FINAL REPORT
Development of Speed Reduction Strategies for Highway Work Zones

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Prepared by

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Georgia Institute of Technology

Primary Authors:

Karen K. Dixon, Ph.D., P.E.
Chunyan Wang

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16. Abstract:
This study was conducted to identify the potential of fluorescent orange sheeting, an innovative message sign, and a changeable message sign with radar (CMR) for reducing speeds in highway work zones. It investigates the effect of each strategy right after implementation as well as several weeks after implementation. In addition to the overall effect of each strategy on all vehicles, the study includes the effect on specific vehicle types during varying lighting conditions. The researchers collected traffic data before, immediately after, and 2-3 weeks after implementation of each strategy (three consecutive weeks for the CMR). They collected data upstream of the work zone, in the advance warning area, and adjacent to the active work area. They used various statistical tests to evaluate the significance of speed changes from phase to phase and adjusted vehicle speeds with the upstream speed changes over time. Results indicate that fluorescent orange sheeting and the innovative message sign do help reduce speeds at highway work zones. There is, however, a novelty effect, and speeds tend to return to normal after a certain period of time. Moreover, both strategies influence reduced vehicle speeds more during the day than at night. Passenger vehicles tend to decrease their speeds more than trucks. CMR radar significantly reduces vehicle speeds in the immediate vicinity of the sign and are not sensitive to a novelty effect.

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EXECUTIVE SUMMARY

Previous speed limit compliance studies performed at highway construction work zones in the State of Georgia have shown that although drivers reduce speeds in the vicinity of active work zones, these speeds are significantly higher than the posted speeds limits. This endangers both workers and drivers and causes crashes within the work zone. Traffic control devices aimed at reducing speeds within work zones may help to limit both the number and severity of these crashes.

The objective of this research was to identify the potential of fluorescent orange sheeting, an innovative message sign, and changeable message signs with radar for reducing speeds in highway work zones. The work included field testing for each strategy to evaluate its ability to influence drivers to reduce vehicle speeds. The research team selected three study sites for evaluation of the fluorescent orange sheeting and innovative signs. A changeable message sign with radar was also tested at one of the sites. The study includes the overall effect of each strategy on all vehicles studied as well as the effect on specific vehicle types during varying lighting conditions. The vehicle categories included passenger vehicles during daylight conditions, passenger vehicles during nighttime conditions, trucks during daylight, trucks during nighttime, and all vehicles for both day and nighttime conditions. The evaluation plan excluded evaluation of inclement weather condition speeds.

To test the effect of fluorescent orange sheeting and innovative signs, the research team collected traffic data for each site prior to strategy implementation, immediately following strategy implementation, and again two or three weeks after implementation (to test for novelty effects). The authors used a two sample paired t-test to evaluate the significance of speed changes from phase to phase.

To test the effect of changeable message signs with radar, the work plan included collection of traffic data prior to implementation and then for three consecutive weeks during the presence of the changeable message sign with radar. Additional statistical analysis included analysis of variance and Tukey's honestly significant differences test for evaluation of speed changes during the study periods.

This study indicates that fluorescent orange sheeting and the innovative message sign do help reduce speeds at highway work zones (by approximately 2 mph). However, there is a novelty effect associated with the use of these strategies and speeds tend to return to normal after a certain period of time. Moreover, fluorescent orange sheeting and/or the innovative sign influence reduced vehicle speeds more during the day than at night. Passenger vehicles tend to decrease their speeds more than trucks. Changeable message signs with radar significantly reduce the vehicle speeds in the immediate vicinity of the sign. However, vehicle speeds tend to return to their original operating speed as the vehicles traverse the lanes adjacent to the active work area. The novelty effects observed for the fluorescent orange signs and innovative signs did not occur for the changeable message sign with radar.

Chapter 1. Introduction

Speed limit compliance studies performed at highway construction work zones in the State of Georgia show that although drivers reduce speeds in the vicinity of active work zones, these speeds are significantly higher than the posted speed limits (Daniel, et al., 1995). This observed driver non-compliance for posted speed limits in work zones might be due to several variables. A study performed by the Wisconsin Department of Transportation identified the two major reasons for work zone crashes as speeding and inattentive driving. Drivers appear to select speeds based on their perception of the safety of the roadway, rather than posted speeds. In a survey of drivers who had just driven through a work zone, 54% of the drivers surveyed believed the work zone to be more hazardous than a non-work zone area (Benekohal et al., 1990). Although 79% of the drivers said the posted speed limit was reasonable, only 59% complied with this speed limit. Driver non-compliance to work zone speed limits is also attributed to the use of unreasonably low speed limits within the work zone as well as maintaining reduced speed limits in place after the work activity is removed (Richards & Dudek, 1986). These actions can undermine the credibility of the work zone speed limit and increase non-compliance of the posted speed. Effective work zone speed control implementation must consider the need for speed reduction, determine a reasonable speed, select a speed reduction treatment based on practicality and cost, and then select an appropriate location for treatment implementation (Dudek et al., 1985). The focus of this study will be on the selection and placement steps in the speed control implementation described above.

Speed limit non-compliance endangers both workers and drivers within the work zone. During the period between 1995 and 1997, a total of 158 fatal crashes or about 52 fatal crashes per year occurred within highway work zones in the State of Georgia. A predominant percentage of these crashes occurred on rural roadways and in idle construction work zones. Most of the crashes were single vehicle crashes, with passenger cars as eighty percent of the involved vehicles. Further details on fatal crashes within work zones in Georgia are provided in Chapter 2 of this report. The statistics indicate a need to improve the safety of work zones in the State of Georgia and suggests the need for strategies aimed at reducing speeds within the work zone.

1.1. Problem Statement

Traffic control devices aimed at reducing speeds within work zones may help to limit both the number and severity of these crashes. Although enforcement of speed limits is an effective measure to reduce speeds within work zones, this strategy is limited due to its expense and extensive manpower requirements. As a result, strategies for reducing speeds within work zones should be effective without the presence of enforcement if feasible. A literature review conducted by the Georgia Department of Transportation (GDOT) identified thirteen strategies used nationwide for reducing speeds in work zones. These strategies include:

1. Changeable message sign,
2. Changeable message sign with radar,
3. Portable billboard speed display,
4. Automated speed enforcement devices,
5. Flagging,
6. Lane width reduction,
7. Regulatory and advisory speed limit signs,
8. Rumble strips,
9. Radar transmissions,
10. Transverse paint stripes,
11. Radar-activated audible message,
12. Flashing beacons on speed limit sign, and
13. Law enforcement.

Many of these strategies have been evaluated by State Departments of Transportation (DOTs) to determine the ability of these strategies to reduce speeds. Following review of all of the above thirteen strategies, the GDOT and the Georgia Tech research team elected to evaluate changeable message sign with radar (item #2 on the list). In addition, they chose to evaluate static signs with conspicuous sheeting (fluorescent orange) and an innovative message sign strategy.

1.2. Research Objectives

The objectives of this research were to identify additional speed control strategies which offer good potential for reducing speeds in highway work zones and to field test select strategies to evaluate their ability to influence drivers to reduce vehicle speeds. The work plan to accomplish these objectives includes three phases. The first phase involved preparing a literature review that identified additional speed reduction strategies used in work zones. The review was intended to supplement the existing literature review performed by the GDOT personnel and references journal articles describing potential speed reduction strategies and the effectiveness of these strategies to reduce speeds. The second phase of the project included: field testing of select speed reduction strategies, and data collection and evaluation of the effectiveness of the strategy to reduce speeds. The third phase included data analysis and associated recommendations regarding potential application of the speed reduction strategies for use in the State of Georgia.

1.3. Report Organization

This report is organized in seven primary sections. Chapter 1 introduces the problem statement and the objectives of the research. Chapter 2 defines several common work zone components, recent research evaluating the speed reduction strategies selected for testing in this study, background on speed distributions within construction work zones, and a review of work zone crash history. The purpose of the crash history review was to identify the roadway types and work zone configurations (if available) where the speed reduction strategies should be tested due to historic speeding and safety issue. Chapter 3 discusses the three selected traffic control strategies in greater detail. Chapter 4 summarizes the data collection plan for this study. Chapter 5 summarizes the collected data and associated evaluation techniques. Chapter 6 provides results of the data analysis and Chapter 7 summarizes report conclusions and general recommendations for prospective treatment strategies.

Chapter 2. Literature Review

2.1. Work Zone Components

The work zone literature uses several general terms commonly associated with work zones and work zone lane closures. Figure 1 graphically depicts these components of a traffic control zone. General terms that will be used throughout this review include the advance warning area, the transition area, the activity area (which includes lateral and longitudinal buffer space, traffic space, and work space), and the termination area. These definitions are further defined in the *Manual on Uniform Traffic Control Devices* (MUTCD) (2000). The transition area is only applicable to work zone regions where the normal traffic pattern must be diverted. For the purposes of this review, a work zone is defined as any road section where maintenance or improvement activities occur adjacent to or on the active travelway.

The *advance warning area* is the region where drivers are provided information regarding the impending lane closure. Signs and flashing lights are often located adjacent to the advance warning area. The area is located immediately upstream of the transition to the lane closure. If the construction occurs in a manner that does not directly interfere with traffic, the advance warning area is not required.

The *transition area* is provided when traffic must be diverted out of its normal path. The transition is generally accomplished through the use of tapers. This region is typically situated between the advance warning area and the activity area.

The *activity area* is the region where the physical work activity occurs. The work space and the traffic space as well as buffer spaces occur in the activity area. The *work space* is the area occupied by workers, material, and equipment. The *traffic space* is the roadway region where traffic has been directed within the activity area. The *buffer space* may be used to provide extra space between the traffic flow and the work activity.

The *termination area* is the region where traffic is returned to normal operations. This area is situated immediately downstream of the activity area.

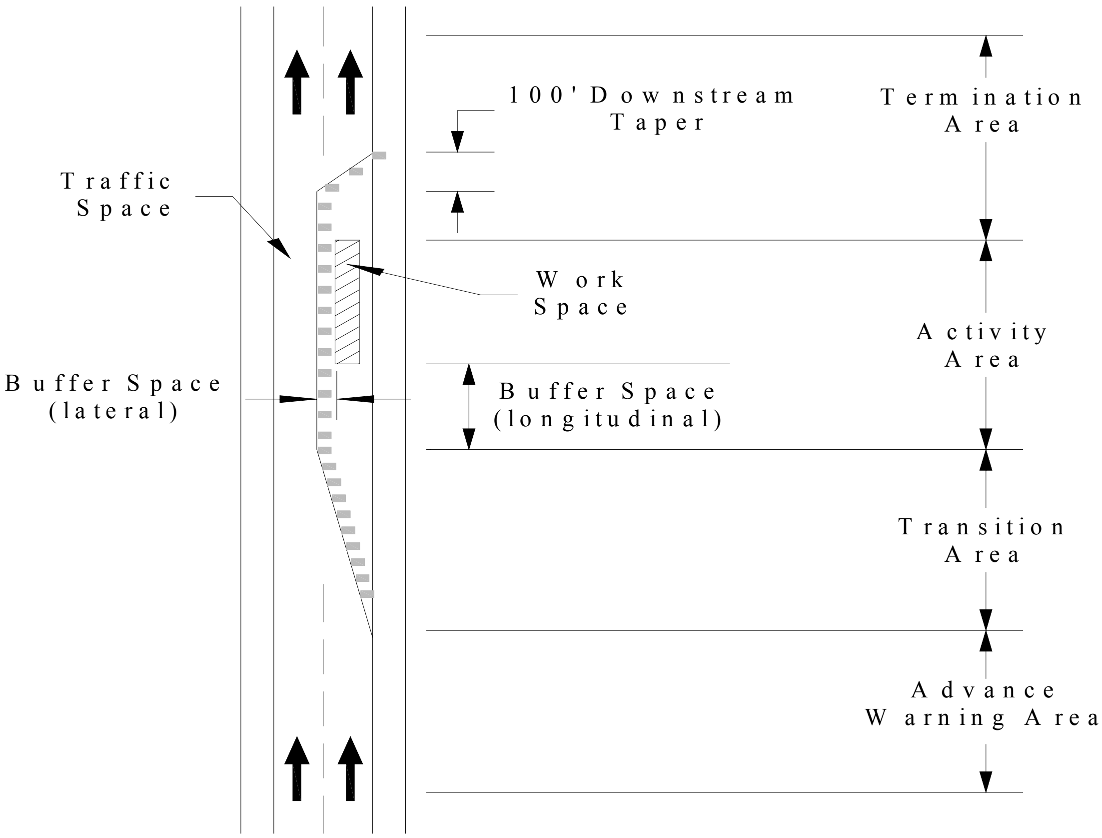

Figure 1. Component Parts of a Temporary Traffic Control Zone
Source: Manual of Uniform Traffic Control Devices – Millennium Edition, 2000.

2.2. Speed Distributions in Work Zones

Several studies have investigated speed distributions in an effort to better understand driver behavior within work zones as well as to identify the proper location for traffic control devices within the work zone. In one study, the speeds of vehicles in the advance warning area were recorded and compared to speeds within the construction zone. The study found that vehicles with higher initial speeds reduced their speeds more than vehicles with lower initial speeds as they entered the construction work zone. These same vehicles, however, kept higher speeds in the work zone when compared to the speeds of vehicles in the lower initial speed groups. About one-third of vehicles classified as "extremely" speeding reduced their speeds and kept reducing them as they traveled in the work activity area. However, about one-third of those who were "excessively" speeding reduced their speeds initially, increased their speed in the work activity area, and then reduced speed when located adjacent to the work space (Benekohal & Wang, 1994).

Another study showed that although vehicles decreased their speeds to the lowest level adjacent to the work space, 65% of automobiles and 47% of trucks still traveled faster than the speed limit in the traffic space adjacent to the work space. The study showed that as drivers traveled into the work zone, their speeds first decreased, then slightly increased, and finally reached their minimum value adjacent to the work space. After passing the work space, speeds continuously increased until vehicles left the study section (Benekohal & Wang, 1993).

2.2.1. Static Signs

Warning signs are commonly positioned within the advance warning area of work zones. Typically these signs exhibit black symbols or messages on an orange background. Recently researchers have studied the operational impact of enhancing warning sign visibility by using the newer fluorescent microprismatic sheeting (often referred to simply as "fluorescent" sheeting) rather than the high intensity sheeting commonly used for work zone warning signs. Burns, et al., (1993) determined that the fluorescent sheeting provides better daytime and nighttime visibility than the conventional sheeting. Hummer and Scheffler (1999) evaluated speed and travel behavior in work zones using the fluorescent sheeting. Generally, drivers responded quicker to the signs (i.e. changed lanes earlier, exhibited fewer vehicle conflicts, etc.), but the mean speeds exhibited a slight increase with the fluorescent sheeting signs over the standard signs. Speed variances, however, tended to decrease for the fluorescent orange sign scenarios. The North Carolina researchers concluded that use of the sheeting is appropriate for locations where warning drivers is critical, but the sheeting is not likely to result in speed reduction.

Unique static signs that draw the attention of the driver to hazardous work zone conditions, though not specifically tested in previous research, may influence speed. For example, one report suggested a static sign with the message "Slow Down My Dad Works Here" (written in a child-like font) may help reduce work zone speeds (USDOT, 1998a).

2.2.2. Changeable Message Sign with RADAR

Changeable message signs (CMS) are sometimes enhanced with a supplemental radar unit that detects the speed of vehicles in the traffic stream. When a vehicle is identified as traveling above some pre-determined speed threshold, the CMS may be programmed to display a warning message to the driver.

In one Virginia study, researchers tested this speed reduction strategy along with four CMS messages at seven work zones on two interstate highways in Virginia. The messages were designed to warn drivers that their speed exceeded the maximum safe speed and included: (1)"YOU ARE SPEEDING, SLOW DOWN", (2) "HIGH SPEED, SLOW DOWN", (3) "REDUCE SPEED IN WORK ZONE", and (4) "EXCESSIVE SPEED, SLOW DOWN." The researchers recommended a threshold speed of 3 mph over the posted speed limit for message activation. Odds ratios were calculated to compare the odds for speeding when using CMS with the odds for speeding when using the MUTCD signing only. These odds ratios indicated that CMS effectively reduced the number of vehicles speeding. All of the messages were found to be effective to significantly reduce the average speeds of those vehicles traveling 59 mph or faster in a 55 mph work zone when compared to MUTCD signing only. The researchers did not observe any significant difference between responses to the four individual messages identified above (Garber & Patel, 1994, 1995).

The South Dakota Department of Transportation tested a CMS with a speed measure laser device. This device is not detectable by standard radar detectors and has greater accuracy than most radar units in exact identification of specific vehicles. The speed warning threshold of the device was initially set at 62 mph (posted speed limit of 75 mph) but was constantly activated. The researchers then modified the speed warning threshold to 70 mph for the data collection phase of the project. The CMS message, when not activated was "RIGHT LANE CLOSED, KEEP LEFT." When the CMS was activated by the laser device the message changed to "YOU ARE SPEEDING, SLOW DOWN NOW." It is important to note that the speed threshold strategy for this study was dramatically different than that for the Virginia study where the posted speed was lower than the CMS threshold speed. The South Dakota researchers observed speed reductions ranging from zero to 1.7 mph. This observed difference was not a statistically significant reduction for the sites studied (Wertjes, 1996).

2.3. Fatal Crashes Study

As previously stated, the objectives of this research are to identify and test strategies which hold good potential for reducing speeds in construction work zones. By reducing speeds, it is expected that the number and severity of crashes within work zones will also be reduced and the safety of the work zone improved. To better understand crashes within work zones, the research team performed a study of fatal crashes occurring within highway work zones in Georgia. A clear understanding of these crashes facilitated the development of strategies aimed at reducing speeds and also helped identify the type of work zone and location of the work zone where speed reduction strategies identified in this study were tested.

Data for this study were obtained from fatal accident reports for 1995 to 1997 received from GDOT personnel. Data were also obtained from the National Highway Traffic Safety Administration's (NHTSA's) Fatality Analysis Reporting System (FARS) database. These sources provided information on the time of day, roadway classification, and type of construction activity.

The research team observed minor discrepancies in fatal crash statistics for GDOT and FARS data. Presumably, these differences occurred as a result of formatting or coding of crash information into the FARS database. It is the authors' opinions that both databases provide useful information regarding road classification and manner of collision regardless of observed frequency discrepancies.

2.3.1. Fatal Crash Summary

From 1995 to 1997 there were a total of 181 fatal crashes within highway work zones in the State of Georgia. Sixty-eight of these crashes occurred in 1995, 56 in 1996 and 57 in 1997. Table 1 shows the type of collision for which these fatal crashes occurred and contrasts the work zone crash condition to the non-work zone locations.

Table 1. Manner of Collision

	Percent of Fatal Crashes	
Manner of Collision	*Work Zone*	*Non-Work Zone*
Single-Vehicle Collision	48.6	56.3
Rear-End	12.1	5.0
Head-On	17.7	16.1
Angle	17.7	20.7
Sideswipe, same direction	2.8	1.1
Sideswipe, opposite direction	1.1	0.8

Source: Daniel, et al., 2000

The predominant types of collision which occurred within highway work zones were single vehicle, head-on, and angle crashes. These three types of collisions represent 84 percent of the crashes, with 48.6 percent single vehicle crashes, and 17.7 percent head-on and angle crashes. Fatal crashes within work zones primarily involve passenger vehicles. These vehicles account for 80 percent of the vehicles involved in fatal crashes (Daniel, et al., 2000).

2.3.2. Temporal Distribution

The Georgia Tech (GT) team examined temporal distribution of fatal crashes to determine the time period when these crashes occurred. This distribution by time of day is provided in Table A-1 of the Appendix. The distribution shows that 20 percent of fatal crashes occurred between 12 midnight and 6 a.m., 50 percent between 6 a.m. and 6 p.m. and 30 percent between 6 p.m. and midnight. Light conditions under which these crashes occurred are shown in Table 2 with 50 percent of fatal crashes occurring during daylight conditions.

The monthly distribution is fairly evenly distributed throughout the year with the highest percentage of fatal crashes occurring in the months of March, August and December. Sixty-five percent of fatal crashes occurred during the weekday and thirty-five percent occurred during the weekend. Of those fatal crashes occurring on the weekend, sixty percent occurred on Saturday.

Table 2. Light Condition

Light Condition	*Percent*
Daylight	50
Dark	42
Dark but Lighted	5
Dawn	2
Dusk	1

Source: NHTSA FARS Database

2.3.3. Spatial Distribution

Table 3 shows the distribution of fatal crashes by roadway classification. Sixty percent of these crashes occurred along rural roadways and approximately 40 percent along urban roadways. The largest percentage of fatal crashes occurred on roadways classified as rural principal arterial non-interstate roadways. The next highest percentage of fatal crashes occurred on urban principal arterials that are part of the Interstate system. Seventy-six percent of fatal crashes occurred along roadways with two travel lanes, seven percent on roadways with three travel lanes and 11 percent on roadways with four travel lanes. Sixty-six percent of fatal crashes occurred on roadways with a speed limit of 55 mph and seventeen percent on roadways with speed limits of 40 mph.

2.3.4. Construction Activity

Table 4 shows the type of work zone where fatal crashes occurred. Ninety-one percent of fatal crashes occurred in construction work zones and six percent in maintenance work zones. Construction and maintenance zones are defined as areas marked by signs, barricades, or other devices indicating that highway construction or highway maintenance activities are ongoing. Fifty-three percent of fatal crashes occurred in work zones that were idle and thirty-four percent occurred in work zones that were in progress. The remaining crashes occurred in work zones that were either not started, not zoned, or the status unknown.

Table 3. Roadway Function of Fatal Crashes

Functional Classification	*Percent of Fatal Crashes*	
	Work Zone	*Non-Work Zone*
Rural Principal Arterial-Interstate	6	5
Rural Principal Arterial, Other	22	10
Rural Minor Arterial	16	13
Rural Major Collector	12	15
Rural Minor Collector	1	4
Rural Local Road or Street	3	10
Urban Principal Arterial-Interstate	18	6
Urban Principal Arterial-Other Freeway	1	2
Urban Principal Arterial – Other	12	10
Urban Minor Arterial	7	11
Urban Collector	0	4
Urban Local Road or Street	3	9

Source: Daniels, et al., 2000

Table 4. Fatal Crashes by Work Zone Type

Work Zone Type	*Percent*
Construction	91
Maintenance	6
Work Zone, Type Unknown	3

Source: NHTSA FARS Database

The accident reports reviewed for these fatal crashes included a construction project activity description for 139 of the crashes. The GT team determined the type of construction or maintenance activity associated with these project numbers as summarized in Table 5. As the table shows, seventy-three percent of fatal crashes occurred at resurfacing and widening construction projects. The remaining crashes occurred at pavement rehabilitation projects, interchange construction, bridge work and other types of construction activity.

Table 5. Construction/Maintenance Activity

Construction/ Maintenance Activity	*Percent of Crashes*
Resurfacing	39
Widening	34
Pavement Rehabilitation	4
Interchange Reconstruction	3
Bridge Work	6
Other	14

Source: GDOT Programming Office

2.3.5. Fatal Study Conclusions

From this fatal crash study the critical locations where speed reduction strategies should be targeted include work zones with the following characteristics:

- Construction work zones rather than maintenance work zones;
- Resurfacing and/or widening construction projects;
- Work zones located on rural principal arterial non-interstate roadways and urban principal arterials;
- Both idle work zones as well as work zones in progress should be targeted; and
- Work zones during both daylight and dark conditions.

Chapter 3. Selected Traffic Control "Speed Reduction" Strategies

Following an evaluation of possible traffic control strategies that may positively influence operating speeds in Georgia work zones, the GT team and GDOT selected three candidate strategies. These strategies included the use of fluorescent microprismatic sheeting (referred to as fluorescent orange sheeting in this report) on standard work zone static signs, innovative message signs, and a changeable message sign with radar. This chapter identifies each strategy and implementation issues.

3.1. Fluorescent Orange Sheeting

Chapter 2 identified recent evaluations of fluorescent orange sheeting; however, only the North Carolina study (Hummer & Scheffler, 1999) specifically studied driver reactions as they relate to speed. Most of the fluorescent orange research to date has focused on conspicuity and durability of the sheeting with the underlying assumption that more conspicuous traffic control devices in a work zone will assure a safer work zone. The North Carolina study found that mean speed increased slightly, but speed variances tended to decrease.

For this study, the research team selected fluorescent diamond grade sheeting manufactured by 3M. The current required work zone sign sheeting in Georgia is standard high intensity orange sheeting, so the fluorescent orange provided a stark contrast to current standard signs. For this reason, the new sheeting was used for all visible signs in the advance warning area.

The specific product used for this test was the 3M Scotchlite™ Durable Fluorescent Diamond Grade Sheeting. The top picture shown in Figure 2 depicts a standard "ROAD WORK 1500 FT" sign with the new sheeting. All the work zones in the study were characterized by multi-lane approaches. As a result, the signs with fluorescent orange sheeting were located to both the left and right of the travel lanes as shown in the bottom part of Figure 2. A common sign configuration included a minimum of eight signs as depicted in Figure 3. For sites where additional signs were included in the advance warning sign configuration, more than eight fluorescent signs were deployed (see Figure 2 and 4 for examples).

Figure 2. Fluorescent Orange Sheeting Example

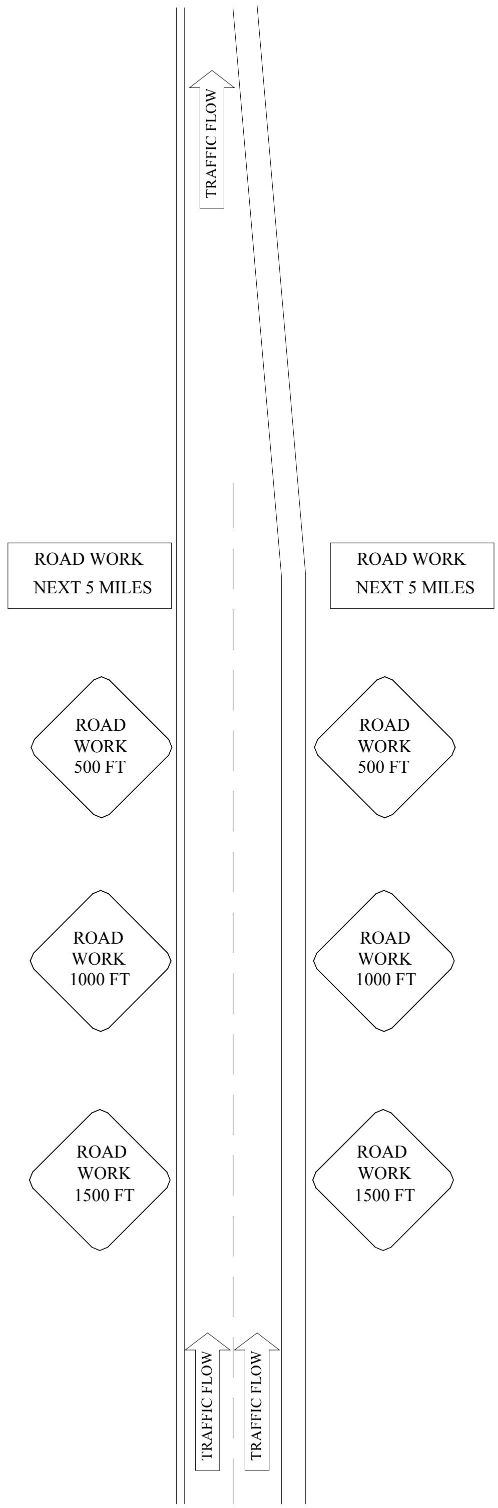

Figure 3. Typical Advance Warning Sign Configuration

Figure 4. Supplemental Warning Signs

3.2. Innovative Message Sign

In September of 1998, the Federal Highway Administration (FHWA) Office of Program Quality Coordination released a report on "Meeting the Customer's Need for Mobility and Safety During Construction and Maintenance Operations" (USDOT, 1998a). The FHWA included a recommendation in this report that, though as yet untested, there may be signing or pavement marking strategies to further enhance safety by reducing speed. They offered a suggestion that an "attention getting" work zone sign such as "Slow Down My Dad Works Here" (written in a child-like font) may positively influence speed reduction.

GDOT and the GT research team elected to include a similar sign for evaluation in the research. Figure 5 shows a photo and the two sign messages included in the study. At each test site, three innovative message signs were installed as supplements to the required warning signs. Figure 6 shows the placement of two of the signs immediately upstream of the standard "ROAD WORK 1500 FT" sign. In addition, the contractor installed a second “DAD” sign adjacent to the active work area as shown in Figure 7. The testing included innovative message signs with standard high intensity sign sheeting at one site and fluorescent orange sheeting at two sites.

3.3. Changeable Message Sign with Radar

Several recent research studies included an evaluation of the changeable message sign with radar (CMR). In general, researchers observed a reduction in work zone operating speeds as a result of CMR implementation (see Chapter 2); however, Georgia had not evaluated this strategy, to date, to determine effectiveness of the CMR for Georgia work zones. As a result, GDOT selected the CMR for evaluation in this study.

The CMR used by the research team was manufactured by American Signal Company and rented for this study from a local vendor. It has a changeable message sign with built-in radar that measures the speed of approaching vehicles. The radar sends a message to the central processing unit of the sign when it detects a vehicle speed in excess of some pre-determined threshold. The radar range of sensing is 0.25 miles for small vehicles and up to 0.5 miles for larger sports utility vehicles. The cone of influence of the radar projects 14-degrees plus or minus one degree. Display text height is six inches and the sign permits a three line message. This letter height permits message visibility 400 to 500 feet upstream of the sign. Lateral placement of the sign must be immediately adjacent to the travel lane so drivers can easily view the message as they approach the CMR. Specifications for the CMR are included in Appendix 2.

