# FINAL REPORT

## EVALUATING SPEED REDUCTION STRATEGIES FOR HIGHWAY WORK ZONES (SMART WORK ZONES)

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## EXECUTIVE SUMMARY

The objective of this research was to (1) evaluate the use of changeable message signs with radar for the travel lanes adjacent to the work zone activity area at two-lane, two-way rural highways, and (2) evaluate portable ITS systems and their influence on operations for freeway work zones. The work included a field test of each strategy to evaluate its potential influence on driver's operational characteristics (speed, selection of alternative routes, safety, etc.).

To test the effect of a changeable message sign with radar, the research team evaluated work zone speed before sign deployment, immediately following sign deployment, and a few weeks following sign deployment (to test for potential novelty effects). The authors used a two sample paired t-test for speed change evaluations.

To evaluate the influence of the portable ITS systems, the research team collected operational information including speeds and system volumes. They also conducted two driver surveys to determine the perceptions of the road user regarding the equipment. A general setup and maintenance evaluation scrutinized equipment deployment and use issues. Finally, the research team acquired the crash reports for one site as well as for a comparison site to determine safety implications of the portable ITS system.

This study determined that the changeable message sign with radar does help reduce the adjacent speed of vehicles at two-lane, two-way rural highway locations. Though the speed reduction is small (ranging from 1 to 3 mph typically), the reduction is maintained over time as well as downstream of the sign placement. Specific speed findings were that drivers of passenger cars for both day and night time driving reduced speeds from 1.9 to 3.1 mph adjacent to the sign and sustained a speed reduction downstream of 1.9 to 2.3 mph. For heavy vehicles during the daylight hours, the sign did not significantly influence the drivers speed selections; however, heavy vehicles at night reduced speeds from 2.2 to 3.5 mph adjacent to the sign and sustained speed reductions ranging from 0.6 to 4.4 mph downstream. The lack of influence on speed choice for daytime heavy vehicle activity can likely be attributed to the adjacent mining activities and the "per load" incentive paid to the drivers of the heavy vehicles.

This study also determined that there are many factors necessary for an adequate operational analysis of the portable ITS system as these systems greatly vary over application, message statement, and work zone activity and placement. In general, the use of the portable ITS system appears to encourage the selection of alternative routes when delays are present within the work zone provided there are obvious alternative routes readily available. The portable ITS system also was well received by motorists, many who suggested that they change their driving behavior as a result of the system. Finally, the portable ITS system influence on safety is perhaps one of the most promising observations. Though crashes were only studied for one site plus a comparison site, it appears that the portable ITS systems provide information about downstream slow or stopped conditions and this substantially reduces rear-end crashes in the lanes adjacent to

a work zone activity area. In addition, the research team observed a reduction in single vehicle crashes involving speeding at the site with the ITS equipment present.

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# CHAPTER 1. INTRODUCTION

Speed limit compliance by motorists at active highway construction zones has been the focus of considerable research in the United States in recent years. The primary concern regarding the perception of speeding in the work zone regions is the safety of motorists and workers in the proximity of this speeding. In 2002, the Georgia Department of Transportation (GDOT) commissioned the Georgia Institute of Technology (GA Tech) to perform a study to determine the location of work zone crashes in Georgia and to test a variety of traffic control strategies and their influence on the speeds at the selected study locations. This previous study focused on the two-lane two-way rural work zone condition with traffic control strategies that included innovative static sign messages, fluorescent orange sign sheeting, and changeable message signs with radar (CMR). Though speed patterns varied between vehicle type and time of day for all of the tested strategies, the CMR located at the work zone transition area significantly reduced the adjacent speed but this speed reduction did not appear to occur adjacent to the work zone activity area. There was not a significant speed reduction observed consistently over time for the other two strategies.

Currently, the State of Georgia is reconstructing many of the freeways in its roadway network. Simple traffic control strategies such as those used for the previous study have little effect on freeway traffic with multiple lanes and high traffic volumes. As a result, the GDOT seeks to evaluate potential work zone strategies for freeways that may improve traffic flow, minimize driver confusion, and potentially reduce operating speeds. Also, GDOT would like to test the influence of the CMR for speed reduction when the device is adjacent to the activity area in rural work zones (the previous study evaluated the CMR placement at the transition area only).

## 1.1. Problem Statement

In recent years, the highway engineering community has evolved technology designed to improve traffic operations and safety with a targeted application of this technology for highway work zone environments. These technologies range from CMR to portable Intelligent Transportation Systems (ITS). The actual influence this technology has on work zone operations is not clear. Unfortunately many work zone crashes can often be attributed to driver confusion or blatant disregard by the driver to work zone traffic control devices such as posted speed limits.

The research summarized in this report evaluates the CMR at a rural two-lane two-way work zone site and three portable ITS systems at Georgia freeway construction sites. The three ITS systems included the Advance Speed Information System (ASIS), the IntelliZone, and the Traffic Information Prediction System (TIPS).

## 1.2. Research Objectives

The primary objective of this research effort was to evaluate the ITS and CMR strategies to determine if they have good potential for *improving traffic operations* and possibly *reducing speed* in highway work zones. Secondary objectives of this research included the evaluation of these strategies for trustworthiness and dependability, determining if drivers easily understand the devices, and identifying issues that may influence the devices such as sun glare or placement strategies.

## 1.3. Report Organization

This report is organized into ten chapters with supplemental appendices. Chapter 1 introduces the problem statement and the objectives of the research. Chapter 2 defines several common work zone components, provides a background on work zone safety issues and brief description of early research, reviews state of the art technology including detailed reviews of technology applications (changeable message signs with radar, video detection systems, speed monitoring displays, automated work zone information systems – ADAPTIR, CHIPS, TIPS/ASIS, IntelliZone), summarizes general guidelines for application of portable work zone systems, and reviews recent developments in portable changeable message signs. Chapter 3 summarizes the CMR data collection plan for this study. Chapter 4 reviews the data summary, evaluation, and findings for the CMR testing. Chapter 5 introduces the portable ITS system data collection plan. Chapter 6 reviews the collected data, associated evaluation techniques for the ITS systems, and provides results of the ITS system data analysis. Finally, Chapter 7 summarizes report conclusions and general recommendations for prospective treatment strategies. References are shown in Chapter 8. Included in the report appendices are supplemental tables and figures, work plans and product specifications, and an acronym definition summary.

# CHAPTER 2. LITERATURE REVIEW

## 2.1. Background

As construction of the interstate highway system approached completion, the Department of Transportation began to shift focus to maintaining the United States' highway infrastructure system. Many of the nation's highways are nearing the end of their targeted life cycle and must be placed into the reconstruction and rehabilitation process. Today, the majority of the highway funds are used on system preservation projects on the existing highway system (FHWA, 1998). To this end, work zones are likely to increase in number, duration, and length while the active travel demands on the associated highways will also continue to increase.

With one of the best transportation systems in the world, Americans are accustomed to nearly unlimited mobility. As congestion rates continue to increase in most major cities, the addition of rehabilitation projects and associated work zones causes severe congestion and limits mobility. To compensate, many construction projects are undertaken during the nighttime hours or on weekends to reduce the effects of lane closures. However this focus of maintained work zone mobility has come with a cost. The lower volume of traffic in the off-peak hours leads to higher travel speeds adjacent to the work zones, thus increasing the hazards to the traveling public and the highway workers.

Over the last few years, the number of fatalities in work zones has been on the increase as shown in Figure 1. In 1997, for example, there were 693 fatalities in work zones. This number increased to 1,093 in 2000 and maintained a similar value of 1,079 in 2001. (FHWA, 2003).

In a study of work zone related crashes by Khattak et al. (2002), researchers found that after controlling for various factors, longer work zone duration significantly increases both injury and non-injury crash frequencies. Using before and after techniques, the researchers gathered data from California work zones including crash frequency and severity, average daily traffic, roadway characteristics, and work zone duration, length, and location. Crash rates and frequencies were then compared for pre-work zone and during-work zone activities. The during-work zone crash rates for freeways were 21.5% higher than the pre-work zone phase. The frequencies also increased with increasing work zone duration, length, and average daily traffic. This research supports movements by the US Department of Transportation to increase the efficiency and safety of work zones through policies in the transportation authorization bills.

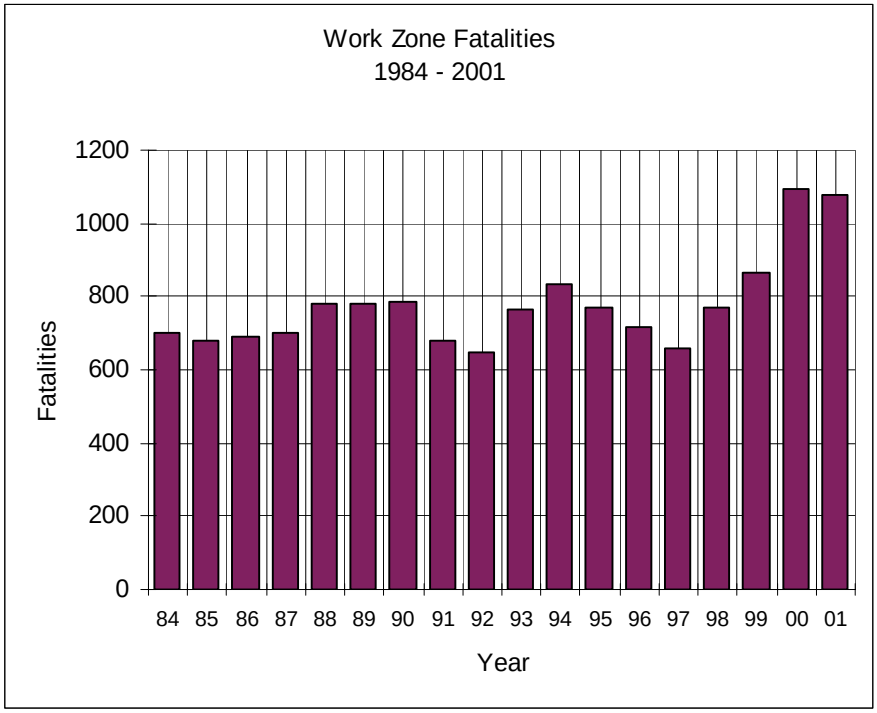


**Figure 1.** U.S. Work Zone Fatalities from 1984-2001

*Source: FHWA, 2001b, 2003*

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, section 1051, required the Secretary of Transportation to develop and implement a work zone safety program to "improve work zone safety at highway construction sites by enhancing the quality and effectiveness of traffic control devices, safety appurtenances, traffic control plans, and bidding practices for traffic control devices and services" (FHWA, 1998). The same bill was instrumental in advancing Intelligent Transportation Systems. In the mid-1980's, components of ITS had already found their way into work zones. Richards, et al. (1985, 1986) evaluated work zone speed control techniques including innovative flagging, law enforcement strategies, changeable message signs (CMSs), rumble strips, and effective lane width reduction. The use of changeable message signs produced recognizable but modest reductions in speeds in comparison to flagging and law enforcement. Reductions were in the range of 3-7%, compared with 19 and 18% for flagging and law enforcement. However, these devices were stationary devices that required little human interaction. At the time, CMS signs were very new technology, and as such, their prices were high and availability was low.

