phi Coefficient		0.2086	
Contingency Coefficient		0.2042	
Cramer's V		0.1204	

Table A-4: Extent of Exceeding the Speed Limit vs. Reason for Speeding

12.) When you speed in school zones, approximately how much over the speed limit are you traveling?

a.) 0-5 mph b.) 5-10 mph c.) 10-15 mph d.) 15-20 mph e.) Over 20 mph

vs.

13.) If you have sped through a school zone before, what was the main reason for speeding?

a.) You were not aware it was a school zone until it was too late.

b.) You were in a hurry or late for something (for example, work or school).

c.) You felt it was unnecessary to slow down due to the absence of children.

d.) You felt it was inconvenient to slow down, even when children were present.

e.) Other

Speed (Question 12)	**Reason for Speeding (Question 13)**				
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Reason (a)**	**Reason (b)**	**Reason (c)**	**Reason (d)**	**Total**
0-5 mph (a)	387 358.5 2.2657 65.37 80.96 87.16	46 53.291 0.9974 7.77 9.62 69.70	41 58.135 5.0505 6.93 8.58 56.94	4 8.0743 2.0559 0.68 0.84 40.00	478 80.74
5-10 mph (b)	38 56.25 5.9211 6.42 50.67 8.56	15 8.3615 5.2706 2.53 20.00 22.73	21 9.1216 15.468 3.55 28.00 29.17	1 1.2669 0.0562 0.17 1.33 10.00	75 12.67
Over 10 mph (c, d, or e)	19 29.25 3.5919 3.21 48.72 4.28	5 4.348 0.0978 0.84 12.82 7.58	10 4.7432 5.8259 1.69 25.64 13.89	5 0.6588 28.608 0.84 12.82 50.00	39 6.59
Total	444 75.00	66 11.15	72 12.16	10 1.69	592 100.00
Frequency Missing = 170					

Statistic	DF	Value	Prob
Chi-Square	6	75.2088	<.0001
Likelihood Ratio Chi-Square	6	53.8808	<.0001
Mantel-Haenszel Chi-Square	1	54.1309	<.0001
Phi Coefficient		0.3564	
Contingency Coefficient		0.3357	
Cramer's V		0.2520	

WARNING: 33% of the cells have expected counts less than 5. Chi-Squared may not be a valid test.

WARNING: 22% of the data are missing since "other" reasons were left out of the analysis.

Table A-5: Age vs. Importance of Vehicles Slowing Down in School Zones

Age derived from question 1.
vs.
7.) In your opinion, how important is it that vehicles slow down in school zones?
Extremely Important   Important   Somewhat Important   Not Important   No Opinion

Age (Question 1)	Importance of Vehicles Slowing Down in School Zones (Question 7)		Total
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Extremely Important**	**Important or Somewhat Important**	**Total**
16-25	221 244.49 2.2564 30.27 79.50 34.42	57 33.512 16.462 7.81 20.50 64.77	278 38.08
26-35	191 181.17 0.5337 26.16 92.72 29.75	15 24.833 3.8934 2.05 7.28 17.05	206 28.22
35-50	147 138.95 0.466 20.14 93.04 22.90	11 19.047 3.3994 1.51 6.96 12.50	158 21.64
Over 50	83 77.392 0.4064 11.37 94.32 12.93	5 10.608 2.9649 0.68 5.68 5.68	88 12.05
Total	642 87.95	88 12.05	730 100.00
Frequency Missing = 32			

Statistic	DF	Value	Prob
Chi-Square	3	30.3820	<.0001
Likelihood Ratio Chi-Square	3	29.5372	<.0001
Mantel-Haenszel Chi-Square	1	21.9668	<.0001
Phi Coefficient		0.2040	
Contingency Coefficient		0.1999	
Cramer's V		0.2040	

Table A-6: Age vs. Helpfulness of SMDs at Informing Drivers of Their Speed

Age derived from question 1.
vs.
15.) How helpful are the electronic signs that display vehicle speeds at informing you of your speed while driving?

a.) Very helpful
b.) Helpful
c.) Sometimes helpful
d.) Rarely helpful
e.) Never helpful; I always know how fast I am going

Age (Question 1)	**Helpfulness of SMDs (Question 15)**					**Total**
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**Very helpful**	**Helpful**	**Sometimes Helpful**	**Rarely Helpful**	**Never Helpful**	
16-25	94 125.8 8.0388 13.00 33.69 28.83	73 64.444 1.136 10.10 26.16 43.71	61 49.008 2.9342 8.44 21.86 48.03	34 23.154 5.0811 4.70 12.19 56.67	17 16.593 0.01 2.35 6.09 39.53	279 38.59
26-35	82 89.278 0.5933 11.34 41.41 25.15	39 45.734 0.9917 5.39 19.70 23.35	41 34.78 1.1123 5.67 20.71 32.28	17 16.432 0.0197 2.35 8.59 28.33	19 11.776 4.4317 2.63 9.60 44.19	198 27.39
35-50	96 70.791 8.9769 13.28 61.15 29.45	35 36.264 0.0441 4.84 22.29 20.96	17 27.578 4.0575 2.35 10.83 13.39	6 13.029 3.7921 0.83 3.82 10.00	3 9.3375 4.3013 0.41 1.91 6.98	157 21.72
Over 50	54 40.13 4.7938 7.47 60.67 16.56	20 20.557 0.0151 2.77 22.47 11.98	8 15.633 3.7273 1.11 8.99 6.30	3 7.3859 2.6044 0.41 3.37 5.00	4 5.2932 0.316 0.55 4.49 9.30	89 12.31
Total	326 45.09	167 23.10	127 17.57	60 8.30	43 5.95	723 100.00
Frequency Missing = 39						

Statistic	**DF**	**Value**	**Prob**
Chi-Square	12	56.9772	<.0001
Likelihood Ratio Chi-Square	12	59.5557	<.0001
Mantel-Haenszel Chi-Square	1	35.3903	<.0001
Phi Coefficient		0.2807	
Contingency Coefficient		0.2703	
Cramer's V		0.1621	

Table A-7: Age vs. Effectiveness of SMDs at Making Drivers Aware of Possible Danger Ahead

Age derived from question 1.
vs.
16.) The electronic signs that display vehicle speeds are effective at making me aware that there might be danger ahead.

Strongly Agree | Agree | Somewhat Agree | No Opinion | Somewhat Disagree | Disagree | Strongly Disagree

Age (Question 1)	Effectiveness of SMDs at making drivers aware of danger ahead (Question 16)							Total
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Strongly Agree**	**Agree**	**Somewhat Agree**	**No Opinion**	**Somewhat Disagree**	**Disagree**	**Strongly Disagree**	**Total**
16-25	45 65.95 6.6553 6.20 16.07 26.32	101 89.091 1.5919 13.91 36.07 43.72	49 49.366 0.0027 6.75 17.50 38.28	31 25.069 1.4033 4.27 11.07 47.69	29 21.983 2.2395 3.99 10.36 50.88	15 19.669 1.1085 2.07 5.36 29.41	10 8.8705 0.1438 1.38 3.57 43.48	280 38.57
26-35	47 47.107 0.0002 6.47 23.50 27.49	45 63.636 5.4578 6.20 22.50 19.48	47 35.262 3.9076 6.47 23.50 36.72	17 17.906 0.0459 2.34 8.50 26.15	15 15.702 0.0314 2.07 7.50 26.32	20 14.05 2.5202 2.75 10.00 39.22	9 6.3361 1.12 1.24 4.50 39.13	200 27.55
35-50	45 36.979 1.7396 6.20 28.66 26.32	54 49.955 0.3276 7.44 34.39 23.38	25 27.68 0.2596 3.44 15.92 19.53	10 14.056 1.1706 1.38 6.37 15.38	10 12.326 0.4391 1.38 6.37 17.54	12 11.029 0.0855 1.65 7.64 23.53	1 4.9738 3.1749 0.14 0.64 4.35	157 21.63
Over 50	34 20.963 8.1081 4.68 38.20 19.88	31 28.318 0.254 4.27 34.83 13.42	7 15.691 4.8142 0.96 7.87 5.47	7 7.9683 0.1177 0.96 7.87 10.77	3 6.9876 2.2756 0.41 3.37 5.26	4 6.2521 0.8112 0.55 4.49 7.84	3 2.8196 0.0115 0.41 3.37 13.04	89 12.26
Total	171 23.55	231 31.82	128 17.63	65 8.95	57 7.85	51 7.02	23 3.17	726 100.00
Frequency Missing = 36								

Statistic	DF	Value	Prob
Chi-Square	18	49.8173	<.0001
Likelihood Ratio Chi-Square	18	52.5394	<.0001
Mantel-Haenszel Chi-Square	1	13.2066	0.0003
Phi Coefficient		0.2620	
Contingency Coefficient		0.2534	
Cramer's V		0.1512	

Table A-8: Location vs. Knowledge of Uniform Reduced School-Zone Speed Limit

Location survey was collected
vs.
8.) What is the uniform speed limit for reduced-speed school zones in Utah?
a.) 15 mph b.) 20 mph c.) 25 mph d.) 30 mph

Location	Knowledge of uniform reduced-speed school zone speed limit (Question 8)			
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**15 mph**	**20 mph**	**25 mph**	**Total**
Goshen/ Santaquin	1 12.532 10.611 0.13 1.69 0.62	56 41.798 4.8254 7.39 94.92 10.43	2 4.6702 1.5267 0.26 3.39 3.33	59 7.78
Logan	34 37.595 0.3438 4.49 19.21 21.12	132 125.39 0.348 17.41 74.58 24.58	11 14.011 0.6469 1.45 6.21 18.33	177 23.35
Provo/ Pleasant Grove	72 70.305 0.0409 9.50 21.75 44.72	231 234.49 0.0521 30.47 69.79 43.02	28 26.201 0.1236 3.69 8.46 46.67	331 43.67
Salt Lake	54 40.569 4.4468 7.12 28.27 33.54	118 135.31 2.2151 15.57 61.78 21.97	19 15.119 0.9964 2.51 9.95 31.67	191 25.20
Total	161 21.24	537 70.84	60 7.92	758 100.00
Frequency Missing = 4				

Statistic	DF	Value	Prob
Chi-Square	6	26.1770	0.0002
Likelihood Ratio Chi-Square	6	33.1821	<.0001
Mantel-Haenszel Chi-Square	1	4.7998	0.0285
Phi Coefficient		0.1858	
Contingency Coefficient		0.1827	
Cramer's V		0.1314	

Table A-9: Location vs. Speed Compliance

Location survey was collected
vs.
11.) I obey the speed limit in school zones… *(Circle one)*

Always | Most of the time | About 75% of the time | About half the time | About 25% of the time | Rarely | Never

Speed Compliance (Question 11)	Location				Total
Frequency Expected Cell Chi-Square Percent Row Pct Col Pct	**Goshen/ Santaquin**	**Logan**	**Provo/ Pleasant Grove**	**Salt Lake**	**Total**
Always	49 38.972 2.5801 6.46 9.94 81.67	115 116.27 0.0138 15.15 23.33 64.25	187 215 3.6459 24.64 37.93 56.50	142 122.76 3.0145 18.71 28.80 75.13	493 64.95
Most of Time	9 15.81 2.9335 1.19 4.50 15.00	51 47.167 0.3114 6.72 25.50 28.49	107 87.22 4.4858 14.10 53.50 32.33	33 49.802 5.6688 4.35 16.50 17.46	200 26.35
~ 75% of Time	0 3.004 3.004 0.00 0.00 0.00	7 8.9618 0.4294 0.92 18.42 3.91	24 16.572 3.3296 3.16 63.16 7.25	7 9.4625 0.6408 0.92 18.42 3.70	38 5.01
~50% or less	2 2.2134 0.0206 0.26 7.14 3.33	6 6.6034 0.0551 0.79 21.43 3.35	13 12.211 0.051 1.71 46.43 3.93	7 6.9723 0.0001 0.92 25.00 3.70	28 3.69
Total	60 7.91	179 23.58	331 43.61	189 24.90	759 100.00
Frequency Missing = 3					

Statistic	DF	Value	Prob
Chi-Square	9	30.1845	0.0004
Likelihood Ratio Chi-Square	9	33.7121	0.0001
Mantel-Haenszel Chi-Square	1	0.1521	0.6966
Phi Coefficient		0.1994	
Contingency Coefficient		0.1956	
Cramer's V		0.1151	

Table A-10: Language vs. Knowledge of Fines

Language (English or Spanish)
vs.
19.) Were you aware that there are increased fines for speeding in school zones?
Yes No

Language	Knowledge of increased fines (Question 19)		Total
Frequency *Expected* *Cell Chi-Square* *Percent* *Row Percent* *Column Percent*	**No, did not know**	**Yes, knew**	**Total**
English	166 160.53 0.186 22.77 23.55 100.00	539 544.47 0.0549 73.94 76.45 95.74	705 96.71
Spanish	0 5.465 5.465 0.00 0.00 0.00	24 18.535 1.6114 3.29 100.00 4.26	24 3.29
Total	166 22.77	563 77.23	729 100.00
Frequency Missing = 33			

Statistic	DF	Value	Prob
Chi-Square	1	7.3173	0.0068
Likelihood Ratio Chi-Square	1	12.6419	0.0004
Continuity Adj. Chi-Square	1	6.0396	0.0140
Mantel-Haenszel Chi-Square	1	7.3072	0.0069
Phi Coefficient		0.1002	
Contingency Coefficient		0.0997	
Cramer's V		0.1002	

Fisher's Exact Test	
Cell (1,1) Frequency (F)	166
Left-sided Pr <= F	1.0000
Right-sided Pr >= F	0.0018
Table Probability (P)	0.0018
Two-sided Pr <= P	0.0025

Table A-11: Gender vs. Importance of Vehicles Slowing Down in School Zones

Gender derived from question 1
vs.
7.) In your opinion, how important is it that vehicles slow down in school zones?
Extremely Important   Important   Somewhat Important   Not Important   No Opinion

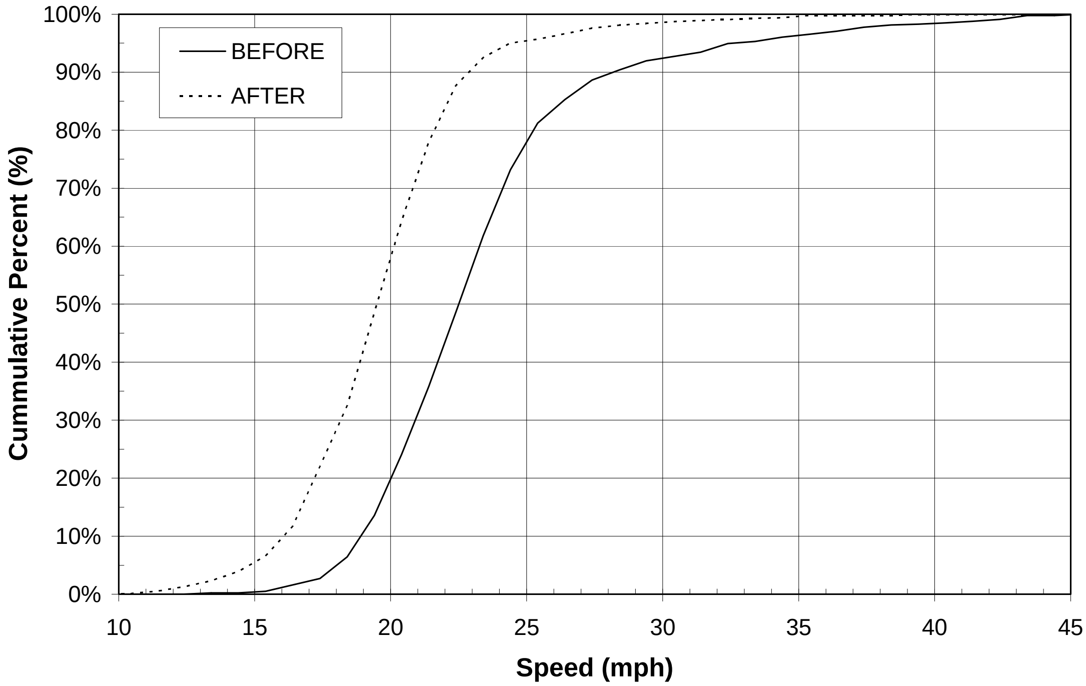
Gender	Importance of Vehicles Slowing Down in School Zones (Question 7)		Total
Frequency Expected Cell Chi-Square Percent Row Percent Column Percent	**Extremely Important**	**Important or Somewhat Important**	**Total**
Female	329 314.32 0.6856 47.61 91.64 54.38	30 44.68 4.8233 4.34 8.36 34.88	359 51.95
Male	276 290.68 0.7414 39.94 83.13 45.62	56 41.32 5.2156 8.10 16.87 65.12	332 48.05
Total	605 87.55	86 12.45	691 100.00
Frequency Missing = 71			