The displayed message depends upon the speed of the vehicle approaching the sign and is intended to make the driver aware that his/her speed has been detected. For vehicles traveling 5 miles or more above the work zone speed limit (45 mph at the study site), the CMR displays a message that says: “YOU ARE SPEEDING, SLOW DOWN NOW.” If there were no vehicles present or vehicles were traveling below 50 mph, the CMR displayed the “ACTIVE WORKZONE, REDUCE SPEED” message. Due to the sharp horizontal geometry at the site (evident in the Figure 8 photograph and Figure 9 schematic), the CMR message was triggered by vehicles as they became visible in the curve of the road. If more than one vehicle was apparent to the device at the same time, the displayed message reflected the first vehicle sensed by the radar. If a vehicle then reduced speed after the driver saw the sign, the message was still displayed for a few seconds (allowing the vehicle to pass the sign with the same displayed message).

Figure 8 shows the roadside placement of the CMR. Figure 9 shows a general graphic of the road configuration at the CMR study site. The CMR message was only visible to the traffic stream approaching the work zone at this location.

Figure 5. Innovative Warning Sign

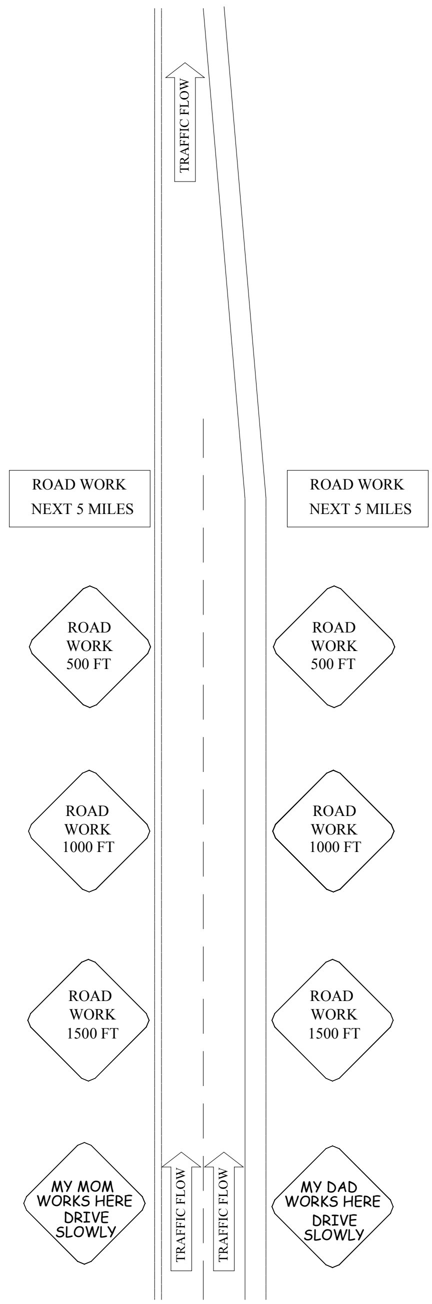

Figure 6. Advance Warning Sign Configuration with Innovative Message Signs

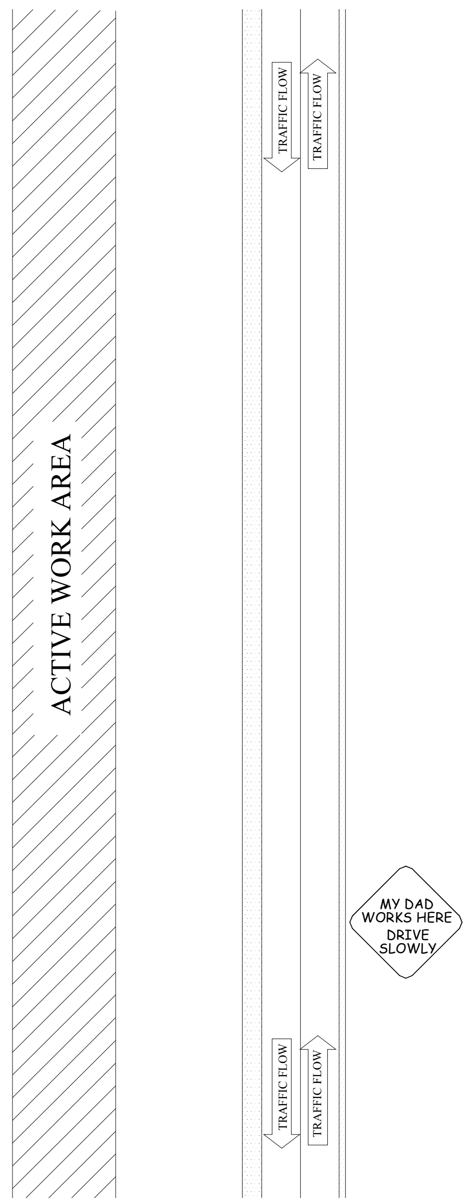

Figure 7. Active Work Zone with Innovative Message Sign

Figure 8. Deployed Changeable Message Sign with Radar

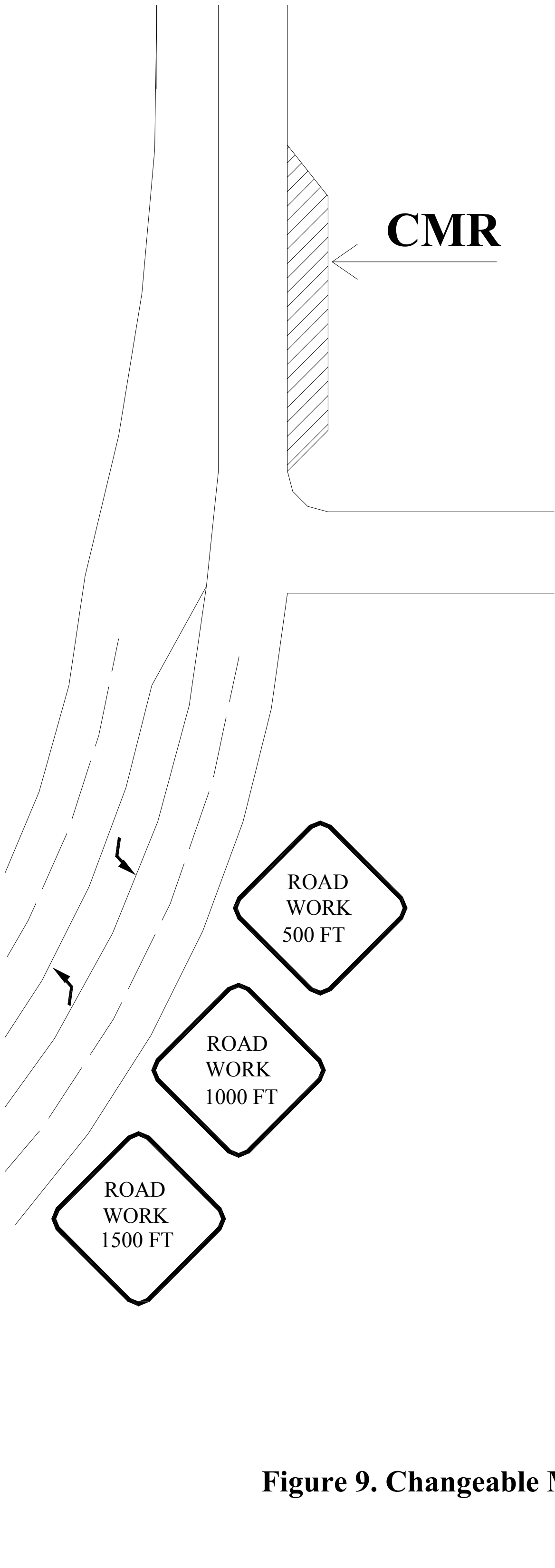

Figure 9. Changeable Message Sign Location

Chapter 4. Data Collection Plan

As previously indicated, this study examines the effects of three prospective work zone speed reduction strategies (described in Chapter 3) at selected work zone sites in Georgia. These strategies included fluorescent orange sign sheeting, innovative message signs, and changeable message signs with radar. The GT team tested the affect of these strategies using a before and after study with comparison group design.

4.1. Site Selection

Prior to site selection, the research team evaluated recent work zone fatal crashes in the state of Georgia to determine a target work zone type with known safety issues. The rural non-interstate principal arterial construction zone represented the largest percentage of crashes at 22 percent (see Table 3). In addition, 66 percent of all the studied work zone fatal crashes occurred on roadways with a speed limit of 55 mph (with a total of 72 percent at work zones with 55 mph or greater speed limits). In addition, 76 percent of the fatal crashes occurred at two-lane highway segments. As a result, the work zone type targeted for this analysis was a rural two-lane highway with adjacent work activity and uninterrupted traffic flow conditions. It is important to note that Georgia is currently upgrading many two-lane highways to multi-lane median separated roads. For this reason, this target work zone is currently more common in the state of Georgia and may help explain the over representation of fatal crashes at these work zone configurations.

For data analysis purposes, highway sections chosen for this study must have free flow traffic conditions most of the data collection period. At free flow speeds, drivers select their operating speed based on road geometry, environmental conditions, and their own vehicle and driving ability. They are not strongly influenced by the presence or behavior of other vehicles in the traffic stream. Accordingly, if any one of these strategies could affect driving behavior, free flow speed drivers are most likely to be influenced by these work zone speed reduction methods.

Georgia work zone study sites selected for evaluation were:

- Site 1: Peachtree Industrial from Rogers Bridge Road to Pinecrest Road in Gwinnett County;
- Site 2: S.R. 1/U.S. 27 in Carroll County;
- Site 3a: Northbound S.R.1/U.S. 27 in Haralson and Polk Counties (located at the southern end of this 12-mile work zone); and
- Site 3b: Southbound S.R.1/U.S. 27 in Haralson and Polk Counties (located at the northern end of this 12-mile work zone).

4.2. Data Collection

The data collection included two specific tasks:

1) Traffic speed and volume data collection; and
2) Traffic control device placement, evaluation, and calibration.

For the first task, the research team placed one data collection device for each specific study location in each data collection period. For the second task, devices that were used for the same data collection effort were lined up in one lane to test if there were any statistically significant differences in the recorded speeds of identical vehicles. The GT team collected volume, speed, vehicle length, and headway data for periods ranging from 24 to 54 continuous hours. Data collection occurred on Tuesdays, Wednesdays, or Thursdays. The GT team did not collect data on Friday through Monday due to the atypical traffic patterns commonly associated with weekends.

4.2.1. Data Collection Devices

The safe collection of traffic data was of paramount importance on this project. The research team (with the help of the individual project contractor) positioned the Nu-Metrics Hi-Star portable traffic classifiers that measure speed, volume, and approximate vehicle length in the center of the active travel lane. Figure 10 shows a schematic of a typical classifier. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle presence). Specifications for the Nu-Metrics Hi-Star classifiers are located in Appendix 2 of this report.

To safely place the devices in the active lane, a gap in traffic of approximately one-minute is required. To safely remove the devices from the active lane, a gap in traffic of approximately two-minutes is required. Due to the low-volume nature of the study sites, data collection devices were safely placed and removed without altering traffic behavior in the region. Georgia Tech personnel coordinated with the individual project contractor for appropriate times and device placement locations. Installation of the Nu-Metrics devices was accomplished by the use of a tape coat product that resembled an asphalt "patch" from a driver's perspective. Figure 11 shows two adjacent Nu-Metric classifiers and their tape coat cover.

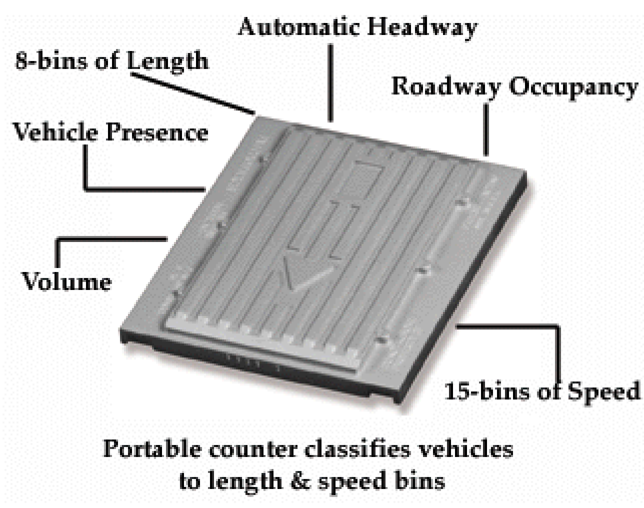

Figure 10. Sample Nu-Metrics Classifier (Model No. NC-97)
Source: http://www.nu-metrics.com

Figure 11. Deployed Classifiers at Work Zone Advance Warning Area

In addition to the unobtrusive data collection devices, the research team also used video cameras for supplemental data collection efforts. A camera was positioned in a vehicle and the vehicle was driven through the work zone by a research team member. The purpose of this "floating vehicle" perspective was to record actual device placement locations (i.e. signs, classifiers, and their locations relative to work activity). The video tape could then be used at any time, as required, during data analysis to help clarify specific site conditions.

Georgia Tech data collectors working adjacent to the active lanes wore safety vests at all times. At no time did the research team initiate data collection efforts at the site without first coordinating this activity with the construction site manager. Data collection efforts ranged from one day to several consecutive days.

4.2.2. Traffic Speed and Volume Data Collection

Traffic control engineers often share a common concern that the effectiveness of many traffic devices deteriorates over time as drivers become more familiar with the presence of the devices. For the purposes of this report, this driver acceptance of traffic control devices will be referred to as the *novelty effect.* In general, immediately following placement of an “attention getting” device, the drivers change their behavior (in this study we assume they adjust their vehicle’s operating speed). If the drivers regularly traverse the same corridor, the initial influence of the traffic control device diminishes and the driver may return to previous driving behaviors. With this possible novelty effect in mind, the GT team structured data collection efforts to include three evaluation phases for each strategy:

- Before Implementation – to provide a comparative baseline prior to strategy implementation;
- Immediate Influence – to evaluate driver responses to the strategy within the first few days of implementation; and
- Novelty Effect – to test driver responses after the strategy had been implemented a few weeks.

Table 6 summarizes the various data collection dates and testing strategies. If a data collection device malfunctioned, the team collected data at the same location the following week (weather permitting). Only the fluorescent orange sheeting was tested at Site 2. Both the fluorescent orange sheeting and the innovative message signs were tested at Sites 1 and 3a, while Site 3b was used for testing of the CMR.

Table 6. Summary of Data Collection Time Periods

Road	*County*	*Date* *from*	*to*	*Phase*
Site 1: Peachtree Industrial (Length: 9 miles)	Gwinnett	8/2/2000	8/3/2000	Before
		8/22/2000	8/24/2000	Innovative Sign (Immediate)
		9/19/2000	9/20/2000	Innovative Sign (Novelty)
		10/24/2000	10/26/2000	New Sheeting (Immediate)
		11/15/2000	11/17/2000	New Sheeting (Novelty)
Site 2: US 27 (Length: 5 miles)	Carroll	4/5/2000	4/7/2000	Before
		7/12/2000	7/13/2000	New Sheeting (Immediate)
		7/18/2000	7/19/2000	New Sheeting
		7/22/2000	7/24/2000	New Sheeting
		8/8/2000	8/10/2000	New Sheeting (Novelty)
Site 3a: US 27 Northbound (Length: 12 miles)	Haralson and Polk	11/13/2001	11/15/2001	Before
		11/27/2001	11/29/2001	New Sheeting (Immediate)
		12/4/2001	12/21/2001	New Sheeting
		12/18/2001	12/21/2001	New Sheeting (Novelty)
		1/29/2002	1/31/2002	Innovative Sign (Immediate)
		2/27/2002	2/28/2002	Innovative Sign (Novelty)
Site 3b: US 27 Southbound (Length: 12 miles)	Haralson and Polk	2/27/2002	2/28/2002	Before
		3/27/2002	3/28/2002	CMS with Radar (Week 1)
		4/3/2002*	4/4/2002	CMS with Radar (Week 2)
		4/10/2002	4/11/2002	CMS with Radar (Week 3)

* Due to rain, data for 4/3/2002 was removed prior to final data analysis

4.2.2.1. Fluorescent Orange Sheeting

The GT team evaluated fluorescent orange sheeting at all three highway work zone sites. At Site 1, the sheeting test was scheduled after the study of the innovative message signs. For this reason, the signs with the new sheeting included the three innovative message signs. At Site 2, the study site included only the new sheeting for the standard work zone advance warning signs. At Site 3, the fluorescent orange sheeting was the first strategy tested so initially only the standard work zone advance warning signs were constructed with fluorescent orange sheeting. See Table 6 for details of these data collection periods.

Figure 12 shows the typical data collection device location used for this analysis. A minimum of six devices were deployed for each data collection phase. The same data collection device was used consistently at the same location unless it malfunctioned and had to be replaced. The devices placed in the two-way, two-lane road adjacent to the active work area were located approximately mid-way into each work zone region and adjacent to daily work activity.

4.2.2.2. Innovative Message Signs

The GT team evaluated the innovative message signs at two of the work zones. At Site 1, innovative message signs constructed of standard high intensity sheeting were first deployed at the site. Following evaluation of the speed effects of the high intensity sheeting, all of the advance warning signs and innovative message signs were replaced (using the same sign poles) with fluorescent orange sheeting signs. This substitution enabled the research team to evaluate the combined effect of both the innovative message sign and the new sheeting. At Site 3a, the innovative message signs were evaluated following testing of the fluorescent orange sheeting. As a result, only fluorescent orange innovative message signs were studied at Site 3a.

The placement of the data collection devices was consistent with that shown in Figure 12. The active work area innovative message sign was placed immediately adjacent to the active work area data collection device. By doing this, any speed change that may result when the driver sees the sign and is reminded of its message (after hopefully seeing the upstream signs) was be captured by the data collection device.

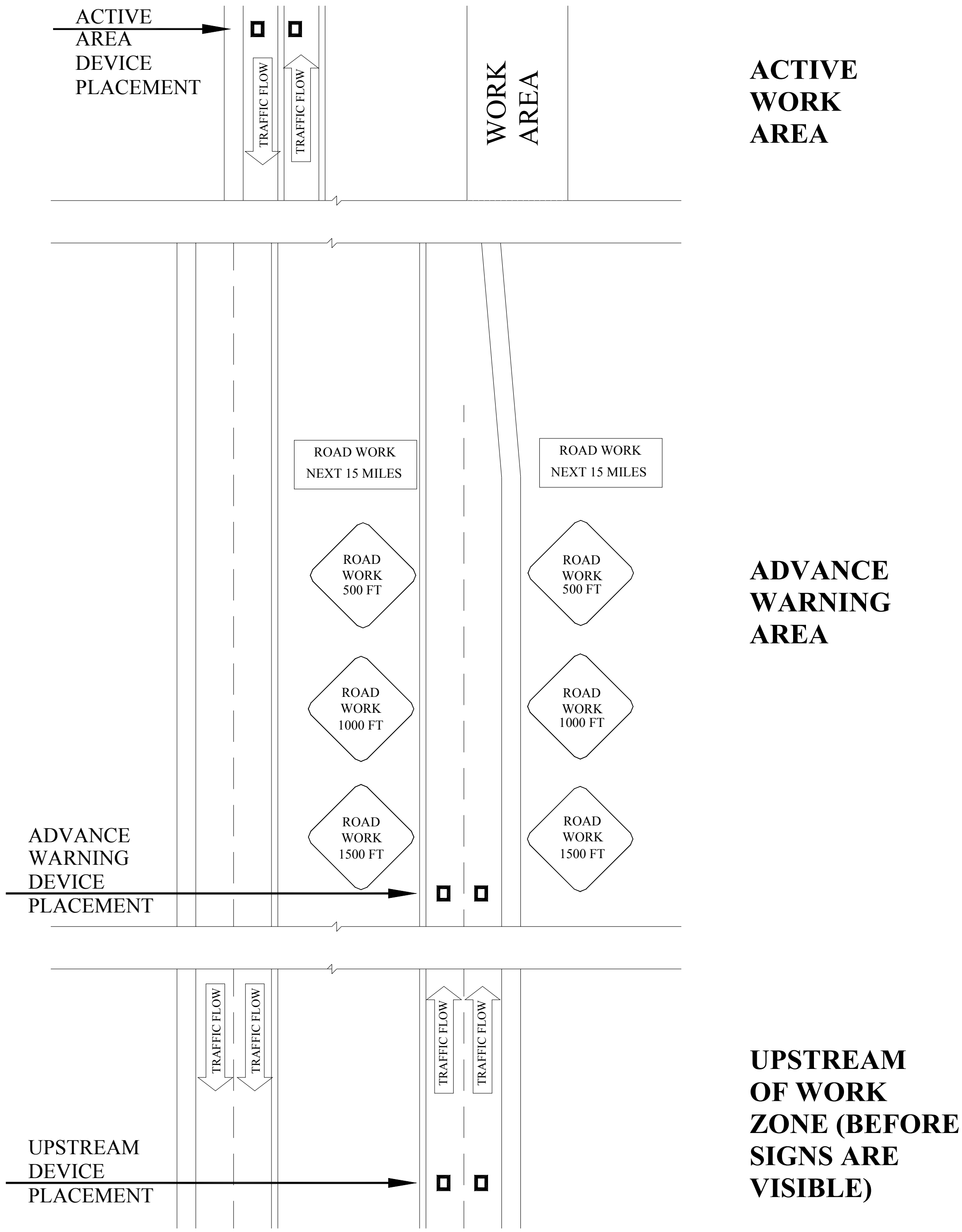

Figure 12. Device Placement

4.2.2.3. Changeable Message Sign with Radar

To test the effect of the CMR on speed reduction at the Site 3b work zone, the traffic analysis work plan included two data collection phases. First, speed and traffic volume data were collected in the southbound direction of travel prior to installation of the CMR. Next, the CMR was deployed near the end of the taper as traffic approached the work zone at the narrowed reduced lane configuration (see Figure 9). The CMR remained at the site at this location for three consecutive weeks so both immediate affects as well as novelty effects could be evaluated. Table 6 depicts the actual data collection dates. The GT team removed data from analysis for one day due to rain. This exclusion is because inclement weather generally influences driver behavior and would, therefore, confound any speed reductions resulting from the CMR technology at the site.

Data was collected during the following three consecutive week period after installation of the CMR. At this site, the research team again used a minimum of six traffic classifiers. Two classifiers were placed in the advance warning sign area (upstream of this location was a dense, signalized arterial road so data collection of free flow speeds prior to work zone was not feasible). Two classifiers were placed adjacent to the CMR with one device capturing each direction of travel. Finally, two devices were placed in the two-way, two-lane active work area to help determine if any effects of the CMR were localized to the region of the sign.

4.2.3. Device Accuracy Evaluation

The manufacturers of the traffic classifiers advertise ± 4.2-percent vehicle speed accuracy and ± 8-percent vehicle length accuracy (see Appendix 2 for additional data collection device information); however, variability between devices could provide misleading speed values if the research team does not consider these potential variations in the data analysis phase of the project.

To eliminate the possible system error caused by varying devices, the GT research team performed a special test to identify the relative recording error of the study devices. Devices were separated into two evaluation groups (six classification devices per group). Those devices which were used for the same study traffic control strategy were allocated to the same evaluation group and lined up close to each other in one lane as depicted in Figure 13. Data was collected all day on March 14, 2002 at Site 3a. Chapter 6 includes required speed adjustments identified as a result of the observed field variations of speeds identified in this field test.

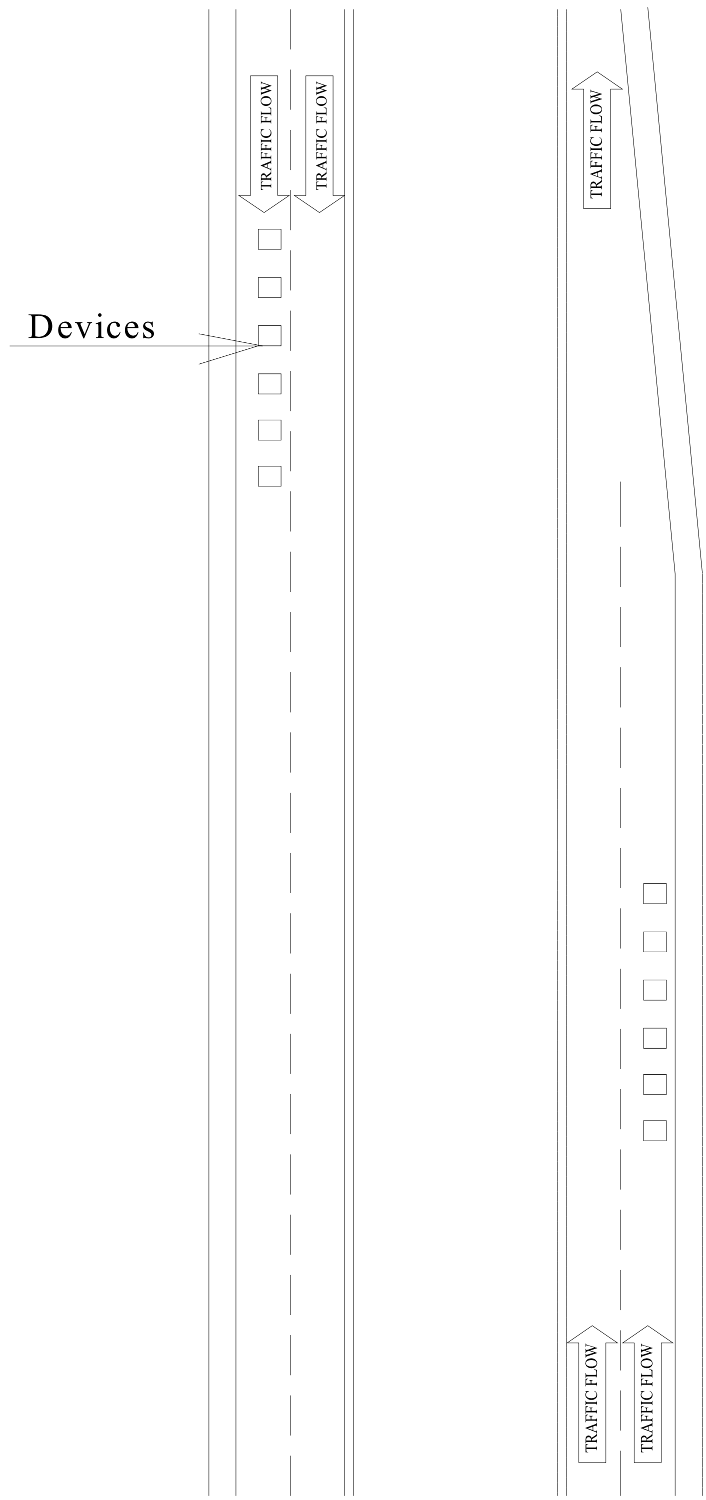

Figure 13. Device Placement for Evaluation

Chapter 5. Data Summary and Evaluation

The speeds and headways of more than 600,000 vehicles were collected during this study. While speeds for all vehicles were recorded, only the speeds of free flow vehicles (defined for the purposes of this study as vehicles having headways of 5 seconds or more) were used in the analysis. An examination of all the vehicle speeds versus just the free flow vehicle speeds showed that free flow speeds at the study sites were normally less than 2 mph higher than those for the entire observed vehicle population.

Following the collection of traffic speed and volume data, the GT research team identified the free flow speed vehicles for each analysis period and tested the significance of changes of vehicle speeds under the different traffic control strategies.

5.1. Sample of Raw Data

Traffic classifiers recorded the speeds and vehicle lengths for the entire vehicle population traversing the work zone during each data collection period. Table 7 shows a sample of raw data downloaded from one traffic counter at one location. The “Speed” column is the operating speed of each vehicle in mph. The “Length” column is the length of the vehicle in feet. The “Seconds” column is the headway in seconds between two adjacent vehicles (Note: This definition does not apply to the first vehicle evaluated during a study period). The “Offset” column is the total time in seconds from the start of data collection. It is the accumulated sum of the “Seconds” column. A separate file contained beginning time, date, and weather conditions.

5.2. Data Summary File

Following the download of the data from the traffic classifiers, the research team next merged the raw data acquired from the classifier with the separate data file that provided date and time information. By doing this, the analysts could determine the exact time that each vehicle passed the device. Table 8 shows the data summary file for the same 40 observations depicted in Table 7. For example, the 40th recorded vehicle shown in Table 8 traveled over the device at 3:36:47 a.m. on April 10, 2002. The purpose of determining the exact time of day was to help differentiate the effects of different traffic control strategies during daytime and night time lighting conditions.