Following ISTEA, a focus on intelligent technology occurred in transportation much like in other engineering fields. In recent years, developers have created technology designed to improve traffic operations and safety with a targeted application of this technology for highway work zone environments. These technologies range from CMRs to portable ITS applications. In 2001, FHWA released a brochure entitled "Informed Motorist, Fewer

Crashes". The brochure stated several potential benefits of using ITS in work zones. The work zone ITS systems use electronic and communication equipment to monitor traffic flow and speeds and provide delay and routing information to drivers and highway agencies. Benefits of these systems include:

- Better informed customers (i.e., the traveling public),
- Improved mobility,
- Improved safety,
- Reduced speeding violations, and
- Better coordination with other agencies.

The remainder of this review focuses specifically on definitions of work zone components, technologies used in work zones, and their general effectiveness in providing the benefits mentioned above.

## 2.2. Work Zone Components

The work zone literature uses several general terms commonly associated with work zones and work zone lane closures. Figure 2 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) (2003). 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.

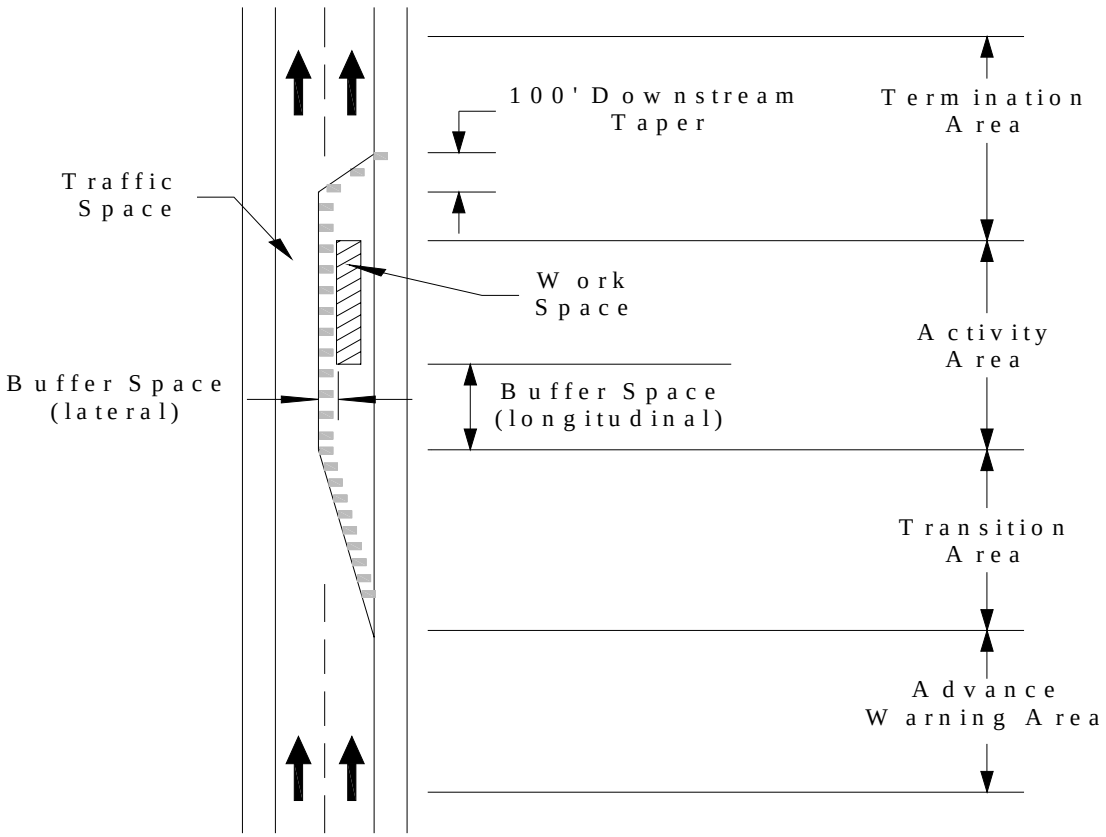


**Figure 2.** Component Parts of a Temporary Traffic Control Zone

*Source: Manual of Uniform Traffic Control Devices – 2003 Edition.*

## 2.3. State of the Art Reviews

In 1998, the Federal Highway Administration completed a work zone scanning tour of 26 states. The information gathered in these visits was published in two documents: 1) *Meeting the Customer's Needs for Mobility and Safety During Construction and Maintenance Operations* (1998), and 2) *Work Zone Operations Best Practices Guidebook* (2000). The guidebook is a reference document that is intended to be updated as new approaches, technologies, and practices become "state-of-the-practice." The information in contains is intended to be descriptive (rather than prescriptive) to help meet the specific needs of the work zone project, agency, and site. While the document does not contain all of the required details necessary to fully understand the practices, it does

provide a description of the practice, reasons for implementing, benefits, applicability, and a contact person in the agency who can provide further information. Each approach is typically reduced to a single-page summary.

State of the art ITS "Smart Work Zone" systems are used to automatically collect and analyze data for before, during, and after traffic flow conditions in a work zone; provide accurate real-time information automatically to motorists and to the construction team; enforce speed; and safely guide motorists through the work zone. According to the Guidebook, portable traffic management systems are recommended for all work zones under the following conditions:

- High-speed, high-volume facilities,
- Lane and ramp closures,
- Severely restricted areas, and
- Major changes to existing traffic patterns.

Table 1 lists the ITS and Technology practices covered by the Guidebook with a brief description of each technology "Best Practice." Several of these technologies (i.e., ADAPTIR, ADDCO PTMS, MN Smart Work Zone) are covered in more detail in the following sections (FHWA, 2000).

In November of 2002, the ITS Joint Program Office of the Federal Highway Administration published an updated state of the practice for ITS in work zones. The report is entitled *Intelligent Transportation Systems in Work Zones: A Cross-Cutting Study*. The report shows positive results from the implementation of ITS systems for work zones to include:

- Delivery of real-time information on problem areas for travelers,
- Reduction or elimination of significant traffic backups,
- Significant reduction in the time it takes to identify and clear incidents, and
- Provision of delay information at strategic locations to allow detours.

The document covers in more detail four ITS applications in work zones. All four sites used ITS for traffic monitoring and management, as well as to provide traveler information. One site also used the system to provide incident management. Table 2 provides an overview of the major site characteristics (FHWA, 2002).

Systems operations diagrams for each location are shown in Figure 3 through Figure 6. All of these systems operate in a manner similar to a standard Traffic Management Center (TMC) operation. Sensors are located in the field, information is gathered and transmitted back to a central location or server, information is processed either automatically or manually, and travel information is posted for travelers or agency personnel through a variety of mechanisms.

**Table 1.** ITS and Technology Best Practice

| | |
|---|---|
| Traffic Control | *Highway Closure and Restriction System* – allows Construction and Maintenance Offices throughout the State to input information relative to roadway closures. This information may be retrieved either through the Internet or by telephone. (Arizona) |
| | *Mobile Surveillance/Ramp Metering via Wireless Communication Systems* – mobile surveillance trailers capture and transmit images and traffic data to the Traffic Management Center (TMC). The trailer can control ramp meters that have experienced surveillance operations interruptions. (California) |
| | *Automated Data Acquisition and Processing of Traffic Information in Real-Time (ADAPTIR)* – senses and processes data relating to current traffic conditions and automatically provides travelers with appropriate speed control, lane control, delay, and diversion advisory messages via variable message signs and highway advisory radio. (Maryland/California) |
| | *Development of an Automated Machine for Cone Placement and Retrieval* – machine reduces maintenance personnel exposure to the hazards of traffic and physical exertion involved in handling the cones. (California) |
| | *Indiana Lane Merge* – dynamic no passing zone placed prior to the taper of a work zone. The first sign includes flashing strobes which are always activated. Additional signs are automatically activated upstream of the work zone depending upon highway capacity variations. (Indiana) |
| | *Advanced Traveler Information System (ATIS) or Indiana Expert System* – enables incident response teams to program messages to travelers from their vehicles at the site of an incident. (Indiana) |
| | *Portable ITS Technology in Work Zones* – includes a variety of technologies including highway advisory radio, variable message signs, Indiana lane merge, 0.2 mile reference markers (to enhance location information), tow truck service, ambulance service, closed circuit TV, and smiley face signs. (Indiana) |
| | *Condition Responsive Work Zone Traffic Control (CRWZTC) System* – portable system designed to provide highway users with real time traffic information in a work zone. The system utilizes changeable message signs, highway advisory radio, queue detectors, and portable sensors all controlled by a central computer system. (Maryland) |
| | *Evaluation of ADDCO's Advanced Portable CCTV System* – used to monitor traffic operation in construction and maintenance work zones. The system consists of one or more cameras and allows the project engineer to monitor the efficiency of traffic operations on an approach to a work zone. (Maryland) |
| | *Remotely Operated Autoflagger (Slow/Stop Sign)* – remotely controlled Stop/Slow Sign to be used in place of a human flagger on low-speed, low-volume, 2-lane highways. (Minnesota) |
| | *Portable Traffic Management System or Smart Work Zone* – uses traffic detection cameras and a series of changeable message signs in and around the work zone area to manage traffic and can be fully deployed and operational within four hours. (Minnesota) |
| Traveler Information | *Orion* – displays real time traffic information on Cable TV and on monitors in parking garages within the central business districts. (Minnesota) |
| | *Trilogy* – sends traffic information created at the TMC to vehicles in real time. Traffic information is overlaid on a graphic navigation display unit in the vehicle. (Minnesota) |