Statistic	DF	Value	Prob
Chi-Square	1	11.4660	0.0007
Likelihood Ratio Chi-Square	1	11.5785	0.0007
Continuity Adj. Chi-Square	1	10.6982	0.0011
Mantel-Haenszel Chi-Square	1	11.4494	0.0007
Phi Coefficient		0.1288	
Contingency Coefficient		0.1278	
Cramer's V		0.1288	

Fisher's Exact Test	
Cell (1,1) Frequency (F)	329
Left-sided Pr <= F	0.9998
Right-sided Pr >= F	5.119E-04
Table Probability (P)	2.951E-04
Two-sided Pr <= P	7.821E-04

Appendix B. Spot Speed Study Results

	Before *(09/13/04 – 09/16/04)*	**After** *(03/28/05 – 03/31/05)*
Mean (mph)	23.24	19.68
Standard Deviation	4.59	3.30
85th Percentile (mph)	26.2	22.1
% Exceeding 20 mph	75.9%	35.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (91.1%)
Sample Size	809	1001



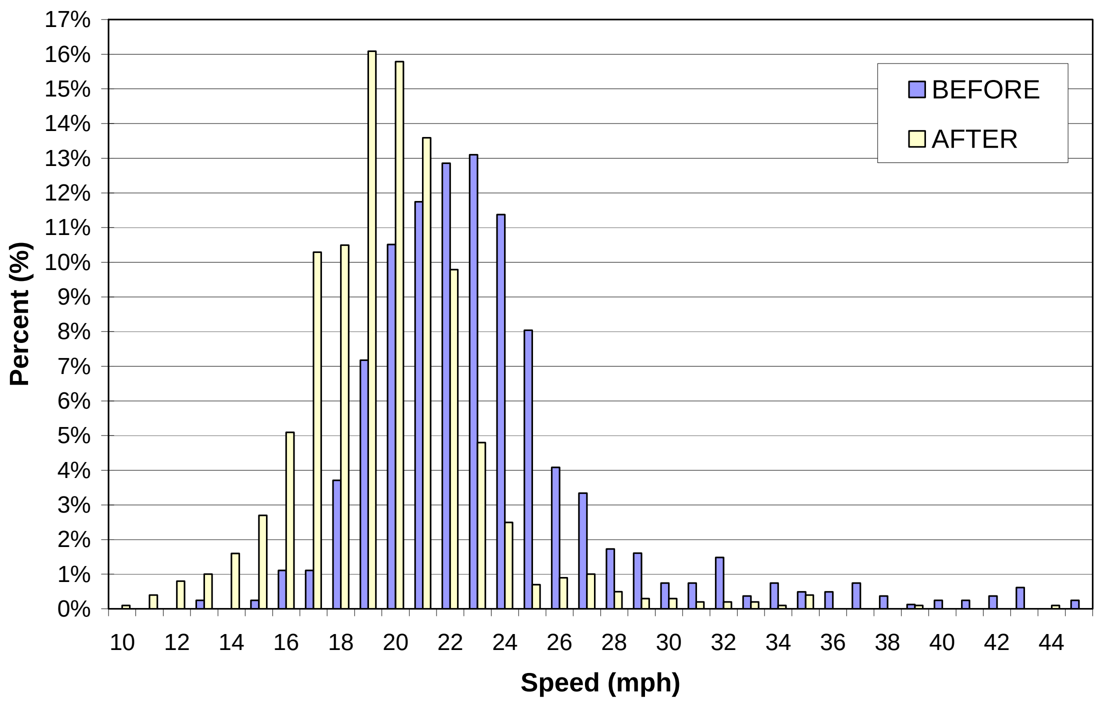
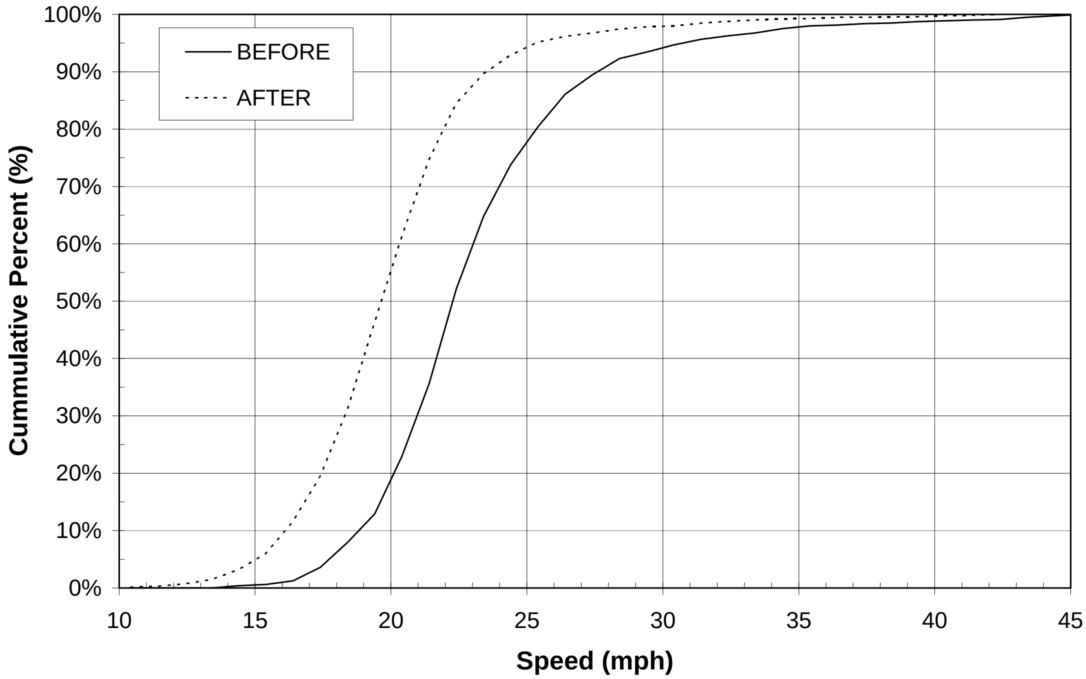


Figure B-1: Logan Westbound Morning (7:30 AM to 8:30 AM)

	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Mean (mph)	22.99	19.97
Standard Deviation	4.22	3.55
85th Percentile (mph)	26.0	22.5
% Exceeding 20 mph	77.0%	38.7%
10 mph Pace (% in Pace)	17 – 27 (85.9%)	14 – 24 (89.7%)
Sample Size	806	1383



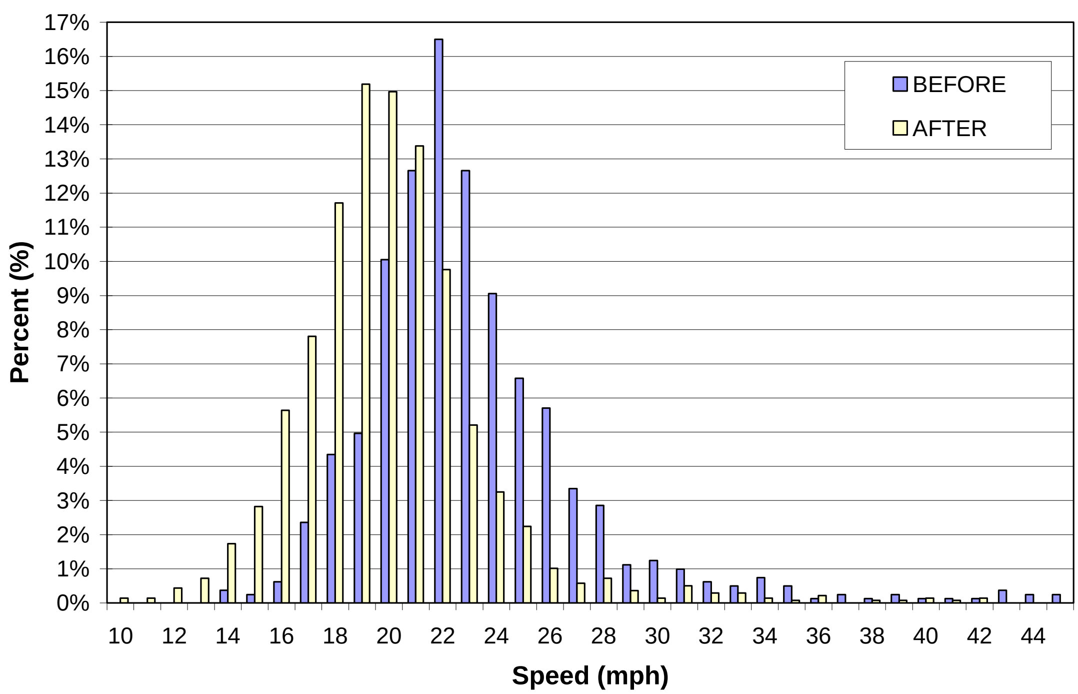
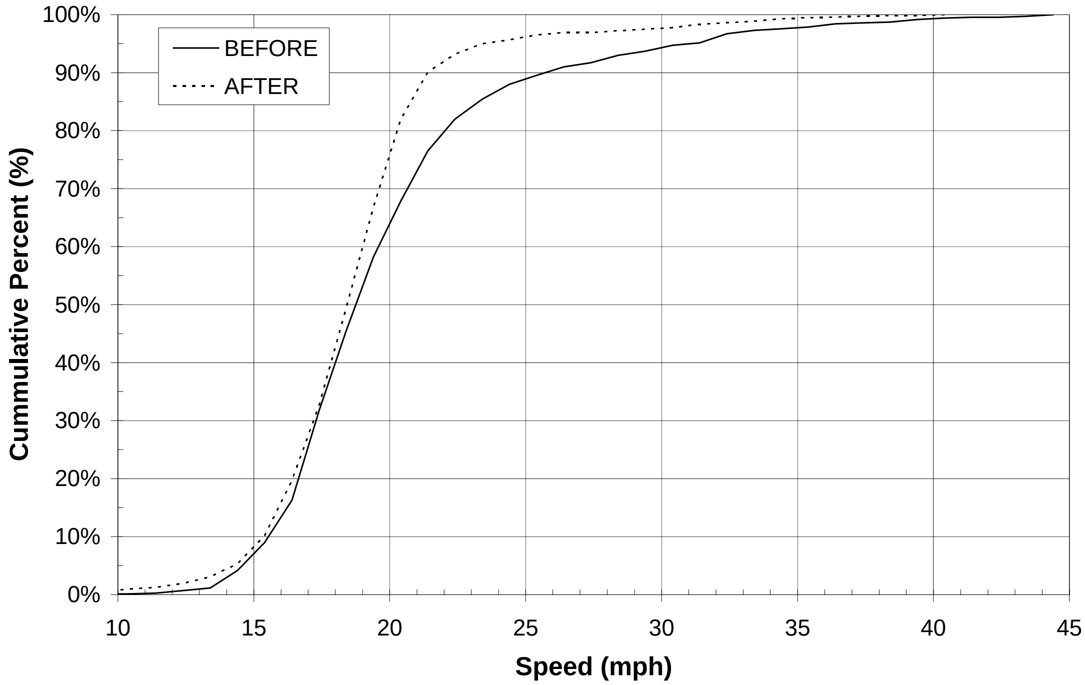


Figure B-2: Logan Westbound Afternoon (2:15 PM to 3:15 PM)

	Before *(09/13/04 – 09/16/04)*	**After** *(03/28/05 – 03/31/05)*
Mean (mph)	19.86	18.70
Standard Deviation	4.88	3.50
85th Percentile (mph)	23.3	20.7
% Exceeding 20 mph	32.2%	18.1%
10 mph Pace (% in Pace)	13 – 23 (84.3%)	13 – 23 (91.9%)
Sample Size	699	717



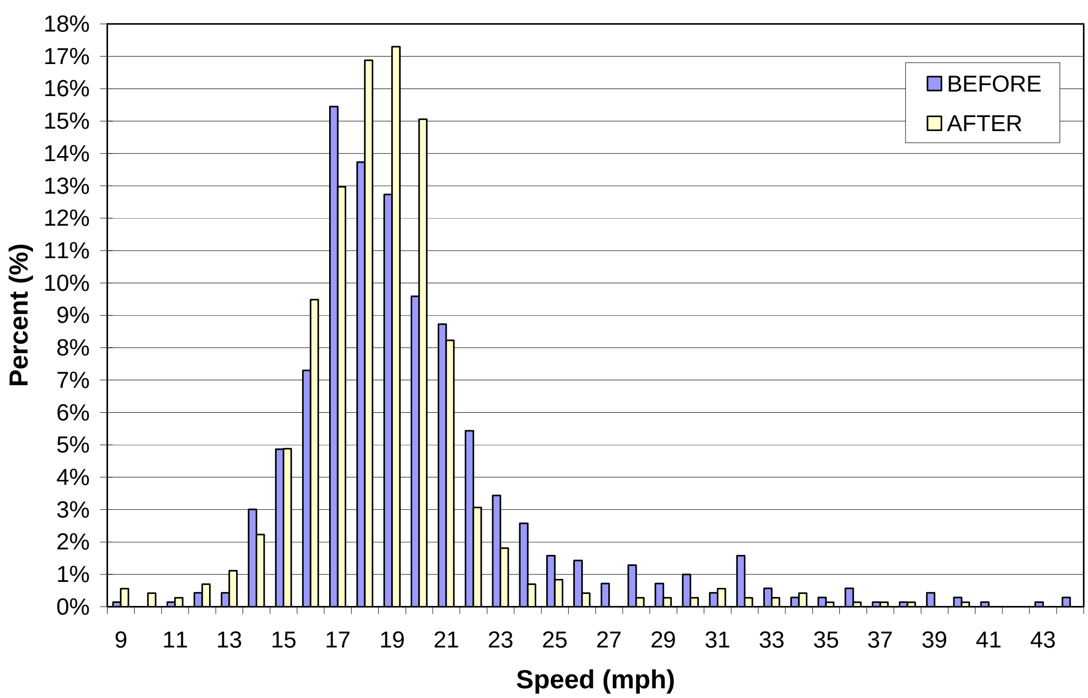
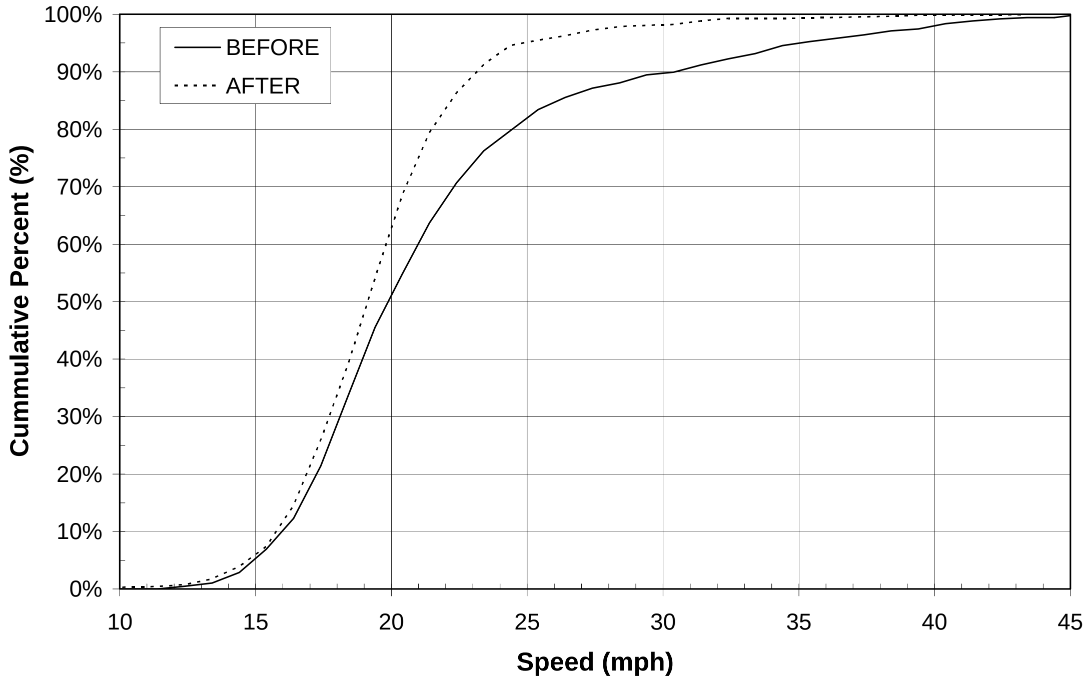