Table 7. Sample Raw Data

Speed	*Length*	*Seconds*	*Offset*	*Speed*	*Length*	*Seconds*	*Offset*
58	20	59	59	58	18	633	6066
57	15	8	67	55	15	18	6084
47	20	105	172	51	15	521	6605
47	14	224	396	47	15	195	6800
60	13	674	1070	66	34	1148	7948
57	11	101	1171	54	59	231	8179
50	32	430	1601	50	56	6	8185
52	10	0	1601	51	31	1213	9398
53	16	37	1638	49	10	1	9399
49	10	89	1727	54	22	511	9910
38	10	355	2082	52	48	1390	11300
44	10	99	2181	51	63	878	12178
63	18	126	2307	62	19	298	12476
59	18	143	2450	51	61	102	12578
47	14	112	2562	49	60	163	12741
51	16	1416	3978	51	40	137	12878
45	17	1114	5092	50	23	96	12974
67	10	49	5141	50	10	1	12975
50	10	96	5237	50	17	16	12991
53	15	196	5433	59	29	16	13007

Table 8. Sample Data Used for Analysis after Data Reduction

ID	*Date*	*Speed (mph)*	*Length (ft)*	*Headway (sec)*	*Offset (sec)*	*Time*	*Hrs*	*Min*	*Sec*
1	04/10/02	58	20	59	59	0.016	0	0	59
2	04/10/02	57	15	8	67	0.019	0	1	7
3	04/10/02	47	20	105	172	0.048	0	2	52
4	04/10/02	47	14	224	396	0.110	0	6	36
5	04/10/02	60	13	674	1070	0.297	0	17	50
6	04/10/02	57	11	101	1171	0.325	0	19	31
7	04/10/02	50	32	430	1601	0.445	0	26	41
8	04/10/02	52	10	0	1601	0.445	0	26	41
9	04/10/02	53	16	37	1638	0.455	0	27	18
10	04/10/02	49	10	89	1727	0.480	0	28	47
11	04/10/02	38	10	355	2082	0.578	0	34	42
12	04/10/02	44	10	99	2181	0.606	0	36	21
13	04/10/02	63	18	126	2307	0.641	0	38	27
14	04/10/02	59	18	143	2450	0.681	0	40	50
15	04/10/02	47	14	112	2562	0.712	0	42	42
16	04/10/02	51	16	1416	3978	1.105	1	6	18
17	04/10/02	45	17	1114	5092	1.414	1	24	52
18	04/10/02	67	10	49	5141	1.428	1	25	41
19	04/10/02	50	10	96	5237	1.455	1	27	17
20	04/10/02	53	15	196	5433	1.509	1	30	33
21	04/10/02	58	18	633	6066	1.685	1	41	6
22	04/10/02	55	15	18	6084	1.690	1	41	24
23	04/10/02	51	15	521	6605	1.835	1	50	5
24	04/10/02	47	15	195	6800	1.889	1	53	20
25	04/10/02	66	34	1148	7948	2.208	2	12	28
26	04/10/02	54	59	231	8179	2.272	2	16	19
27	04/10/02	50	56	6	8185	2.274	2	16	25
28	04/10/02	51	31	1213	9398	2.611	2	36	38
29	04/10/02	49	10	1	9399	2.611	2	36	39
30	04/10/02	54	22	511	9910	2.753	2	45	10
31	04/10/02	52	48	1390	11300	3.139	3	8	20
32	04/10/02	51	63	878	12178	3.383	3	22	58
33	04/10/02	62	19	298	12476	3.466	3	27	56
34	04/10/02	51	61	102	12578	3.494	3	29	38
35	04/10/02	49	60	163	12741	3.539	3	32	21
36	04/10/02	51	40	137	12878	3.577	3	34	38
37	04/10/02	50	23	96	12974	3.604	3	36	14
38	04/10/02	50	10	1	12975	3.604	3	36	15
39	04/10/02	50	17	16	12991	3.609	3	36	31
40	04/10/02	59	29	16	13007	3.613	3	36	47

5.3. Data Reduction

To enable quick and consistent speed data evaluation for the GDOT work zone project, the research team developed a computer program which is able to identify traffic data with varying characteristics. The program permits the user to sort data based on the following three characteristic options:

- Available Headway Options -- Category includes all vehicles, those with time headways for 3 seconds or more, or those with time headways for 5 seconds or more;
- Vehicle Length Options -- Category includes all vehicles, vehicles 20 feet long or less, and vehicles longer than 20 feet; and
- Lighting Conditions -- Category includes all times, daylight only, or nighttime conditions only. (Note: The daylight time period began 30 minutes after sunrise and ended 30 minutes before sunset for the specific day. Similarly, nighttime conditions started 30 minutes after sunset and lasted until 30 minutes before sunrise. These one-hour gaps were designed to remove the influence of dawn and dusk lighting conditions.)

The program user can select any combination of these three options using a "drop box menu" that provides the available options. For example, if the program user is interested in free flow speed information of passenger vehicles with greater than five second headways during daytime lighting conditions, he or she would simply select "5 SEC. OR LARGER", "20 FT. OR LESS", and "DAYLIGHT ONLY" from the options menus. The source database (comprised of the summary data files for each site in a format similar to the example shown in Table 8) is then identified by the program user in the text box labeled "Database Name" as shown in Figure 14.

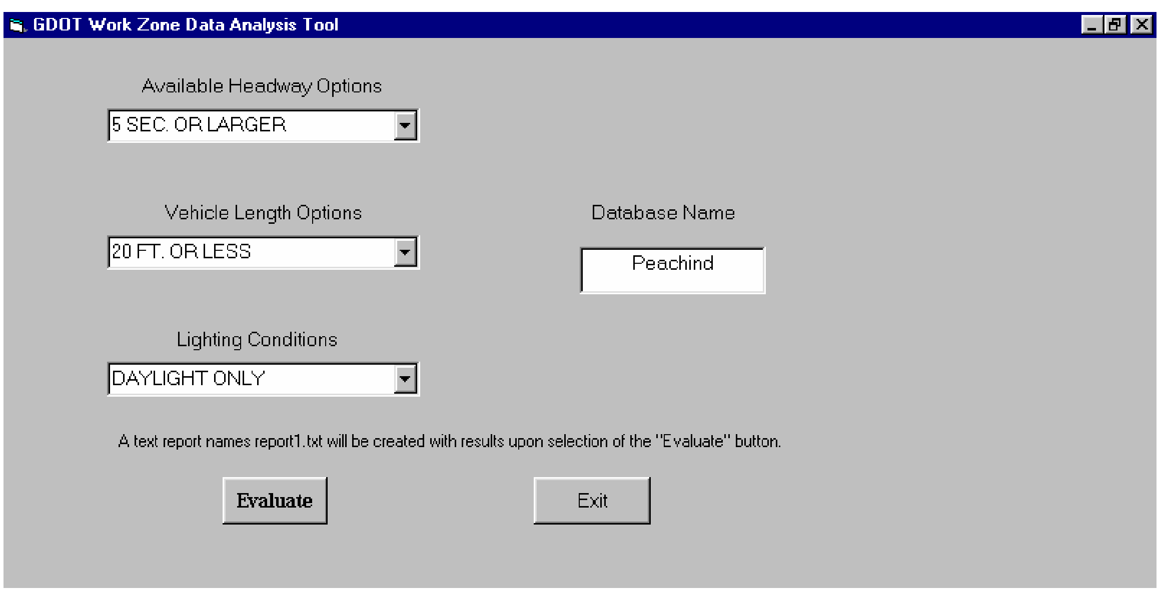

Figure 14. Interface of Data Summary Program

After a click on the “Evaluate” button, a text report named report1.txt will be created as illustrated in Figure 15. This report is a summary of data collected which meets the analysis needs as determined by the user selection criteria specified in the program query. The output file has information regarding the Data Collection Site, the user selected criteria, a “Location” code for the data collection device (a unique code programmed by the data collector prior to deployment of the device), the average speed (“Avg. Speed”) of vehicles observed for the required criteria, the “Sample Size” (the number of observed vehicles that met the selection criteria); and the “Description” of the traffic data relative to the work zone and work plan locations. This report provided the researchers with a rough overview of how the speed changed across all data collection locations and conditions.

```
GDOT Work Zone Summary File

File Name:   Us27
Headway Condition:    5 SEC. OR LARGER
Vehicle Type:    20 FT. OR LESS
Lighting Condition:    DAYLIGHT ONLY

               Avg.  Sample
Location       Speed  Size   Description
--------       -----  ------  ------------------------------
ACTIVE_NB_A    53.2   2612   Before - NB Active Work
ACTIVE_NB_B    59.6   2528   New Sheeting - NB Active Work
ACTIVE_SB_A    49.9   2806   Before - SB Active Work
ACTIVE_SB_B    46.5   2128   New Sheeting - SB Active Work
ADV_LT_A       63.7   495    Before - NB Adv. Lt Lane
ADV_LT_B       63.2   427    New Sheeting - NB Adv. Lt Lane
ADV_LT_C       59.9   508    New Sheeting (Novelty) - NB Adv. Lt Lane
ADV_RT_B       59.6   2196   New Sheeting - NB Adv. Rt Lane
ADV_RT_C       64.4   2089   New Sheeting (Novelty) - NB Adv. Rt Lane
SIGN_LT_A      54.8   753    Before - NB Signs Lt Lane
SIGN_LT_C      56.9   525    New Sheeting (Novelty) - NB Signs Lt Lane
SIGN_LT_C1     58.2   526    New Sheeting (Novelty) - NB Signs Lt Lane
SIGN_RT_A      52.0   2723   Before - NB Signs Rt Lane
SIGN_RT_B      52.3   2320   New Sheeting(1) - NB Signs Rt Lane
SIGN_RT_B1     49.2   3216   New Sheeting(2) - NB Signs Rt Lane
SIGN_RT_C      54.4   2922   New Sheeting (Novelty) - NB Signs Rt Lane
```

Figure 15. Summary for Daytime Passenger Vehicles with ≥ 5 sec Headways

5.4. Statistical Tests

In general, the GT research team used three fundamental statistical tests for data evaluation. They included a paired t-test, analysis of variance, and Tukey’s honestly significant differences test. Each test is briefly discussed in the following sections, with specific test results included in Appendix 1.

Generally to determine statistical significance, the analyst postulates a hypothesis and then proceeds to test the validity of that hypothesis. For this study, the research team evaluated the following 26 hypotheses:

Hypothesis 1: The speeds in the advanced warning area do not change immediately after installation of fluorescent orange warning signs compared with the speeds before installation.

Hypothesis 2: The speeds in the advanced warning area do not change several weeks after installation of fluorescent orange warning signs compared with the speeds before installation.

Hypothesis 3: The speeds in the advanced warning area do not change several weeks after installation of fluorescent orange warning signs compared with the speeds immediately after installation.

Hypothesis 4: The speeds in the active work area do not change immediately after installation of fluorescent orange warning signs compared with the speeds before installation.

Hypothesis 5: The speeds in the active work area do not change several weeks after installation of fluorescent orange warning signs compared with the speeds before installation.

Hypothesis 6: The speeds in the active work area do not change several weeks after installation of fluorescent orange warning signs compared with the speeds immediately after installation.

Hypothesis 7: The speeds in the advanced warning area do not change immediately after installation of innovative warning signs compared with the speeds before installation.

Hypothesis 8: The speeds in the advanced warning area do not change several weeks after installation of innovative warning signs compared with the speeds before installation.

Hypothesis 9: The speeds in the advanced warning area do not change several weeks after installation of innovative warning signs compared with the speeds immediately after installation.

Hypothesis 10: The speeds in the active work area do not change immediately after installation of innovative warning signs compared with the speeds before installation.

Hypothesis 11: The speeds in the active work area do not change several weeks after installation of innovative warning signs compared with the speeds before installation.

Hypothesis 12: The speeds in the active work area do not change several weeks after installation of innovative warning signs compared with the speeds immediately after installation.

Hypothesis 13: The influence of high intensity sheeting innovative warning sign on speeds in the advance warning area is the same as influence of fluorescent orange innovative warning signs. (For Peachtree Industrial site only)

Hypothesis 14: The influence of high intensity sheeting innovative warning sign on speeds in the active work area is the same as influence of fluorescent orange innovative warning signs. (For Peachtree Industrial site only)

Hypothesis 15: All data collection devices in one group record the same speed.

Hypothesis 16: The speed reductions for the CMR during all three weeks are the same.

Hypothesis 17: The upstream speeds in each data collection phase are the same for each site.

Hypothesis 18: Device A and device B record the same speed. (A and B can be any combination of devices in one group)

Hypothesis 19: The speeds in the advance warning area do not change after installation of CMR compared with speeds before installation.

Hypothesis 20: The speeds in active work area do not change after installation of CMR compared with speeds before installation.

Hypothesis 21: The speeds at CMR do not change immediately after installation compared with speeds before installation.

Hypothesis 22: The speeds at CMR do not change several weeks after installation compared with speeds before installation.

Hypothesis 23: The speeds at CMR do not change several weeks after installation compared with speeds immediately after installation.

Hypothesis 24: The speeds in active work area do not change immediately after installation of CMR compared with speeds before installation.

Hypothesis 25: The speeds in active work area do not change several weeks after installation of CMR compared with speeds before installation.

Hypothesis 26: The speeds in active work area do not change several weeks after installation of CMR compared with speeds immediately after installation.

5.4.1. Two sample procedure --- general procedure

The GT researchers conducted a two-sample t-test to determine if the implementation of a specific traffic control strategy resulted in a statistically significant reduction in operating speeds. Due to the variable nature of the traffic data, the data collection periods did not have similar sample sizes. As a result, before using the t-test the data variance must be examined to determine the appropriate approach for statistical evaluation. Note that the two-sample t-tests can be used without pooling the variances or with a pooled variance estimate. The pooled variance procedure is based on the assumption that the population variances σ_A^2 and σ_B^2 are equal, whereas the general paired t-test procedure makes no assumptions about the population variances. It is therefore appropriate to use the general procedure, as summarized below, for this study.

Hypothesis testing: H$_0$: μ_A - μ_B = 0

H$_A$: μ_A - μ_B $\neq$ 0

Test statistic: $$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{s_x^2}{n} + \frac{s_y^2}{m}}}; \; X \sim t_\nu, \qquad \text{where } \nu = \frac{(\frac{s_x^2}{n} + \frac{s_y^2}{m})^2}{\frac{s_x^4}{n^2(n-1)} + \frac{s_y^4}{m^2(m+1)}}$$

Size α hypothesis tests: Accept H$_0$, if $|t| \leq t_{\alpha/2,\nu}$

Reject H$_0$, if $|t| > t_{\alpha/2,\nu}$

Where:

- H$_0$ is null hypothesis which states that two population means are equal,
- μ_A is mean of population A,
- H$_A$ is alternative hypothesis which states that two population means are not equal,
- μ_B is mean of population B,
- $\bar{x}$ is mean of sample of population A,
- $\bar{y}$ is mean of sample of population B,
- s_x^2 is sample variance of population A,
- s_y^2 is sample variance of population B,
- n is number of cases of sample of population A,
- m is number of cases of sample of population B,
- t is test statistic,

- $t_{\alpha/2,\nu}$ is critical value for two sided t test with $1-\alpha$ confidence and a degree of freedom of ν

The researchers applied the two-sample t-test for each site and traffic control strategy. Hypotheses 1 through 6 tested the fluorescent orange sings, hypotheses 7 through 14 evaluated speed for the innovative message signs, and hypotheses 21 through 26 tested the CMR speeds.

These hypotheses were tested not only for all vehicles, but also were tested for different combinations of traffic stream characteristics and lighting conditions to see if there were any specific influences for a given traffic control strategy. Chapter 6 reviews the results of these statistical tests.

5.4.2. Analysis of Variance

It is important to verify that data collection devices used repeatedly for speed comparison purposes provide similar results, or in lieu of similar results, the limitations of the data provided by the devices be known. With the use of multiple devices at one location (in one lane and testing identical vehicles), the analysis of variance (ANOVA) test is appropriate. ANOVA merges all the speed data into one metric known as the F-value and this value can then be used to estimate the probability that a certain hypothesis (known as the null hypothesis) is correct.

The ANOVA can also be used to evaluate large data sets with a normal distribution. This procedure can be used to compare variances to see if there is any evidence to reject the hypothesis. Often with large data sets, the equivalence in variance requirement will be difficult to achieve. For this reason, a third statistical procedure (Tukey's Test) may be appropriate (as discussed in the following section).

The ANOVA was used to evaluate Hypotheses 15 though 17.

5.4.3. Tukey's HSD (Honestly Significant Differences) Test

Although ANOVA tells you that at least two means are significantly different from one another, it does not tell you which specific mean pairs are significantly different. As we are interested in specific observed differences in speeds, the research team conducted a post hoc analysis, Tukey's HSD test, to further explore the effects of treatments if hypotheses are rejected.

Tukey's test creates a single value (often called the critical difference) that enables the analyst to determine if a significant difference was observed between treatments. If the mean difference is greater than the critical difference (referred to as HSD), then one may conclude there is a significant difference between treatments. The equation for HSD is expressed as:

$$HSD = q\sqrt{\frac{MSE}{n}}$$

Where:

- q is a value from the Studentized range table,
- MSE is the mean square error (from the ANOVA table), and
- N is the number of observations per treatment group.

Hypotheses 18 through 20 were tested using the Tukey's test.

Chapter 6. Results

6. 1. Data Validation

To assure consistent evaluation for comparable traffic conditions, the graph shown in Figure 16 displays a representative sample depicting the number of vehicles at the active work area for Site 3a during each data collection hour. Traffic characteristics at the site resembled common daily traffic volume patterns with morning and afternoon peak hours. This graphic demonstrates relatively consistent vehicle distributions over time.

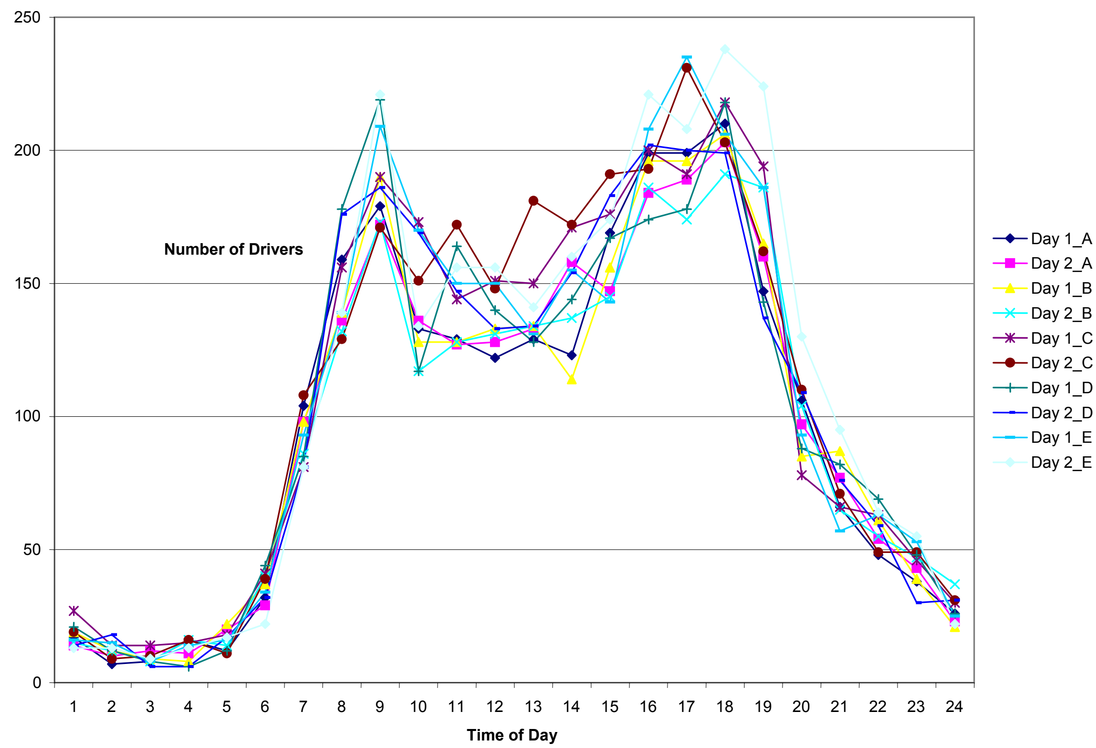

Figure 16. Vehicles at Site 3a Active Work Area

6. 2. Device Evaluation

As discussed in Section 4.2.3 of this report, the GT team evaluated data collection device accuracy by deploying the devices into two analysis groups and testing them for systemic errors in the accuracy of speeds they recorded. Since the devices were lined up close together in the same lane (see Figure 13), the speeds they recorded should be equivalent for the identical vehicle. The research team then performed an ANOVA test to determine if there were any statistically significant differences in recorded speeds. The device speeds did indeed vary and were determined to have statistically significant difference (thereby rejecting hypothesis 18 in Chapter 5). Tukey's HSD tests were then performed by the team to determine the level of difference between the speeds recorded by each pair. Table 9 summarizes the observed mean speeds, and Tables 10 and 11 show speed difference matrices for the devices. The “Device ID” indicator represents the last 4-digits of the serial number for each classification device. The speed difference varies from -8.8 to 6.9 mph. Therefore, it was extremely important to use the same data collection device at the same location throughout the study so that it is meaningful to compare the speeds in different data collection time periods and test the effect of each treatment.

Table 9. Average Speeds Recorded by Devices

	Group 1					
Device ID	2590	2513	2512	4736	2593	2592
Mean Speed (mph)	63.77	60.4	59.99	63.34	60.72	65.26
	Group 2					
Device ID	2630	2591	2597	2511	2596	2510
Mean Speed (mph)	56.87	54.13	59.85	57.45	62.96	56.05

Table 10. Speed Differences of Device Pairs in MPH (Group 1)

Device ID	*2590*	*2513*	*2512*	*4736*	*2593*	*2592*
2590						
2513	3.37					
2512	3.78	0.40				
4736	0.43	-2.94	-3.35			
2593	3.05	-0.33	-0.73	2.62		
2592	-1.49	-4.86	-5.27	-1.92	-4.54	

Table 11. Speed Differences of Device Pairs in MPH (Group 2)

Device ID	*2630*	*2591*	*2597*	*2511*	*2596*	*2510*
2630						
2591	2.74					
2597	-2.98	-5.72				
2511	-0.59	-3.33	2.39			
2596	-6.09	-8.83	-3.11	-5.50		
2510	0.82	-1.92	3.80	1.40	6.91	

6.3. Test of upstream speeds

The GT team used the Bartlett's test to determine if there were any differences in speed variance of upstream traffic across all data collection phases. As indicated in Table 12, the variances of speeds upstream were generally different from each other in different phases. Numbers in bold represent variances that were not statistically significant. The research team applied alternative paired t-tests to all sites to verify if the different upstream speeds were significantly different from each other. If they were different, the speed changes in Table 13 to Table 17 have been adjusted to reflect the changes in upstream speeds.

Table 12. Bartlett's Test to Test Equal Variance

Site		all vehicles	pass, day	pass, night	truck, day	truck, night
Site1: Peachtree Industrial	Left Lane	20.06	5.63	33.29	10.55	**0.30**
	Right Lane	330.86	303.58	45.65	75.81	14.27
Site 2: US27 in Carroll	Left Lane	132.49	80.59	21.21	**2.58**	20.66
	Right Lane	6298.00	3312.40	1319.58	819.67	149.69
Site 3a: US27 in Haralson/Polk	Left Lane	52.57	12.75	54.29	**4.94**	**6.46**
	Right Lane	84.96	23.88	68.52	**2.16**	**10.37**
Site 3b: US27 in Haralson/Polk	Left Lane	24.13	12.46	22.12	15.44	**7.26**
	Right Lane	28.23	30.42	16.23	**2.05**	**5.38**

6.4. Fluorescent Orange Sheeting

The study team evaluated the fluorescent orange sheeting at Sites 1, 2, and 3a (see Appendix 2 for data collection work plans for each site). Since more than one strategy was tested at sites 1 and 3a, a minimum of five time periods were included in the data collection process at these sites. Figure 17 shows an example data collection observation for daylight passenger cars at Site 3a. Similar graphics for the other data collection sites are included in Appendix 1. Figure 18 similarly shows the nighttime trucks for Site 3a. As can be observed in this graphic, the influence of the tested traffic control strategies had only minimal influence on free flow trucks in the nighttime traffic stream.

Paired t-tests were performed for each hypothesis at each study site. First, all vehicles with larger than 5 seconds headway were included in the test of overall significance of the influence of treatments. Then these free flow vehicles were stratified by vehicle type and lighting conditions to test effects of treatments on a specific group of vehicles. Four additional free flow speed groups that were tested include: passenger vehicles driving during the day, passenger vehicles driving at night, trucks driving during the day, and trucks at night.

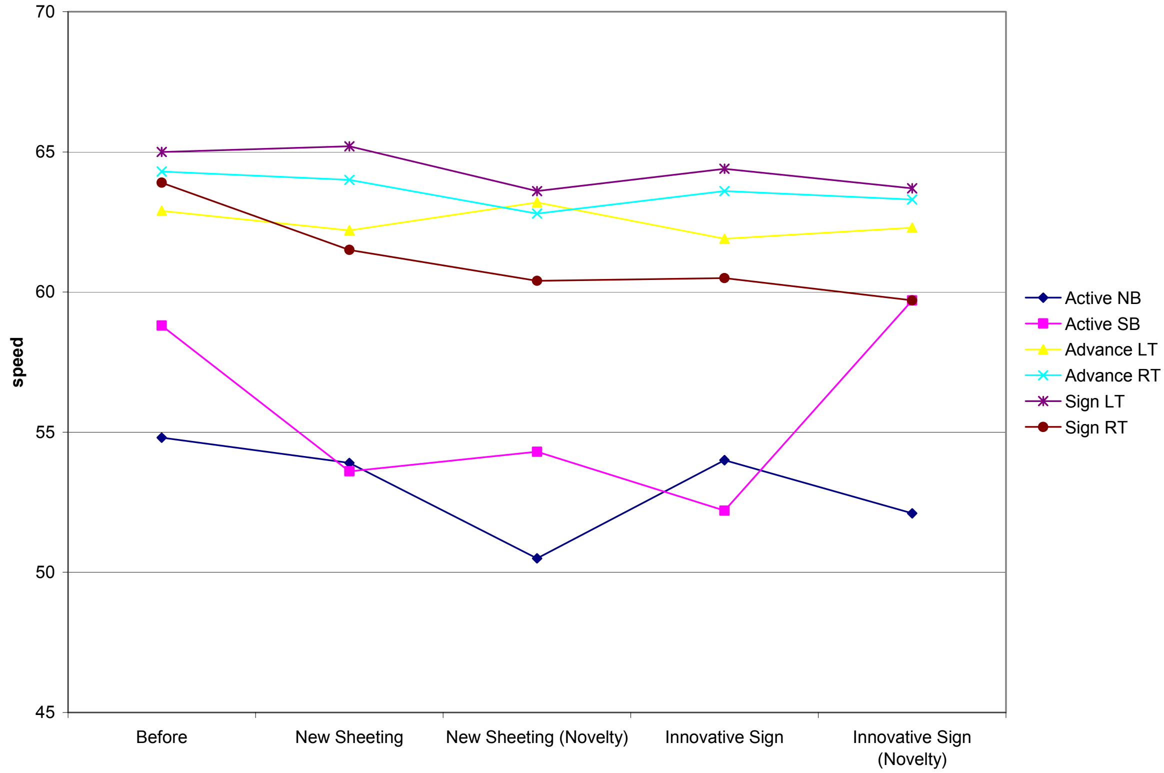

Figure 17. Average speeds at Site 3a (Passenger Vehicles, Day)

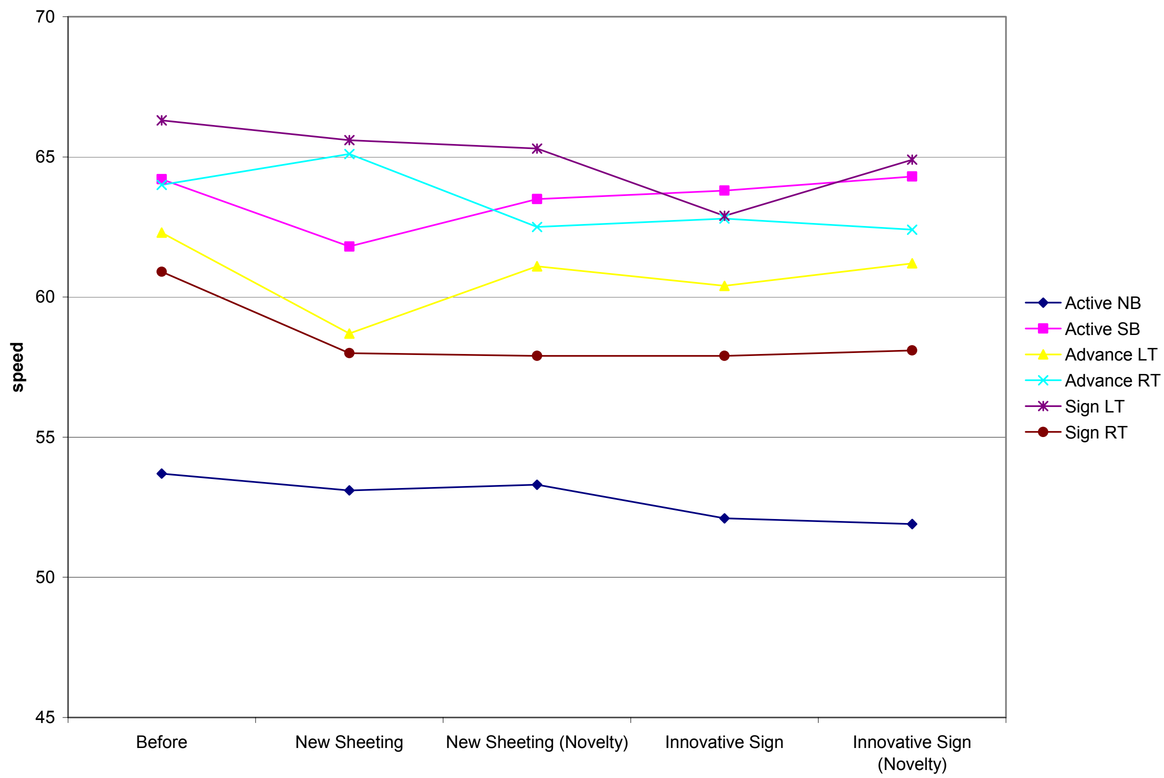

Figure 18. Average speeds at Site 3a (Trucks, Night)

Tables A-2 through A-31 provide observed mean speed differences and specific statistical analysis results for the fluorescent orange sheeting. Table 13 summarizes the analysis for the immediate speed changes following installation of the fluorescent orange advance warning signs. Table 14 depicts the statistical evaluation for the novelty effect of the fluorescent orange sheeting.