*Source: FHWA, 2000*

**Table 2.** ITS Test Site Characteristics

| Site Characteristic | Illinois | Michigan | New Mexico | Arkansas |
|---|---|---|---|---|
| **Location** | I-55, Springfield | I-496, Lansing | I-40/I-25, Albuquerque | I-40, West Memphis |
| **Primary Purpose** | Traffic monitoring and management, traveler information | Traffic monitoring and management, traveler information | Incident management, traffic monitoring and management | Traffic monitoring and management, traveler information |
| **Real-time Information on the Internet** | Yes (map of congestion levels) | Yes (camera images and map of travel speeds) | Yes (camera images) | No |
| **Real-time Information on Dynamic Message Signs** | Yes | Yes | For major incidents (manually activated) | Yes |
| **Staffed Traffic Management Center** | No | Yes (5:00 a.m. to 7:00 p.m.) | Yes (5:00 a.m. to 8:00 p.m.) | No |
| **Temporary or Permanent Deployment** | Temporary | Temporary | Parts of system permanent | Temporary |

*Source: FHWA, 2002*

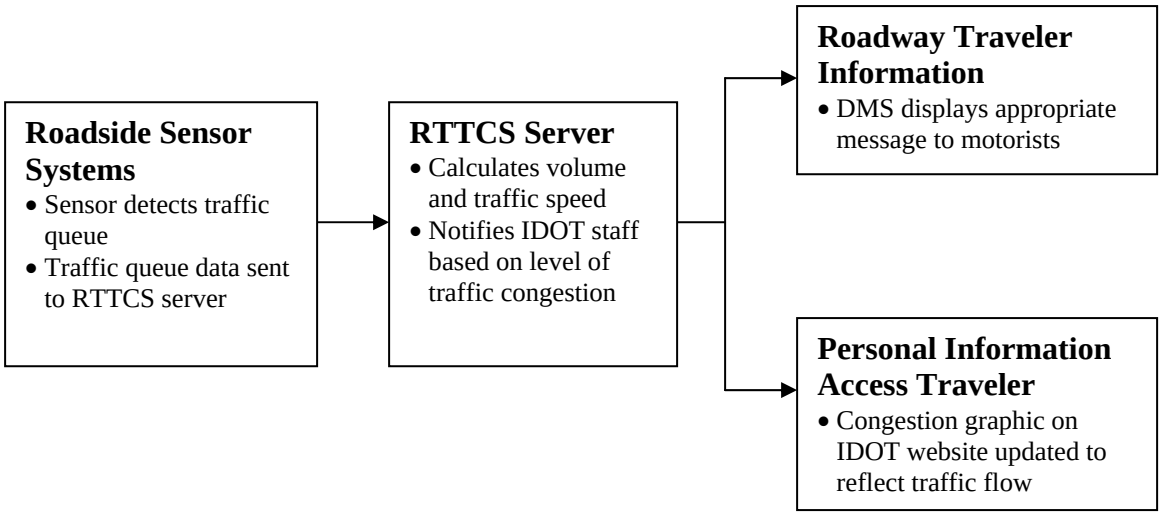


**Figure 3.** Springfield, Illinois ITS Work Zone Concept

The main goals of the Springfield Automated Portable Real-Time Traffic Control System (RTTCS) were to provide traveler information and to enhance traveler safety. The Real-Time Traffic Control System included 17 remotely controlled portable changeable message signs, eight portable traffic sensors electronically linked to a central base station server, and four portable closed circuit television (CCTV) cameras electronically linked to a central base station using wireless communications.

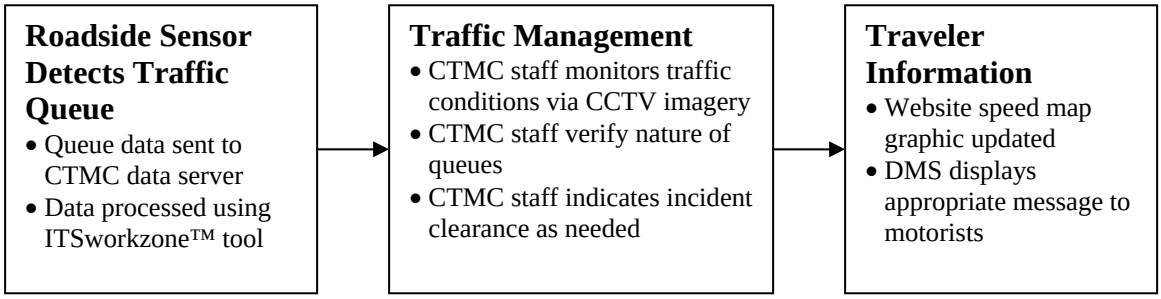


**Figure 4.** Lansing, Michigan ITS Work Zone Concept

The Michigan Department of Transportation's (MDOT) main goal for the ITS work zone application was to provide motorists with complete and accurate traffic information in real-time so that travelers were able to make better decisions in a less stressful driving environment. MDOT used its mobile traffic monitoring and management system as a virtual traffic management center. The system included 17 cameras, 12 dynamic message signs (DMS), six queue detectors, and the National Sign and Signal ITSworkzone™ software package to gather and process data on current conditions and display advanced traveler information to the public.

The main goals of using ITS in the I-40/I-25 interchange reconstruction in New Mexico were: to provide traffic management capabilities and traveler information on traffic routing, detours, and significant incidents; to minimize capacity restrictions due to incidents by more quickly identifying incidents and determining an appropriate and effective response to clear the roadway; and to enhance traveler safety. The system included eight fixed CCTV cameras, eight modular (expandable) DMSs, four arrow dynamic signs, four all light-emitting diode (LED) portable DMS trailers, four ADDCO, Inc. Smart Zone® portable traffic management systems, which integrate CCTV cameras and dynamic message signs on one fully portable traffic management system, and four highway advisory radio (HAR) units. The cameras and DMSs were linked electronically to base station computers in a TMC using an Internet platform with both wireline and wireless communications. In addition to the DMSs and HAR, information on traffic conditions was distributed via websites, use of media outlets such as radio, newspaper and television, pagers provided by a commercial paging service, and fax and e-mail distribution lists.