Figure B-3: Logan Eastbound Morning (7:30 AM to 8:30 AM)

	Before *(09/13/04 – 09/16/04)*	After *(03/28/05 – 03/31/05)*
Mean (mph)	21.46	19.49
Standard Deviation	5.98	3.51
85th Percentile (mph)	26.0	22.3
% Exceeding 20 mph	45.2%	31.5%
10 mph Pace (% in Pace)	14 – 24 (76.9%)	14 – 24 (90.7%)
Sample Size	863	1131



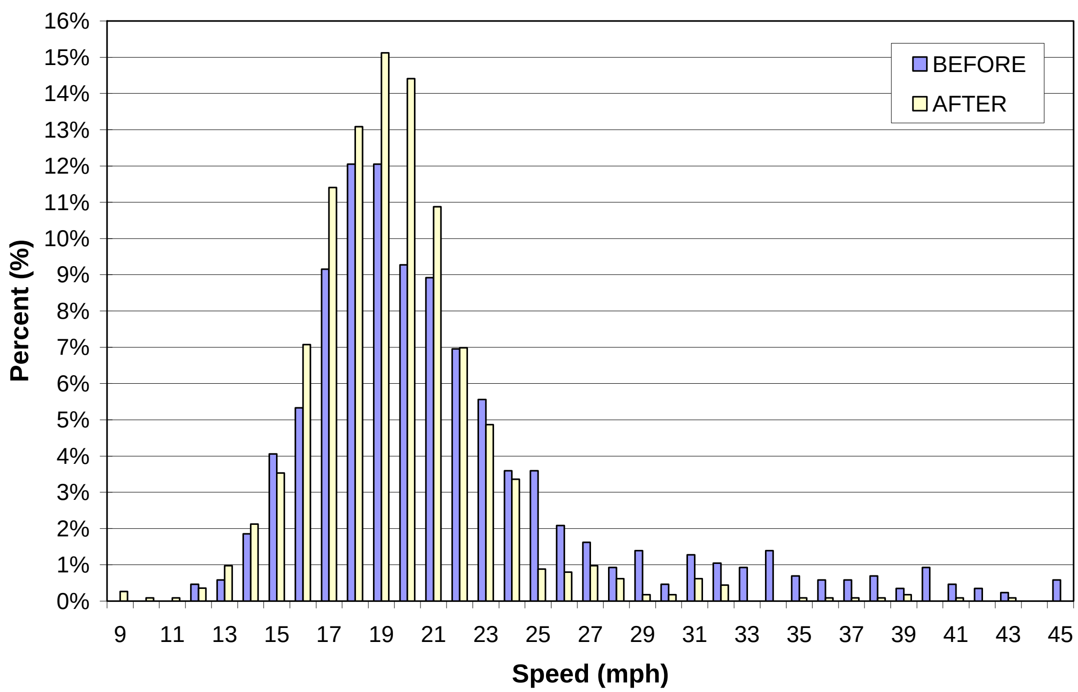
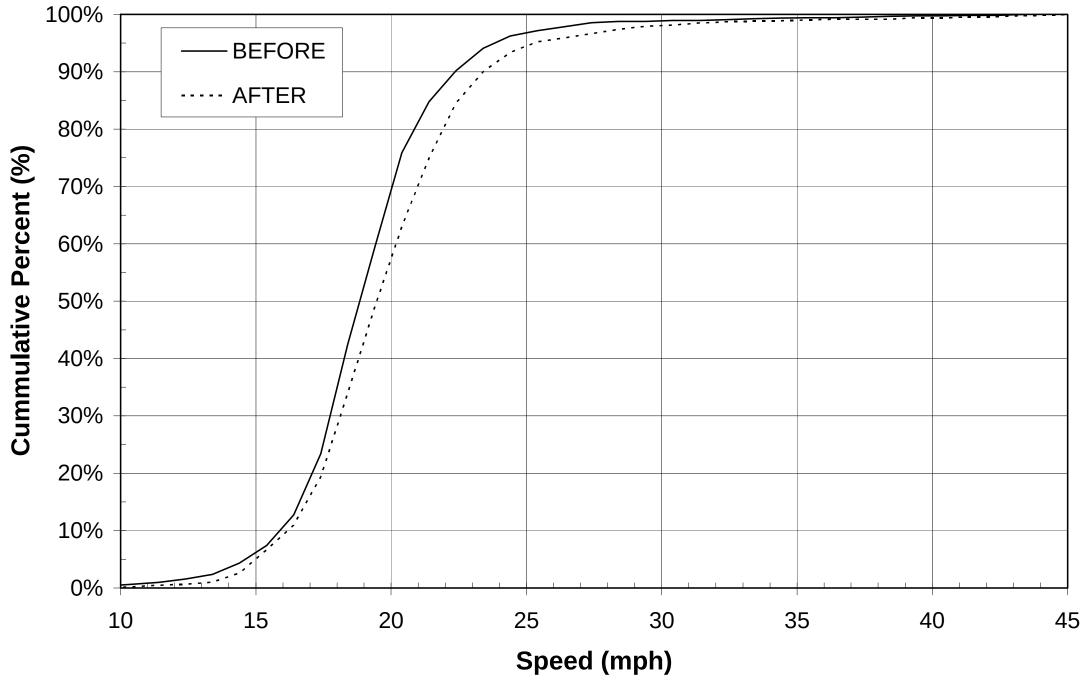


Figure B-4: Logan Eastbound Afternoon (2:15 PM to 3:15 PM)

	Before *(09/20/04 – 09/23/04)*	**After** *(04/04/05 – 04/07/05)*
Mean (mph)	19.06	19.85
Standard Deviation	3.23	3.70
85th Percentile (mph)	21.4	22.4
% Exceeding 20 mph	24.1%	37.0%
10 mph Pace (% in Pace)	14 – 24 (91.9%)	14 – 24 (90.7%)
Sample Size	1223	1069



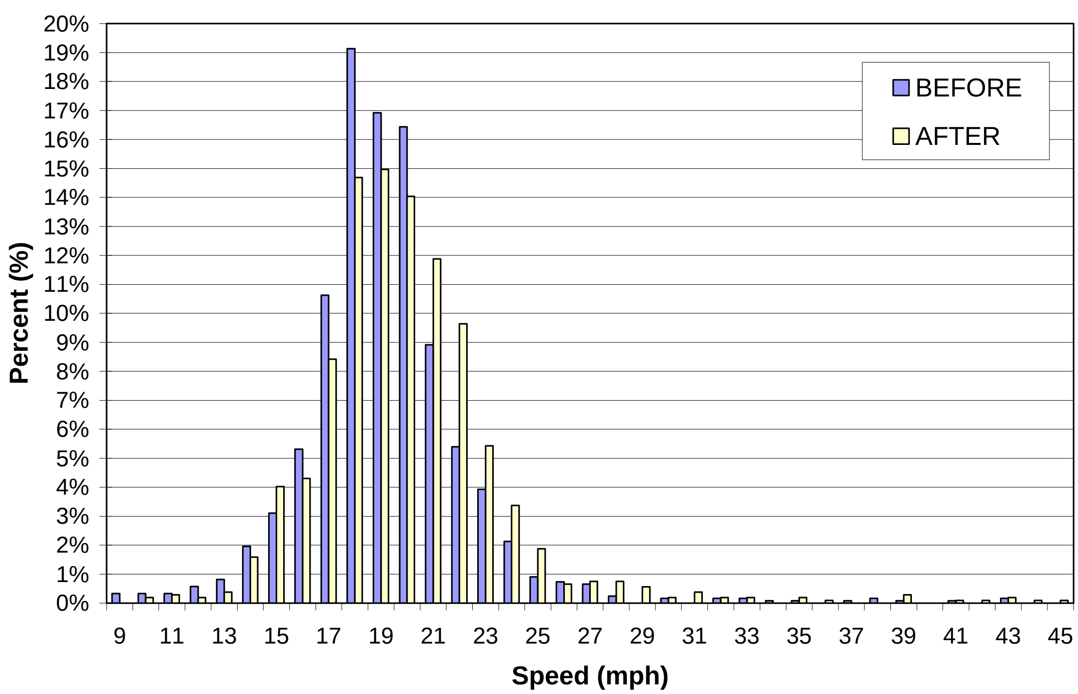
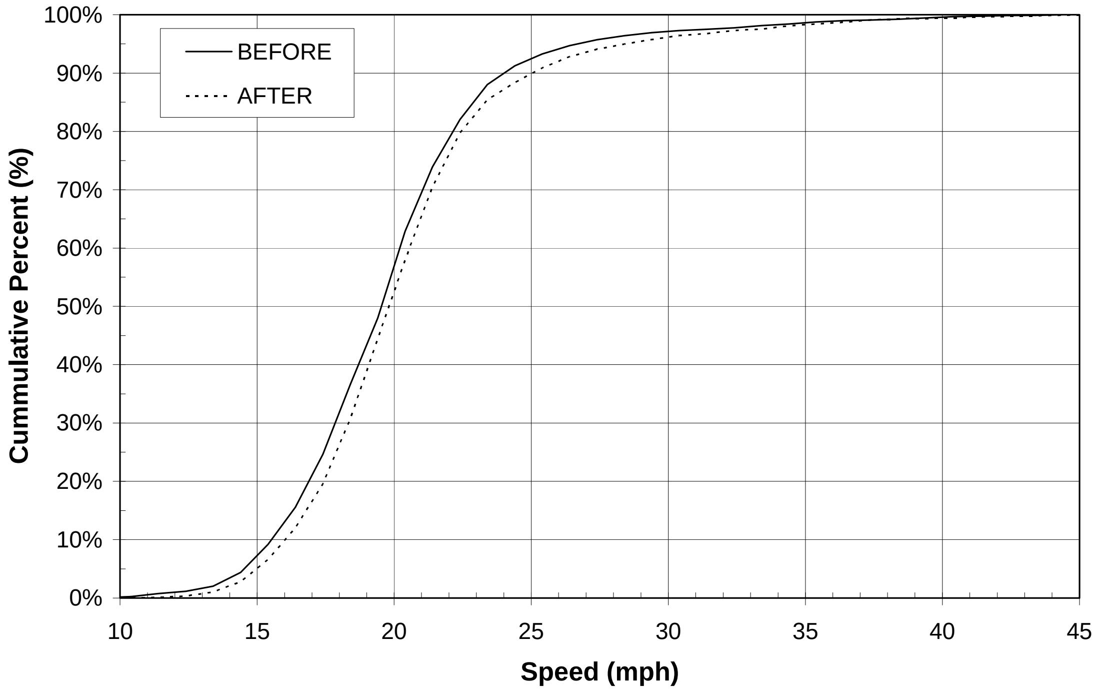


Figure B-5: Salt Lake City Northbound Morning (7:30 AM to 8:25 AM)

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.85	20.39
Standard Deviation	4.14	4.29
85th Percentile (mph)	22.8	23.3
% Exceeding 20 mph	37.1%	42.0%
10 mph Pace (% in Pace)	14 – 24 (86.9%)	14 – 24 (85.6%)
Sample Size	2056	1796



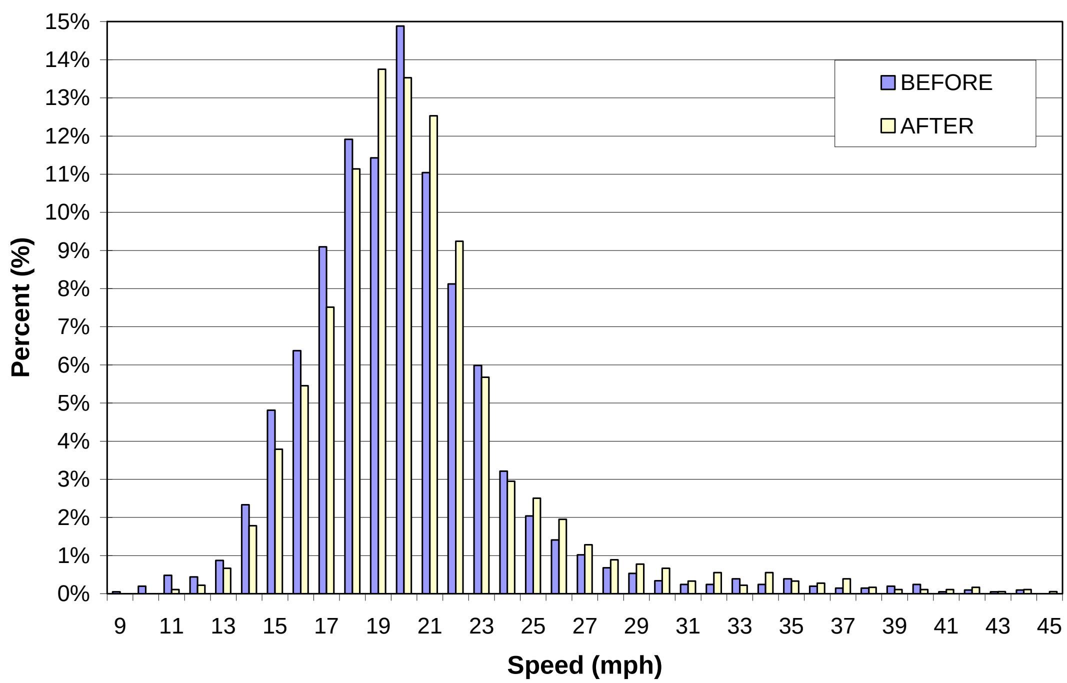
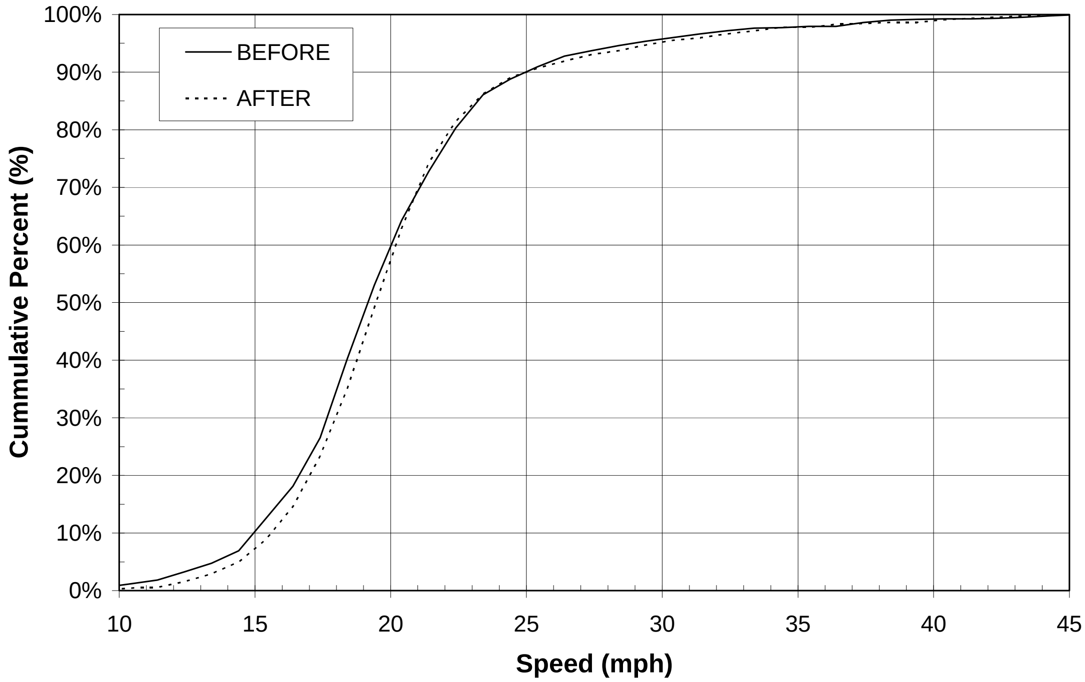


Figure B-6: Salt Lake City Northbound Mid-Day (10:55 AM to 12:15 PM)

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.82	20.15
Standard Deviation	4.90	4.77
85th Percentile (mph)	23.2	22.9
% Exceeding 20 mph	35.7%	37.1%
10 mph Pace (% in Pace)	14 – 24 (81.9%)	14 – 24 (84.1%)
Sample Size	926	891