In general, the new sheeting resulted in reduced speeds of 1 to 3 mph during daylight conditions at Site 1. At Site 3a, vehicles in the left lane did not consistently reduce speeds as did vehicles in the right lane. Minor speed increases were observed for Site 2. The influence of this sign strategy for truck activity was less obvious with generally little or no influence (particularly for nighttime truck activity). In fact at some locations on the sites, trucks increased their speeds with this strategy. Though not specifically tested in this study, this speed increase may be due to the more conspicuous signage during reduced lighting conditions. Speed reductions of 1 to 2 mph were generally observed adjacent to the active work area.

The long term influence of the fluorescent orange sheeting on reduced speeds appears to diminish over time. As shown in Table 14, speeds slowly began to increase at Sites 1 and 3 several weeks after placement of the new sign sheeting. However, Site 2 speeds generally decreased several weeks after placement of the new sign sheeting.

Table 13. Speed Change for Before versus Immediately After New Sheeting

(Tests Hypotheses 1 and 4)

	*Advance Warning Area***			*Active Work Area*	
	Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition	*Left Lane*	*Right Lane*			
Site 1:					
All Free Flow Vehicles	-1.1	-2.4	Yes/Yes	-1.7	Yes
Passenger Vehicles, Day	-0.9	-2.5	Yes/Yes	-1.7	Yes
Passenger Vehicles, Night	0.1	-0.6	No/Yes	-1.5	Yes
Trucks, Day	-3.5	-3.6	Yes/Yes	-2.6	Yes
Trucks, Night	3.5	-0.8	No/No	-2.3	No
Site 2:					
All Free Flow Vehicles	--	0.3	na/No	6.9	Yes
Passenger Vehicles, Day	--	0.3	na/No	6.4	Yes
Passenger Vehicles, Night	--	0.2	na/No	7.2	Yes
Trucks, Day	--	3.3	na/Yes	7.5	Yes
Trucks, Night	--	-0.6	na/No	10.9	Yes
Site 3a:					
All Free Flow Vehicles	-0.8	-2.6	No/Yes	-0.8	Yes
Passenger Vehicles, Day	0.2	-2.4	No/Yes	-0.9	Yes
Passenger Vehicles, Night	-0.6	-1.9	Yes/Yes	-0.5	No
Trucks, Day	1.3	-3.4	No/Yes	-1.0	Yes
Trucks, Night	-0.7	-2.9	No/Yes	-0.6	Yes

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means the left lane was not statistically significant but the right lane was statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Average speed changes in advance warning area are adjusted 1) by average upstream speed changes when upstream speed changes are significant in both lanes; or 2) by half of the significant speed changes when upstream speed changes are significant in one lane only.*

Table 14. Speed Change for Novelty Effect Test with New Sheeting

(Tests Hypotheses 3 and 6)

	*Advance Warning Area****			*Active Work Area*	
	Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition	*Left Lane*	*Right Lane*			
Site 1:					
All Free Flow Vehicles	2.4	1.8	Yes/Yes	0.8	Yes
Passenger Vehicles, Day	3.4	1.7	Yes/Yes	1.8	Yes
Passenger Vehicles, Night	-0.6	0.8	No/No	0.1	No
Trucks, Day	4.4	3.8	Yes/Yes	2.3	Yes
Trucks, Night	1.0	-0.4	No/No	-1.2	No
Site 2:					
All Free Flow Vehicles	--**	-2.9	na/Yes	--	--
Passenger Vehicles, Day	--	-2.7	na/Yes	--	--
Passenger Vehicles, Night	--	0	na/Yes	--	--
Trucks, Day	--	-7.4	na/Yes	--	--
Trucks, Night	--	-6.3	na/Yes	--	--
Site 3a:					
All Free Flow Vehicles	-2.8	0.9	Yes/Yes	-1.4	Yes
Passenger Vehicles, Day	-1.6	0.1	Yes/Yes	-3.4	Yes
Passenger Vehicles, Night	-3.0	1.3	Yes/No	-0.1	No
Trucks, Day	0.0	1.7	No/Yes	-2.1	Yes
Trucks, Night	-0.3	2.5	No/No	0.2	No

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means the left lane was not statistically significant but the right lane was statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Due to a device malfunction, data was only available for two time periods at the active work area northbound and advanced warning area northbound left lane and was therefore not applicable to t test.*

**** Average speed changes in advance warning area are adjusted 1) by average upstream speed changes when upstream speed changes are significant in both lanes; or 2) by half of the significant speed changes when upstream speed changes are significant in one lane only.*

6.5. Innovative Message Sign

The GT team evaluated the innovative message signs at Sites 1 and 3a (see Appendix 2 for approved data collection work plans at each site). Original plans were to also test the innovative message sign at Site 2, but coordination with the project construction supervisor deemed this option infeasible. Sample average speed conditions are depicted in Figures 17 and 18 for Site 3a. Similar graphics for other site locations or traffic characteristics are included in Appendix 1.

Statistical tests similar to those described in Section 6.4 evaluated the short-term and long-term influences of the innovative message sign on speed. Tables A-2 through A-11 and Tables A-22 through A-31 summarized observed mean speed differences and specific statistical analysis results for the innovative message sign (Hypotheses 8 through 12 as defined in Chapter 5). Table 15 summarizes the analysis for the immediate observed speed changes following installation of the innovative message warning signs. Table 16 includes the results for the novelty effect statistical tests.

Table 15. Speed Change for Before versus Immediately After Innovative Message Sign Placement

(Tests Hypotheses 7 and 10)

	*Advance Warning Area***			*Active Work Area*	
	Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition	*Left Lane*	*Right Lane*			
Site 1:					
All Free Flow Vehicles	-1.6	-0.9	Yes/Yes	-0.3	Yes
Passenger Vehicles, Day	-1.8	-1.4	Yes/Yes	-0.6	Yes
Passenger Vehicles, Night	0.0	0.1	No/Yes	0.2	Yes
Trucks, Day	-0.2	-2.6	No/Yes	-1.0	Yes
Trucks, Night	5.8	-0.3	No/No	-0.6	No
Site 3a:					
All Free Flow Vehicles	1.9	-0.2	Yes/No	1.3	Yes
Passenger Vehicles, Day	2.1	-0.7	No/No	3.5	Yes
Passenger Vehicles, Night	2.5	-0.6	No/No	-0.3	Yes
Trucks, Day	-1.6	0.4	No/No	3.6	Yes
Trucks, Night	-2.4	0.0	Yes/No	-1.2	Yes

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means only the left lane was not statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Average speed changes in advance warning area are adjusted 1) by average upstream speed changes if upstream speed changes were significant in both lanes; or 2) by half of the significant speed changes if upstream speed changes are only significant in one lane.*

Table 16. Speed Change for Novelty Effect Test for Innovative Message Sign

(Tests Hypotheses 9 and 12)

	*Advance Warning Area***			*Active Work Area*	
	Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition	*Left Lane*	*Right Lane*			
<u>*Site 1:*</u>					
All Free Flow Vehicles	0.5	-0.6	Yes/No	-0.3	No
Passenger Vehicles, Day	0.4	-1.1	No/No	-0.5	Yes
Passenger Vehicles, Night	0.8	1.2	No/No	0.1	No
Trucks, Day	0.2	0.4	No/No	0.7	No
Trucks, Night	-6.0	-0.2	Yes/No	1.7	No
<u>*Site 3a:*</u>					
All Free Flow Vehicles	0	0.1	No/No	-1.0	Yes
Passenger Vehicles, Day	-0.7	-0.8	No/Yes	-1.9	Yes
Passenger Vehicles, Night	0.7	0.4	No/No	1.1	Yes
Trucks, Day	-0.2	-0.1	No/No	-3.0	Yes
Trucks, Night	2.0	0.2	No/No	-0.2	No

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means the left lane was not statistically significant but the right lane was statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Average speed changes in advance warning area are adjusted 1) by average upstream speed changes when upstream speed changes are significant in both lanes; or 2) by half of the significant speed changes when upstream speed changes are significant in one lane only.*

Placement of the innovative message sign at Site 1 occurred prior to use of fluorescent orange sheeting. As a result, the test for the innovative message sign at Site 1 directly evaluated only the additional message signs and did not include confounding influences due to the alternative sign sheeting (as at Site 3a). As can be observed in Table 15, the sign effected a speed reduction for daylight conditions (ranging from 0.2 mph for trucks up to 1.8 mph for passenger vehicles). The innovative message sign had no effect on nighttime driving conditions. Little significant change in speed occurred during the Site 1 test for a novelty effect as shown in Table 16.

Site 3a innovative message signs were constructed of fluorescent orange sheeting. As a result, possible speed reductions could be masked by speed influences due to fluorescent orange sheeting. Table 15 shows speed changes ranging from -2.4 mph up to +3.6 mph.

Similarly tests for the novelty effects were inconclusive. Table 16 shows novelty test speed changes ranging from -3.0 mph up to 1.1 mph. In general, speeds decreased slightly for daylight conditions and increased slightly for nighttime conditions.

Table 17 summarizes the change of innovative message sign sheeting from standard to fluorescent orange (Hypotheses 13 and 14, Chapter 5).

Table 17. Speed Change for Sheeting Effect Test for Innovative Message Sign

(Tests Hypotheses 13 and 14)

	*Advance Warning Area***			*Active Work Area*	
	Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition	*Left Lane*	*Right Lane*			
<u>*Site 1:*</u>					
All Free Flow Vehicles	-1.3	1.7	Yes/Yes	-1.0	Yes
Passenger Vehicles, Day	-1.4	1.9	Yes/Yes	-2.2	Yes
Passenger Vehicles, Night	0.9	2.3	No/Yes	-1.4	Yes
Trucks, Day	-3.3	2.2	Yes/Yes	-1.9	Yes
Trucks, Night	-2.5	1.7	No/No	-0.6	No

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means the left lane was not statistically significant but the right lane was statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Average speed changes in advance warning area are adjusted 1) by average upstream speed changes when upstream speed changes are significant in both lanes; or 2) by half of the significant speed changes when upstream speed changes are significant in one lane only.*

6.6. Changeable Message Sign with Radar

Following deployment of the CMR, the GT research team collected traffic data for three consecutive weeks (weeks 1, 2 and 3). These data were compared to data collected before installation of the CMR. Analysis using a paired t-test, Bartlett's test, and Tukey's HSD test was performed (see Appendix A, Tables A-29 through A-61) in an effort to determine what significant speed changes occurred at the site.

Table 18 shows the average speed change for the southbound lane (where the CMR was visible to the driver) and the adjacent (opposing) northbound lane. In general, immediately following implementation the speeds in the southbound lane reduced significantly (from 6 to 8 mph); however, the adjacent northbound lane also exhibited minor speed reductions up to 2 mph. This finding indicates a possible reduction of speed solely due to the CMR of 5 to 7 mph. The speed in the active work zone remained constant and the influence of the CMR did not appear to extend into the active work area.

Over the three week period, the lanes adjacent to the CMR continued to exhibit minimal speed reductions while the opposing lane and active work area speeds remained relatively constant. This indicates that the novelty effect (speeds returning to normal upon driver familiarity) observed for the other strategies did not occur for the CMR site. The CMR, therefore, appears to provide long term speed reductions adjacent to the sign and no quantitative speed reduction in the active work area.

Table 18. Speed Change after Changeable Message Sign Placement

(Tests Hypotheses 21 and 24, 23 and 26)

		*Advance Warning Area***			*Active Work Area(SB)***	
		Average Speed Change (mph)		*Statistically Significant Change?**	*Average Speed Change (mph)*	*Statistically Significant Change?*
Traffic Condition		*Left Lane*	*Right Lane*			
Site 3b:						
Before Versus Immediately After	All Free Flow Vehicles	-1.8	-7.2	Yes/Yes	1.6	Yes
	Passenger Vehicles, Day	-2.4	-7.4	Yes/Yes	4.3	Yes
	Passenger Vehicles, Night	-1.4	-6.5	Yes/Yes	1.9	Yes
	Trucks, Day	-1.5	-8.7	Yes/Yes	-0.9	Yes
	Trucks, Night	0.3	-8.5	No/Yes	-2.9	Yes
Site 3b:						
Novelty Effect	All Free Flow Vehicles	0.7	-1.9	Yes/Yes	-1.6	Yes
	Passenger Vehicles, Day	1.2	-1.8	Yes/Yes	-2.2	Yes
	Passenger Vehicles, Night	-0.4	-1.4	No/Yes	0.6	Yes
	Trucks, Day	0.5	-2.6	No/Yes	-0.6	Yes
	Trucks, Night	0.2	-2.6	No/No	-2.5	No

** Designations with two answers separated by a "/" refer to the individual lanes. For example, "No/Yes" means the left lane was not statistically significant but the right lane was statistically significant. If both lanes had similar results, only one value is included in this column.*

*** Average speed changes in advance warning area and active work area (SB) are adjusted 1) by average upstream speed changes when upstream speed changes are significant in both lanes; or 2) by half of the significant speed changes when upstream speed changes are significant in one lane only.*

Figure 19 shows the observed passenger car daytime speeds adjacent to the CMR. The "disconnected" line in the figure is due to a malfunctioning data collection device during week "2" of the data collection effort. (Note: Week "0" represents traffic conditions prior to the placement of the CMR.)

Figure 20 shows the high speeds of the trucks at night adjacent to the active work area.

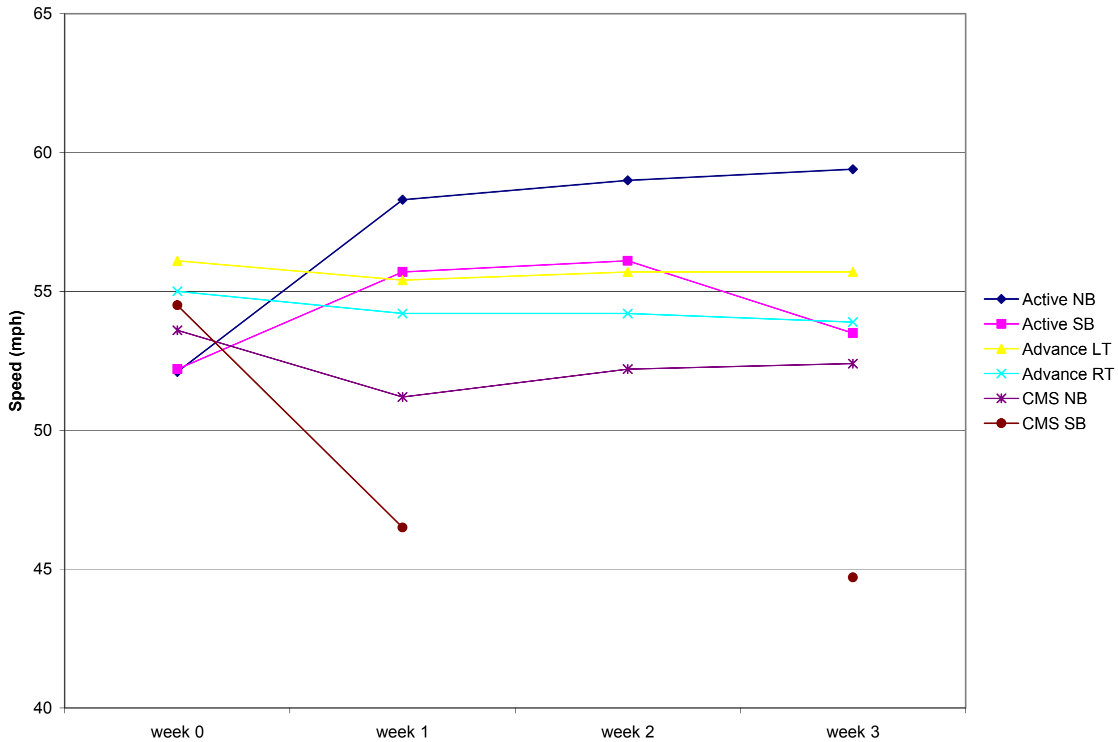

Figure 19. Average speeds at Site 3b (Passenger Vehicles, Day)

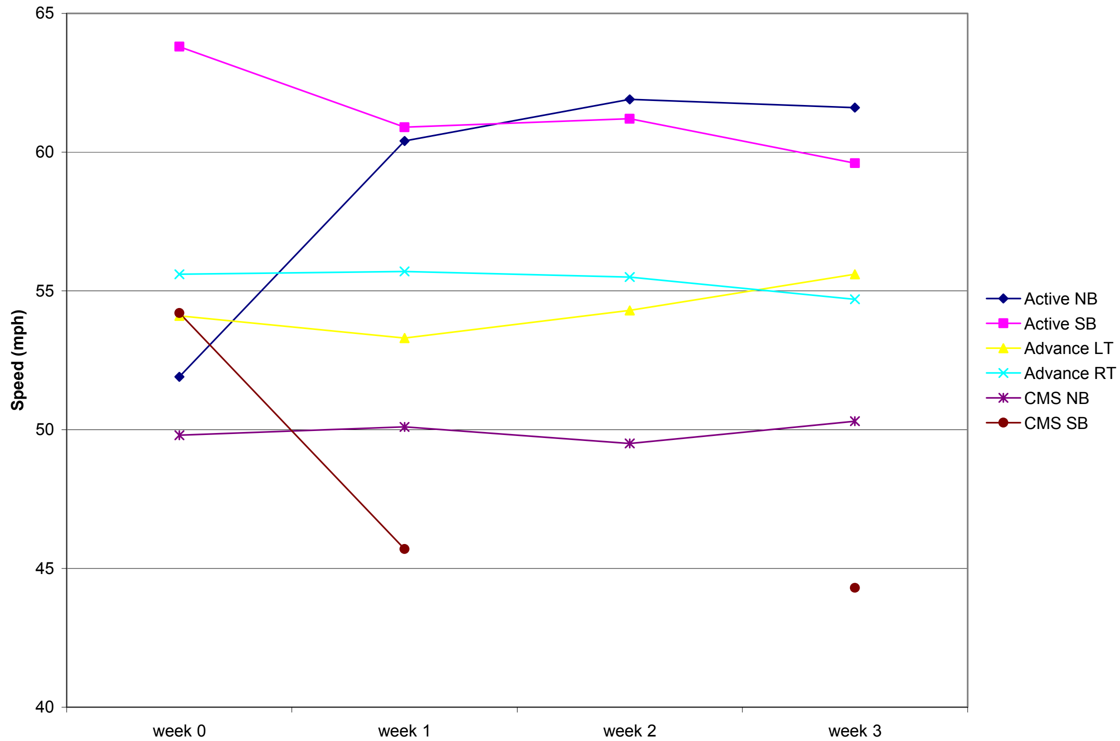

Figure 20. Average speeds at Site 3b (Trucks, Night)

Chapter 7. Conclusions and Future Research Recommendations

Safety and speed are strongly correlated traffic stream characteristics. This research evaluated the effect of three traffic control strategies on operating speed at highway work zones. The use of fluorescent orange sheeting, innovative message signs, and changeable message signs with radar provided varying impacts on work zone traffic speed. In general, the findings of this study can be summarized in the following sections.

7.1. General Observations

7.1.1. Fluorescent Orange Sheeting Observations

- Fluorescent orange sheeting generally influences speed reductions by 1 to 3 mph in both the advanced signage area and the active work area following initial implementation during daylight conditions.
- Fluorescent orange sheeting has little positive influence on speed reduction during nighttime conditions.
- Several weeks following deployment of the fluorescent orange sheeting signs, work zone speeds return to values similar to those initially observed prior to implementation of the fluorescent orange sheeting strategy.

7.1.2. Fluorescent Orange Considerations

The use of fluorescent orange sheeting provides a more conspicuous work zone (particularly during reduced lighting conditions). For this reason, the use of the sheeting almost assuredly heightens a driver's awareness of the work zone; however, the sheeting also tends to offer greater nighttime illumination of the work zone and "guides" the driver through the region. As a result, it is reasonable to assume that drivers at night are more comfortable with the visible work zone and, as a result, they may actually increase their work zone operating speeds. This may explain the lack of positive influence observed for nighttime conditions.

Heightened daytime visibility of signs may help drivers recognize the work zone sooner and adjust their vehicle speeds, but any initial influence of this heightened sign visibility appears to diminish over time as drivers become adjusted to the more conspicuous work zone signs.

7.1.3. Innovative Message Sign Observations

- The use of innovative message signs resulted in a speed reduction of 0.2 to 2.6 mph during daylight conditions (immediately following implementation);

however, the use of innovative message signs has little positive influence on speed reduction during nighttime conditions.

- Innovative message signs that have fluorescent orange sheeting provide an additional 1 to 3 mph speed reduction for the left lane and active work area single lane, yet have speed increases for the right lane of approximately 2 mph. This results in a net combined speed reduction of approximately 3 mph for the left lane and active work area lane. For the right travel lane, the combined influence of the innovative message sign and fluorescent orange sheeting resulted in speed changes from +0.5 mph to -0.4 mph (i.e. negligible changes).

- Several weeks following deployment of the innovative message signs, work zone speeds returned to values similar to those observed before implementation irregardless of the type of sign sheeting (high intensity or fluorescent orange).

7.1.4. Innovative Message Sign Considerations

The innovative message sign strategy had a positive influence on speed reduction each time attention was drawn to the sign. As a result, immediately after sign placement the vehicle speeds slightly dropped during the daytime driving hours. When the conspicuous sign sheeting was added at one site this further influenced initial speed reduction. Unfortunately, after drivers read the message several times its effectiveness appeared to wear off and speeds returned to normal. The limited observed influence on the right travel lane in the advanced sign region may be because the slower drivers were already in that lane so the sign did not have a substantial impact on their behavior. The research team did not have a strong hypothesis about why nighttime drivers were not influenced by the sign. One possible reason may be that these drivers are less likely to be influenced by a sentimental sign compared to the mixed daytime driving population.

Since the innovative sign lost its effectiveness over time, this strategy may be appropriate for short-term work zones applications provided that a variety of messages are used so that drivers do not become accustomed to the same message at every short-term work zone.

7.1.5. Changeable Message Signs with Radar Observations

- Changeable message signs with radar (CMR) provide significant speed reductions (6 to 7 mph) for approaching traffic at locations immediately adjacent to the CMR.

- Changeable message signs with radar (located at the beginning of the work zone) did not alter the operating speeds in the active work area for the study site.

- ➢ The novelty effect observed for the fluorescent orange and innovative message signs does not appear to occur adjacent to the CMR (speeds remain reduced and do not return to "before" speeds).

7.1.6. Changeable Message Signs with Radar Considerations

The changeable message sign with radar had the greatest influence on speed reduction in this study. The lack of visible influence of the strategy adjacent to the active work area is likely unique to the study site. Ideally, a strategy should be applied in close proximity to the region where it would exert the most influence. The available work zone for this study was 12 miles long and the active work area was approximately 6 miles downstream of the location where the changeable message sign was located. As a result, the drivers who adjusted their speed at the CMR sign had traveled for 6 miles without any additional speed reduction strategy and their vehicle speeds crept back to normal. It is possible that 2 to 3 miles into the work zone a residual effect of the CMR may exist, but an extensive length of work zone may not have speed reductions for the entire length.

7.2. Future Research Recommendations

The fluorescent orange sheeting or the innovative message sign strategies did not result in substantial speed reductions for the rural study corridors. The CMR sign, however, appears to be more effective initially as well as after a few weeks of implementation. This difference can be attributed to the static nature of the first two strategies compared to the dynamic nature of the CMR. For this reason, future research should look at dynamic or interactive traffic control devices that may aid in work zone speed reduction.

In addition, future research on the CMR that analyzes the zone of influence of the sign is appropriate to help determine the optimal work zone length for which this application is appropriate. It may also be reasonable to consider multiple CMR placement where possible to assure a series of devices for speed reduction.

Finally, the study sites for this research effort focused on rural two-lane corridors. Application of speed reduction traffic control strategies to other work zone configurations may help identify additional traffic control devices suitable for improving work zone speeds and as a result enhancing the safety of our work zones.

Chapter 8. References

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Appendix 1

Tables and Figures

Table A-1. Fatal Crashes by Time of Day

Time	*Percent*	*Time*	*Percent*
12 - 1 AM	3	12 - 1 PM	6
1 - 2 AM	6	1 - 2 PM	5
2 - 3 AM	3	2 - 3 PM	3
3 - 4 AM	3	3 - 4 PM	6
4 - 5 AM	2	4 - 5 PM	6
5 - 6 AM	3	5 - 6 PM	4
6 - 7 AM	3	6 - 7 PM	4
7 - 8 AM	4	7 - 8 PM	6
8 - 9 AM	3	8 - 9 PM	4
9 -10 AM	3	9 -10 PM	4
10 -11AM	3	10 -11PM	5
11 -12 PM	4	11 -12 PM	6

Source: Daniels et al., 2000

Table A-2. Hypothesis Tests at Site 1 (All Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-7.2	2.6	10.5	-10.8	-4.6	4.2	-6.8	-4.7	2.0	-1.9	-3.6	-1.9	-5.2	-13.2
Reject?	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES	YES
RT(SB)	-13.1	-1.3	12.4	na	na	na	-5.9	-4.5	1.3	-11.2	na	na	-12.2	2.3
Reject?	YES	NO	YES	na	na	na	YES	YES	NO	YES	na	na	YES	YES

Table A-3. Change in Speed at Site 1 (All Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-1.1	0.6	2.4	-1.7	-0.9	0.8	-1.6	-1.1	0.5	-0.3	-0.6	-0.3	-1.3	-2.0
RT(SB)	-2.4	-0.2	1.8	na	na	na	-0.9	-0.7	-0.6	-2.1	na	na	1.7	0.5

Table A-4. Hypothesis Tests at Site 1 (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-5.6	5.5	11.3	-8.3	0.4	6.7	-6.5	-4.9	1.3	-3.1	-5.5	-2.5	-4.4	-11.1
Reject?	YES	YES	YES	YES	NO	YES	YES	YES	NO	YES	YES	YES	YES	YES
RT(SB)	-9.2	2.8	11.6	na	na	na	-6.9	-5.3	1.4	-6.4	na	na	-8.2	4.2
Reject?	YES	YES	YES	na	na	na	YES	YES	NO	YES	na	na	YES	YES

Table A-5. Change in Speed at Site 1 (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-0.9	1.6	3.4	-1.7	0.1	1.8	-1.8	-1.4	0.4	-0.6	-1.1	-0.5	-1.4	-2.2
RT(SB)	-2.5	0.6	1.7	na	na	na	-1.4	-1.1	-1.1	-1.5	na	na	1.9	1.2

Table A-6. Hypothesis Tests at Site 1 (Passenger Vehicles, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	0.2	-1.0	-1.6	-4.4	-3.7	0.3	0.0	1.3	1.3	0.5	0.7	0.3	1.7	-4.2
Reject?	NO	NO	NO	YES	YES	NO	NO	NO	NO	NO	NO	NO	NO	YES
RT(SB)	-2.3	-3.4	-1.3	na	na	na	3.3	3.5	0.4	2.1	na	na	-2.0	-1.2
Reject?	YES	YES	NO	na	na	na	YES	YES	NO	YES	na	na	YES	NO

Table A-7. Change in Speed at Site 1 (Passenger Vehicles, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	0.1	-0.5	-0.6	-1.5	-1.4	0.1	0.0	0.8	0.8	0.2	0.3	0.1	0.9	-1.4
RT(SB)	-0.6	-0.9	0.8	na	na	na	0.1	1.1	1.2	0.7	na	na	2.3	-0.4

Table A-8. Hypothesis Tests at Site 1 (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-2.9	0.9	4.0	-4.6	-0.4	3.2	-0.2	0.0	0.2	-2.0	-0.5	1.3	-2.6	-3.6
Reject?	YES	NO	YES	YES	NO	YES	NO	NO	NO	YES	NO	NO	YES	YES
RT(SB)	-4.7	0.3	5.1	na	na	na	-4.3	-3.5	0.7	-5.6	na	na	-4.3	0.9
Reject?	YES	NO	YES	na	na	na	YES	YES	NO	YES	na	na	YES	NO

Table A-9. Change in Speed at Site 1 (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	-3.5	0.9	4.4	-2.6	-0.3	2.3	-0.2	0.0	0.2	-1.0	-0.3	0.7	-3.3	-1.9
RT(SB)	-3.6	0.2	3.8	na	na	na	-2.6	-2.2	0.4	-4.1	na	na	2.2	0.8

Table A-10. Hypothesis Tests at Site 1 (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	1.5	1.9	0.5	-1.5	-2.3	-0.7	1.0	0.0	-2.0	-0.3	0.7	1.1	-0.9	-0.3
Reject?	NO	NO	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO	NO	NO
RT(SB)	-0.6	-0.9	-0.3	na	na	na	-0.2	-0.3	-0.2	-1.5	na	na	-0.8	-2.5
Reject?	NO	NO	NO	na	na	na	NO	NO	NO	NO	na	na	NO	YES