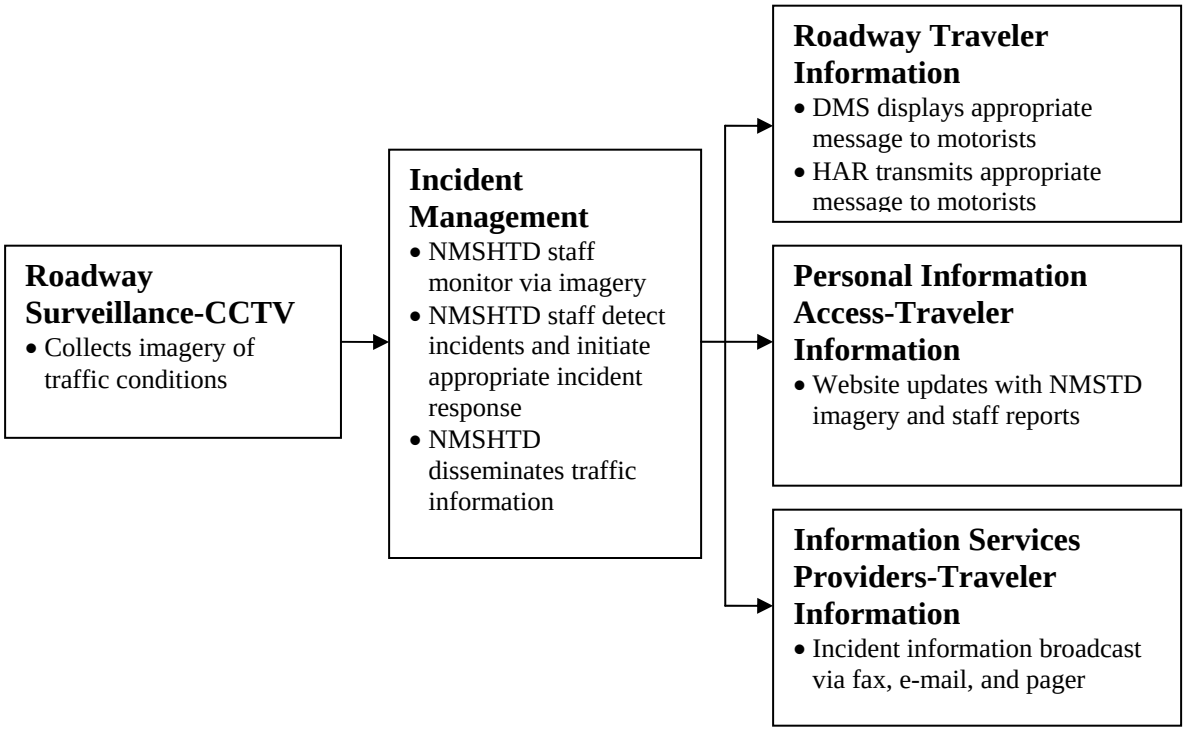


**Figure 5.** Albuquerque, New Mexico ITS Work Zone Concept

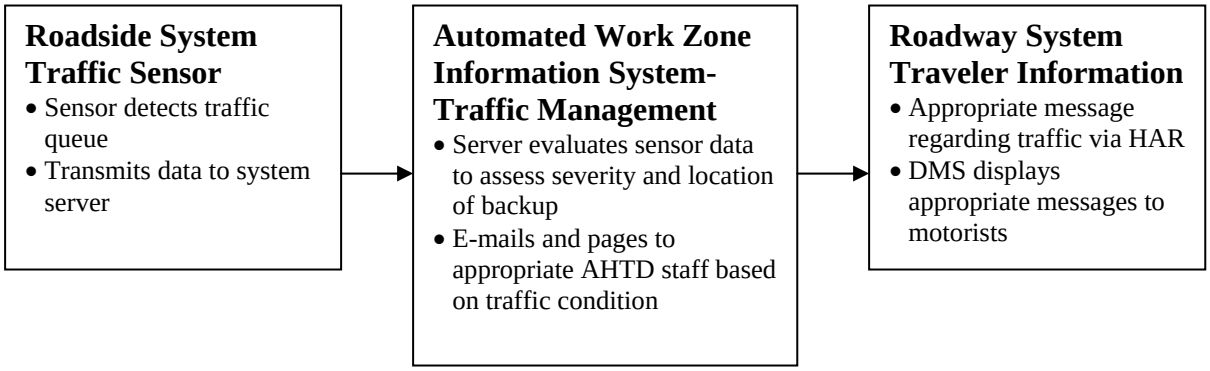


**Figure 6.** West Memphis, Arkansas ITS Work Zone Concept

The main goals of the Automated Work Zone Information System (AWIS) in West Memphis Arkansas were to provide traveler information and to enhance traveler mobility and safety for motorists approaching and traveling through the work zone area. By notifying travelers of traffic conditions, the AWIS assisted travelers in making decisions about which route to take, thereby reducing traffic backups, which in turn was expected

to reduce traveler stress and potential "road rage" incidents. In addition, the Arkansas State Highway and Transportation Department (AHTD) hoped that the system could provide faster incident response, thereby restoring capacity and reducing the opportunity for secondary crashes.

The system detected traffic conditions approaching the work zone and used that information to determine what messages to transmit to travelers in real-time via DMSs and HAR. West Memphis used the Computerized Highway Information Processing System (CHIPS) developed by ASTI Transportation Systems. CHIPS consisted of sensors, a wireless communications network, a control center with a computer and interface for processing the sensor data, and output devices. Specifically, the system included 12 queue detectors and five remotely controlled DMSs linked to a central base station server using wireless communications, three highway advisory radio units, five pagers, and an e-mail alert system. The detectors were spread over a seven-mile stretch extending before and after the work zone on each side, while the message boards were spread over about nine miles approaching the work zone from both sides. The range of the HARs was approximately 23 miles.

The perceived benefits of these four systems include:

- I-55 Springfield, Illinois
    - No significant traffic back ups;
    - Reduced rate of speeding violations and traffic citations; and
    - Only two crashes – one attributed to fatigue and the other to alcohol.
- I-496 Lansing, Michigan
    - Real-time information on problem areas for travelers;
    - More efficient communications with local agencies;
    - Helped enable use of full road closure which reduced construction time (two seasons to one); and
    - Quicker incident response.
- I-40/I-25 Albuquerque, New Mexico
    - 44 % reduction in incident response and clear time;
    - 32 % reduction in initial crashes and fewer secondary crashes;
    - Better maintenance of traffic flow;
    - Praise from travelers and the public safety sector (60 % of survey respondents found data to be accurate and timely); and
    - Better communication with incident management community.
- I-40 West Memphis, Arkansas
    - Information at strategic locations for alternate routes;
    - Improved safety through traveler information on traffic backups;
    - Better relations with the public and neighboring agencies;
    - Better incident response; and
    - Reduced delay through better construction traffic coordination.

Several important lessons were learned at the four ITS work zone sites. While lessons from each site are available in the report, the following were common for all four deployments:

- It is important to allow start-up time when deploying a system.
- It is important to use a proactive approach in building public awareness of the project and the information that the ITS application will provide.
- It is vital to deliver accurate information to the public.
- Other stakeholder agencies, such as those responsible for incident management, need to be involved early.
- It is important to carefully consider how to set up automated information delivery and share this information with other agencies.

## 2.4. Detailed Review of Work Zone Technology Applications

The four systems described previously represent only a handful of the ITS solutions deployed and evaluated by transportation agencies. Since many of the systems contain similar technologies and have similar goals and operations, it is somewhat difficult to classify them into discrete categories. However to simplify the compilation of information from the literature, this report includes some general concepts that could be found in common amongst groups of deployments. The four technology divisions used in this review are as follows:

- Speed Monitoring Displays,
- Changeable Message Signs with Radar,
- Queue/Speed Detection and Alert Systems, and
- Video Detection and Portable Traffic Management Systems.

The state of the art systems described above fall in the latter two groups of technologies and are considered to be the more complex of the applications reviewed. The first three deployments (Springfield, Illinois; Lansing, Michigan; and Albuquerque, New Mexico) include video detection and from the standpoint of this literature review, would be included with the Video Detection and Portable Traffic Management Systems technologies. The latter system deployed in West Memphis, Arkansas contains several integrated components that are typically considered portions of traffic management systems (i.e., highway advisory radio, email alert system); however, this system is included in the Queue/Speed Detection and Alert System primarily due to the level of automation and lack of cameras.

The four technology classifications represent a continuum of simple to complex Intelligent Transportation Systems for work zones. In the sections to follow, evaluations of each of these four types of technologies will be reviewed in detail. Each technology division will include a table that summarizes the reference dates, sponsoring and conducting agencies, locations, and systems reviewed.

### 2.4.1. Speed Monitoring Displays

#### *2.4.1.1. Technology Description*

*Speed monitoring displays (SMD)* are at the least complex end of the smart work zone technology array. These devices are usually stand-alone systems that can be placed individually, or in a series. The system consists of a self-contained trailer unit equipped with radar to measure the speed of approaching vehicles. Approach vehicle speeds are displayed on LED panels along with the posted work zone speed limit, and a message stating "Your Speed". The systems are typically battery powered to last up to or more than one week. The objective of the system is to inform the drivers of their speeds and encourage them to slow down, thereby reducing speeds and increasing speed limit compliance. The systems may also include additional features such as strobe lights or horns that can be activated when critical speed thresholds are exceeded. Similarly, some LED speed display panels can also be set to flash when thresholds are exceeded. In states without prohibitive laws, a camera system can be installed for automatic enforcement. One potential drawback to these types of systems is that some drivers may intentionally exceed the speed limit to test the limits of the radar system and ultimately test their vehicles and driving abilities. This activity can be minimized by setting a maximum speed to be displayed. Figure 7 and Figure 8 depict speed monitoring displays developed by SpeedGuard and MPH Industries, respectively.

**Figure 7.** SpeedGuard Speed Monitoring Display

*Source: MWSWZDI, 2000*

**Figure 8.** MPH Industries, Inc. Speed Monitoring Display

*Source: Kamyab, 2000*

*2.4.1.2. Sample Applications and Results*

**Table 3.** Radar Speed Monitoring Displays Summary

| Sponsor/Research Organizations | Location | Road Name (Length) | System | Reference |
|---|---|---|---|---|
| South Dakota DOT<br>University of Nebraska | Sioux Falls, SD | I-90 | Fabricated by SDDOT | McCoy, et al., 1995 |
| Nebraska DOT<br>University of Nebraska | Lincoln, NE | I-80<br>(2.7 mi.) | SpeedGuard | MWSWZDI, 2000<br>Pesti & McCoy, 2002 |
| Kansas DOT<br>University of Kansas | Topeka, KS | I-70<br>(5 mi.) | SpeedGuard | Meyer, 2000<br>MWSWZDI, 2000 |
| Iowa DOT<br>Center for Transportation Research and Education | IA | I-35 | MPH Industries | Kamyab, et al., 2000<br>MWSWZDI, 2000 |

*South Dakota Study*

McCoy et al. (1995) evaluated the speed monitoring display for its influence on speeds within the active work zone. The South Dakota Department of Transportation fabricated a unit for the test which consisted of a self-contained trailer with radar measurement device and solar power. Mounted on the trailer were a work zone warning sign, a speed display with 9 inch digits, an advisory speed plate, and a "YOUR SPEED" guide sign. The research team tested the SMD on a section of I-90 near Sioux Falls, SD during a bridge replacement project. The AADT was 9,000. The interstate was in an urban area and the normal speed limit was posted at 55 mph. The work zone speed limit was posted at 45 mph. Researchers placed two SMDs on both sides of a two-lane section 310 feet in advance of the taper area. Data were collected on the day prior to the installation of the SMDs and one day approximately one week after installing the SMDs. Speeds were monitored at 3 locations near the site. Only free-flowing speeds were used in the analysis (defined as headway greater than 4 seconds).

The results of the McCoy study showed mean speeds of two axle vehicles reduced by about 4 mph, and vehicles with more than two axles had reductions of 5 mph. After the SMDs were installed, the number of drivers exceeding the speed limit was reduced in two axle vehicles by 20% and by 40% in vehicles with more than two axles. Researchers noted that the ultimate spacing between the SMDs and the standard MUTCD traffic control devices was small. This may have reduced the conspicuity of the SMDs, and therefore some drivers may not have had adequate time to comprehend the messages.