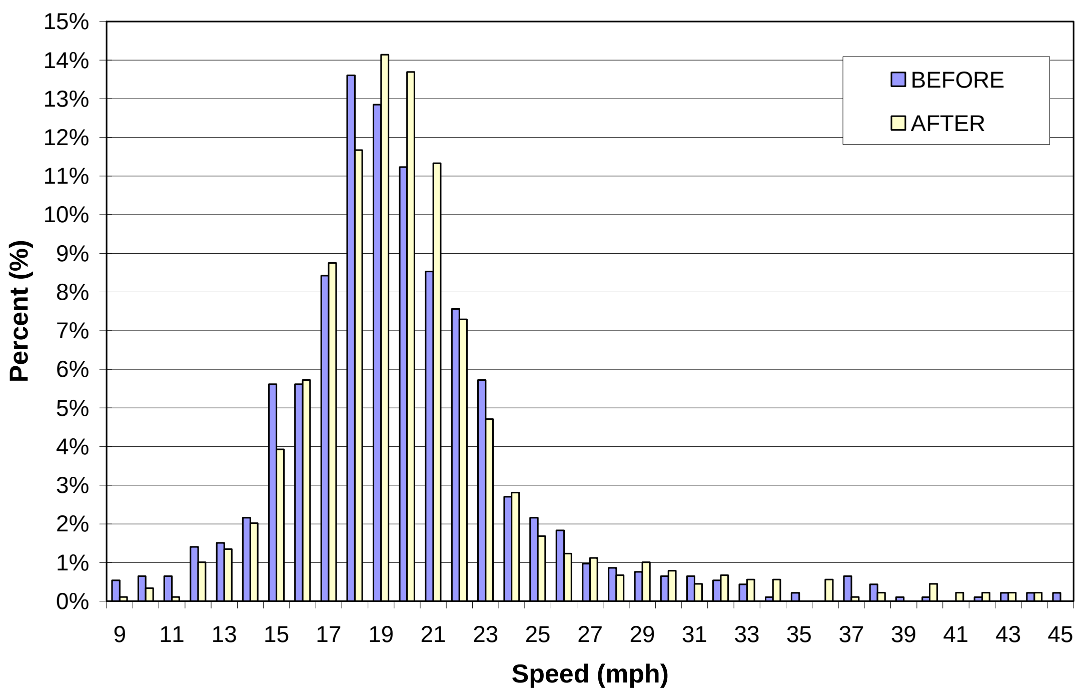
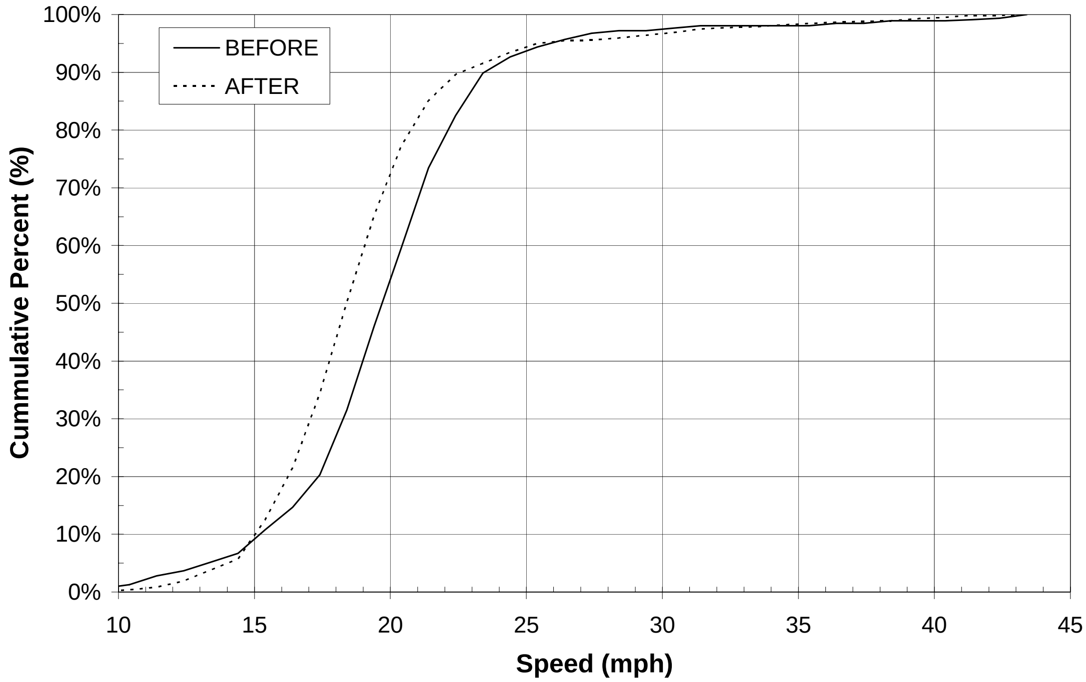


Figure B-7: Salt Lake City Northbound Afternoon (2:30 PM to 3:15 PM)

	Before *(09/20/04 – 09/23/04)*	**After** *(04/04/05 – 04/07/05)*
Mean (mph)	19.83	18.94
Standard Deviation	4.36	4.23
85th Percentile (mph)	22.7	21.3
% Exceeding 20 mph	40.4%	22.8%
10 mph Pace (% in Pace)	14 – 24 (86.0%)	13 – 23 (87.7%)
Sample Size	463	838



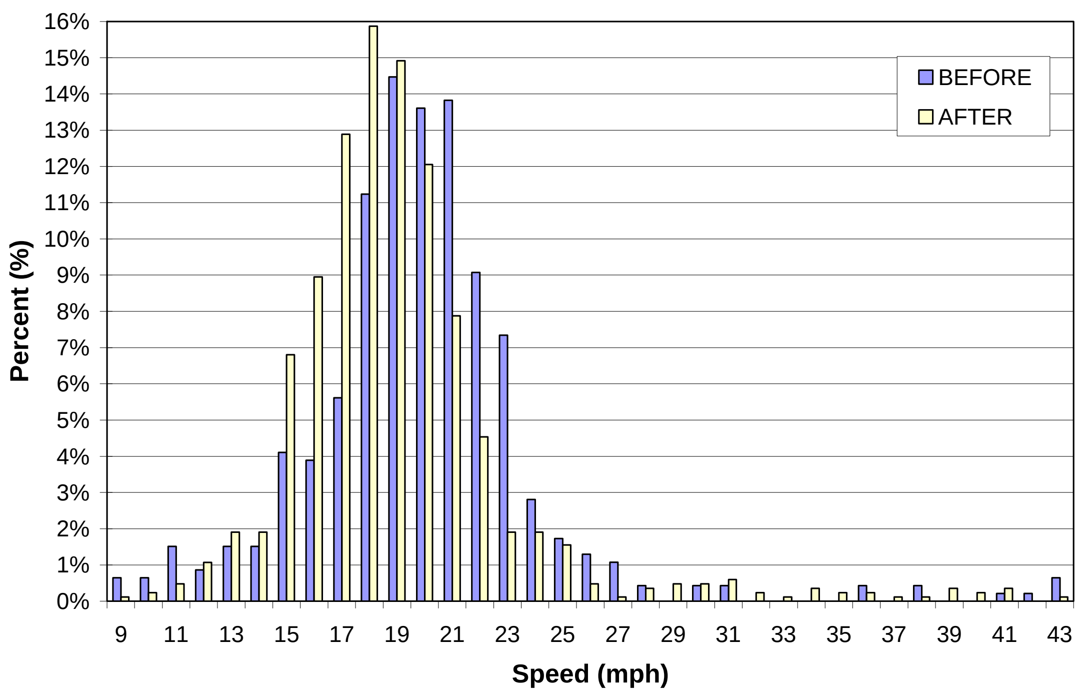
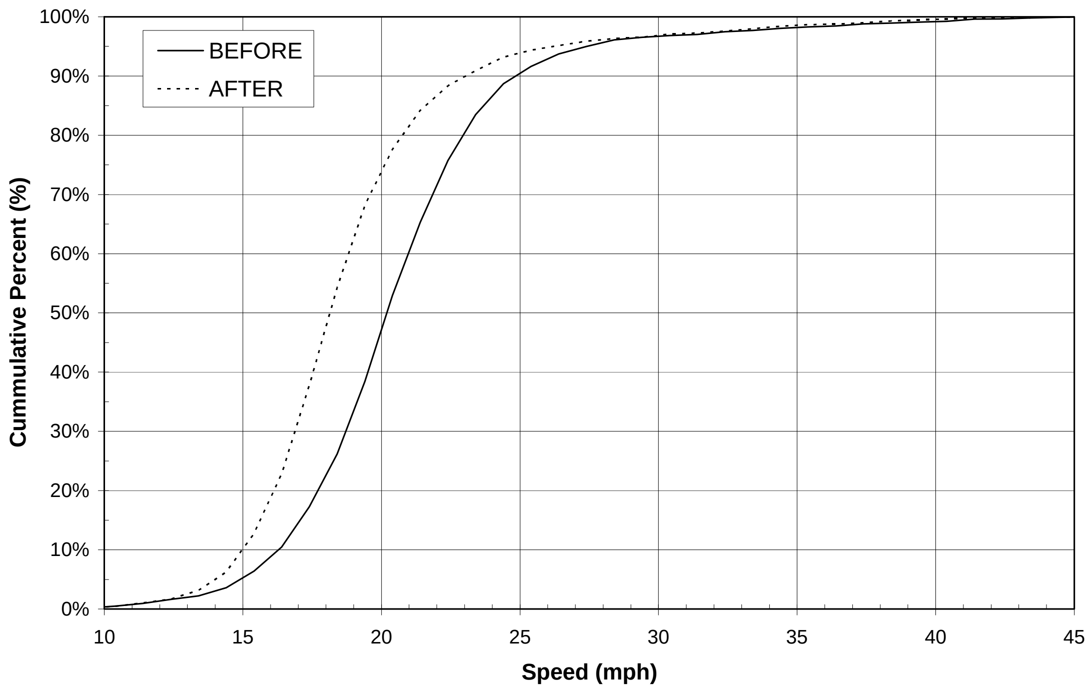


Figure B-8: Salt Lake City Southbound Morning (7:30 AM to 8:25 AM)

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	20.61	18.84
Standard Deviation	4.32	4.24
85th Percentile (mph)	23.6	21.5
% Exceeding 20 mph	47.1%	22.4%
10 mph Pace (% in Pace)	15 – 25 (85.2%)	13 – 23 (87.7%)
Sample Size	1994	2129



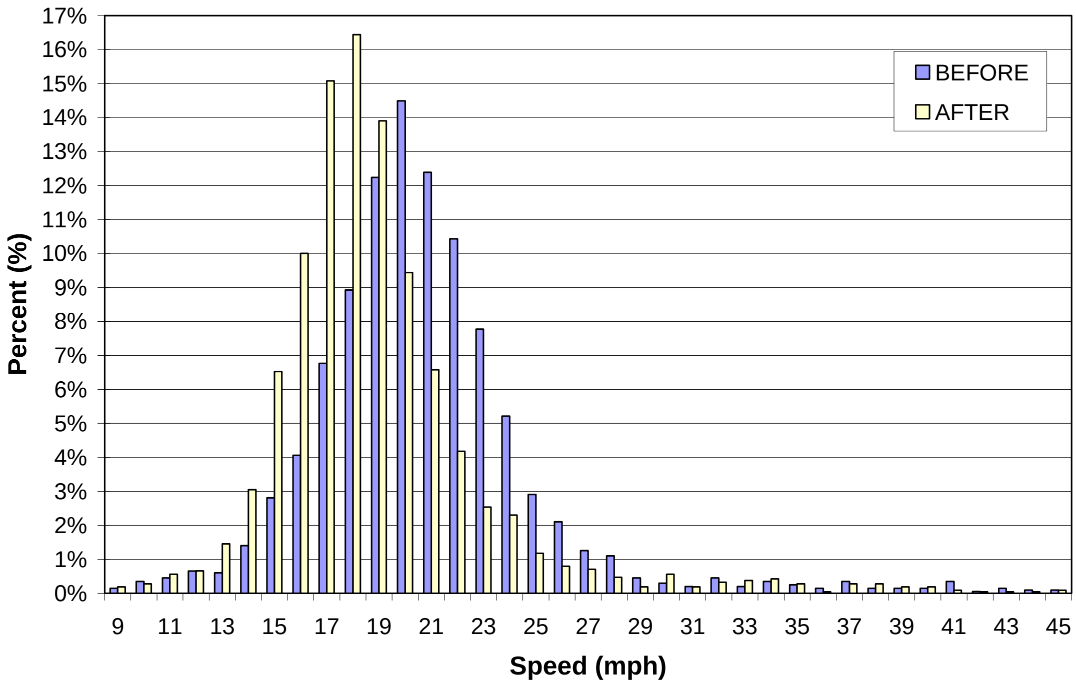
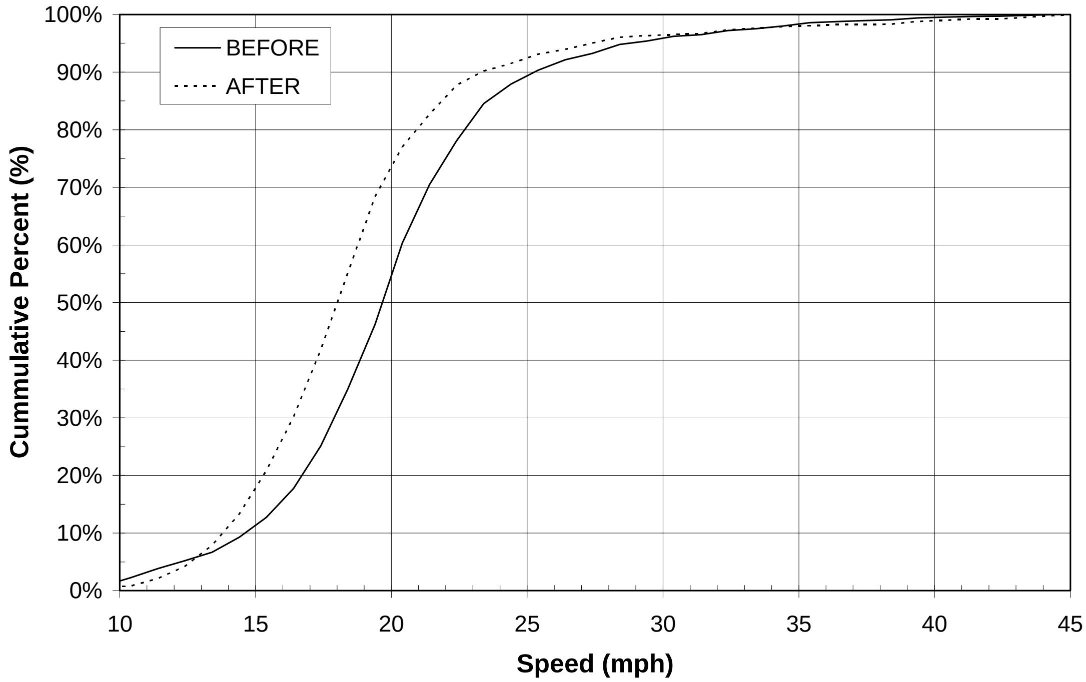


Figure B-9: Salt Lake City Southbound Mid-Day (10:55 AM to 12:15 PM)

	Before *(09/20/04 – 09/23/04)*	After *(04/04/05 – 04/07/05)*
Mean (mph)	19.95	18.65
Standard Deviation	4.90	4.96
85th Percentile (mph)	23.5	21.8
% Exceeding 20 mph	39.7%	23.0%
10 mph Pace (% in Pace)	14 – 24 (78.6%)	12 – 22 (83.5%)
Sample Size	1409	1091