Table A-11. Change in Speed at Site 1 (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
LT(NB)	3.5	4.5	1.0	-2.3	-3.5	-1.2	5.8	-0.2	-6.0	-0.6	1.1	1.7	-2.5	-0.6
RT(SB)	-0.8	-1.2	-0.4	na	na	na	-0.3	-0.5	-0.2	-2.5	na	na	1.7	-4.7

Table A-12. Hypothesis Tests at Site 2 (Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	6.3	na	38.4	na	na
Reject?	na	YES	na	YES	na	na
RT(SB)	1.7	14.2	11.7	-19.4	na	na
Reject?	NO	YES	YES	YES	na	na

Table A-13. Change in Speed at Site 2 (Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	2.8	na	6.9	na	na
RT(SB)	0.3	2.4	-2.9	-3.6	na	na

Table A-14. Hypothesis Tests at Site 2 (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	3.8	na	26.4	na	na
Reject?	na	YES	na	YES	na	na
RT(SB)	1.3	10.9	8.8	-14.3	na	na
Reject?	NO	YES	YES	YES	na	na

Table A-15. Change in Speed at Site 2 (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	2.1	na	6.4	na	na
RT(SB)	0.3	2.4	-2.7	-3.4	na	na

Table A-16. Hypothesis Tests at Site 2 (Passenger Vehicles, Night)

Hypothesis	1	2	3	4	5	6
LT(NB)	na	3.9	na	19.2	na	na
Reject?	na	YES	na	YES	na	na
RT(SB)	0.5	5.3	4.6	-10.6	na	na
Reject?	NO	YES	YES	YES	na	na

Table A-17. Change in Speed at Site 2 (Passenger Vehicles, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	4.3	na	7.2	na	na
RT(SB)	0.2	2.1	0	-4.8	na	na

Table A-18. Hypothesis Tests at Site 2 (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	2.2	na	14.2	na	na
Reject?	na	YES	na	YES	na	na
RT(SB)	5.0	8.7	3.2	-8.1	na	na
Reject?	YES	YES	YES	YES	na	na

Table A-19. Change in Speed at Site 2 (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	4.2	na	7.5	na	na
RT(SB)	3.3	5.2	-7.4	-4.8	na	na

Table A-20. Hypothesis Tests at Site 2 (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	2.7	na	13.8	na	na
Reject?	na	YES	na	YES	na	na
RT(SB)	-0.5	1.9	2.4	-5.6	na	na
Reject?	NO	NO	YES	YES	na	na

Table A-21. Change in Speed at Site 2 (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*
LT(NB)	na	8.4	na	10.9	na	na
RT(SB)	-0.6	2.1	-6.3	-4.8	na	na

Table A-22. Hypothesis Tests at Site 3a (Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT(NB)	-1.5	-4.3	-4.8	-4.0	-10.2	-6.3	2.4	2.4	0.0	6.0	1.4	-5.2
Reject?	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	YES
RT(SB)	-12.9	-15.7	-2.2	-4.4	-16.0	-11.1	-1.1	-0.5	0.5	2.3	-1.5	-3.2
Reject?	YES	YES	YES	YES	YES	YES	NO	NO	NO	YES	NO	YES

Table A-23. Change in Speed at Site 3a (Free Flow Vehicles)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT (NB)	0.8	-2.3	-2.8	-0.8	-2.2	-1.4	1.9	0.8	0	1.3	0.3	-1.0
RT (SB)	-2.6	-3	0.9	-1.3	-4.9	-3.6	-0.2	-0.1	0.1	1.2	-0.5	-1.7

Table A-24. Hypothesis Tests at Site 3a (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT(NB)	0.3	-2.0	-3.5	-2.8	-11.2	-8.7	1.7	0.2	-1.6	9.3	4.4	-6.8
Reject?	NO	YES	YES	YES	YES	YES	NO	NO	NO	YES	YES	YES
RT(SB)	-7.6	-10.9	-3.5	-1.5	-9.8	-7.8	0.3	-2.1	-2.4	0.7	-2.1	-2.1
Reject?	YES	YES	YES	NO	YES	YES	NO	YES	YES	NO	YES	YES

Table A-25. Change in Speed at Site 3a (Passenger Vehicles, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT (NB)	0.2	-1.4	-1.6	-0.9	-4.3	-3.4	2.1	0.1	-0.7	3.5	1.6	-1.9
RT (SB)	-2.4	-3.5	0.1	-0.9	-6.1	-5.2	-0.7	-0.7	-0.8	0.7	-1.4	-2.1

Table A-26. Hypothesis Tests at Site 3a (Passenger Vehicles, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT(NB)	-3.0	-4.2	-2.2	-1.2	-1.6	-0.3	0.9	1.9	0.9	-0.8	2.0	2.3
Reject?	YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	YES	YES
RT(SB)	-4.1	-3.4	1.3	-5.4	-7.5	-1.6	-1.6	-0.5	0.9	1.9	-1.4	-2.7
Reject?	YES	YES	NO	YES	YES	NO	NO	NO	NO	NO	NO	YES

Table A-27. Change in Speed at Site 3a (Passenger Vehicles, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT (NB)	-0.6	-4.6	-3.0	-0.5	-0.6	-0.1	2.5	1.3	0.7	-0.3	0.8	1.1
RT (SB)	-1.9	-1.4	1.3	-4	-5.2	-1.2	-0.6	-0.2	0.4	2.3	-1.1	-3.4

Table A-28. Hypothesis Tests at Site 3a (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT(NB)	1.1	1.1	0.0	-2.0	-4.8	-3.1	-1.8	-2.5	-0.2	5.7	0.9	-7.4
Reject?	NO	NO	NO	YES	YES	YES	NO	YES	NO	YES	NO	YES
RT(SB)	-5.9	-9.8	-3.5	-0.7	-9.8	-9.1	1.1	0.8	-0.3	4.4	2.4	-3.0
Reject?	YES	YES	YES	NO	YES	YES	NO	NO	NO	YES	YES	YES

Table A-29. Change in Speed at Site 3a (Trucks, Day)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT (NB)	1.3	1.3	0	-1	-3.1	-2.1	-1.6	-1.8	-0.2	3.6	0.6	-3.0
RT (SB)	-3.4	-3.6	1.7	-0.3	-5.2	-4.9	0.4	0.3	-0.1	3.6	1.3	-2.3

Table A-30. Hypothesis Tests at Site 3a (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT(NB)	-0.1	-0.2	-0.2	-1.0	-0.7	0.3	-2.0	-0.3	1.3	-2.2	-2.3	-0.3
Reject?	NO	NO	NO	NO	NO	NO	YES	NO	NO	YES	YES	NO
RT(SB)	-5.6	-5.6	-0.2	-0.2	-3.8	-3.6	0.0	0.4	0.4	1.9	2.7	0.3
Reject?	YES	YES	NO	NO	YES	YES	NO	NO	NO	NO	YES	NO

Table A-31. Change in Speed at Site 3a (Trucks, Night)

Hypothesis	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
LT (NB)	-0.7	-1.0	-0.3	-0.6	-0.4	0.2	-2.4	-0.4	2.0	-1.2	-1.4	-0.2
RT (SB)	-2.9	-3.0	2.5	-0.1	-2.5	-2.4	0.0	0.2	0.2	1.7	2.0	0.3

Table A-32. Hypothesis Tests at Site 3b (All Free Flow Vehicles)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-9.3	-5.6	3.3	31.2	38.9	5.9
Reject?	YES	YES	YES	YES	YES	YES
SB	-42.3	-53.9	-10.7	3.0	-2.2	-5.9
Reject?	YES	YES	YES	YES	YES	YES

Table A-33. Change in Speed at Site 3b (All Free Flow Vehicles)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-1.8	-1.1	0.7	6.2	7.4	1.2
SB	-7.2	-9.7	-1.9	1.6	-0.7	-1.6

Table A-34. Hypothesis Tests at Site 3b (Passenger Vehicles, Day)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-8.3	-4.2	3.8	22.4	27.0	3.8
Reject?	YES	YES	YES	YES	YES	YES
SB	-30.4	-38.7	-7.8	6.5	2.3	-4.9
Reject?	YES	YES	YES	YES	YES	YES

Table A-35. Change in Speed at Site 3b (Passenger Vehicles, Day)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-2.4	-1.2	1.2	6.2	7.3	1.1
SB	-7.4	-9.8	-1.8	4.3	1.3	-2.2

Table A-36. Hypothesis Tests at Site 3b (Passenger Vehicles, Night)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-2.9	-3.5	-0.7	5.6	10.4	3.5
Reject?	YES	YES	NO	YES	YES	YES
SB	-15.5	-19.0	-2.9	1.4	2.2	0.7
Reject?	YES	YES	YES	NO	YES	NO

Table A-37. Change in Speed at Site 3b (Passenger Vehicles, Night)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-1.4	-1.8	-0.4	3.2	5.3	2.1
SB	-6.5	-8.6	-1.4	1.9	1.8	0.6

Table A-38. Hypothesis Tests at Site 3b (Trucks, Day)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-3.6	-2.4	1.2	23.8	26.6	3.2
Reject?	YES	YES	NO	YES	YES	YES
SB	-20.7	-27.1	-7.2	-2.2	-5.0	-3.2
Reject?	YES	YES	YES	YES	YES	YES

Table A-39. Change in Speed at Site 3b (Trucks, Day)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	-1.5	-1.0	0.5	9.4	10.6	1.2
SB	-8.7	-12	-2.6	-0.9	-2.2	-0.6

Table A-40. Hypothesis Tests at Site 3b (Trucks, Night)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	0.5	0.7	0.3	12.3	14.5	1.7
Reject?	NO	NO	NO	YES	YES	NO
SB	-10.6	-11.8	-1.5	-3.9	-5.2	-1.8
Reject?	YES	YES	NO	YES	YES	NO

Table A-41. Change in Speed at Site 3b (Trucks, Night)

Hypothesis	*21*	*22*	*23*	*24*	*25*	*26*
NB	0.3	0.5	0.2	8.5	9.7	1.2
SB	-8.5	-9.9	-2.6	-2.9	-4.2	-2.5

Table A-42. ANOVA Test for Site 3b (Free Flow Vehicles)

	Sign NB	*Sign SB*	*Active NB*	*Active SB*
F Value	28.19	1622.83	608.83	19.02

Table A-43. Tukey HSD Test for Site 3b NB at Active Work Zone Area (Free Flow Vehicles)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	-40.17			
Week 2	-46.00	-5.83		
Week 3	-47.94	-7.77	**-1.94**	

Table A-44. Tukey HSD Test for Site 3b SB at CMR (Free Flow Vehicles)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	61.09			
Week 2				
Week 3	75.97	14.88		

* Number in bold are insignificant

Table A-45. Change in Speed at Site 3b County (Free Flow Vehicles)

Location	*Immediate Effect*	*Three week Effect*	*Novelty Effect*
Advanced Warning Area (NB)	-1.8	-1.1	0.7
Advanced Warning Area (SB)	-7.8	-9.7	-1.9
Active Area (NB)	6.2	7.4	1.2
Active Area (SB)	0.9	-0.7	-1.6

Table A-46. ANOVA test for Site 3b (Passenger Vehicles, Day)

	Sign NB	*Sign SB*	*Active NB*	*Active SB*
F Value	22.27	854.88	299.11	22.63

Table A-47. Tukey's HSD Test for Site 3b NB at Active Work Area (Passenger Vehicles, Day)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	-28.46			
Week 2	-31.67	-3.21		
Week 3	-33.51	-5.05	-1.84	

Table A-48. Tukey's HSD Test for Site 3b SB at CMR (Passenger Vehicles, Day)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	45.79			
Week 2				
Week 3	56.09	10.30		

Table A-49. Change in Speed at Site 3b (Passenger Vehicles, Day)

Location	*Immediate Effect*	*Three week Effect*	*Novelty Effect*
Advanced Warning Area (NB)	-2.4	-1.2	1.2
Advanced Warning Area (SB)	-8	-9.8	-1.8
Active Area (NB)	6.2	7.3	1.1
Active Area (SB)	3.5	1.3	-2.2

Table A-50. ANOVA Test for Site 3b (Passenger Vehicles, Night)

	Sign NB	*Sign SB*	*Active NB*	*Active SB*
F Value	521.97	16361.98	2789.76	1422.45

Table A-51 . Tukey's Test for Site 3b NB at Active Work Area (Pass. Vehicles, Night)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	-8.27			
Week 2	-11.88	-3.62		
Week 3	-13.69	-5.43	-1.81	

Table A-52. Tukey's HSD Test for Site 3b SB at CMR (Passenger Vehicles, Night)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	21.69			
Week 2				
Week 3	25.90	4.22		

Table A-53. Change in Speed at Site 3b Site (Passenger Vehicles, Night)

Location	*Immediate Effect*	*Three week Effect*	*Novelty Effect*
Advanced Warning Area (NB)	-1.4	-1.8	-0.4
Advanced Warning Area (SB)	-7.2	-8.6	-1.4
Active Area (NB)	3.2	5.3	2.1
Active Area (SB)	1.2	1.8	0.6

Table A-54. ANOVA Test for Site 3b (Trucks, Day)

	Sign NB	*Sign SB*	*Active NB*	*Active SB*
F Value	9.63	407.25	255.82	9.49

Table A-55. Tukey's HSD Test for Site 3b NB at Active Work Area (Trucks, Day)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	-33.17			
Week 2	-34.58	-1.41		
Week 3	-37.41	-4.23	-2.82	

Table A-56. Tukey's HSD Test for Site 3b SB at CMR (Trucks, Day)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	28.03			
Week 2				
Week 3	38.66	10.63		

Table A-57. Change in Speed at Site 3b (Trucks, Day)

Location	*Immediate Effect*	*Three week Effect*	*Novelty Effect*
Advanced Warning Area (NB)	-1.5	-1	0.5
Advanced Warning Area (SB)	-8.7	-12	-3.3
Active Area (NB)	9.4	10.6	1.2
Active Area (SB)	-0.9	-2.2	-1.3

Table A-58. ANOVA Test for Site 3b (Trucks, Night)

	Sign NB	*Sign SB*	*Active NB*	*Active SB*
F Value	0.52	86.66	94.88	11.95

Table A-59. Tukey's HSD Test for Site 3b NB at Active Work Area (Trucks, Night)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	-17.48			
Week 2	-20.57	-3.09		
Week 3	-19.95	-2.47	0.62	

Table A-60. Tukey's HSD test for Site 3b SB at CMR (Trucks, Night)

	Week 0	*Week 1*	*Week 2*	*Week 3*
Week 0				
Week 1	13.89			
Week 2				
Week 3	16.18	2.29		

Table A-61. Change in Speed at Site 3b (Trucks, Night)

Location	*Immediate Effect*	*Three week Effect*	*Novelty Effect*
Advanced Warning Area (NB)	0.3	0.5	0.2
Advanced Warning Area (SB)	-8.5	-9.9	-1.4
Active Area (NB)	8.5	9.7	1.2
Active Area (SB)	-2.9	-4.2	-1.3

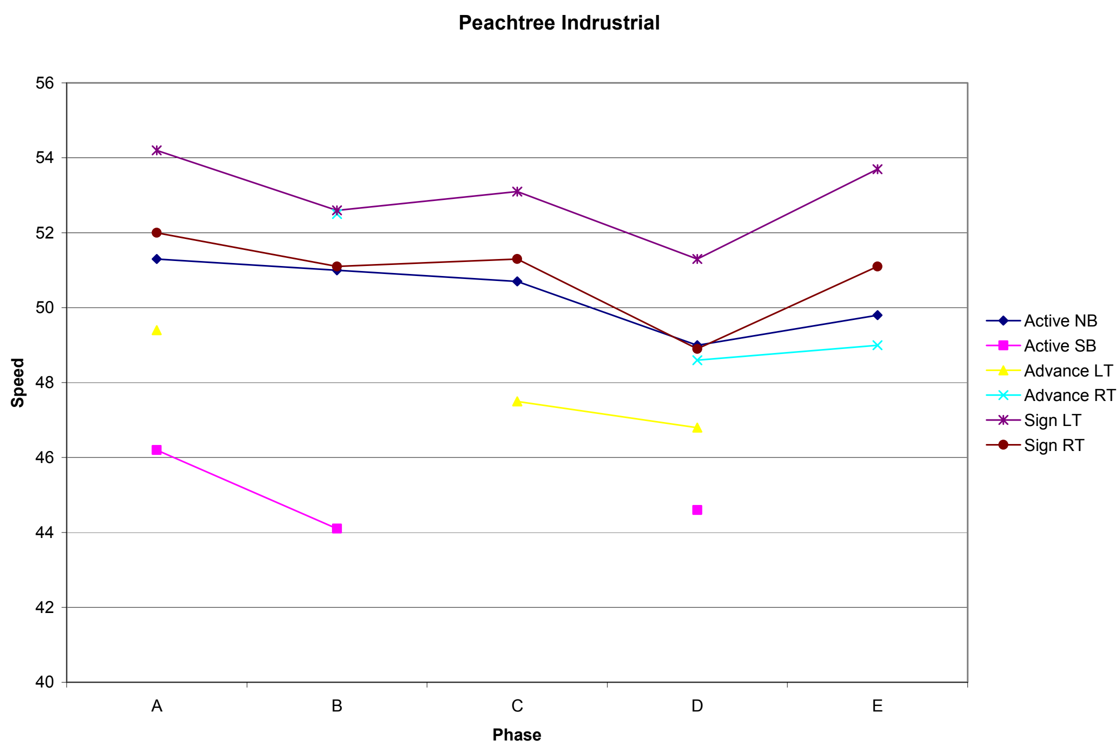

Figure A-1. Average Speeds at Site 1 (All Free Flow Vehicles)

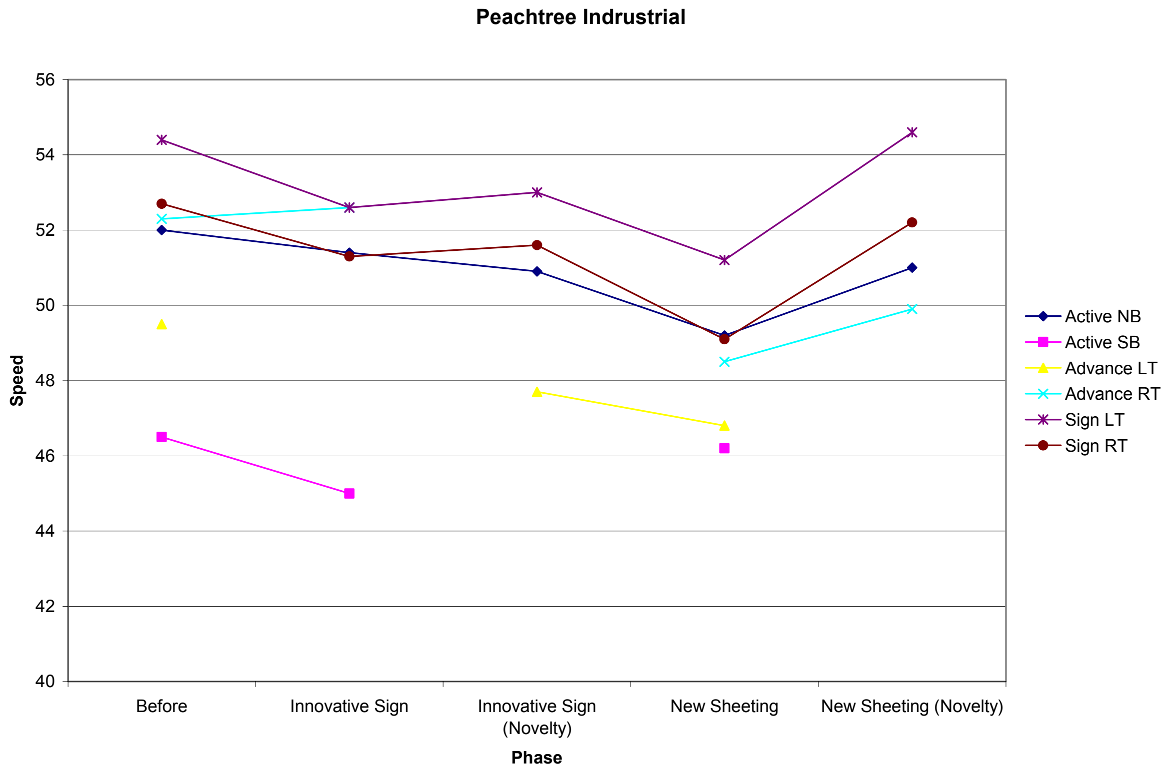

Figure A-2. Average Speeds at Site 1 (Passenger Vehicles, Day)

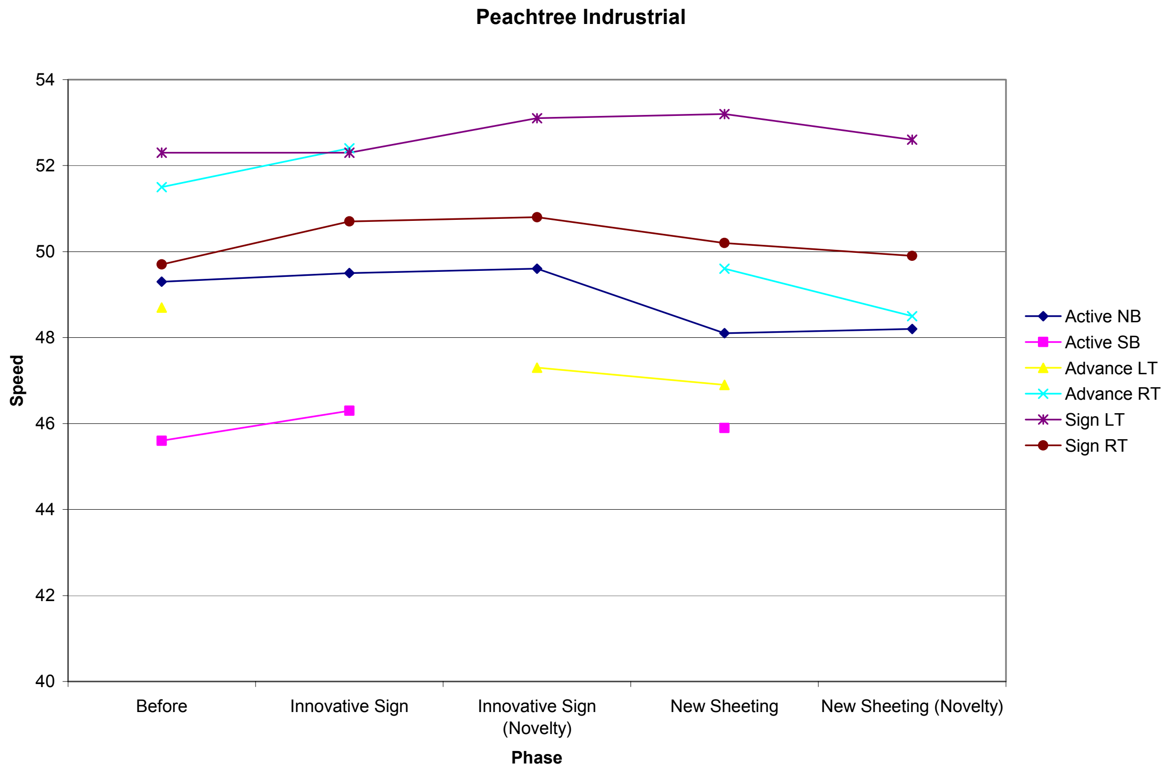

Figure A-3. Average Speeds at Site 1 (Passenger Vehicles, Night)

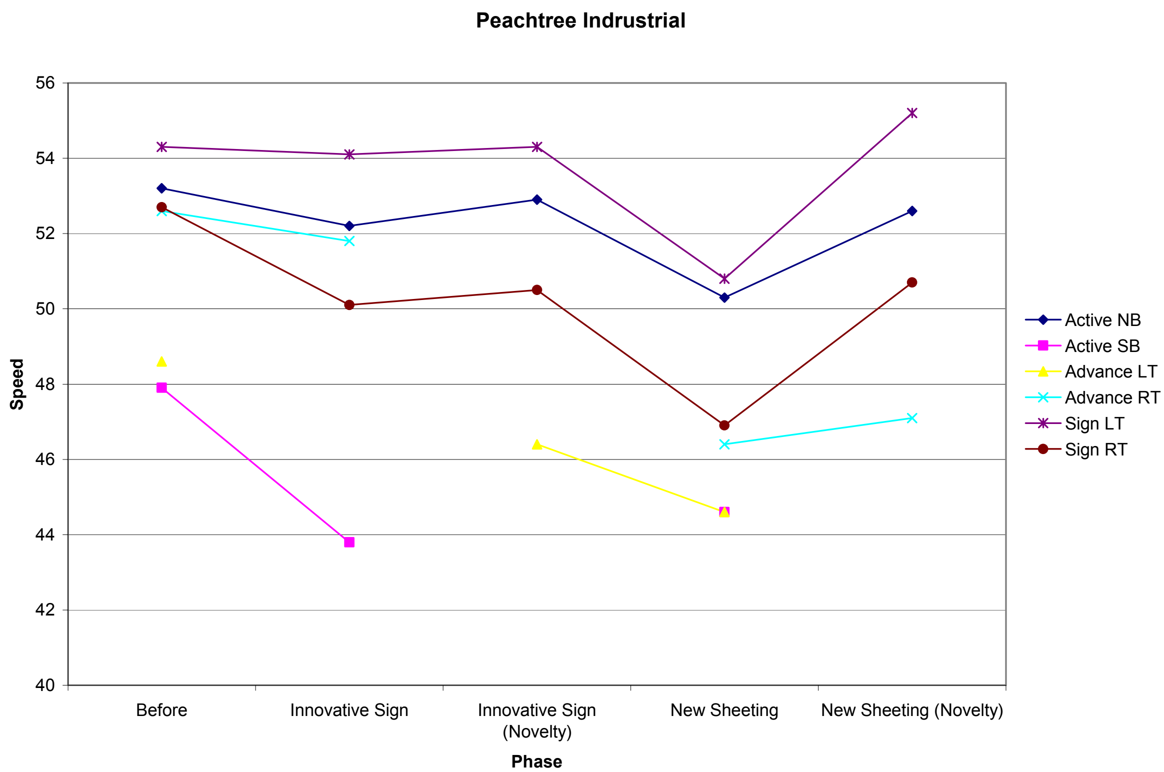

Figure A-4. Average Speeds at Site 1 (Trucks, Day)

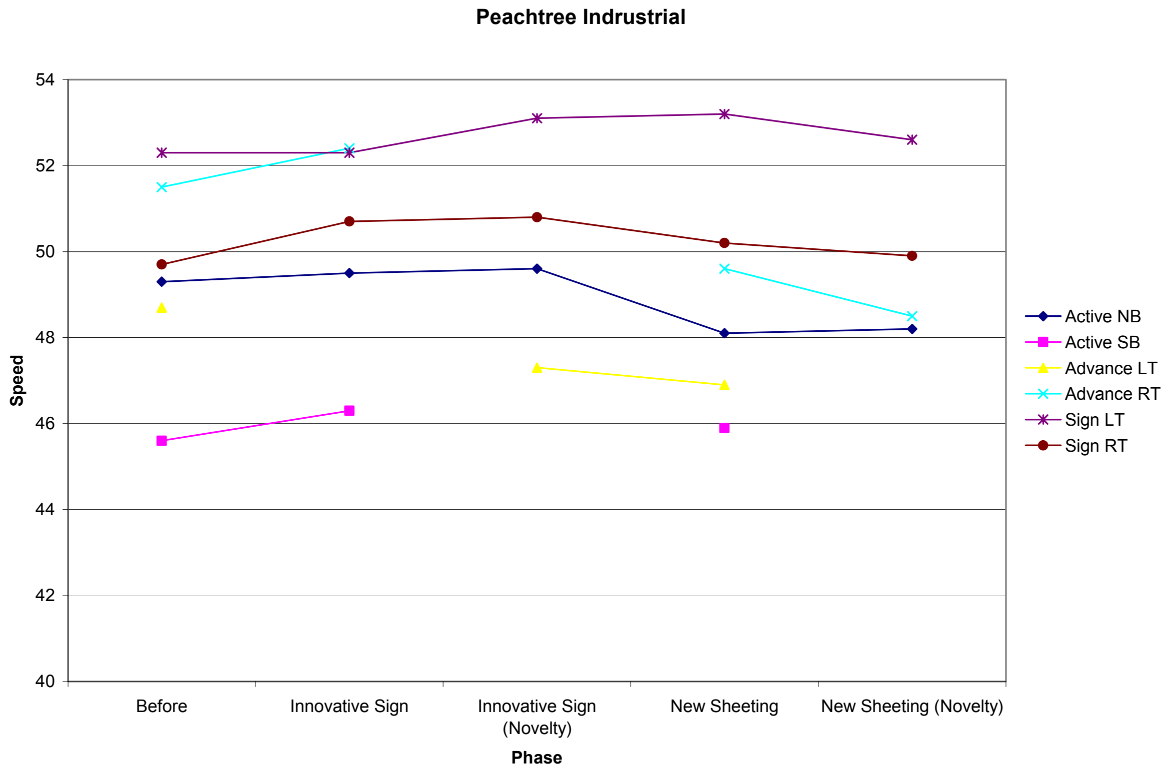

Figure A-5. Average Speeds at Site 1 (Trucks, Night)