*Nebraska Study*

Several years later, SMD tests were undertaken by Nebraska, Kansas, and Iowa under the Midwest Smart Work Zone Deployment Initiative (MWSWZDI). The tests in Nebraska (MWSWZDI, 2000; Pesti & McCoy, 2002) were the most comprehensive. The objectives of the tests were to evaluate the long-term effectiveness of the SMDs in long duration work zones in rural areas. To evaluate, three SpeedGuard SMDs were placed in a work zone on I-80 near Lincoln, Nebraska. The researchers studied the site for over five weeks. The SMD trailer had LED numeric displays 24 inches in height reporting travel speed with an advisory speed limit sign and a message sign stating "YOUR SPEED". The available photo enforcement and audible alert features were not activated during the tests.

The study section of I-80 was a four-lane divided interstate highway between two relatively long sections of head-to-head operations. Drivers routinely used this section for passing maneuvers, accelerating well above the 55 mph posted speed in the work zone; therefore, speed compliance was a noted problem. The normal speed limit is posted at 75 mph. The ADT was 38,000 vehicles per day with 22%

commuter traffic and 21% truck traffic. The locations for the test SMDs were determined based on existing speed profiles.

For the test, speeds were measured once before the SMDs were placed and five times (once each week) over the next five weeks. Speeds were measured once again one week after removal of the SMDs to discern whether there were any residual effects. Only free-flow speeds were used in the analysis (defined as headway greater than or equal to 5 seconds). The researchers defined six measures of effectiveness (MOE) as:

- Mean speed,
- Standard deviation,
- 85$^{th}$ percentile speed,
- Percent complying with the speed limit,
- Percent complying with the speed limit plus 5 mph, and
- Percent complying with the speed limit plus 10 mph.

The analysis showed improvements in all MOEs at measurement sites downstream of SMDs during deployment. The improvement was about a 3 to 4 mph reduction in mean speed; 2 to 7 mph reduction in 85$^{th}$ percentile speed; and about a 20 to 40 % increase in speed compliance. None of the MOEs returned to the levels observed before deployment of the SMDs in the week after their removal. Therefore some residual effect is thought to exist. Persistent reductions of 3 mph mean speed and 4 mph 85$^{th}$ percentile speeds were observed for passenger cars over the five week period of SMD operations. The researchers noted that 78% of traffic was non-commuter traffic and drivers of those vehicles may have been seeing the SMDs for the first time. Long-term and residual effects should thus be studied at a location with higher commuter traffic percentages.

*Kansas Study*

In Kansas, researchers developed a five-tier data collection effort (Meyer, 2000; MWSWZDI, 2000). Prior to deployment of radar drones and subsequently SMDs (one device week each), the Kansas research team collected one week of baseline data collection. Immediately following the deployment of the SMD, the Kansas Highway Patrol provided active speed enforcement. Data were also recorded immediately following each enforcement period. The SMD had a few optional settings, including allowance of a maximum speed to be set for display, thus discouraging drivers from challenging their vehicles to obtain higher speeds (a practice common to teenage drivers on weekend evenings). A strobe was also activated when speeds exceed a preset threshold.

The speed monitoring display resulted in significant reductions in mean speeds, 85$^{th}$ percentile speeds, the percent of drivers exceeding the speed limit and speed variations. The impact of law enforcement on speeds was nearly identical to that of

the SMD. However, post-law enforcement speed analysis indicated that speeds not only increased to normal, but exceeded baseline speeds. The portability and ease of setup were noted as significant advantages of the SMDs. Kansas plans to further evaluate the distance over which the speed reductions deteriorate and potential enhancements to the display. Researchers mentioned displaying a projected fine based on the excessive speed measurement. This could be completed using standard changeable message sign with radar equipment.

*Iowa Study*

The system deployed in Iowa (Kamyab, 2000; MWSWZDI, 2000) is depicted in Figure 8. The display had 18-inch LED characters which were visible from up to 1000 feet away. This unit had an "over-speed" option, which flashes the drivers speed if it is above the speed limit. Researchers only observed modest speed decreases during SMD operations, and determined that the size of the display characters was too small for freeway operations. The researchers suggested that the device may be better suited for arterial operations.

### 2.4.2. Changeable Message Signs with Radar

#### *2.4.2.1. Technology Description*

The next tier of work zone technologies reviewed is the *Changeable Message Sign with Radar*. This type of sign can also be used as a standalone device or in a series. The changeable message sign is a typical three line display with a built-in radar to measure the speed of approaching vehicles. Figure 9 is a picture of a typical CMR. The radar signal is processed onboard, and depending on the preset speed threshold can display a variety of programmed messages. Typical messages may include a default message that says: "ACTIVE WORKZONE, REDUCE SPEED" or "RIGHT LANE CLOSED, KEEP LEFT <<<<", and a secondary message that is triggered when a speed threshold (e.g. 5 mph over the work zone speed limit) is exceeded stating: "YOU ARE SPEEDING, SLOW DOWN NOW." Unlike the previous speed monitoring display, these signs typically do not post the speed of the approaching vehicle, but instead post a message that alerts the driver that his or her excessive speed has been detected. Messages can be seen 400-500 feet in advance of the sign allowing sufficient viewing time by drivers.

**Figure 9.** Changeable Message Sign with Radar

*Source: Garber, 1998*

*2.4.2.2. Sample Applications and Results*

**Table 4.** Changeable Message Signs with Radar Summary

| Sponsor/Research Agency | Location | Road Name (Length) | Reference |
|---|---|---|---|
| FHWA, Virginia DOT VTRC | Misc. Sites in VA | 7 sites | Garber & Patel, 1995 |
| South Dakota DOT Benshoot & Associates | Sioux Falls, SD | I-90 | Wertjes, 1996 |
| FHWA, Virginia DOT VTRC | Misc. Sites in VA | I-81, South Bristol (0.5 mi.) | Garber & Srinivasan, 1998 |
| | | I-81, North Bristol (0.5 mi.) | |
| | | Route 19 (1 mi.) | |
| Georgia DOT Georgia Tech | Haralson/ Polk County, GA | SR 1/US 27 | Dixon & Wang, 2002 |

*Virginia 1995 Study*

Ten years had passed since the work of Richards et al. (1985, 1986), where CMSs were introduced into the work zone safety arena. The advances in technology related to ITS made CMSs readily available for many applications – including work zones. Garber and Patel (1995) studied the effect of switching from passive traffic control as specified in the Manual of Uniform Traffic Control Devices (MUTCD) to changeable message signs with radar to warn drivers that they are exceeding maximum safe speeds in the work zone.

The Garber and Patel study was designed to study the effects of different messages in varying environments. The researchers designed four messages and tested them at seven work zones. The messages ranked in order of effectiveness are as follows:

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

The objectives of the study were:

- Determine the speed characteristics (average speed, 85$^{th}$ percentile speed, and speed variance) of the work zones using both standard Manual of Uniform Traffic Control Devices signing and CMR technology;
- Assess the overall effect of CMR on speed characteristics in the work zone;
- Determine the effect of CMR on driver behavior – particularly high speed drivers; and
- Determine to what extent and under what conditions CMR will be most effective.

The Virginia team established several conditions for the determination of suitable target sites. The length of the work zone had to be at least 1500 feet in length, and 30% of traffic had to be considered free-flowing in order to determine drivers' desired speeds. Finally, general safety measures had to be accommodated. Seven sites were chosen on two interstates in Virginia. Speeds were collected at three stations: (1) the advance warning area – just before the transition; (2) the midpoint of active work zone area; and (3) just before the end of the work zone. For all messages tested, vehicle speeds were reduced at the midpoint and end of the work zone. The messages "HIGH SPEED, SLOW DOWN" and "YOU ARE SPEEDING, SLOW DOWN" appeared to have the greatest impact as they reduced speeds to values at or below posted speed limits. The sign "REDUCE SPEED IN WORK ZONE" had significant effects on average speeds at the midpoint of work zone activity, but speeds tended to increase at the end of the work zone.

The researchers recommended that the threshold for activation of the changeable message sign be set at 3 mph above the posted work zone speed limit. The

placement of the CMR should be just before the beginning of the transition area to allow it to capture the uninterrupted attention of drivers. The message "YOU ARE SPEEDING, SLOW DOWN" was recommended for the display since it had the most significant effects. Researchers also noted that the long-term effects were unknown and should be studied further.

*South Dakota Study*

In 1996, Wertjes released a report on evaluation of CMR technology in South Dakota. The study objectives were to identify a speed monitoring display suitable for use in highway work zones and to evaluate its effectiveness in reducing speeds. This report contains a comprehensive listing of equipment and features available at the time and serves as a good primer for those wanting to learn more about this technology. The researchers spent a significant amount of time evaluating various equipment configurations in terms of their structure/power source, communications features, operational ease, and cost effectiveness. The resulting device was a Lidar laser radar mounted on a CMS. The radar was set to trigger the CMS when approaching vehicles exceeded 70 mph. At this point, the message changed from the default "RIGHT LANE CLOSED, KEEP LEFT" to "YOU ARE SPEEDING, SLOW DOWN NOW".

The device was tested at a short-term (3-5 day) work zone project during the repair of a concrete pavement joint. The short duration resulted in the need to collect before and after data at different locations. The researchers used a data collection plan for automatic speed data collection similar to that of Garber and Patel (1995). Again, researchers chose a speed threshold that would activate the special CMS message for approximately one-third of the drivers. Twenty-four hours of data were collected in both the before and after periods. Speeds were filtered for headways under 5 seconds. Based on the results, the CMS was activated for approximately 20% of approaching vehicles. Decreases of 0 to 1.7 mph were observed in average speeds from the before to after studies which was not found to be significant. The researchers determined that this was not a significant speed change. There was a dramatic effect in the difference between vehicles traveling greater than 70 mph in the before and after periods – greater than a 10% reduction. Higher speed motorists were influenced by the CMR, resulting in significant reductions in 85$^{th}$ percentile speeds. The researchers suggested selection of a lower speed threshold could possibly further reduce average speeds.