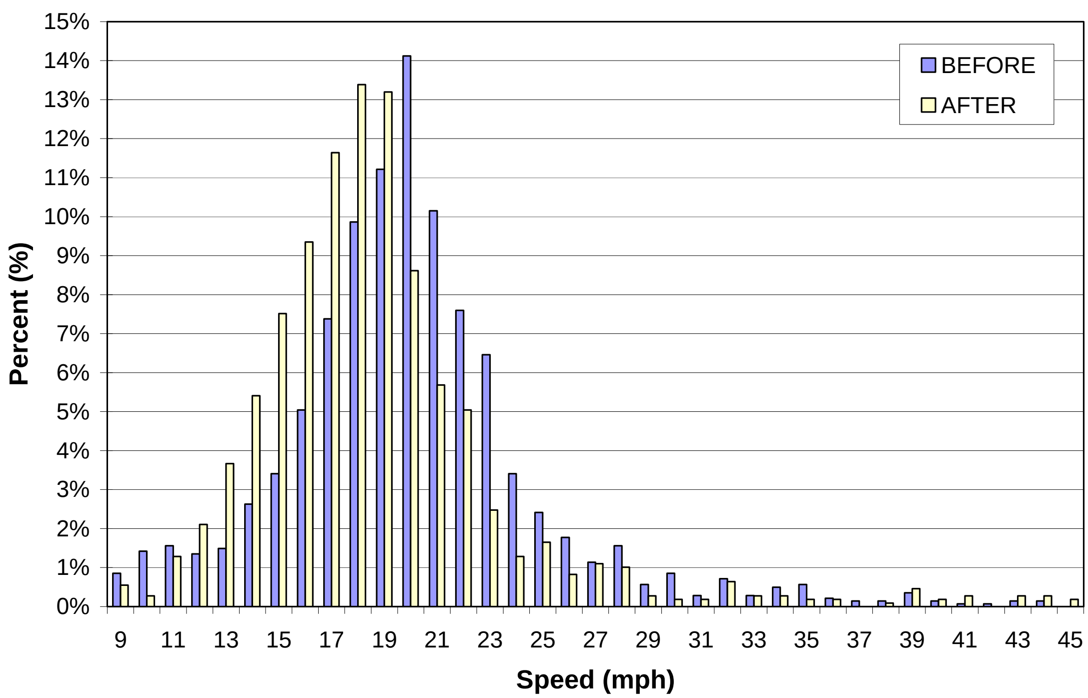
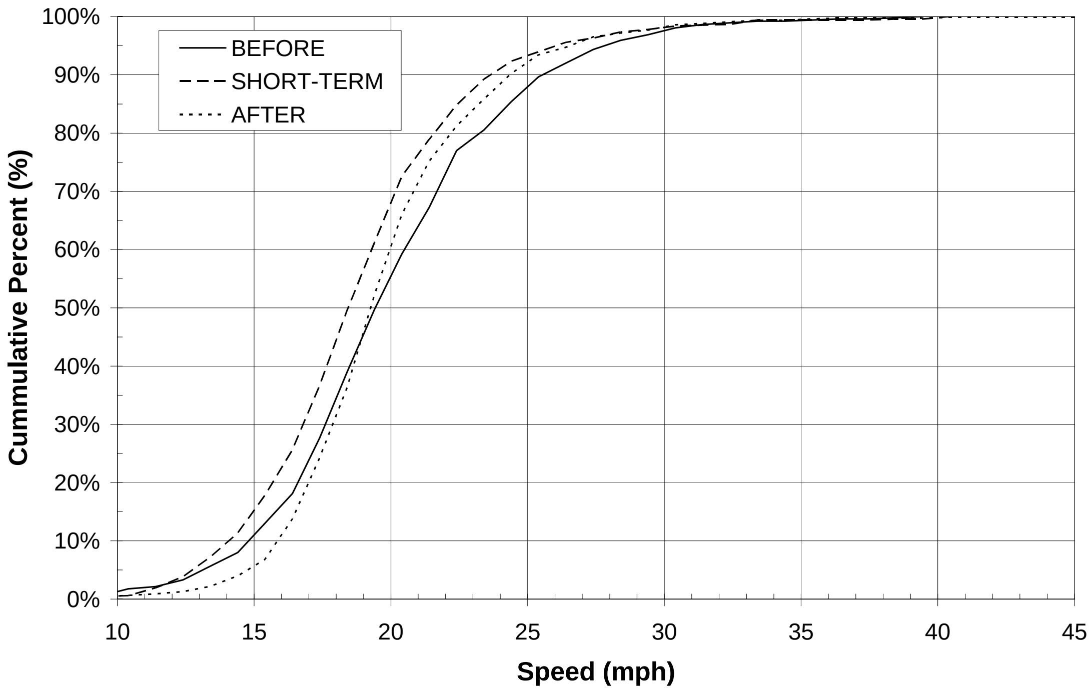


Figure B-10: Salt Lake City Southbound Afternoon (2:30 PM to 3:15 PM)

	Before *(10/04/04 – 10/07/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	19.88	18.81	19.80
Standard Deviation	4.44	4.16	3.78
85th Percentile (mph)	24.2	22.4	23.3
% Exceeding 20 mph	40.7%	27.4%	34.0%
10 mph Pace (% in Pace)	14 – 24 (77.4%)	13 – 23 (82.0%)	15 – 25 (86.6%)
Sample Size	513	678	777



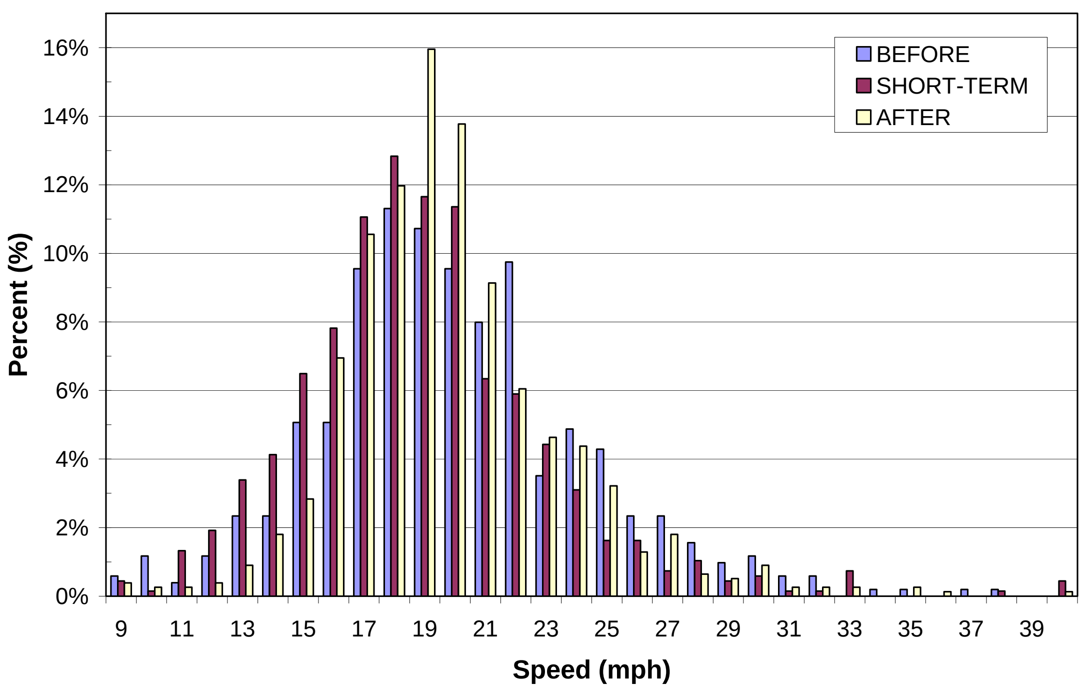
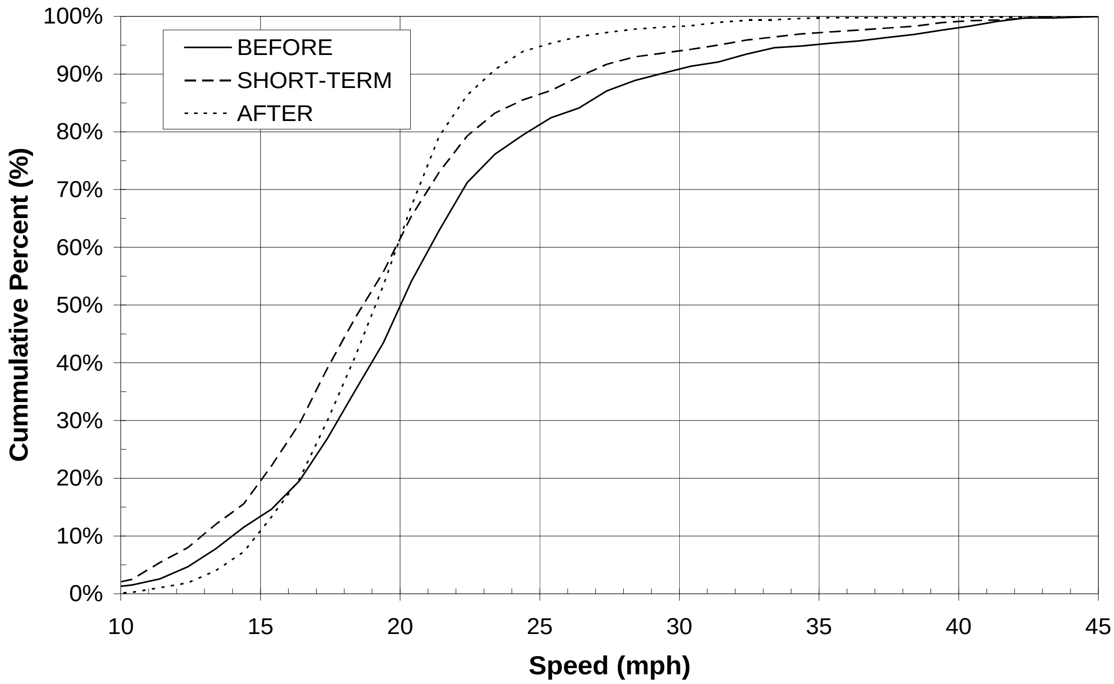


Figure B-11: Pleasant Grove Northbound Morning (8:15 AM to 8:50 AM)

	Before *(10/04/04 – 10/07/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	20.98	19.38	19.25
Standard Deviation	6.33	5.84	3.70
85th Percentile (mph)	26.7	24.2	22.1
% Exceeding 20 mph	45.9%	34.7%	32.9%
10 mph Pace (% in Pace)	13 – 23 (68.3%)	13 – 23 (71.3%)	13 – 23 (86.8%)
Sample Size	1052	926	856



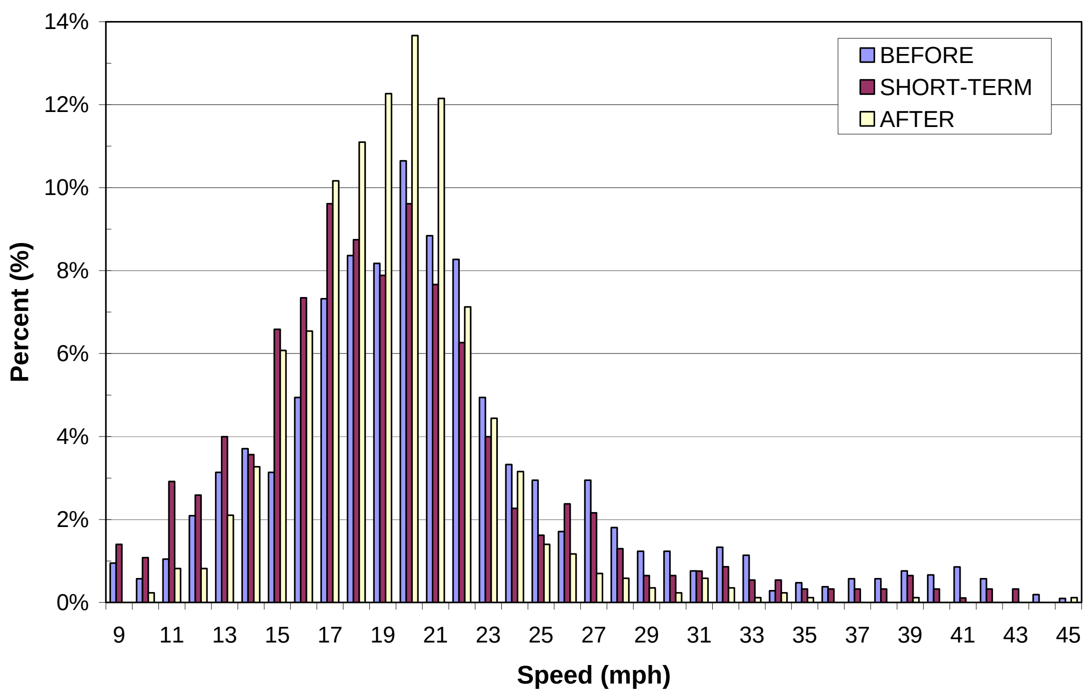
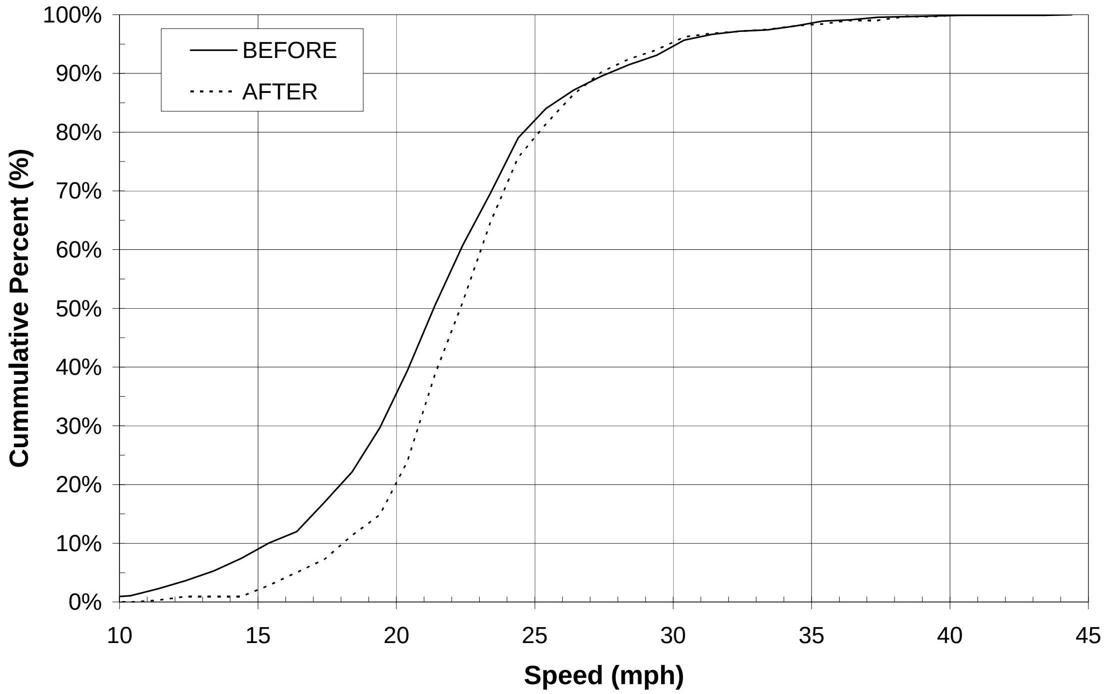


Figure B-12: Pleasant Grove Northbound Afternoon (3:25 PM to 4:00 PM)

	Before *(10/04/04 – 10/07/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	21.58	22.69
Standard Deviation	4.92	4.09
85th Percentile (mph)	25.7	26.1
% Exceeding 20 mph	60.6%	76.0%
10 mph Pace (% in Pace)	16 – 26 (75.2%)	17 – 27 (83.0%)
Sample Size	926	317