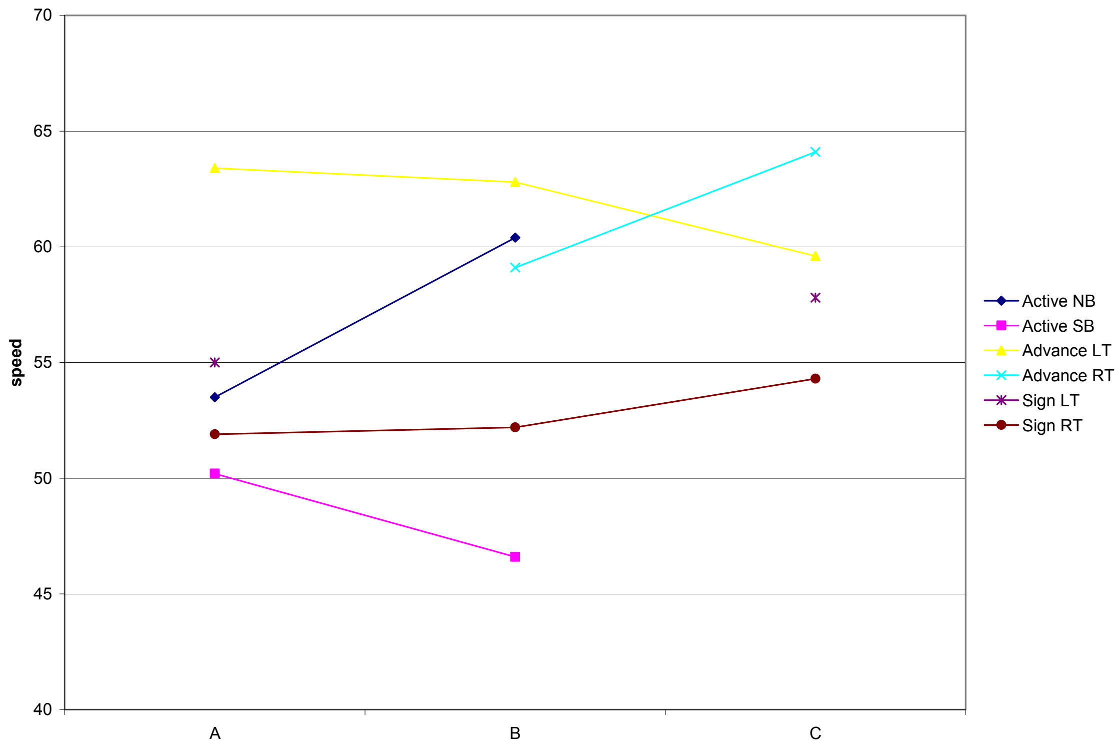

Figure A-6. Average speeds at Site 2 (Free Flow Vehicles)

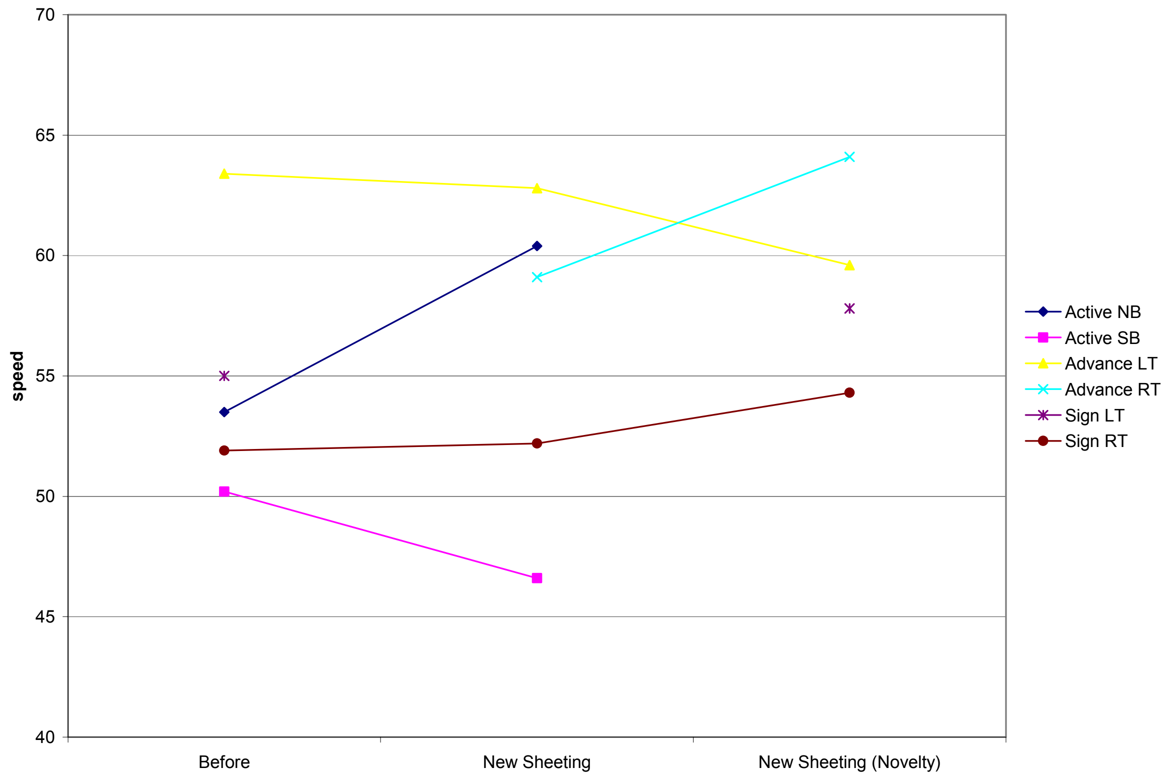

Figure A-7. Average Speeds at Site 2 (Passenger Vehicles, Day)

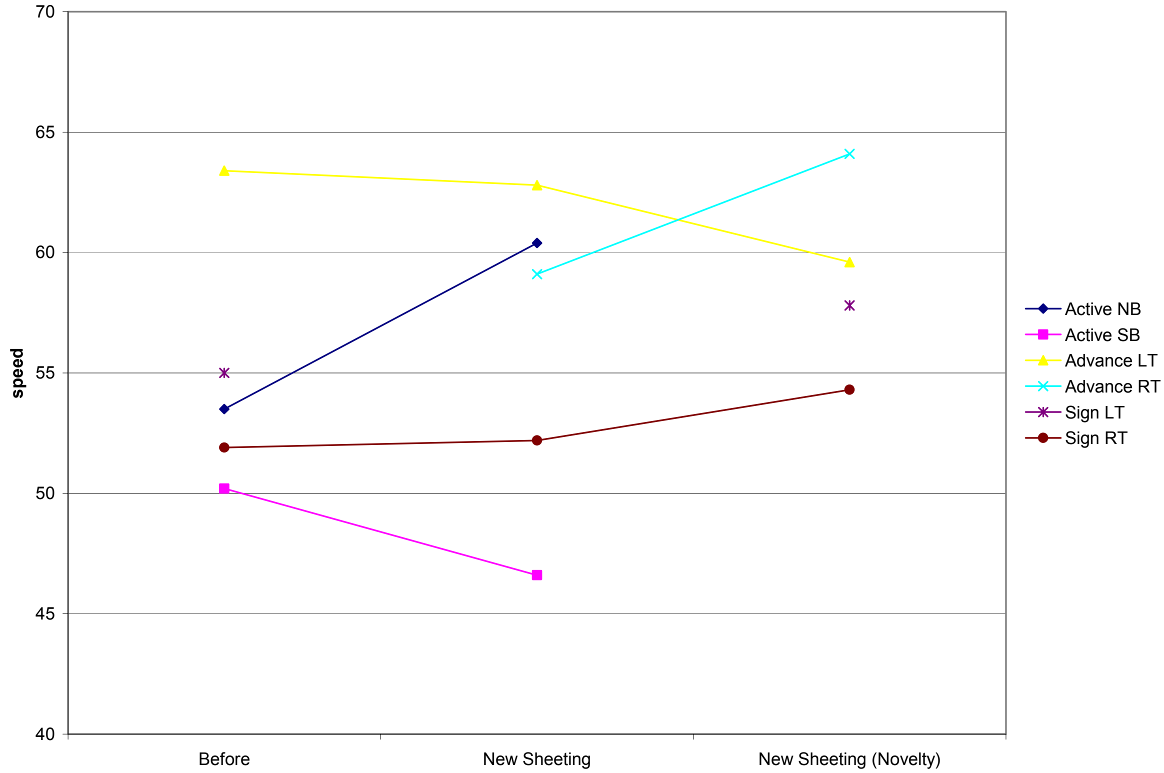

Figure A-8. Average Speeds at Site 2 (Passenger Vehicles, Night)

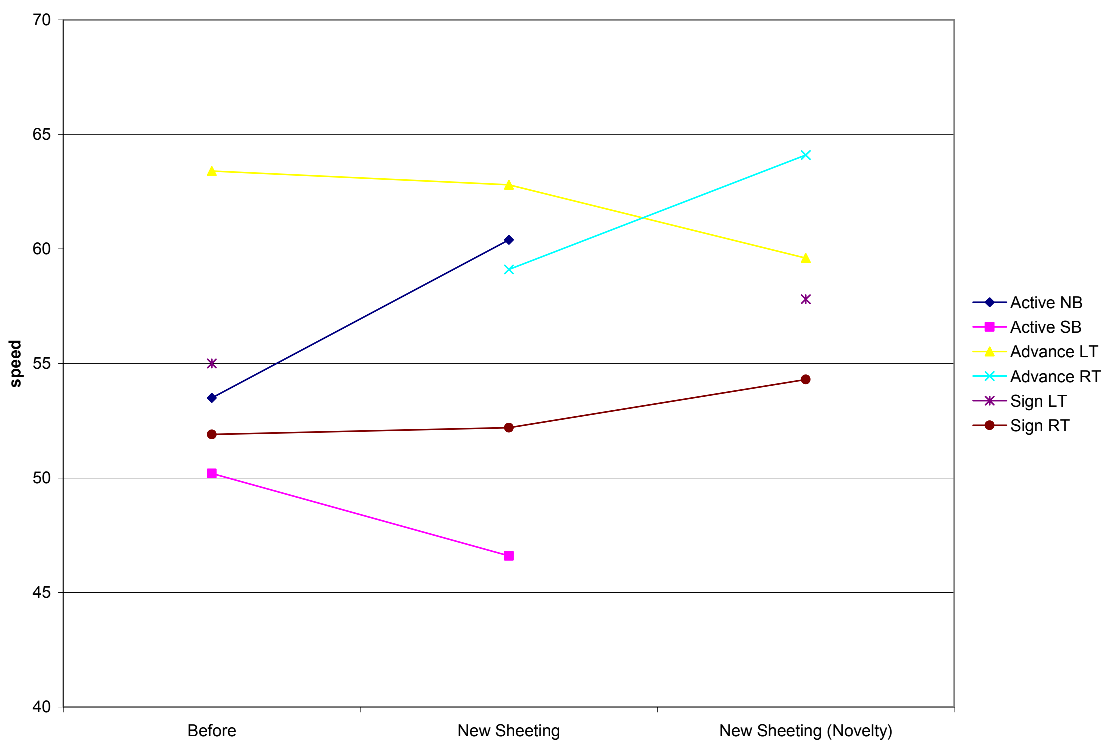

Figure A-9. Average Speeds at Site 2 (Trucks, Day)

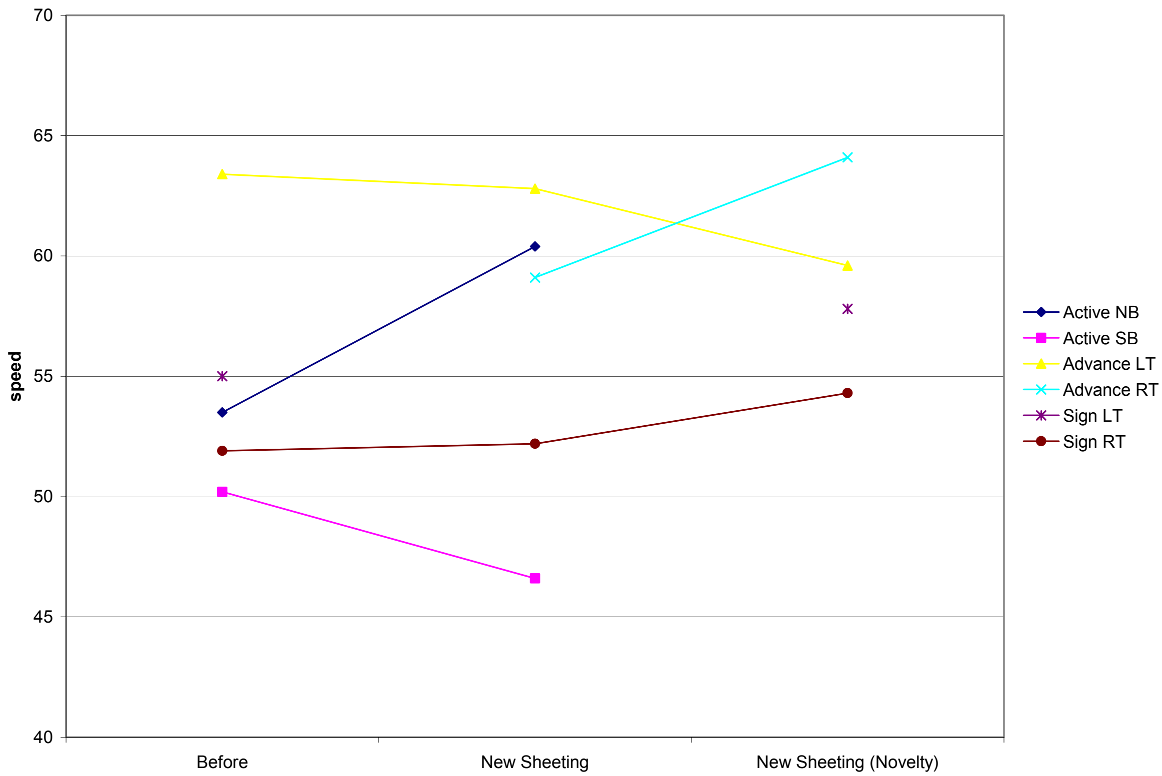

Figure A-10. Average Speeds at Site 2 (Trucks, Night)

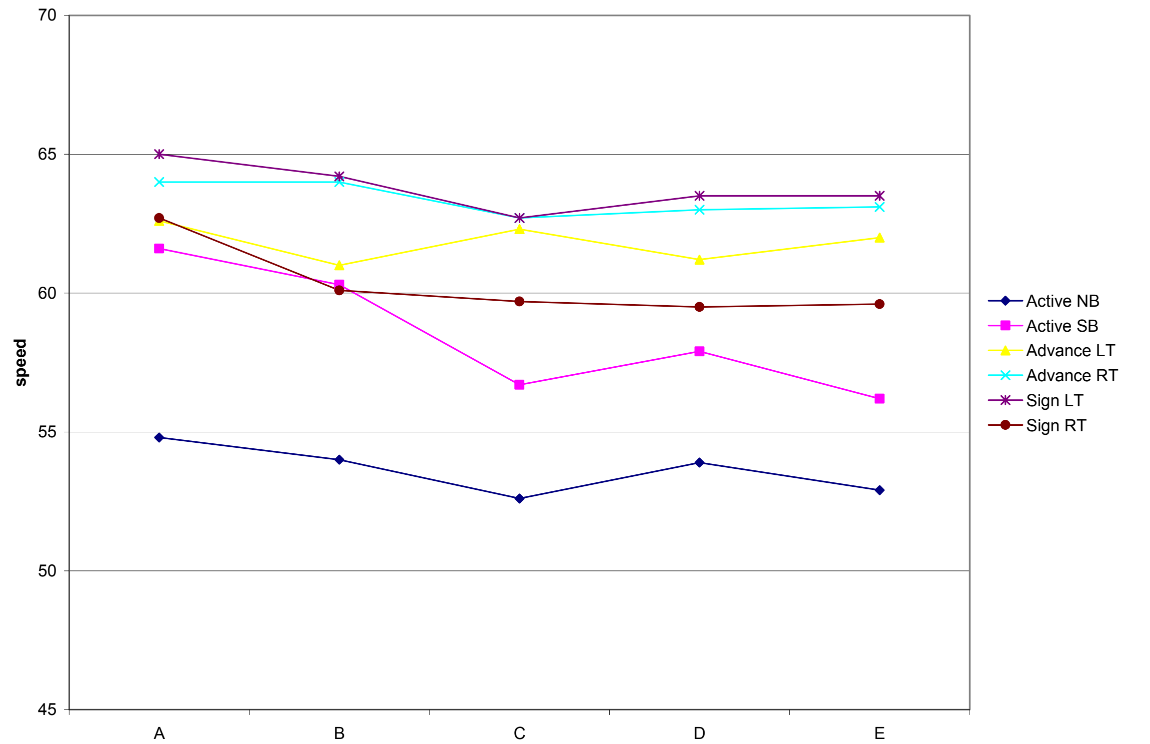

Figure A-11. Average speeds at Site 3a (Free Flow Vehicles)

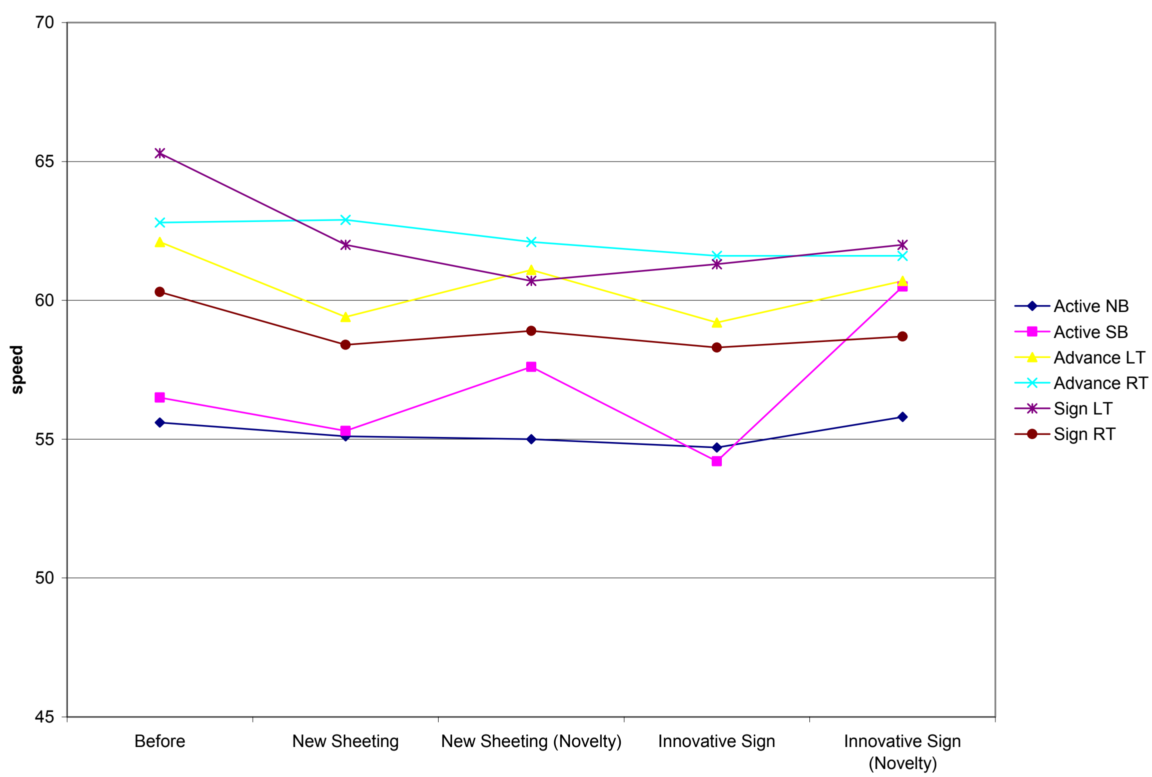

Figure A-12. Average speeds at Site 3a (Passenger Vehicles, Night)

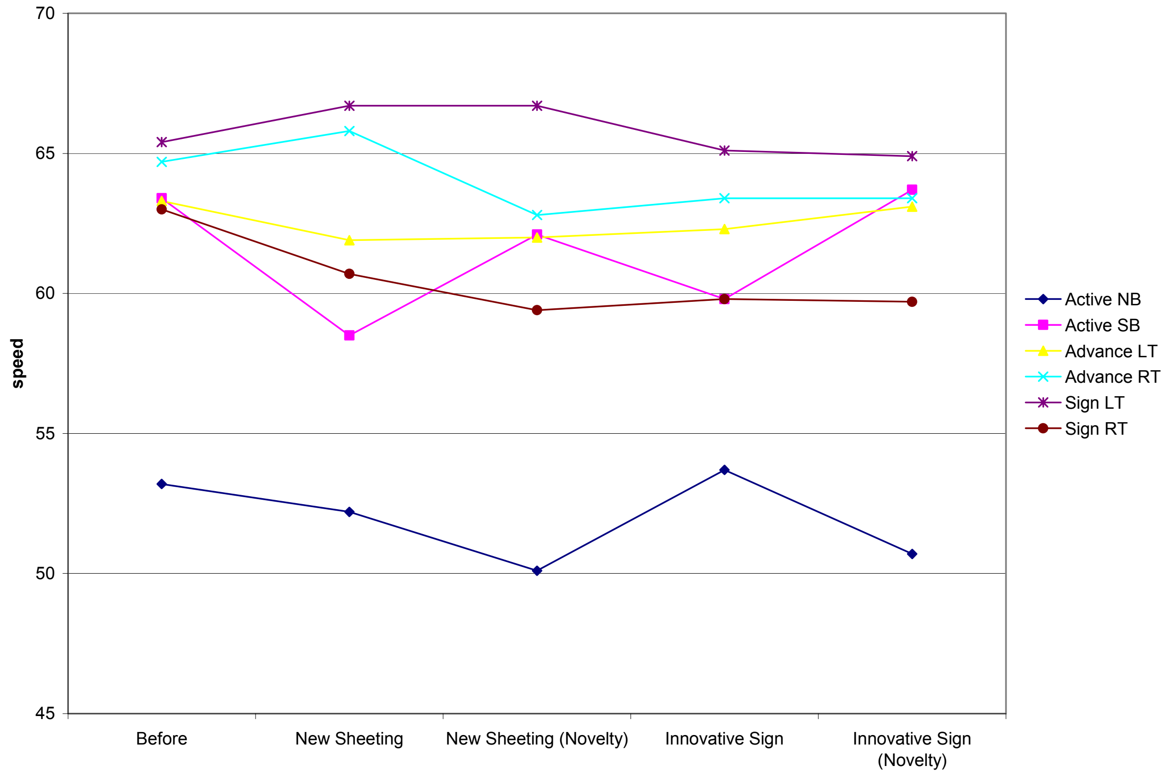

Figure A-13. Average speeds at Site 3a (Trucks, Day)

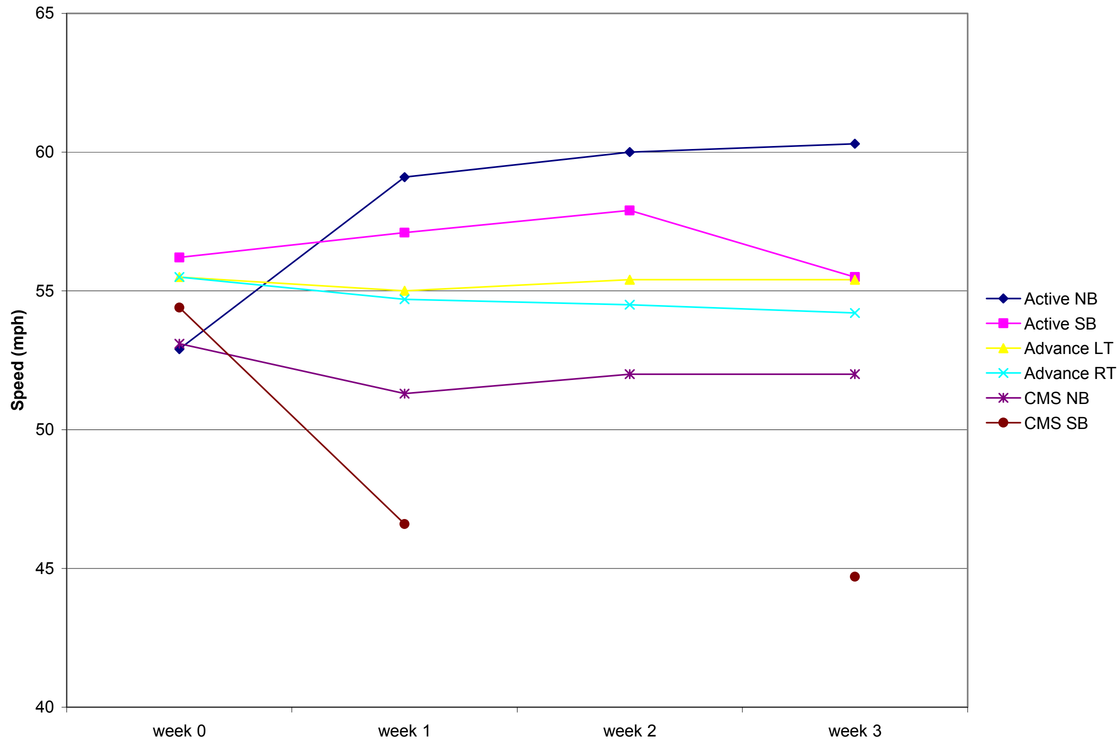

Figure A-14. Average speeds at Site 3b (Free Flow Vehicles)

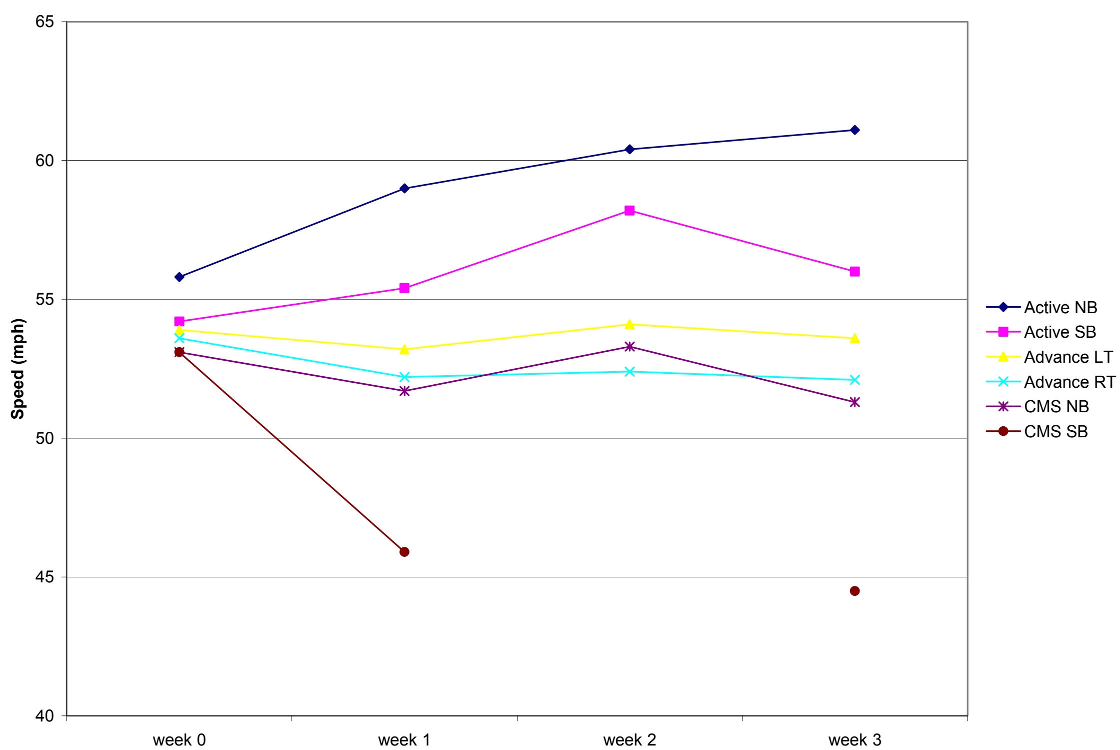

Figure A-15. Average speeds at Site 3b (Passenger Vehicles, Night)

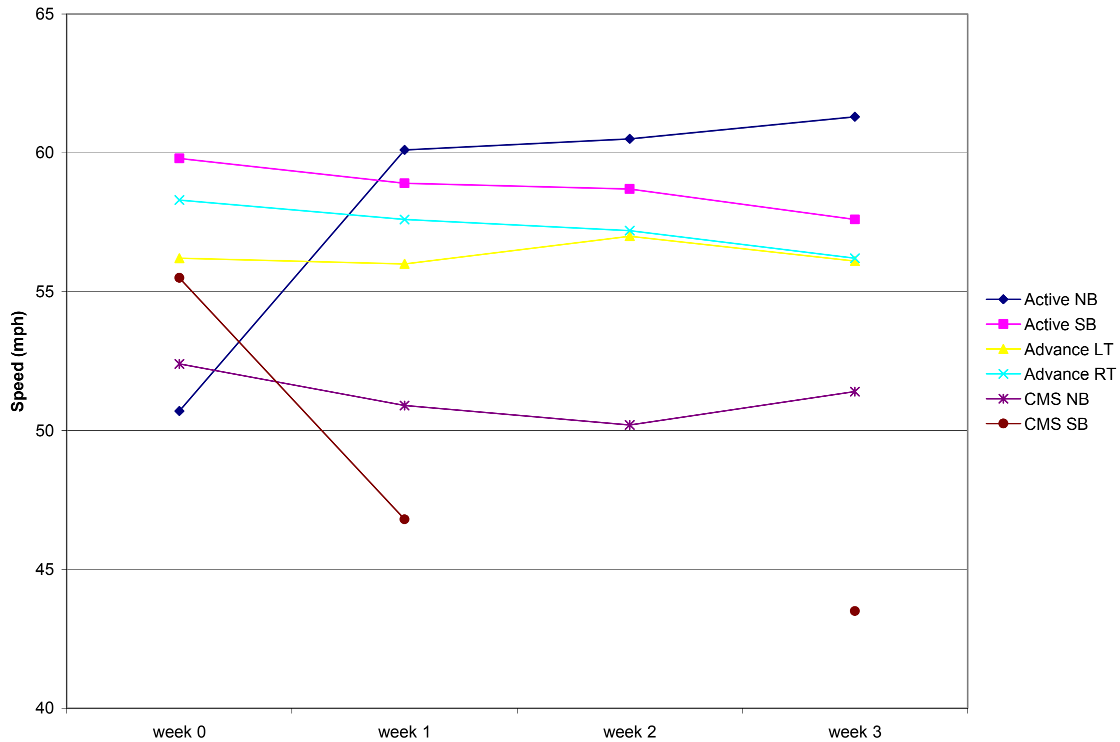

Figure A-16. Average speeds at Site 3b (Trucks, Day)

APPENDIX 2

Work Plans and Product Specifications

GDOT Project 9810
(Georgia Tech Project E-20-E24)
Development of Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
Peachtree Industrial from Rogers Bridge Road to
Pinecrest Road in Gwinnett County [STP-190-1]

The Georgia Institute of Technology research team for the above project would like to initiate data collection and device testing for the above referenced project at Peachtree Industrial in Gwinnett County. Two specific project tasks are necessary for successful project completion. They are (1) traffic control device placement and evaluation, and (2) traffic speed and volume data collection. This work plan summarizes these two tasks for the proposed project corridor.