*Virginia 1998 Study*

Garber and Srinivasan (1998) followed up the previous Virginia study of message content to determine effects of the CMR technology over long-term work zone deployments. They used the same selection criteria; however, this time there was also a requirement added for repeat driver traffic. The researchers conducted surveys

at rest areas, employment centers and ramps at each potential site to determine the approximate percentages of repeat drivers.

The Virginia team ultimately selected three sites for evaluation. Two sections of I-81 had 65% repeat drivers whereas a site at Route 19 had an 80% repeat driver rate. At two sites, data were collected on the first, third, fifth, and seventh weeks. The third site had a somewhat shorter timeframe and data were collected for three consecutive weeks. The three-station speed data collection set up was again utilized. The speed message for all three sites if triggered read "YOU ARE SPEEDING, SLOW DOWN". The threshold was set at 3 mph above the posted speed limit of 55 mph on I-81, and 45 mph on Route 19. The researchers also developed a sophisticated tracking system to track speeders through the work zone to discern patterns applicable to high-speed drivers.

At all three sites, the presence of the data collection team had a marginal effect on traffic speeds. The speeds were lower by 0.5 to 2 mph, however, the effects of the CMR were still clear with total speed reductions under CMR operations of 8 to 9 mph on average. Speed reductions were found to be significant even after seven weeks of exposure. The research team was not able to identify a specific relationship between the speed reduction and the duration of exposure. All vehicle types responded to the CMR with significance, and there were no significant differences between groups. The 95$^{th}$ percent confidence bands for the speed reductions at interstate sites ranged from 4.8 mph to 11.6 mph. Probabilities of speeding, average speeds, and 85$^{th}$ percentile speeds were all significantly reduced at all sites.

*Georgia Study*

In response to reported effectiveness of CMR in other states, the Georgia Department of Transportation funded a study of several work zone devices to test their effectiveness in Georgia work zones. The implementation of the CMR sign included a tiered message. For vehicles traveling 5 mph or more above the work zone speed limit (45 mph at the study site), the CMR displayed a message that said, "YOU ARE SPEEDING, SLOW DOWN NOW." For vehicles traveling below 50 mph, the CMR displayed a default message "ACTIVE WORK ZONE, REDUCE SPEED." Researchers selected a test site by evaluating recent work zone fatal crashes in Georgia. The rural non-interstate principal arterial construction zone represented the largest percentage of fatal crashes at 22 %. Roads with speed limits of 55 and greater accounted for 72% of the fatal work zone crashes, and 76% of these occurred on two-lane highway with adjacent construction. As a result, researchers chose a work zone site on a rural two-lane highway with adjacent work activity and uninterrupted traffic flow conditions. The site had free-flow conditions for most of the study period, thus changes in speed could be attributed to CMR versus reactions to other vehicles in the traffic stream.

Researchers collected traffic speed and volume data using NuMetrics Histar devices for periods before implementation, immediately after implementation, and a few

weeks after implementation to account for novelty effects. Immediately following the implementation of the CMR, the speeds in the direction of travel for the CMR reduced significantly by 6 to 8 mph. However, lanes in the opposite direction also experienced minor reductions up to 2 mph. Speed reductions attributed to the CMR ranged from 5 to 7 mph. Speeds in the active work zone remained constant and the influence of the CMR did not appear to extend into the active work area (a distance several miles downstream of the CMR placement).

The CMR continued to provide speed reductions throughout the three-week post implementation period. The opposing lane speeds remained constant. Therefore, the CMR provided long-term speed reductions adjacent to the sign. Researchers noted that it may be possible for a residual effect to continue into the active work area if the CMR was placed in closer proximity. Research to determine the zone of influence for the CMR would help to determine optimal work zone length for which this technology is suitable. Multiple CMR in series may also extend the effectiveness.

### 2.4.3. Queue / Speed Detection and Alert Systems

#### *2.4.3.1. Technology Description*

The third tier of technology, the Queue/Speed Detection and Alert Systems, embody even more properties of an Intelligent Transportation System. Composed of multiple sensors, multiple changeable message signs, and a communications medium, along with other optional features, these systems are considerably more complex than speed monitoring displays and changeable message signs with radar. The basic premise for the deployment of these systems is to provide the traveling public with information regarding the status of the traffic or safety hazards (i.e., slowing/stopped traffic conditions) through the work zone. By providing this type of information, drivers are able to better control their vehicles or adapt to conditions by taking alternate routes. These systems also help reduce the frustration levels experienced by drivers caught in work zone traffic by providing information that will help the driver understand what lies ahead. There are several manufacturers of these systems, most are proprietary in nature. The systems covered herein include: ADAPTIR, CHIPS, TIPS/ASIS, and IntelliZone. The TIPS, ASIS, and IntelliZone systems will be further evaluated in the associated research program sponsored by the Georgia Department of Transportation.

*TIPS*

The basic components, as implemented in the Traffic Information Prediction System, for example, include: multiple traffic sensors, a central computer, radio communications, and changeable message signs to provide travel time information to traveling public. The general outline of the operations for these systems typically

involves multiple steps. In the example of the TIPS system, there are six core operations components:

1. Microwave radar sensors located in the approach to the work zone and throughout the work zone detect vehicles in each lane;
2. A microcontroller at the sensor trailer calculates traffic volume and occupancy for each lane;
3. A radio, also located at the sensor trailer, transmits traffic flow data to a central computer usually located on-site at the field office;
4. The central computer runs a travel-time estimation model to compute the expected travel time through the work zone;
5. Radios are again used to transmit travel times from the central computer back to the work zone to portable changeable message signs;
6. Changeable message signs display travel time information to motorists (See Figure 10).

**(a)** **(b)**

**Figure 10.** TIPS System Changeable Message Signs

PDP Associates designed the TIPS system as a portable, real-time system for predicting and displaying travel times for motorists in advance of and through work zones. TIPS displays travel time messages on CMSs as shown in Figure 10. The messages take on the format "XX MINUTES TO END OF WORK ZONE" where XX is calculated at 30-second intervals and displayed in real-time. TIPS also allows custom messages to be delivered on the CMSs such as "ACCIDENT AHEAD" or "FREEWAY CLOSED AT RT. 123" during incident management and demand management scenarios.

*IntelliZone*

Figure 11 shows a representative equipment layout of a similar system developed by Highway Information Systems – the IntelliZone System. The major differences between the IntelliZone System and the TIPS system are in the message format and

the central computing/communications. In the IntelliZone system, the control unit (or central computer/processor) is located in the field in the last trailer position downstream. This unit communicates with the other units in the field as well as the changeable message signs collecting volume, speed, and headway data and analyzing the data to determine which messages should be posted. The messages are different in that there is no default message, rather messages are only displayed when there are reductions in speed or when queues begin developing downstream. Each changeable message sign receives messages based on the traffic data from the sensor located two miles downstream. Messages in the IntelliZone system are also generally speed or route related versus travel time/distance related as in the TIPS system.

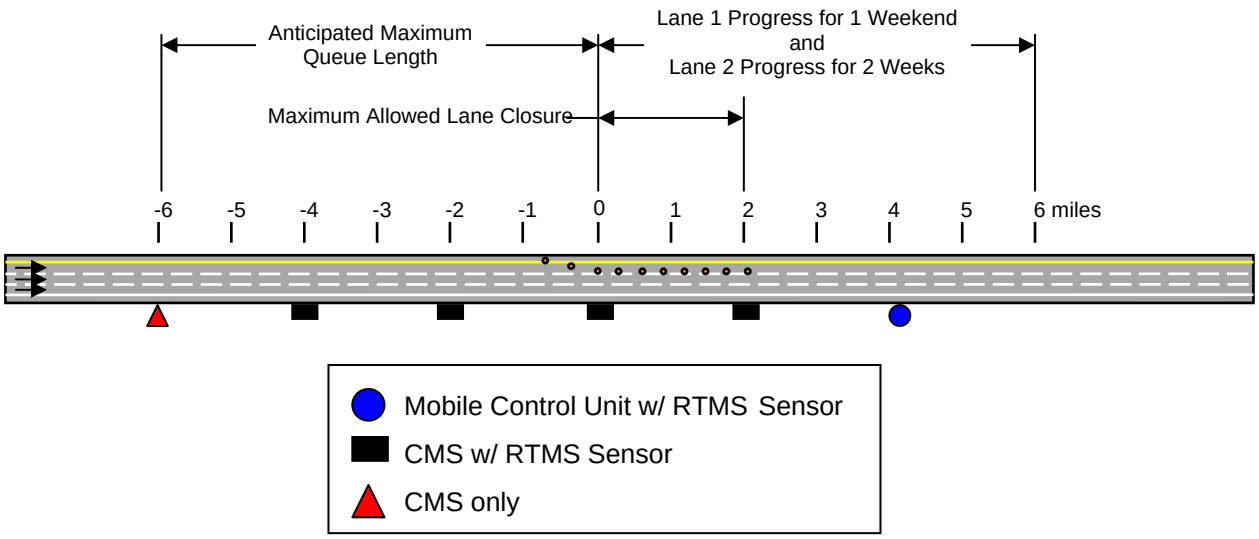


**Figure 11.** Typical Layout of the IntelliZone System by HIS

*ADAPTIR*

Scientex Corporation developed the Automated Data Acquisition and Processing Traffic Information in Real-Time (ADAPTIR) System in 1996 with funding from FHWA and the Maryland State Highway Administration (FHWA, 1999). Scientex designed the system to provide a flexible, cost-effective ITS solution building upon existing inventory of portable traffic management system equipment. The intent of the system is to forewarn drivers of closed lanes and congestion downstream; alert drivers to dangerous speed conditions; encourage diversion to alternate routes during excessive delays; and provide optimal radio messages for navigational assistance during detours.