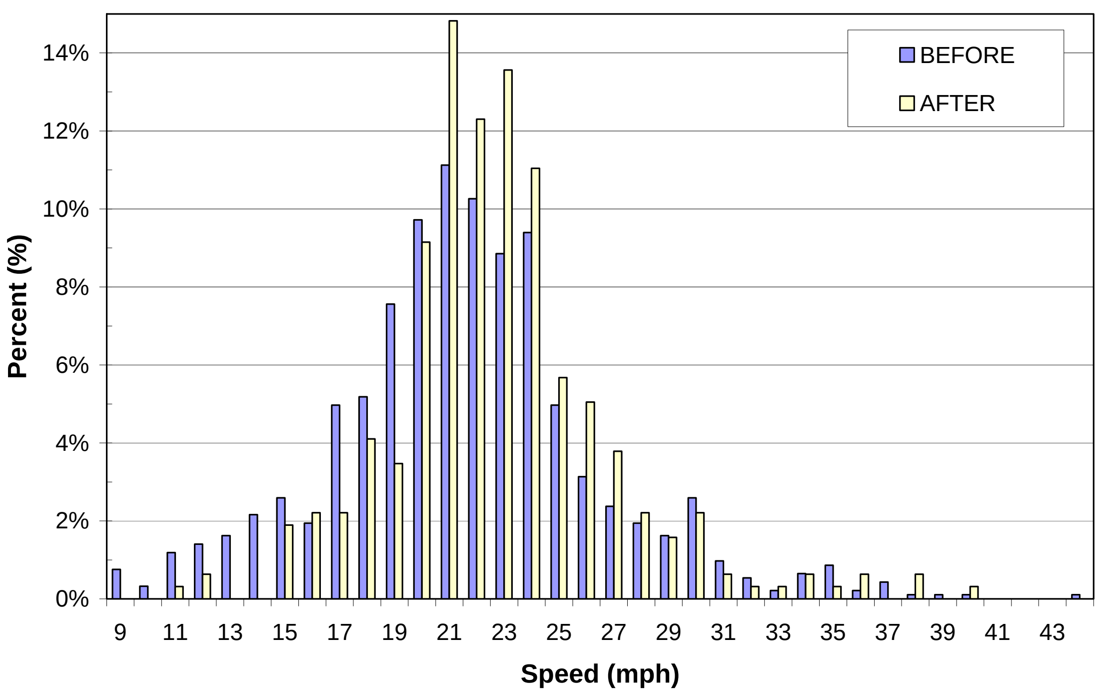
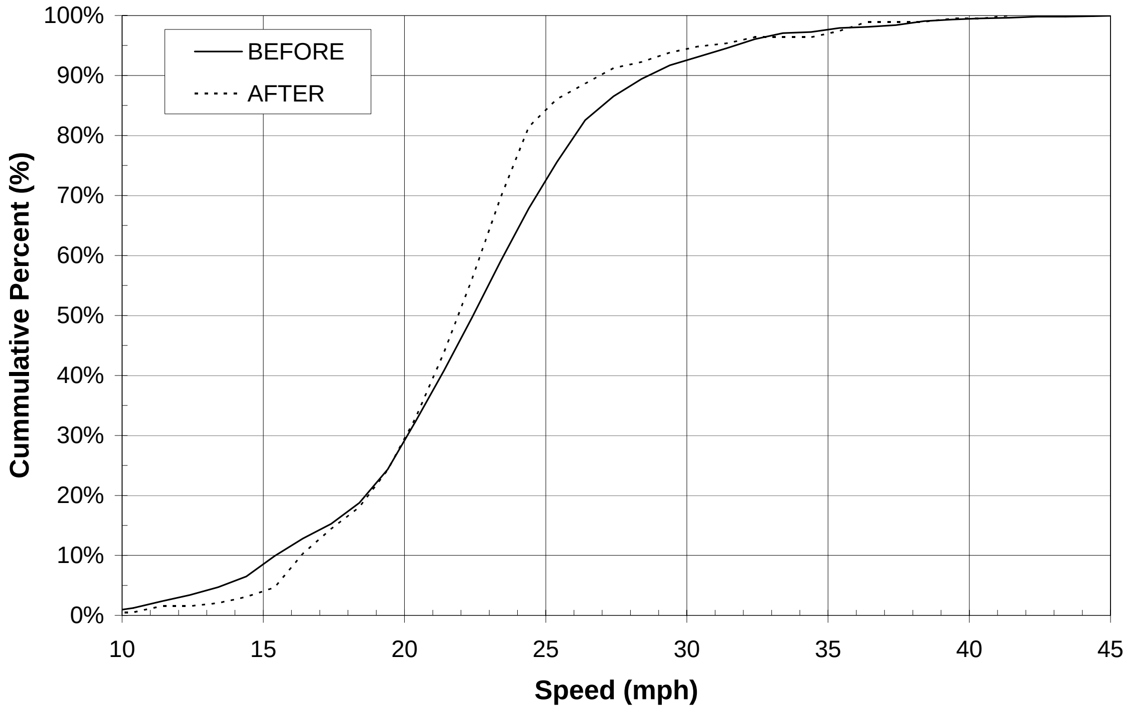


Figure B-13: Pleasant Grove Southbound Morning (8:15 AM to 8:50 AM)

	Before *(10/04/04 – 10/07/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	22.49	22.04
Standard Deviation	5.37	4.72
85th Percentile (mph)	27.0	25.2
% Exceeding 20 mph	67.6%	67.0%
10 mph Pace (% in Pace)	17 – 27 (71.3%)	15 – 25 (81.4%)
Sample Size	1061	194



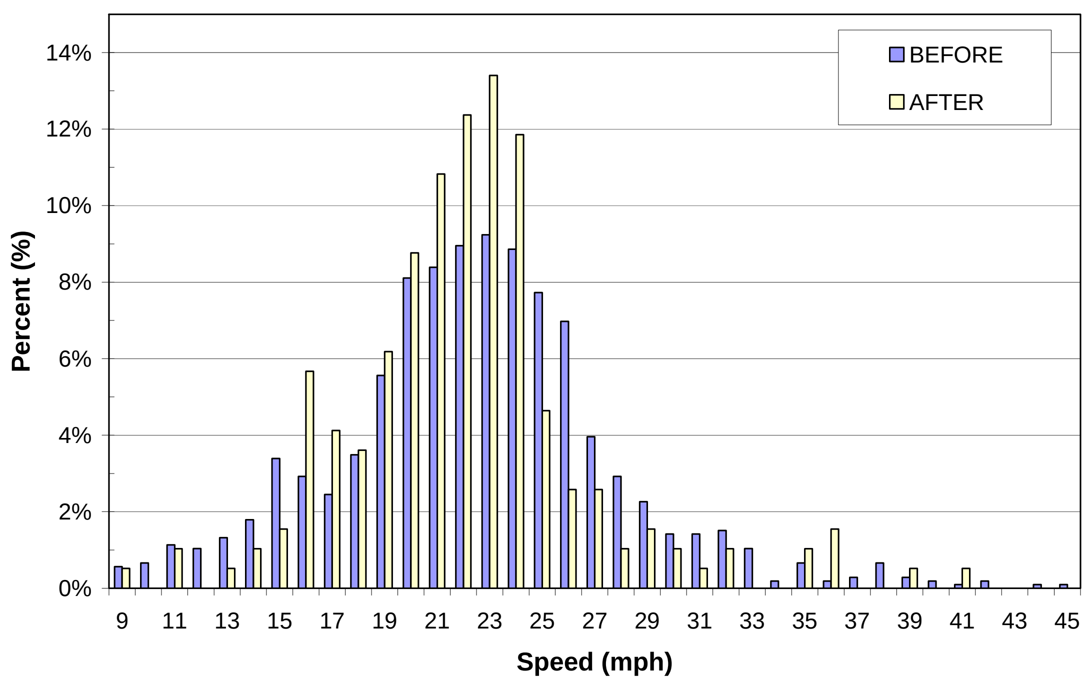
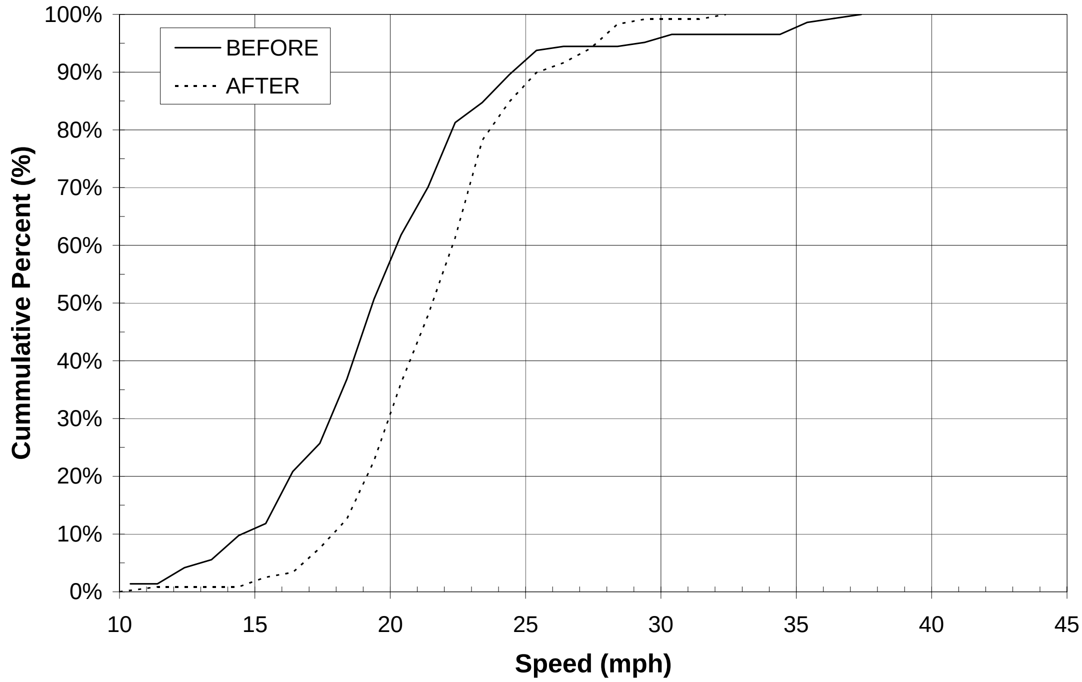


Figure B-14: Pleasant Grove Southbound Afternoon (3:25 PM to 4:00 PM)

	Before *(09/27/04 – 09/30/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	19.75	21.66
Standard Deviation	4.69	3.18
85th Percentile (mph)	23.4	24.4
% Exceeding 20 mph	38.2%	63.9%
10 mph Pace (% in Pace)	15 – 25 (81.9%)	16 – 26 (88.2%)
Sample Size	144	119



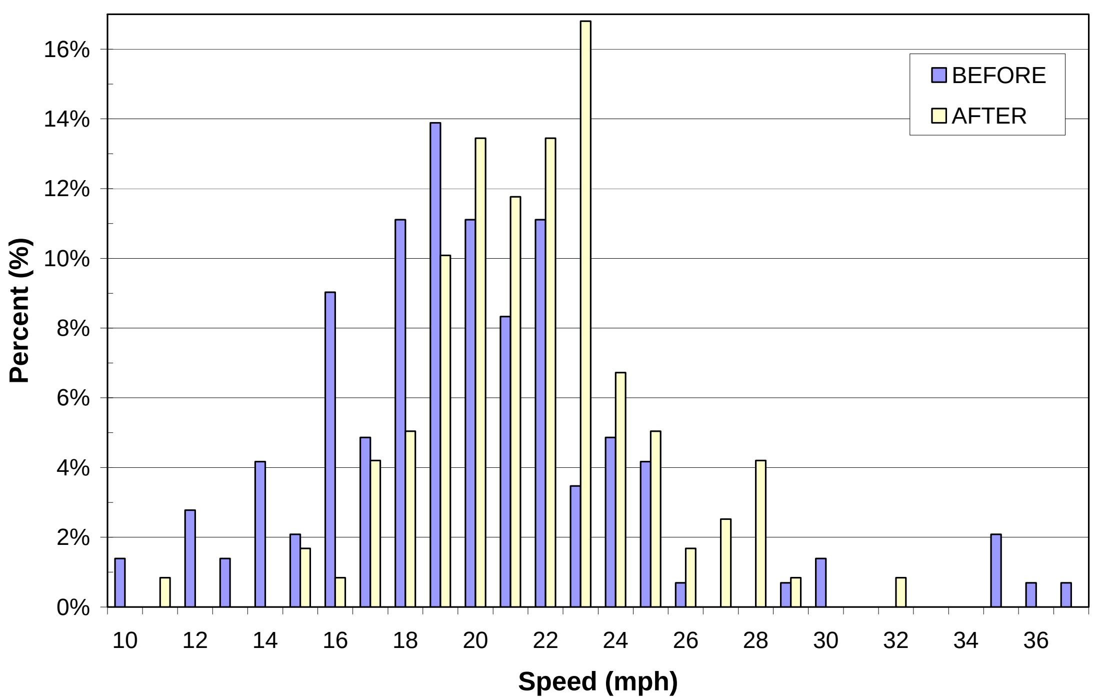
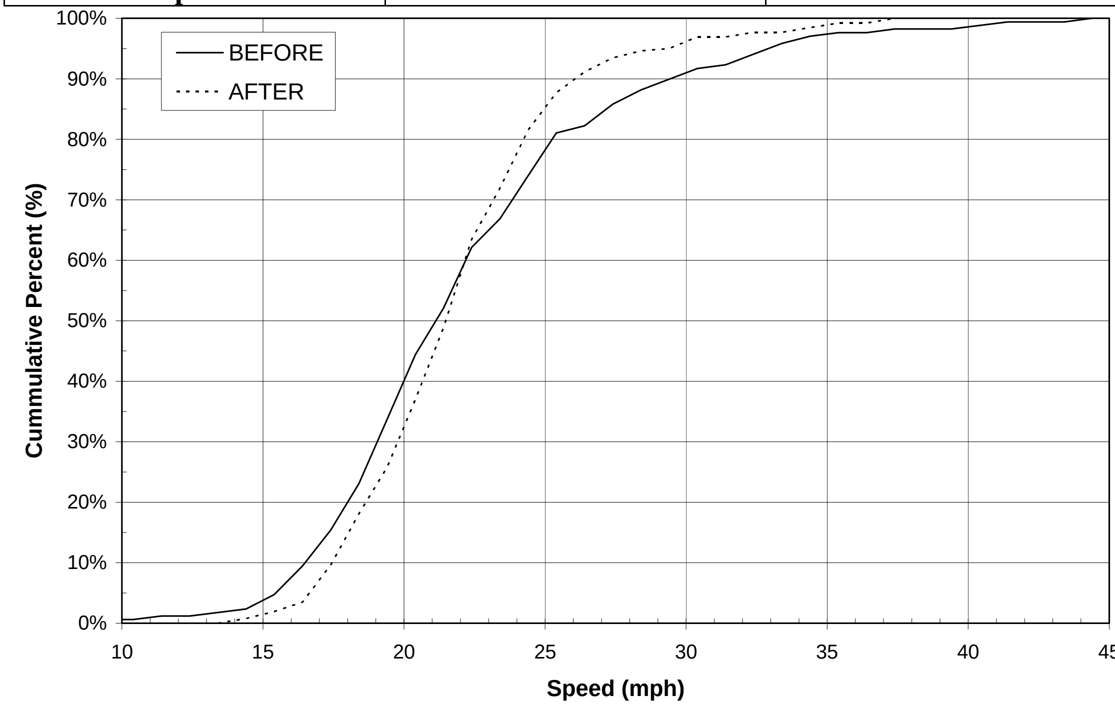


Figure B-15: Goshen Eastbound Morning (8:10 AM to 9:00 AM)

	Before *(09/27/04 – 09/30/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	22.17	21.88
Standard Deviation	5.53	3.81
85^{th} Percentile (mph)	27.0	24.9
% Exceeding 20 mph	55.6%	63.1%
10 mph Pace (% in Pace)	15 – 25 (76.3%)	16 – 26 (87.7%)
Sample Size	169	260