Traffic Control Device Placement

A three-phase analysis is proposed for this project. First, speed and traffic volumes will be evaluated for the current sign configuration (see Figure 1) in the northbound direction of travel. Second, two additional innovative message signs will be added as shown in Figure 2. Additionally, approximately one mile into the active work zone another innovative sign (with a message similar to the first signs) will be placed on the right side of the two-lane two-way active travel way as depicted in Figure 3. Finally, after a reasonable period of time (four to six weeks) the advance sign series shown in Figure 2 (proposed sign configuration with twelve signs) and the individual sign depicted in Figure 3 will be modified so that all thirteen signs shown will be replaced with fluorescent orange sheeting signs bearing the same messages as currently displayed. These signs will be located on the same poles as the existing signs. The signs will be provided to the contractor for the purpose of this study, but following the study the signs will remain Georgia Department of Transportation property. The third phase of the project will remain in place for several weeks so both immediate effects as well as novelty affects may be evaluated.

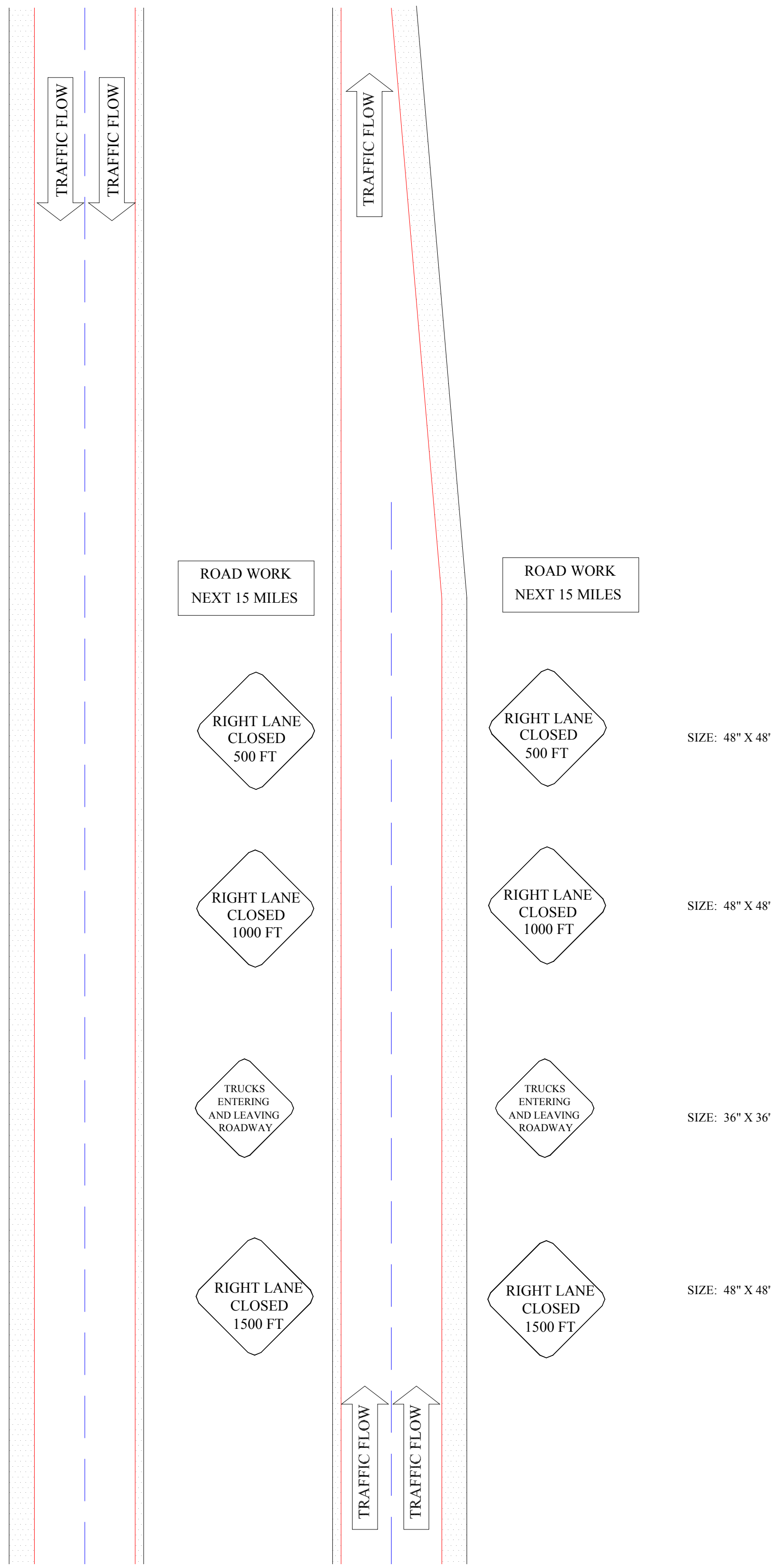

FIGURE 1. CURRENT ADVANCE WARNING SIGNS
PEACHTREE INDUSTRIAL IN GWINNETT COUNTY

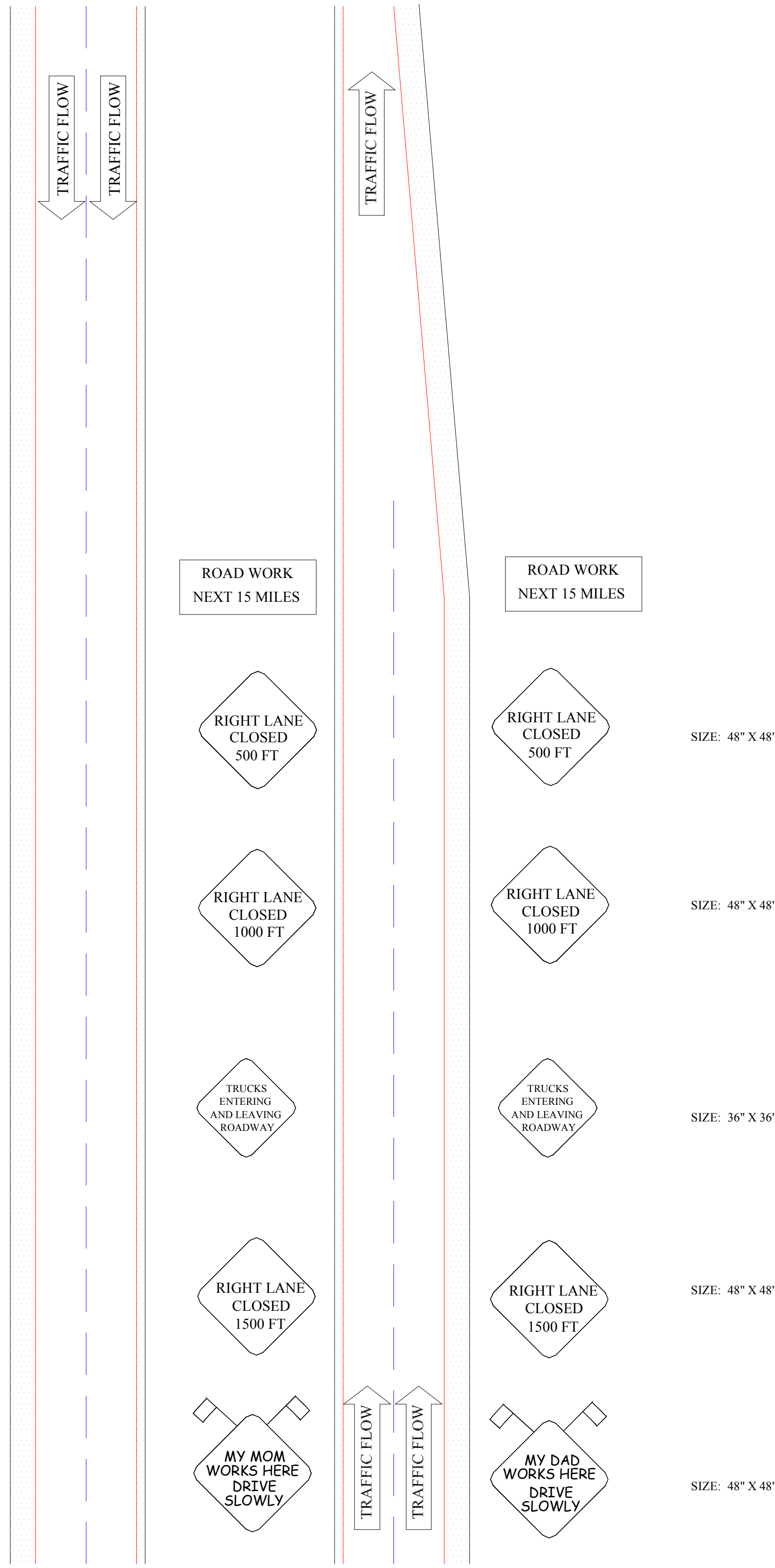

FIGURE 2. PROPOSED ADVANCE WARNING SIGNS
PEACHTREE INDUSTRIAL IN GWINNETT COUNTY

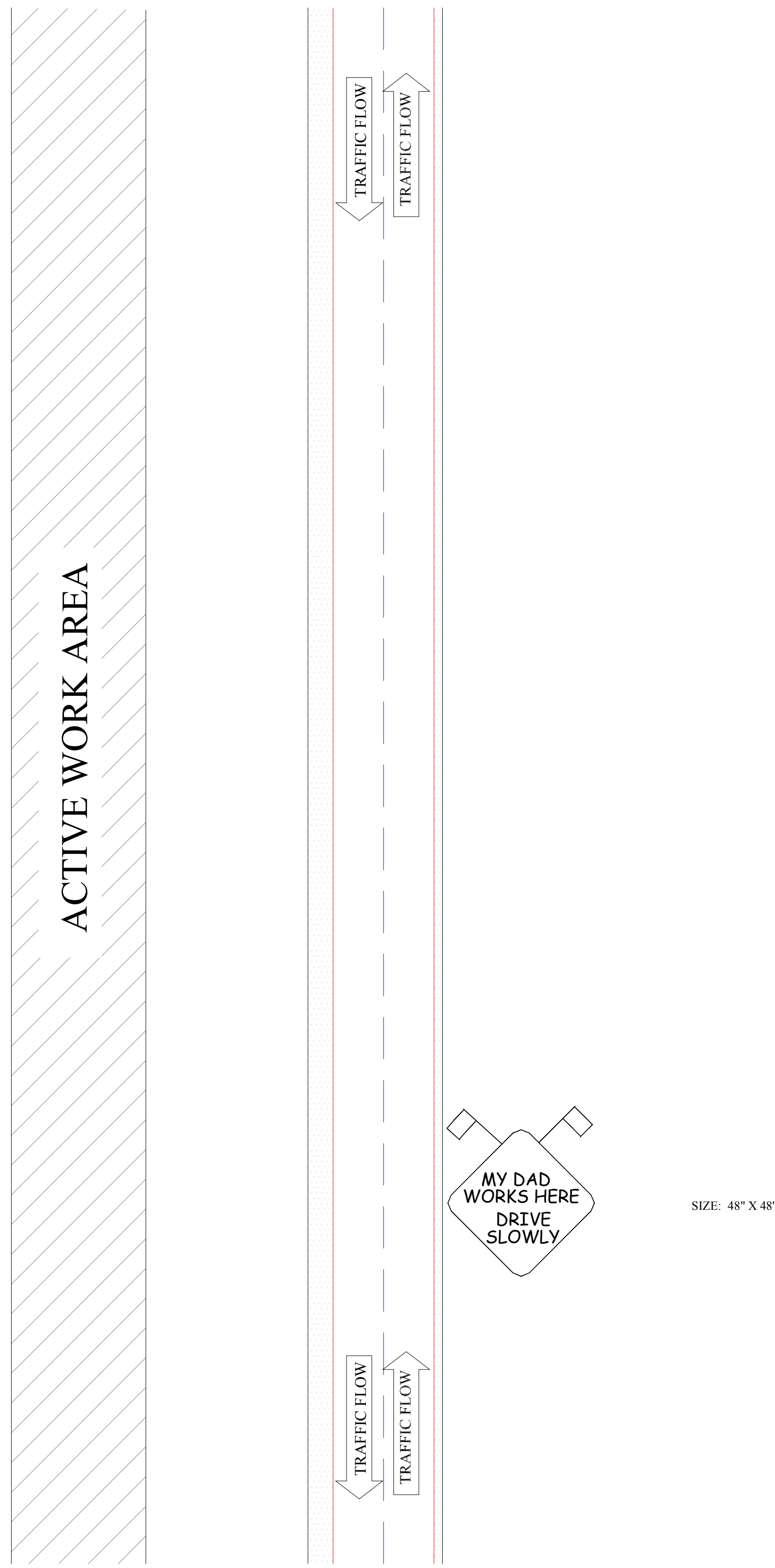

FIGURE 3. SIGN PLACEMENT ADJACENT TO WORK ACTIVITY
PEACHTREE INDUSTRIAL IN GWINNETT COUNTY

Traffic Speed and Volume Data Collection

Safe collection of traffic data is of paramount importance on this project. Nu-Metrics traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the northbound lanes. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). In addition, Nu-Metric devices may be positioned in the adjacent southbound lanes for speed comparison purposes. To safely place the devices in the active lane, a gap in traffic of approximately one-minute is required. To safely remove the devices from the active lane, a gap in traffic of approximately two-minutes is required. Due to the nature of the site, it appears devices can be safely placed and removed without altering traffic behavior in the region. Georgia Tech personnel will coordinate with the Contractor's representative for appropriate times and device placement locations. Nu-Metric devices can be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Figure 4 shows the schematic of a typical classifier.

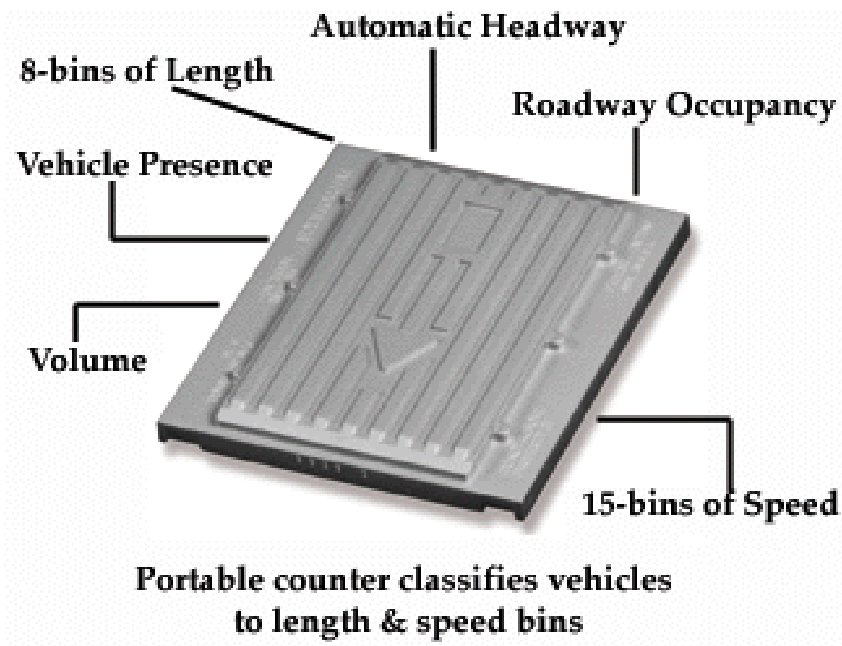

FIGURE 4. SAMPLE NU-METRICS CLASSIFIER (MODEL NO. NC-97)

In addition to the unobtrusive data collection devices, the research team will also use video cameras for supplemental data collection efforts. Video cameras will be used in two capacities. First, a camera will be positioned in a Georgia Tech vehicle and the vehicle will be driven through the work zone. The purpose of this "floating vehicle" perspective is to record actual device placement locations (i.e. signs, classifiers, and their locations relative to work activity). Static location video cameras may also be utilized on

a limited basis to observe driver reaction to the lane closure or traffic control device placement. For example, brake tapping at the location of the innovative sign may indicate a speed reduction influence of the device. Similarly, lane changing/merging behavior may be video taped to enable the research team to compare sign configurations and driver reactions at similar sites.

Georgia Tech data collectors working adjacent to the active lanes will wear safety vests and hats. At no time will the research team initiate data collection efforts at the site without first coordinating this activity with the Contractor's designated representative, Mr. Larry Deavers of E. R. Snell Contractor, Inc. Data collection efforts may range from one day to several consecutive days. We anticipate approximately five data collection periods. These discrete time periods are:

1. Prior to implementation of any additional traffic control devices (this data set will function as a baseline for future data collected),

2. Immediately following implementation of the additional innovative wording signs physically located prior to the ten signs indicated in item 1 above as well as the sign located approximately one-mile into the activity region,

3. A few weeks following implementation of the innovative signs,

4. Immediately following implementation of the fluorescent orange advance warning sign series (twelve signs as shown in Figure 2) and active work area sign (Figure 3),

5. A few weeks following implementation of the fluorescent orange advance warning sign series (twelve signs) and active work area sign.

Upon completion of the data collection effort, the advance warning fluorescent signs and the innovative wording fluorescent signs will be removed from the site and become property of the Georgia Department of Transportation.

Please contact Karen Dixon at Georgia Tech [phone: (404) 894-5830] if you have any questions regarding this proposed work plan.

GDOT Project 9810
(Georgia Tech Project E-20-E24)
Development of Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
S.R. 1 / U.S. 27 in Carroll County [EDS-27(125)]

The Georgia Institute of Technology research team for the above project would like to initiate data collection and device testing for the above referenced project at S.R. 1 / U.S. 27 in Carroll County. Two specific project tasks are necessary for successful project completion. They are (1) traffic control device placement and evaluation, and (2) traffic speed and volume data collection. This work plan summarizes these two tasks for the proposed project corridor.

Traffic Control Device Placement

A three-phase analysis is proposed for this project. First, speed and traffic volumes will be evaluated for the current sign configuration in the northbound direction of travel. Second, the advance sign series shown in Figure 1 (current sign configuration with eight signs) will be modified so that all eight signs shown will be replaced with fluorescent orange sheeting signs bearing the same messages as currently displayed. These signs will be located on the same poles as the existing signs. Finally, after a reasonable period of time (four to six weeks) two additional innovative message signs will be added as shown in Figure 2. Additionally, approximately one mile into the active work zone another innovative sign (with a message similar to one of the first signs) will be placed on the right side of the two-lane two-way active travel way as depicted in Figure 3. As discussed in a preliminary meeting with the project contractor, Bruce Albea, sign poles will be provided and placed by contractor personnel. The signs will be provided to the contractor for the purpose of this study. This third phase of the project will remain in place for several weeks so both immediate affects as well as novelty affects may be evaluated.

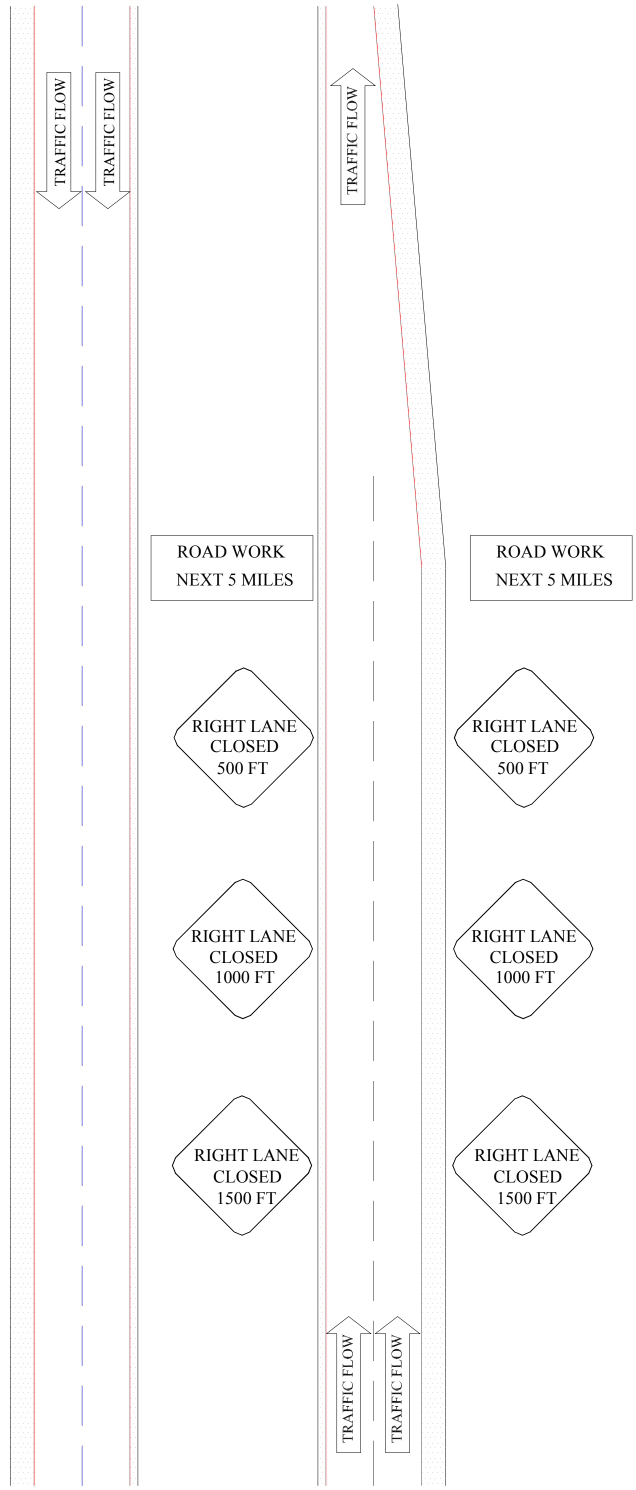

FIGURE 1. CURRENT ADVANCE WARNING SIGNS
SR 1 / US 27 IN CARROLL COUNTY

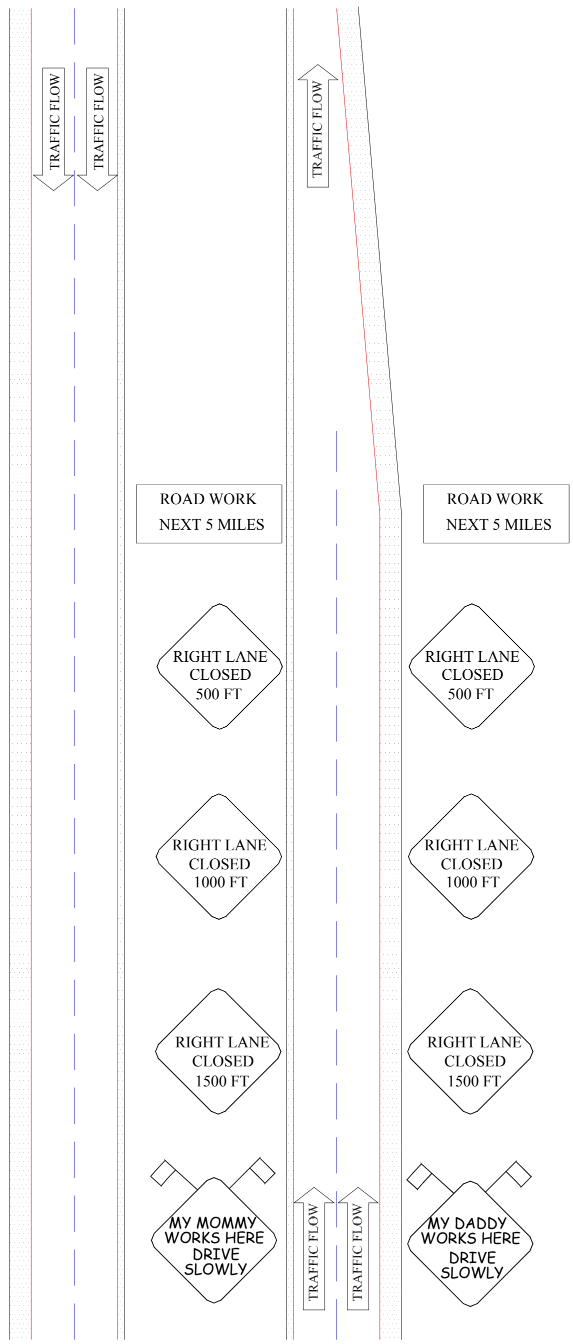

FIGURE 2. PROPOSED ADVANCE WARNING SIGNS
SR 1 / US 27 IN CARROLL COUNTY

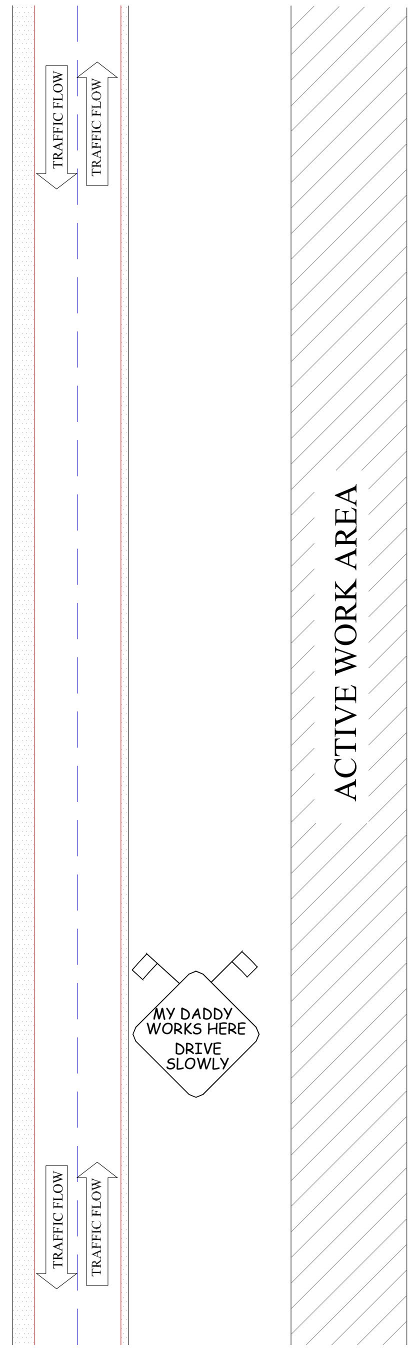

FIGURE 3. SIGN PLACEMENT ADJACENT TO WORK ACTIVITY
SR 1 / US 27 IN CARROLL COUNTY

Traffic Speed and Volume Data Collection

Safe collection of traffic data is of paramount importance on this project. Nu-Metrics traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the northbound lanes. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). In addition, Nu-Metric devices may be positioned in the adjacent southbound lanes for speed comparison purposes. To safely place the devices in the active lane, a gap in traffic of approximately one-minute is required. To safely remove the devices from the active lane, a gap in traffic of approximately two-minutes is required. Due to the nature of the site, it appears devices can be safely placed and removed without altering traffic behavior in the region. Georgia Tech personnel will coordinate with Jimmy Green of Bruce Albea Contracting, Inc. for appropriate times and device placement locations. Nu-Metric devices can be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Figure 4 shows the schematic of a typical classifier.