The ADAPTIR system measures speeds using Doppler radar at several points within and upstream of work zone activity. Wireless communications allow transmission of data to the central control system, which analyzes data to determine areas of congestion.

Depending on conditions and the location of delay, the system chooses specific messages from preset scenarios and displays them on CMSs just upstream of the work zone as shown in Figure 12. The messages alert motorists of traffic conditions ahead. The system can display several classes of messages, as well as customized messages. The most common are lane closure messages, speed advisory messages, delay messages, diversion messages, and time stamp messages. Using the two-page format message, common messages displayed by the system include:

| PAGE ONE MESSAGE | PAGE TWO MESSAGE |
|---|---|
| 15 MIN DELAY AHEAD | SLOW TO 25 MPH ***NOW*** |
| ALT. ROUTE EXIT 19 | TUNE RADIO TO 530 AM |
| ROADWORK ADVISORY 2:24 PM | SLOW TO 25 MPH ***NOW*** |

**Figure 12.** ADAPTIR Enhanced VMS

*Source: FHWA, 1999*

**CHIPS**

ASTI Transportation Systems, Inc. developed the Computerized Highway Information Processing System (CHIPS) as an all-encompassing off-the-shelf traffic management program. The software system can handle a number of inputs (queue detection, over-height vehicle sensors, and flood sensors) and requires minimal programming to adjust to the users' needs. This system, like the ADAPTIR and TIPS systems described previously, allows sensors to send data to a control location via wireless communications. Based on preset criteria, motorists receive messages transmitted to CMSs and HAR based on the sensor input. Figure 13 shows the queue detection trailer used in the CHIPS system.

**Figure 13.** CHIPS Queue Detection Trailer

*Source: ASTI, 2003*

As an example of a common CHIPS system in operation, queue detectors are deployed adjacent to the highway, each with its own transmitter. CHIPS software runs on the central computer with a communications base station. Upon detection of a blockage, the queue detector triggers a wireless transmission to the control center where the CHIPS user interface displays the blockage. CHIPS in turn sends a signal to one or more CMSs changing the messages to reflect the change in traffic conditions.

*2.4.3.2. Sample Applications and Results*

**Table 5.** Queue/Speed Detection and Alert Systems Summary

| Sponsor/Research Agency | Location | Road Name (Length) | System | Reference |
|---|---|---|---|---|
| ADAPTIR<br>Scientex Corp.<br>MWSWZD1 | Lincoln/Omaha, NE | I-80 | ADAPTIR<br>Scientex Corp. | McCoy & Pesti, 2003<br>MWSWZDI, 2000 |
| ADAPTIR<br>Arkansas DOT | Carlisle, AR | I-40<br>(6.3 mi. rural) | ADAPTIR<br>Scientex Corp. | Tudor et al., 2003 |
| CHIPS<br>Arkansas DOT | North Little Rock, AR | I-40<br>(8.6 mi. urban) | CHIPS | Tooley et al., 2002<br>Tudor et al., 2003 |
| Wisconsin DOT<br>Marquette Univ.<br>Univ. of Wisconsin | Milwaukee County, WI | I-94<br>(12.5 mi. urban) | TIPS<br>PDP Associates | MWSWZDI, 2001 |
| FHWA<br>Ohio DOT<br>Univ. of Cincinnati | Dayton, OH | I-75<br>(13 mi. urban) | TIPS<br>PDP Associates | Zwahlen & Russ, 2002a & 2002b |
| Missouri DOT<br>University of Missouri | St. Louis, MO | I-70 | IntelliZone Highway Information Systems | MWSWZDI, 2003 |
| MWSWZDI<br>University of Nebraska | Green Bay, WI | US-41 | IntelliZone Highway Information Systems | MWSWZDI, 2003 |

*Nebraska Study*

The ADAPTIR system was tested in Nebraska (McCoy and Pesti, 2003; MWSWZDI, 2000) as part of the Midwest Smart Work Zone Deployment Initiative. Researchers tested the equipment as deployed at a work zone on I-80 between Lincoln and Omaha, Nebraska. The roadway section consisted of four lanes median-divided with head-to-head operations on either end. The average ADT was 38,000, and the area was rural. The ADAPTIR system included 3 CMSs with radar detection devices, 1 arrow panel with radar detection, wireless communications between the devices, and a control computer. Every four minutes (eight minutes in off-peak) speeds from the four sensors were measured and compared with those downstream. When the difference in speeds exceeded 10 mph between two stations, the CMSs displayed a speed alert message warning of downstream conditions.

Three video cameras were also located in the work zone allowing traffic counts and speeds to be determined through video image processing. The equipment measured and compiled average speed data for evaluation of traffic conditions. A third source of data included a rest-area driver survey. The researchers used three speed parameters (mean speed, 85$^{th}$ percentile speed, and mean speed of vehicles traveling faster than the 85$^{th}$ percentile) in lieu of speed data from individual vehicles since the data from the signs were saved in aggregate form. Researchers evaluated the relationships between CMS messages and speed parameters collected at the downstream camera locations. During higher-density flow conditions, the speed messages appeared more effective because of the combined effect of the increased density of traffic flow as well as driver response to the messages.

Speed alerts informed drivers of speed reductions downstream, encouraging and preparing them to slow down. In a period of 16 days, researchers collected 46.5 hours of speed data for analysis. During this period, three CMSs displayed 323 speed advisories. The closer the CMS was positioned to the lane taper, the more messages it displayed. CMS #1 displayed 130 messages, CMS #2 displayed 102 messages, and CMS #3 displayed 91 messages. Advisory speed messages ranged from 5 to 55 mph with the most frequent between 20-25 mph. Speed advisories of 50 to 55 were also common with speeds of 5 to 10 mph being least common.

The researchers did not find any statistically significant differences in the speed parameters before and after implementation at 500 and 2000 feet from lane closure taper. However, researchers noted that before and after data were collected during periods of un-congested flow and the CMSs displayed few messages. Failure to observe significance due to these factors is not surprising. The advisory speed messages had little effect on the 85$^{th}$ percentile speeds, whereas a stronger relationship existed for the 85$^{th}$ percentile and density of traffic. Advisory speed messages displayed during periods of lower density (< 45 vehicles per mile per lane) were not effective in reducing speeds. However, at higher density time periods, these messages were effective when located in close proximity to the work zone and where drivers were likely to perceive a need to slow down. Researchers considered the use of CMS spacings of 1.1, 2.0, and 4.7 miles to be too long and suggested studying optimal location of signs.

From the driver survey, respondents noticed the page on timestamp message ("ROADWORK ADVISORY X:XX XM" ) the least. Drivers did not seem to understand the meaning and questioned its usefulness. Most drivers understood the speed advisory sign; however, the drivers also said that they did not see a need to slow down and thus questioned the signs' reliability. The "XX MIN DELAY AHEAD" sign was also confusing to drivers. The drivers stated that they did not know where the delay was or what was causing it. Some had already experienced delay, and others said that the actual delay was much shorter than that projected. All drivers that encountered the sign "CONSIDER ALT. ROUTE" understood the meaning, but less than half thought it was useful because it did not indicate an

alternate route. The researchers suggested further research to determine the effectiveness of the sign messages and effect of blank signs.

*Arkansas ADAPTIR Study*

Tudor et al. (2003) studied the ADAPTIR system in Arkansas along with other smart work zone technologies such as CHIPS (discussion follows). The main goal of deploying such systems is to provide a queue detection system that will prevent/reduce rear-end collisions and provide real-time information to the motorists regarding potential backups caused by lane closures. The Arkansas deployment configuration was similar to that previously defined for the Nebraska study. However, the Arkansas system included 5 sensors, 5 CMSs, 2 HAR stations, 1 central controller and 2 supplemental speed detection stations. The total cost for 350 days was $322,500. The deployment was on Interstate 40 in Lonoke County between Highway 31 and the city limits of Carlisle. The construction zone was 6.3 miles in length, carried an ADT of 36,350, and maintained 43% truck traffic in a rural setting.

In operation, the system displayed downstream traffic information followed by delay through 40 preset messages. If the difference in speeds between two consecutive sensors was greater than 10 mph, the upstream signs displayed "REDUCE SPEED TO XX MPH" followed by "YY MINUTE DELAY." The system operated on a 10 minute cycle time. The HAR provided general project information as well as delay in minutes. Finally, the system also relayed messages to project engineers if delay exceeded 20 minutes.

The system encountered a few problems during deployment. The Remote Traffic Microwave Sensors (RTMS) sensors were difficult to calibrate due to the high percentage of trucks. Doppler radar detectors ultimately replaced the RTMS sensors in the system. Delay estimates were also not accurate enough and did not receive public approval. Operators simplified the messages to state "EXPECT DELAYS" or "EXPECT LONG DELAYS." Researchers considered the cycle length to contribute to flaws in the delay estimates. Loss of communications in the rural area also paralyzed the system in some instances.

To determine the accuracy of delay information, researchers compared actual travel times to projected travel times. Free-flow travel times were between 13 and 17 minutes for eastbound and westbound directions respectively. Researchers made 144 travel time runs divided evenly between the two directions to determine accuracy of the system estimations. Of the total, 14 runs fell outside of their pre-determined acceptable range of error (10%). The maximum overestimate was 12 minutes and 35 seconds, and the maximum underestimate was 2 hours and 11 minutes.

A fatal crash comparison between the ADAPTIR equipped site and two similar sites without smart work zone technologies revealed a reduction in fatal crash rates at the

ADAPTIR project site. Rear-end crashes at the site were lower than one of the comparison sites, but higher than the other. The project engineer stated that he believed the system enhanced crash prevention and congestion management, but did not believe there were any changes in incident response times.