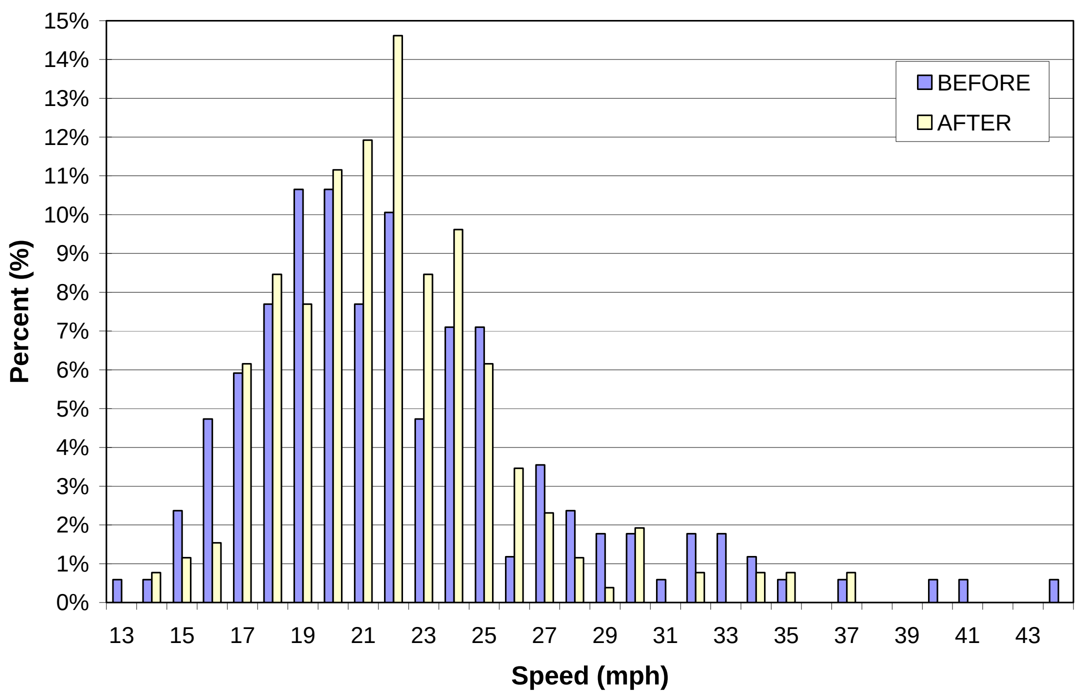
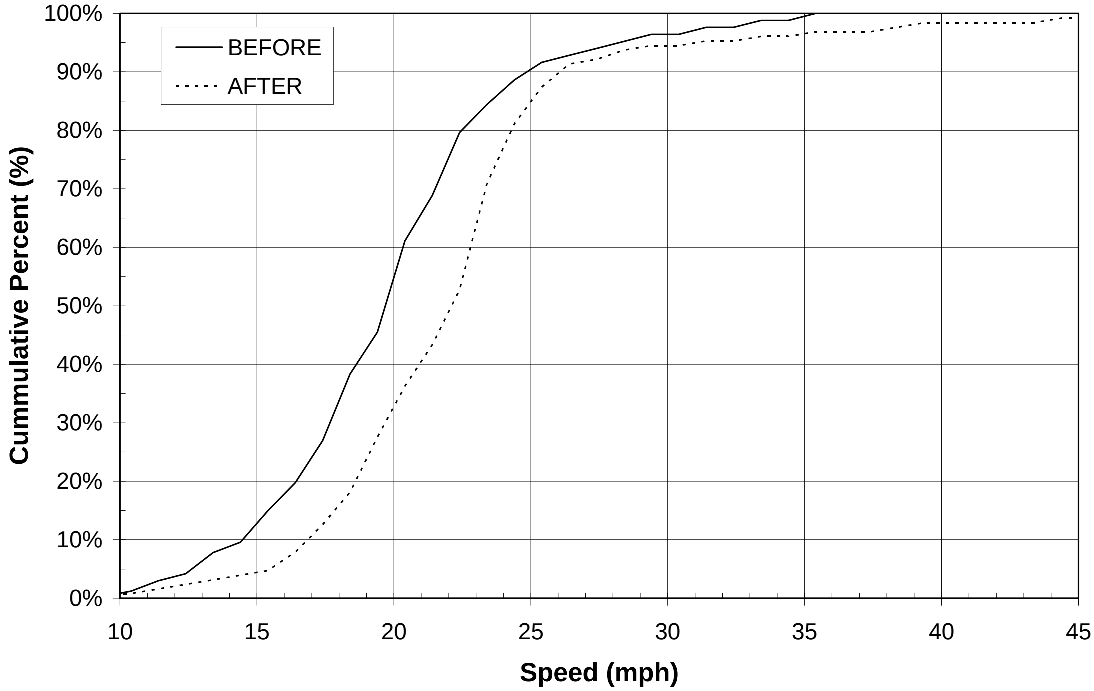


Figure B-16: Goshen Eastbound Mid-day (11:15 to 11:45 AM; 12:10 to 12:45 PM)

	Before *(09/27/04 – 09/30/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	19.72	22.05
Standard Deviation	4.48	5.27
85th Percentile (mph)	23.5	24.9
% Exceeding 20 mph	38.9%	63.8%
10 mph Pace (% in Pace)	14 – 24 (79.0%)	16 – 26 (83.5%)
Sample Size	167	127



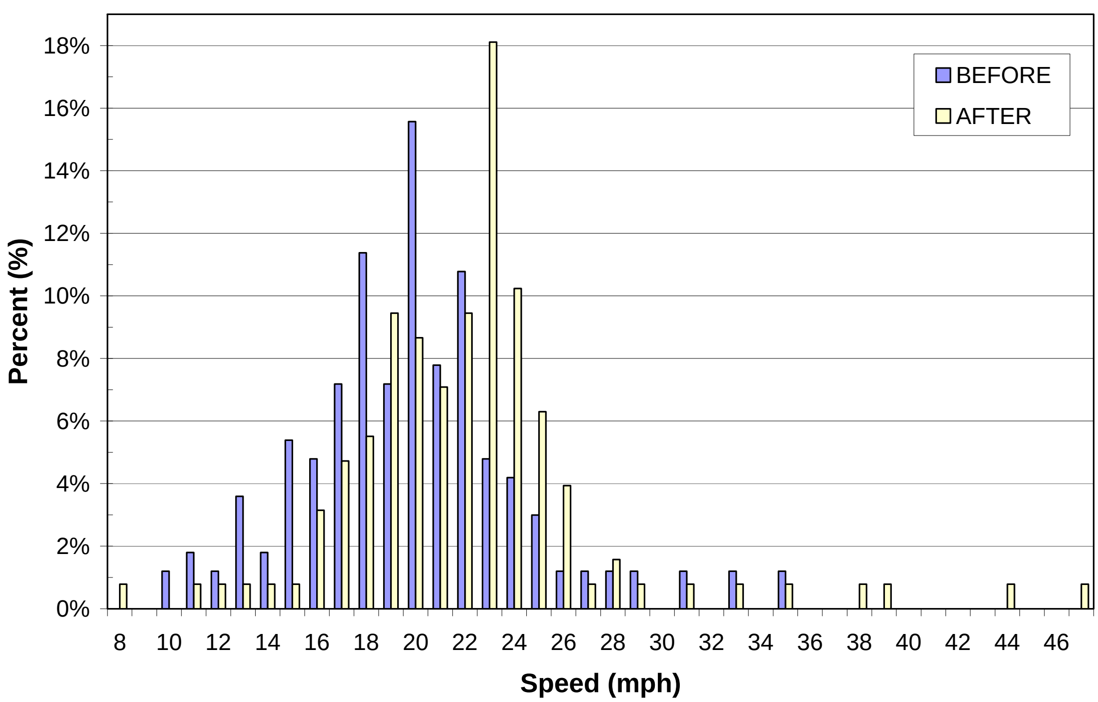
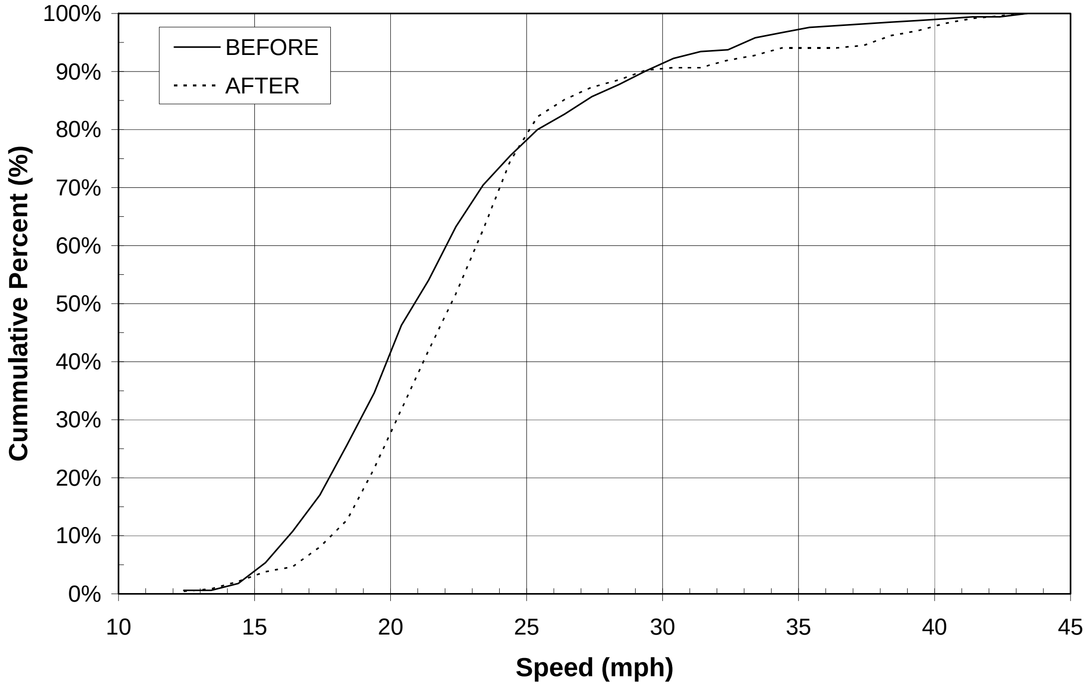


Figure B-17: Goshen Eastbound Afternoon (2:45 to 3:20 PM)

	Before *(09/27/04 – 09/30/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	22.02	23.12
Standard Deviation	5.33	5.54
85th Percentile (mph)	27.3	26.4
% Exceeding 20 mph	53.7%	68.2%
10 mph Pace (% in Pace)	15 – 25 (74.6%)	16 – 26 (80.5%)
Sample Size	335	236



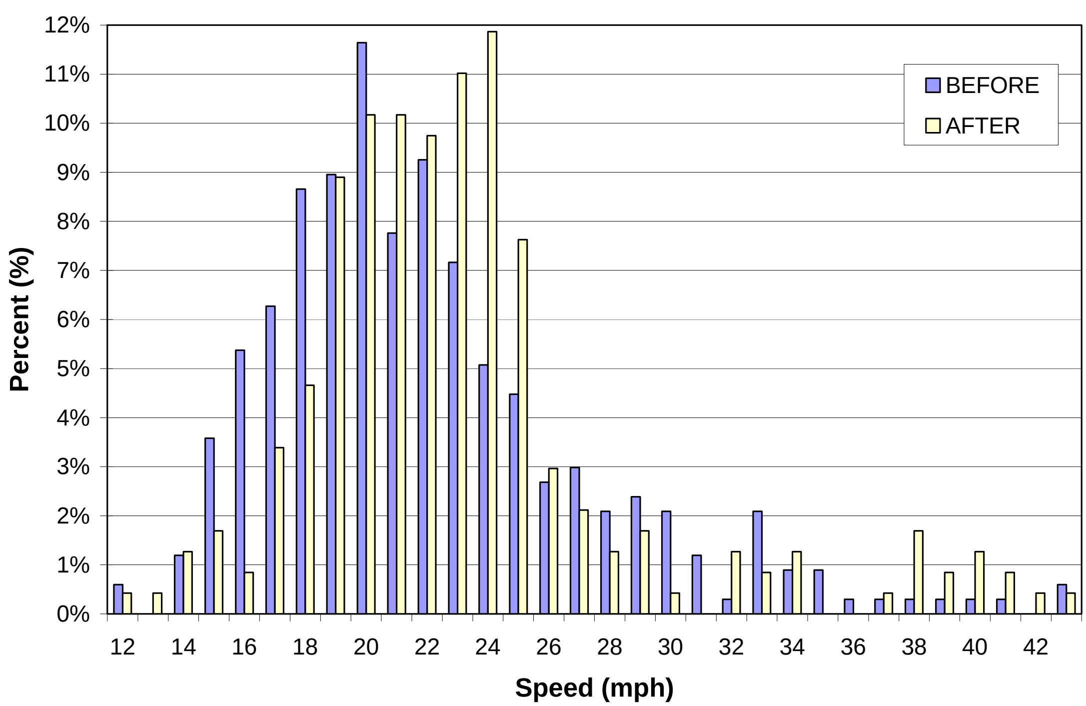
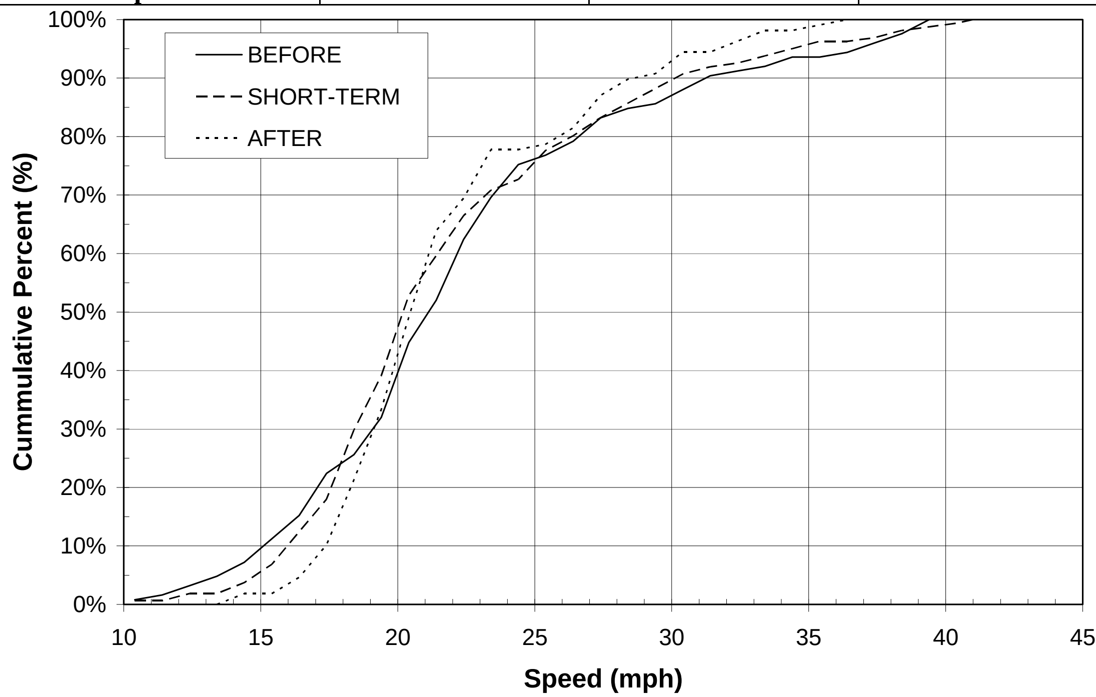


Figure B-18: Goshen Eastbound Late-Afternoon (3:45 to 5:00 PM)

	Before *(09/27/04 – 09/30/04)*	**Short-term** *(11/29/04 – 12/02/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	22.09	21.86	21.77
Standard Deviation	6.36	5.93	4.56
85th Percentile (mph)	28.3	27.8	27.3
% Exceeding 20 mph	55.2%	47.2%	50.9%
10 mph Pace (% in Pace)	14 – 24 (68.0%)	15 – 25 (70.8%)	16 – 26 (76.9%)
Sample Size	125	161	108



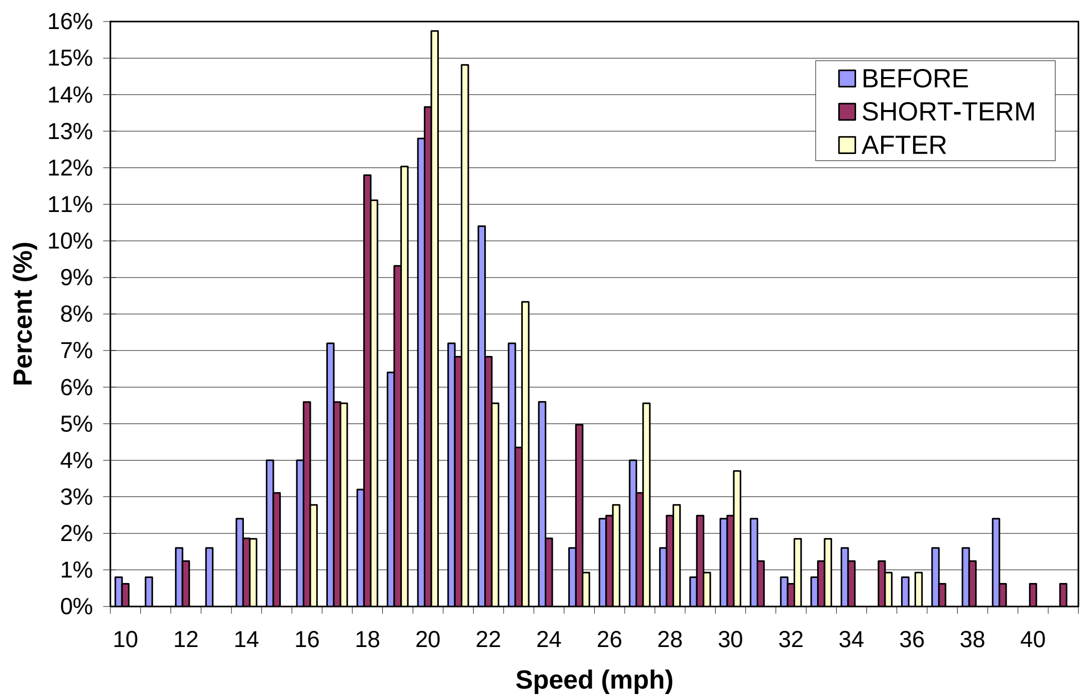
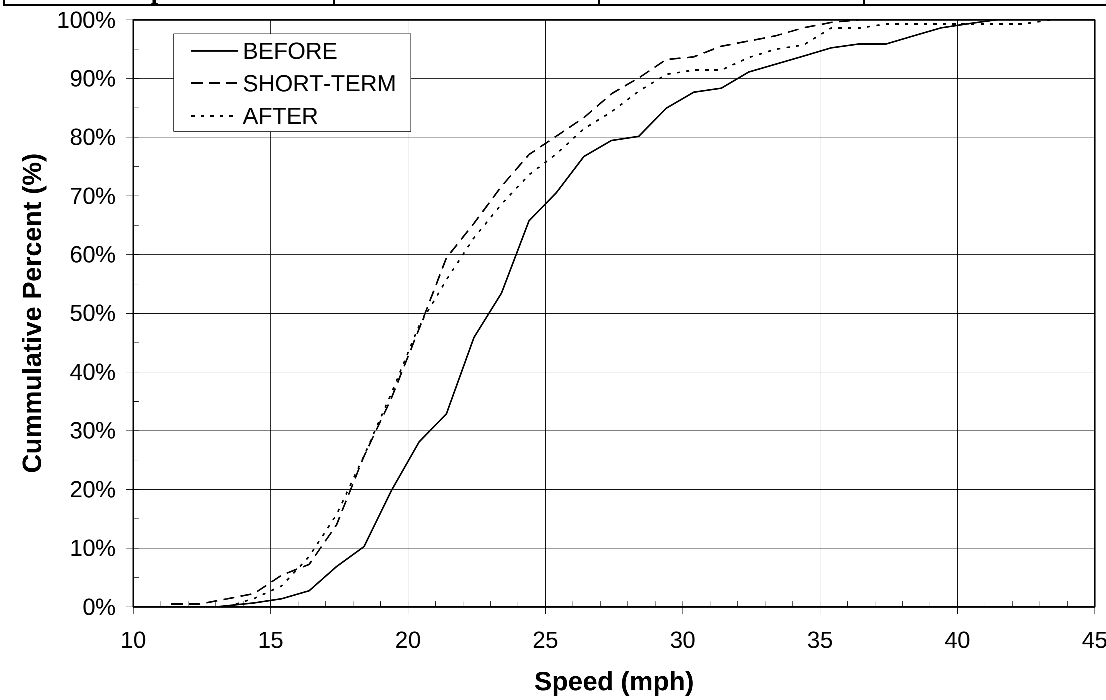