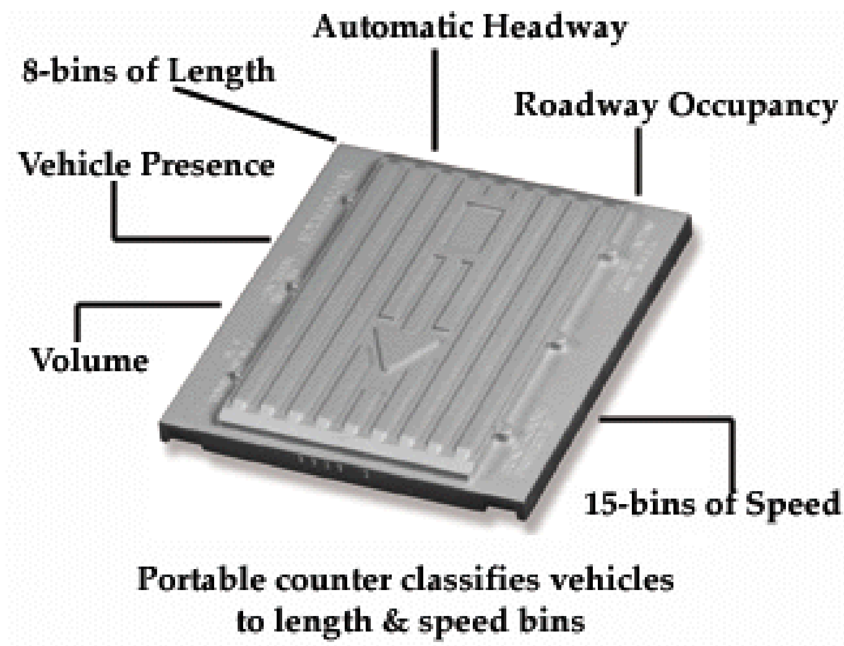

FIGURE 4. SAMPLE NU-METRICS CLASSIFIER (MODEL NO. NC-97)

In addition to the unobtrusive data collection devices, the research team will also use video cameras for supplemental data collection efforts. Video cameras will be used in two capacities. First, a camera will be positioned in a Georgia Tech vehicle and the vehicle will be driven through the work zone. The purpose of this "floating vehicle" perspective is to record actual device placement locations (i.e. signs, classifiers, and their locations relative to work activity). Static location video cameras may also be utilized on

a limited basis to observe driver reaction to the lane closure or traffic control device placement. For example, brake tapping at the location of the innovative sign may indicate a speed reduction influence of the device. Similarly, lane changing/merging behavior may be video taped to enable the research team to compare sign configurations and driver reactions at similar sites.

Georgia Tech data collectors working adjacent to the active lanes will wear safety vests and hats. At no time will the research team initiate data collection efforts at the site without first coordinating this activity with Mr. Green (as previously identified). Data collection efforts may range from one day to several consecutive days. We anticipate approximately five data collection periods. These discrete time periods are:

6. Prior to implementation of any additional traffic control devices (this data set will function as a baseline for future data collected),
7. Immediately following implementation of the fluorescent orange advance warning sign series (eight signs),
8. A few weeks following implementation of the fluorescent orange advance warning sign series (eight signs),
9. Immediately following implementation of the additional innovative wording signs physically located prior to the eight signs indicated in period 2 and 3 as well as the sign located approximately one-mile into the activity region,
10. A few weeks following implementation of the fluorescent orange innovative signs.

Upon completion of the data collection effort, the advance warning fluorescent signs and the innovative wording fluorescent signs will be removed from the site and become property of the Georgia Department of Transportation.

Please contact Karen Dixon at Georgia Tech [phone: (404) 894-5830] if you have any questions regarding this proposed work plan.

GDOT Project 9810
(Georgia Tech Project E-20-E24)
Development of Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
S.R. 1 / U.S. 27 in Haralson and Polk Counties [EDS-27(136) & BHN-17-2(52)]

The Georgia Institute of Technology research team for the above project would like to initiate data collection and device testing for the above referenced project at S.R. 1 / U.S. 27 in Haralson and Polk Counties. Two specific project tasks are necessary for successful project completion. They are (1) traffic control device placement and evaluation, and (2) traffic speed and volume data collection. This work plan summarizes these two tasks for the proposed project corridor.

Traffic Control Device Placement

A three-phase analysis is proposed for this project. First, speed and traffic volumes will be evaluated for the current sign configuration in one direction of travel. Second, the advance sign series shown in Figure 1 (current advance warning sign configuration) will be modified so that all advance warning signs shown will be replaced with fluorescent orange sheeting signs bearing the same messages as currently displayed. These signs will be located on the same poles as the existing signs. Finally, after a reasonable period of time (four to six weeks) two additional innovative message signs will be added as shown in Figure 2. Additionally, approximately one mile into the active work zone another innovative sign (with a message similar to one of the first signs) will be placed on the right side of the two-lane two-way active travel way as depicted in Figure 3. Sign poles will be provided and placed by contractor personnel. The signs will be provided to the contractor for the purpose of this study. This third phase of the project will remain in place for several weeks so both immediate affects as well as novelty affects may be evaluated.

Traffic Speed and Volume Data Collection

Safe collection of traffic data is of paramount importance on this project. Nu-Metrics traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the analysis lanes. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). In addition, Nu-Metric devices may be positioned in the adjacent, opposing direction lanes for speed comparison purposes. To safely place the devices in the active lane, a gap in traffic of approximately one-minute is required. To safely remove the devices from the active lane, a gap in traffic of approximately two-minutes is required. Due to the nature of the site, it appears devices can be safely placed and removed without altering traffic behavior in the region. Georgia Tech personnel will coordinate with a designated representative of Sunbelt for appropriate times and device placement locations. Nu-Metric devices can be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Figure 4 shows the schematic of a typical classifier.

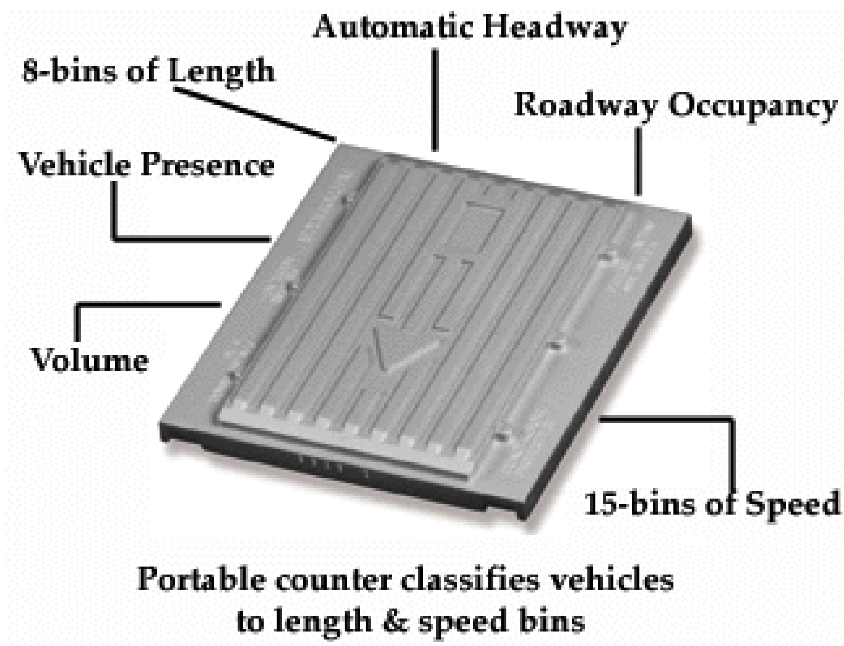

FIGURE 4. SAMPLE NU-METRICS CLASSIFIER (MODEL NO. NC-97)

In addition to the unobtrusive data collection devices, the research team will also use video cameras for supplemental data collection efforts. Video cameras will be used in two capacities. First, a camera will be positioned in a Georgia Tech vehicle and the vehicle will be driven through the work zone. The purpose of this "floating vehicle" perspective is to record actual device placement locations (i.e. signs, classifiers, and their locations relative to work activity). Static location video cameras may also be utilized on

a limited basis to observe driver reaction to the lane closure or traffic control device placement. For example, brake tapping at the location of the innovative sign may indicate a speed reduction influence of the device. Similarly, lane changing/merging behavior may be video taped to enable the research team to compare sign configurations and driver reactions at similar sites.

Georgia Tech data collectors working adjacent to the active lanes will wear safety vests at all times. Data collection efforts may range from one day to several consecutive days. We anticipate approximately five data collection periods. These discrete time periods are:

11. Prior to implementation of any additional traffic control devices (this data set will function as a baseline for future data collected),
12. Immediately following implementation of the fluorescent orange advance warning sign series,
13. A few weeks following implementation of the fluorescent orange advance warning sign series,
14. Immediately following implementation of the additional innovative wording signs physically located as shown in Figure 2 as well as the sign located approximately one-mile into the activity region (Figure 3),
15. A few weeks following implementation of the fluorescent orange innovative signs.

Upon completion of the data collection effort, the advance warning fluorescent signs and the innovative wording fluorescent signs will be removed from the site and become property of the Georgia Department of Transportation.

Please contact Karen Dixon at Georgia Tech [phone: (404) 894-5830] if you have any questions regarding this proposed work plan.

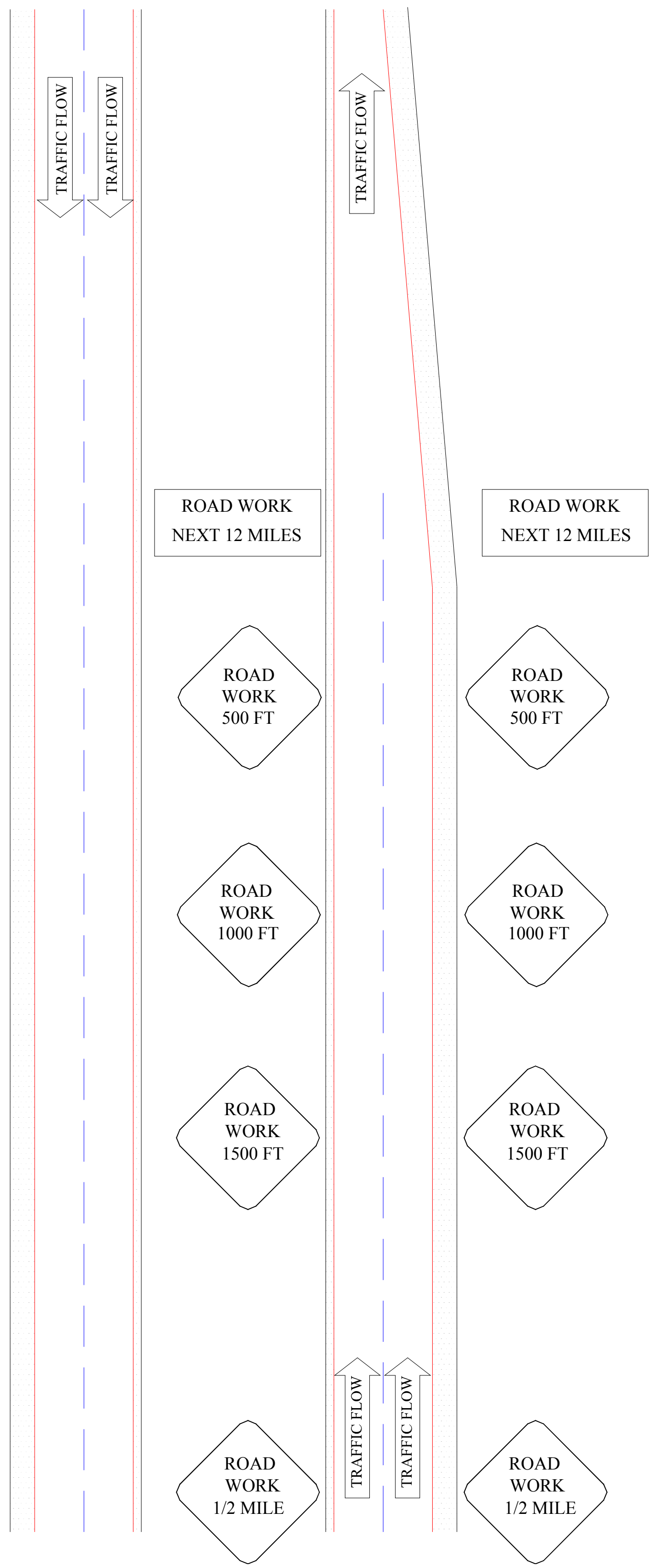

FIGURE 1. CURRENT ADVANCE WARNING SIGNS
SR 1 / US 27 IN HARALSON & POLK COUNTY

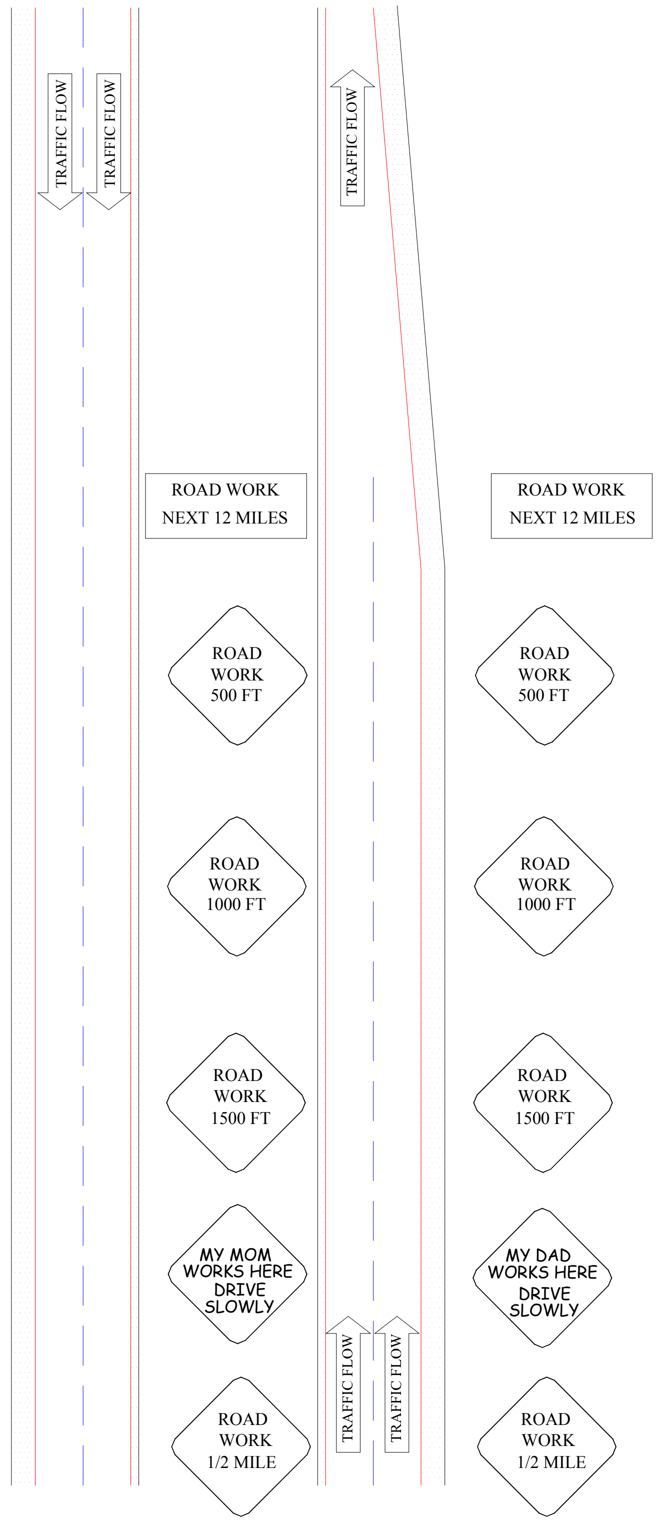

FIGURE 2. PROPOSED ADVANCE WARNING SIGNS
SR 1 / US 27 IN HARALSON & POLK COUNTY

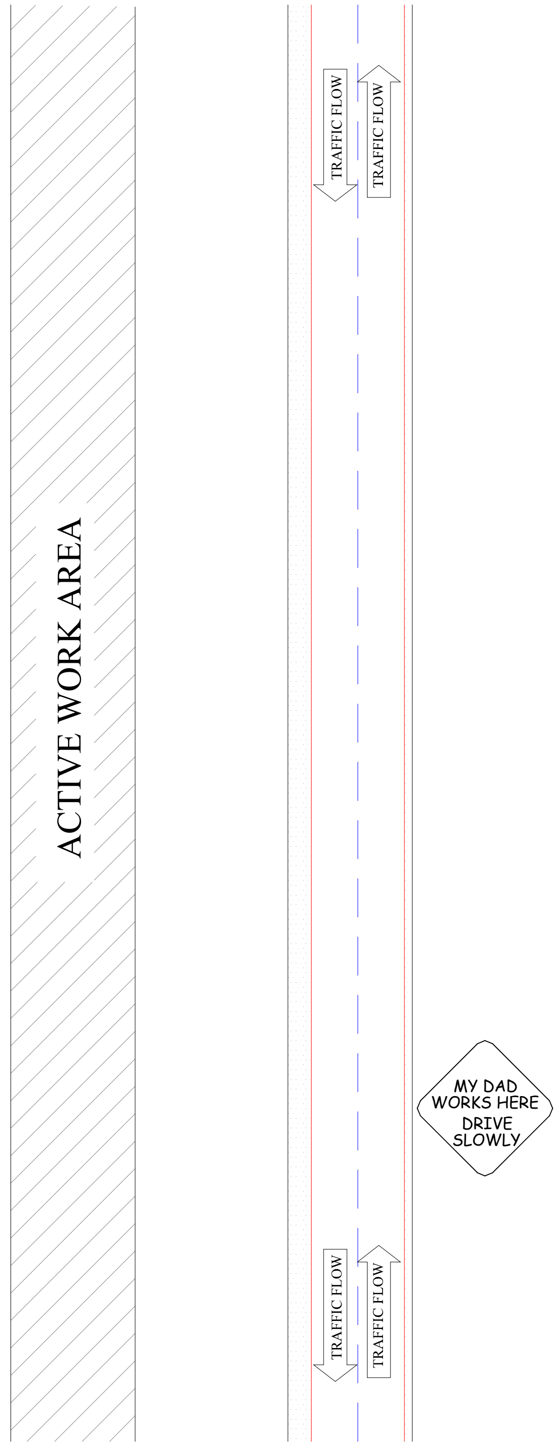

FIGURE 3. SIGN PLACEMENT ADJACENT TO WORK ACTIVITY
SR 1 / US 27 IN HARALSON & POLK COUNTY

GDOT Project 9810
(Georgia Tech Project E-20-E24)
Development of Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
S.R. 1 / U.S. 27 in Haralson and Polk Counties [EDS-27(136) & BHN-17-2(52)]

The Georgia Institute of Technology research team for the above project would like to initiate data collection and device testing for the above referenced project at S.R. 1 / U.S. 27 in Haralson and Polk Counties. Two specific project tasks are necessary for successful project completion. They are (1) traffic control device placement and evaluation, and (2) traffic speed and volume data collection. This work plan summarizes these two tasks for the proposed project corridor.

Traffic Control Device Placement

A two-phase analysis is proposed for this project. First, speed and traffic volumes will be evaluated for the current sign configuration in the southbound direction of travel. Next, a changeable message sign with radar (CMR) will be placed at the southbound lane transition area as shown in Figure 1. Sign placement will be near the end of the taper in the transition area. This changeable message sign will remain continuously in place for approximately three weeks. During the first week of sign placement, the research team will collect work zone speed information to determine the effectiveness of the sign. During the third week of sign placement, the research team will again collect work zone speed information to determine if any initial influences by the sign on work zone speed may diminish over time (novelty effects).

A CMR is a changeable message sign with built-in radar that measures the speed of approaching vehicles. The radar will send a message to the central processing unit of the sign when it detects a vehicle speed in excess of some pre-determined threshold. If there are no vehicles present, the CMR does not display a message. Text height is six inches and the sign permits a three-line message. This letter height permits message visibility 400 to 450 feet upstream of the sign. Lateral placement of the sign must be immediately adjacent to the travel lane to drivers can easily view the message as they approach the CMR.

The CMR will have three proposed messages. The displayed message will depend upon the speed of the vehicle approaching the sign and is intended to make the driver aware that his/her speed has been detected. For vehicles travelling 5 miles above the work zone speed limit the CMR message will read: "ACTIVE WORKZONE, REDUCE SPEED." For vehicles travelling between 5 and 10 miles above the posted speed limit the CMR will display a message that indicates: "YOU ARE SPEEDING, SLOW DOWN NOW." Finally, for vehicles travelling more than 10 miles above the work zone speed limit the sign message will display: "EXCESSIVE SPEED, SLOW DOWN." The Virginia Department of Transportation recently tested messages similar to the three proposed

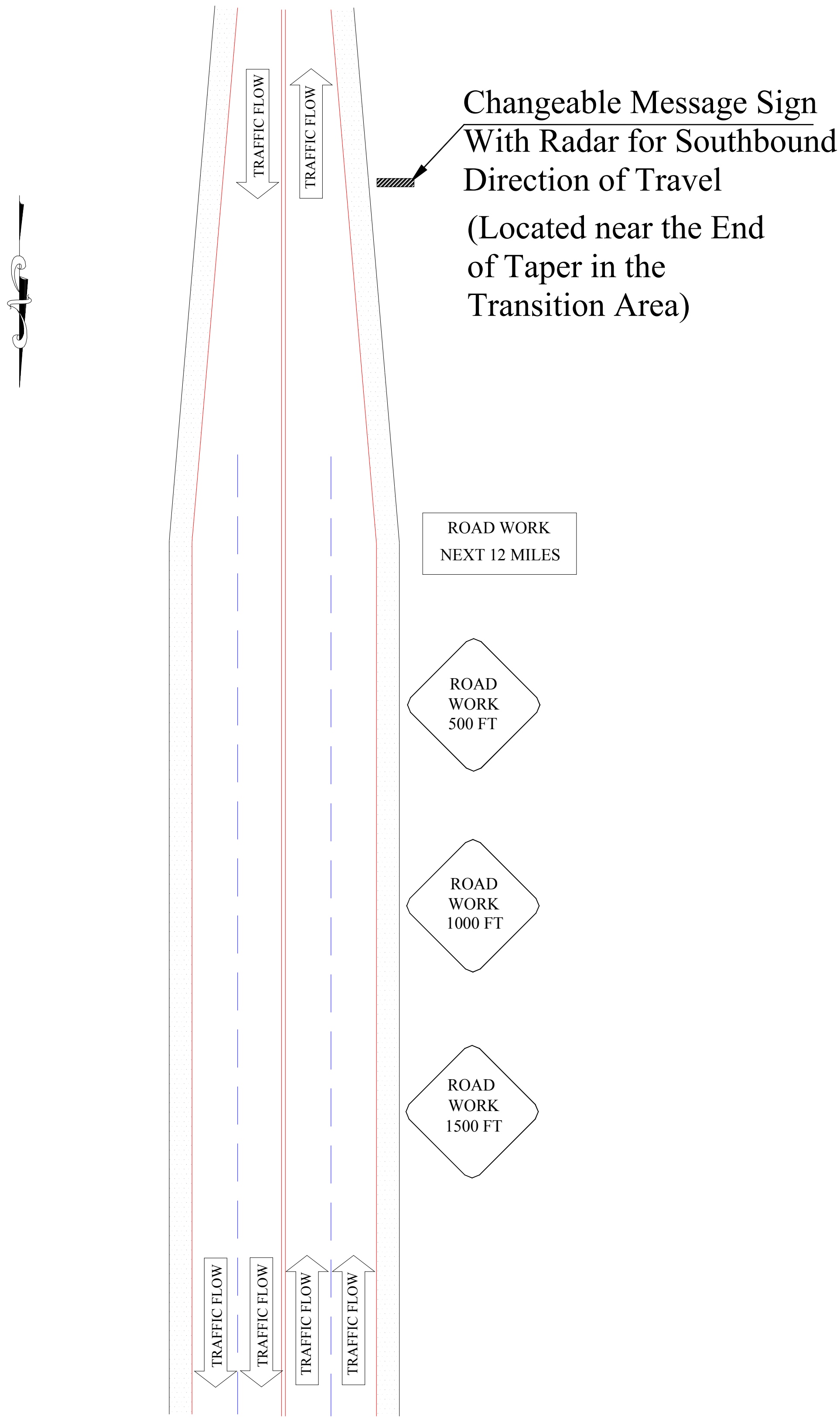

FIGURE 1. APPROXIMATE CMR PLACEMENT
SR 1 / US 27 IN HARALSON & POLK COUNTY

messages. The South Dakota Department of Transportation also tested the "YOU ARE SPEEDING, SLOW DOWN NOW" message. Both states found the messages effective in average speed reduction.

The CMR will be delivered to the site and setup by representatives of Interstate Material Supplies (IMS) of Georgia. IMS is the owner of the CMR and will be renting it to Georgia Tech for the study period. In the event of vandalism to the device, Georgia Tech has insured the CMR for its replacement value of $20,000.

<u>Traffic Speed and Volume Data Collection</u>

Safe collection of traffic data is of paramount importance on this project. Nu-Metrics traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the analysis lanes. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). In addition, Georgia Tech and Sunbelt representatives will position Nu-Metric devices in the adjacent, opposing direction lanes for speed comparison purposes. To safely place the devices in the active lane, a gap in traffic of approximately one-minute is required. To safely remove the devices from the active lane, a gap in traffic of approximately two-minutes is required. Due to the nature of the site, it appears devices can be safely placed and removed without altering traffic behavior in the region. Georgia Tech personnel will coordinate with a designated representative of Sunbelt for appropriate times and device placement locations. Nu-Metric devices will be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Each device is 6.5" long by 5.5" wide and is protected by a rubber cover that is approximately twice the size of the Nu-Metric classifier. Figure 2 shows the schematic of a typical classifier.

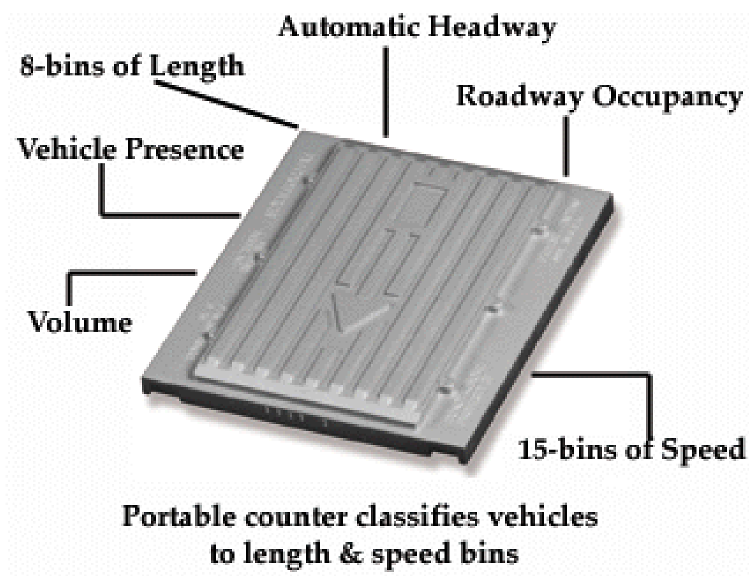

FIGURE 2. SAMPLE NU-METRICS CLASSIFIER (MODEL NO. NC-97)

In addition to the unobtrusive data collection devices, the research team will also use video cameras for supplemental data collection efforts. Video cameras will be used in two capacities. First, a camera will be positioned in a Georgia Tech vehicle and the vehicle will be driven through the work zone. The purpose of this "floating vehicle" perspective is to record actual device placement locations (including CMR, static signs, classifiers, and their locations relative to work activity).

The research team is also proposing a second camera data collection effort at the site if physically possible. The researchers intend to use a static location video camera on a limited basis (two to three hours per before, immediately following implementation, and week three study period) to observe driver reaction to the lane closure or traffic control device placement. For example, brake tapping at the location of the CMR may indicate a speed reduction influence. Similarly, lane changing/merging behavior may be video taped to enable the research team to compare sign configurations and driver reactions at similar sites. The southbound direction of travel immediately upstream of the work zone has a sharp horizontal curve to the left. After IMS has delivered and set up the CMR, the research team will evaluate if it is possible to capture the sign, its message, and the adjacent lane vehicles in a camera field of view without inadvertently influencing traffic operations due to the presence of the camera. If feasible, the static camera placement will be located approximately 300 to 450 feet upstream of the CMR location.

Georgia Tech data collectors working adjacent to the active lanes will wear safety vests at all times. The use of headphones or portable radios will not be permitted. Data collection efforts may range from one day to several consecutive days. We anticipate approximately three data collection periods. These discrete time periods are:

16. Prior to implementation of any additional traffic control devices (this data set will function as a baseline for future data collected),
17. Immediately following implementation of the CMR,
18. The third week of CMR placement.

Specific safety requirements can be separated into data collection at a specific location or data collection in a moving vehicle. The data collection team will adhere to the following criteria:

Safety Precautions at the Data Collection Site:

1. At no time will a person assigned to collect data enter the active traveled way (the region between edges of road dedicated to vehicle activity).
2. If an individual needs to leave his or her data collection post for personal reasons, he or she will contact the team leader via radio or telephone and arrangements will be made for a vehicle to pick-up the person and transport them safely away from the site.
3. Each person should stay alert to errant vehicles. Avoid turning your back completely to traffic.

4. Do not interfere with existing traffic patterns or participate in any activity (other than those required for the data collection efforts) that may distract drivers or alter driver conditions.
5. Stay as far from the active travel way as possible.
6. If any team member is confronted or threatened during data collection by someone who wants the data collection equipment, do not resist -- surrender the equipment and then immediately report the loss to the project director and then the police.

Data Collection within a Moving Vehicle:

1. When performing moving data collection studies, allow the driver of the vehicle to collect data only if the activity does not detract from his or her ability to drive.
2. When in a vehicle collecting data in the traffic stream, keep seat belts buckled and do not block the vision of or distract the driver.

Upon completion of the data collection effort, the CMR will be immediately removed from the site.

Please contact Dr. Karen Dixon, Project Director at Georgia Tech at (404) 894-5830 [karen.dixon@ce.gatech.edu] or David Jared, GDOT Project Monitor at (404) 363-7569 [david.jared@got.state.ga.us] if you have any questions regarding this proposed work plan.