Figure B-19: Goshen Westbound Morning (8:10 AM to 9:00 AM)

	Before *(09/27/04 – 09/30/04)*	Short-term *(11/29/04 – 12/02/04)*	After *(03/21/05 – 03/24/05)*
Mean (mph)	23.99	21.56	22.17
Standard Deviation	5.47	4.66	5.29
85th Percentile (mph)	29.4	26.5	27.5
% Exceeding 20 mph	71.9%	52.7%	52.1%
10 mph Pace (% in Pace)	16 – 26 (74.0%)	16 – 26 (76.1%)	15 – 25 (73.6%)
Sample Size	146	222	140



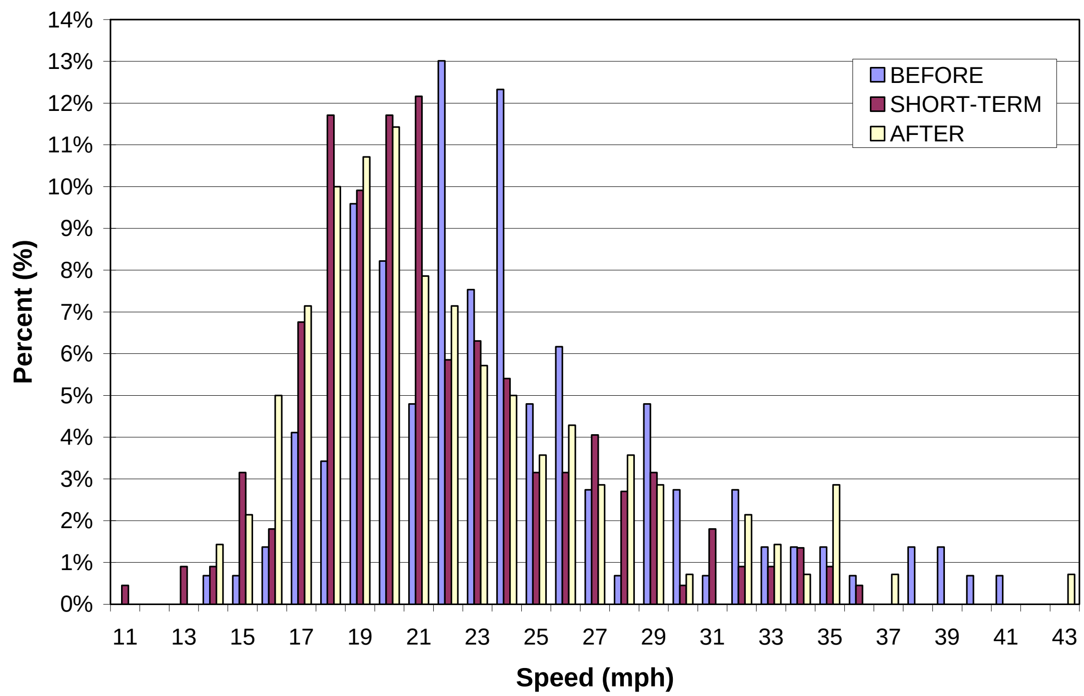
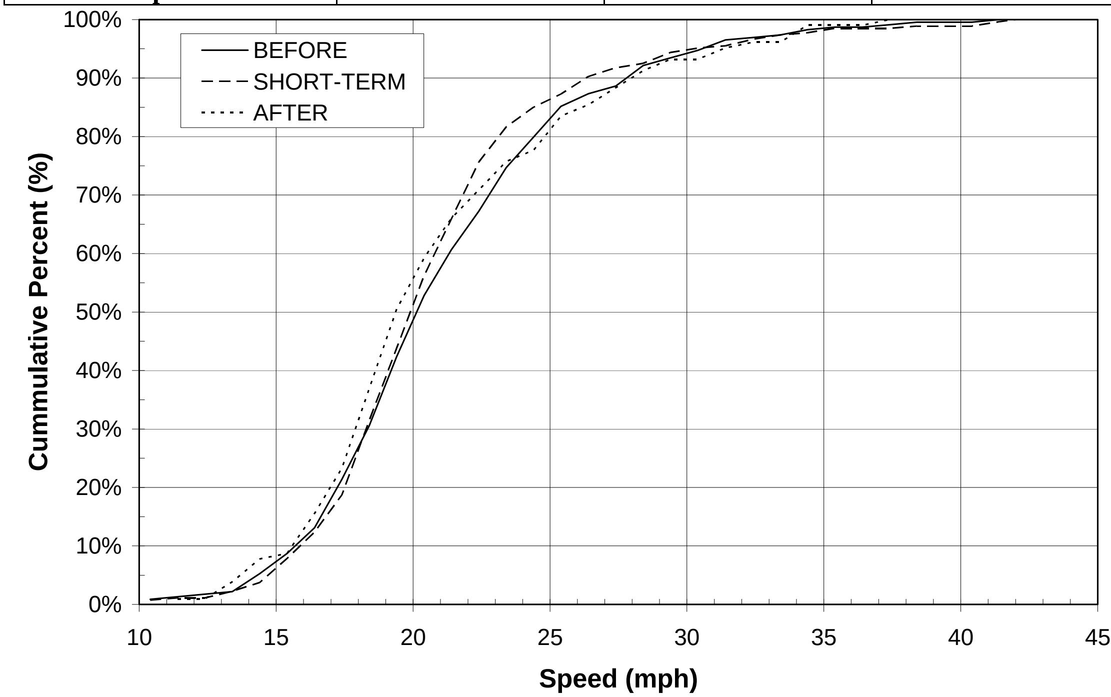


Figure B-20: Goshen Westbound Mid-day (11:15 to 11:45 AM; 12:10 to 12:45 PM)

	Before *(09/27/04 – 09/30/04)*	**Short-term** *(11/29/04 – 12/02/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	20.96	20.68	20.79
Standard Deviation	4.94	4.81	5.04
85th Percentile (mph)	25.3	24.3	25.8
% Exceeding 20 mph	47.2%	43.8%	40.8%
10 mph Pace (% in Pace)	15 – 25 (76.4%)	14 – 24 (81.3%)	15 – 25 (74.8%)
Sample Size	229	267	103



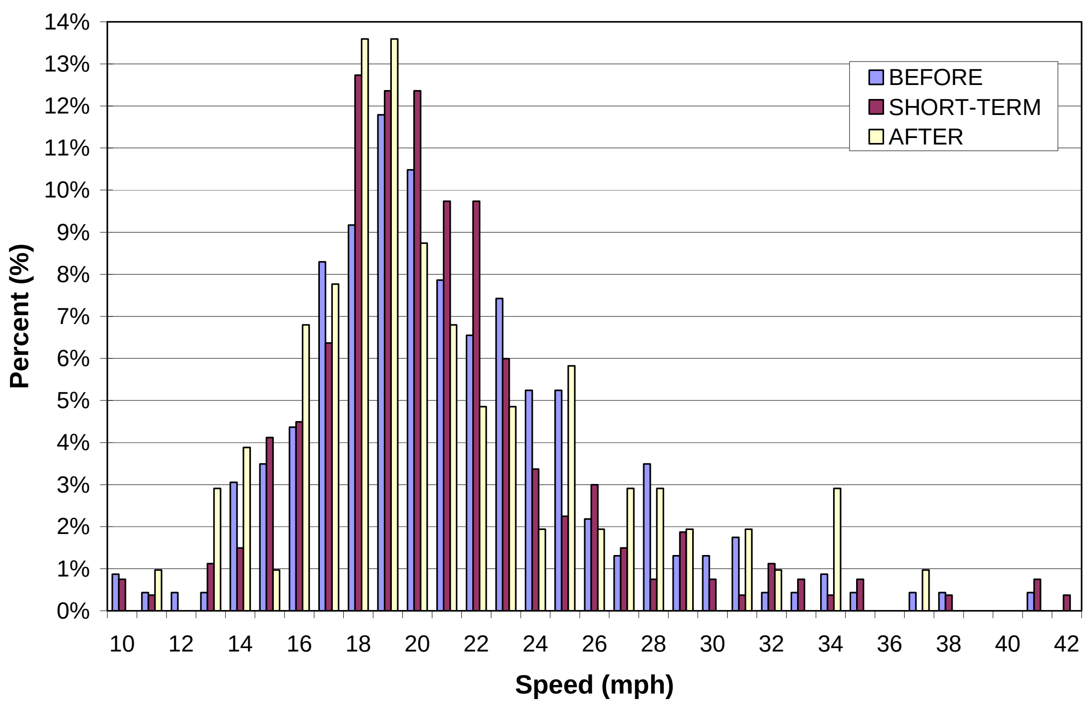
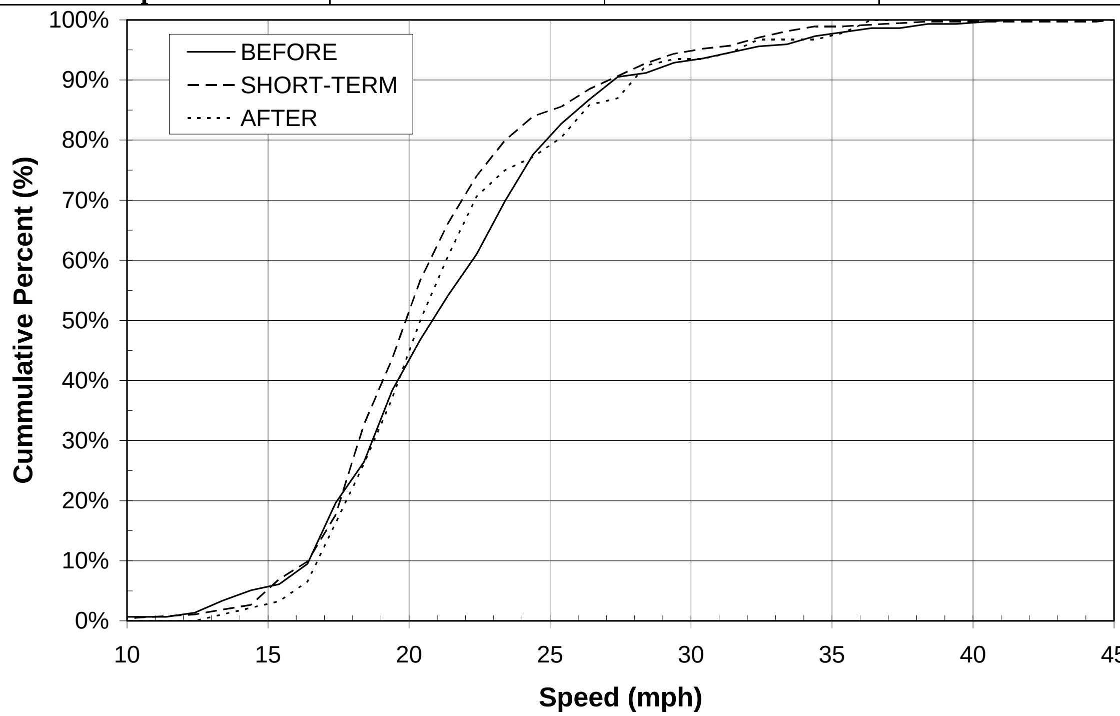


Figure B-21: Goshen Westbound Afternoon (2:45 to 3:20 PM)

	Before *(09/27/04 – 09/30/04)*	**Short-term** *(11/29/04 – 12/02/04)*	**After** *(03/21/05 – 03/24/05)*
Mean (mph)	21.61	20.73	21.49
Standard Deviation	5.09	4.60	4.75
85th Percentile (mph)	25.9	24.8	26.3
% Exceeding 20 mph	53.2%	43.3%	50.0%
10 mph Pace (% in Pace)	16 – 26 (77.3%)	14 – 24 (81.3%)	16 – 26 (79.3%)
Sample Size	295	374	92



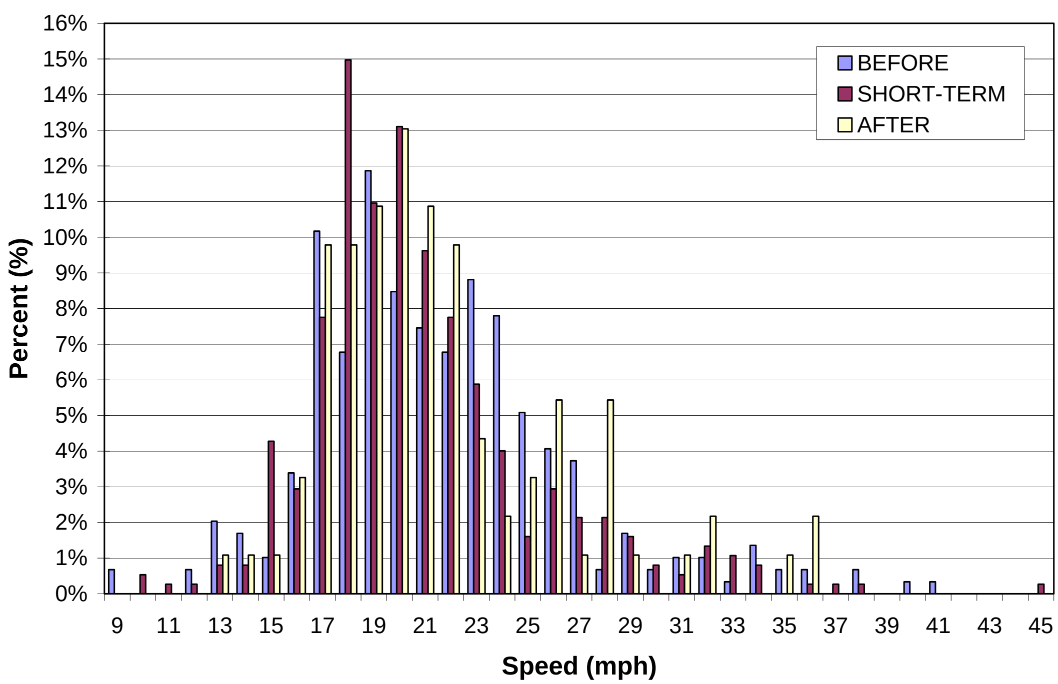


Figure B-22: Goshen Westbound Late-Afternoon (3:45 to 5:00 PM)