*Arkansas CHIPS Study*

Tudor et al. (2003) studied the CHIPS system deployed on an urban section of I-40 from Highway 67 to the Lonoke County line in North Little Rock. The section has an ADT of 44,000 and a truck percentage of 35%. The construction zone in this area is 8.6 miles in length. The system consisted of a central system controller computer, HAR, one CMS and six traffic sensors in the westbound direction, and one CMS and nine traffic sensors in the eastbound direction. The cost of the system for 1000 days of deployment was $490,000. The system provided motorists with real-time traffic, delay and diversion advisories; and operators received pager and email alerts when traffic reached preset thresholds.

The sensors were located throughout the work zone area in both directions to provide accurate information regarding traffic delays due to the construction activities. The two CMSs were located prior to alternative route diversion points to provide information to travelers prior to the opportunity to take the alternative route. The system had a cycle time of 5.8 minutes and 80 pre-programmed message scenarios. Preset messages included:

| PAGE ONE MESSAGE | PAGE TWO MESSAGE |
|---|---|
| XX MILE BACKUP YY MILES AHEAD | BE PREPARED TO STOP |
| SLOW TRAFFIC AHEAD | BE PREPARED TO STOP |
| DRIVE SAFELY | BUCKLE UP |

As with many ITS system deployments, the research team experienced a few technical problems. A loss of phone lines required the team to utilize DSL/Cable modems for data transmission. Cell phone communications with sensors and signs experienced carrier drops especially during queue conditions when motorists were clogging the cellular towers. The team reverted to POTS lines (plain old telephone system) to communicate with success. Operators also added a second computer at the central control facility to handle utility tasks such as email and paging. The master computer running CHIPS continued to monitor and operate the field devices.

To determine the accuracy of the messages, researchers collected actual travel time information by driving through the work zone repeatedly. Of 77 runs made through the work zone, 69 (or 90%) of the corresponding messages matched the actual travel times. Researchers also collected traffic counts on Highway 70 – the alternate route for westbound travel. The analysis of this data in comparison with the sign data revealed a direct correlation between traffic volume increases on Highway 70 and delay messages appearing on the CMSs. Westbound traffic increased by a factor of

2 for vehicles, and a factor of 9 for trucks on Highway 70 when a range of delay messages were posted on the CMSs. The project engineer stated that the system worked well and appeared to be effective in preventing/reducing rear-end collisions and enhancing congestion management. He also stated that public confidence in the system was high, and that he had received several positive comments.

Tooley et al. (2002) also examined the effectiveness of the CHIPS system along with studying levels of traffic flow leading to congestion where two-lane sections of roadway reduce to one-lane. Operators provided CHIPS data logs and researchers collected simultaneous speed and video for validation of the system messages. The CHIPS system recorded backups when vehicles traveled at speeds less than 30 mph. The researchers set their delay threshold to travel speeds of 50 mph or less. In total, researchers made 726 paired-comparisons. The analysis showed that field observations agreed with CHIPS projections 88% of the time. This result is similar to that of 90% accuracy reported by Tudor et al. (2003).

Researchers collected volumes to identify levels at which backups occurred in work zones at five different locations on I-40 between North Little Rock and West Memphis. Researchers counted the number of times different flow rates (e.g., between 1200 and 1299 passenger car equivalents per hour) resulted in a back up. Three and five minute moving sum flow rates had higher predictive powers than that of one-minute intervals. Shown in Figure 14 is a graph of the probability of backup with a three-minute interval.

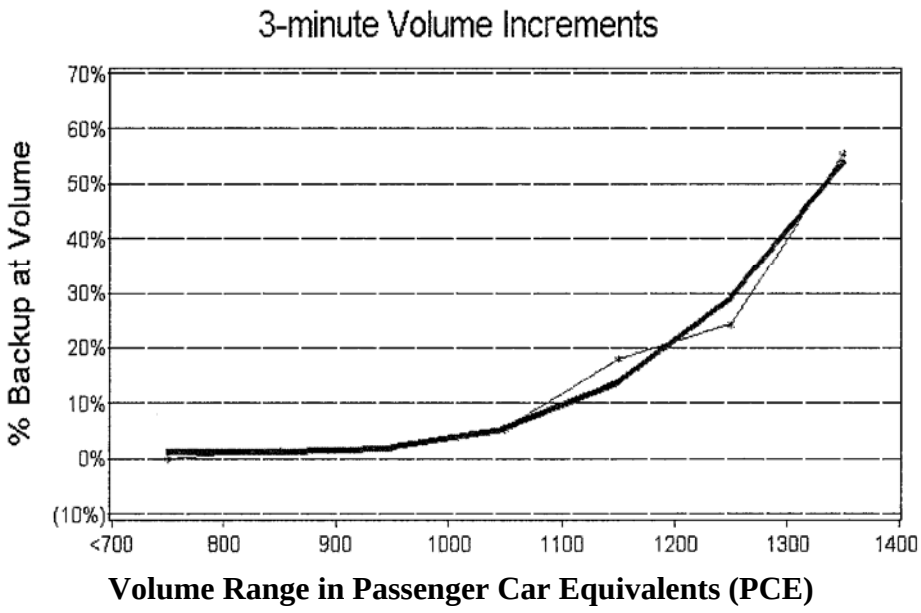


**Figure 14.** Probability of Backup Occurring with 3-minute Moving Volume Interval

*Source: Tooley et al., 2002*

All observed backups began in the one-lane section and propagated upstream. Researchers noted no instance of backups occurring from the merge area. Once backups formed, they tended to persist. Contractor activities can contribute to formation of backups. These activities can include repositioning equipment and obstructing traffic, and construction vehicles slowing to exit into the active work area while in the remaining open travel lane. Short taper exit ramps can also cause vehicles to slow unnecessarily low in the remaining travel lane.

*Wisconsin TIPS Study*

Notbohm et al. (2001) studied the TIPS system deployed in Wisconsin on I-94 in Milwaukee and Racine Counties. The system consisted of four CMSs positioned prior to freeway entry and exit points so that drivers would have the opportunity to exit (or not enter) the freeway under delay conditions. System operators placed the signs on I-94 prior to two exits, and on two arterials prior to entry to the freeway. The length of the corridor had three 12-foot lanes in each direction with a median divide. The corridor was inside the urban area to the north, and rural to the south. Isolated development was present at most interchanges. The weekday ADT was 79,263 vehicles per day in 1999, with traffic peaking on Fridays between June and August at 100,849 vehicles per day. The directional split was 50/50.

The evaluation focused on measuring the accuracy of predicted travel times. Researchers obtained data from two CMSs installed on I-94. Trip diversions were also evaluated during periods of active messaging. The research team collected actual travel times by driving through the work zone during high traffic periods on Thursday, Friday and Sunday. TIPS system logs collected information regarding CMS message postings and traffic conditions. Researchers collected 210 travel time runs for analysis.

TIPS displays travel times in 4-minute increments (4, 8, 12, 16, 20, etc. minutes) and updates the system at 3-minute intervals. Therefore, the evaluators considered the frequency with which TIPS travel time predictions were within +/- 4 minutes of actual travel times. Based on the 4-minute increment travel time, inherent error is built into the system. In general, researchers found the actual and predicted travel times to match well. The percentage of TIPS predictions within the +/- 4 minutes was 45.2% for CMS 1 and 57.7% for CMS 3. Predictions exceeding 4 minutes accounted for 41.8% and 27.1% of the observations for CMS 1 and CMS 3 respectively; whereas, under predictions were 13.0% and 15.2% respectively. In total, 67.3% and 75.8% of the differences were within +/- 5 minutes of the actual travel time respectively. The average difference was -2.1 minutes for CMS 1 and -1.0 minutes for CMS 3. Overall, differences in actual and TIPS travel times were small for practical purposes. Posted travel times exceeding their median value led to only modest travel diversions.

Researchers recommended revisiting the +/- 4 minute criterion. Four minutes represented 25% of the actual travel time for the corridor under free-flow conditions, and system designers considered this value reasonable for performance monitoring. Additional detectors would also provide benefit if installed along the entire length of the construction zone, especially near potential bottlenecks – sensing congesting much sooner than the evaluated system.

*Ohio TIPS Study*

Helmust Zwahlen and Andrew Russ (2002a and 2002b) studied both the accuracy of the travel times as well as motorist acceptance of the TIPS deployment in Ohio. The work zone was along a section of I-75 near downtown Dayton, Ohio and this site experienced regularly recurring congestion problems. The system consisted of three CMSs and five sensors. The CMSs displayed travel times to the end of the work zone and alternated with a message giving the miles to the end of the work zone. As with the Wisconsin deployment, the system predicted travel times in 4-minute increments, with updates at 3-minute intervals. Researchers aided by ODOT crews collected travel times runs over three 12-hour days collecting 119 runs in total. Researchers found that readings from any CMS or for all CMSs were accurate within +/- 4 minutes 88% of the time. At half that range (+/- 2 minutes) the data are still stable at 65-70% of travel times falling in that range. If +/- 2 minutes was required for 90% of the observations, the system would fail. For a travel time of 8 minutes, a +/- 4 minute difference represents a 50% error. At a predicted travel time of 12 minutes, a +/- 4 minute difference still represents a 33% error. Researchers recommended refinement of the prediction time steps (presently 4 minutes), the holding time (presently 3 minutes) as well as the prediction algorithm to possibly increase prediction accuracy.

While collecting travel time data, ODOT crews recorded 3177 license plate numbers from passenger vehicles within the traffic stream. ODOT mailed a questionnaire to each of the registered addresses of these vehicles. Drivers completed and returned 660 surveys. About half of the respondents were frequent users of the roadway section under construction. Approximately 42% of the respondents reported that the travel times were sometimes accurate and reliable and sometimes not accurate nor reliable. Therefore, drivers perceived a certain inaccuracy in the system. The system represents a definite improvement over static signs. Almost 97% of public respondents felt that the system was helpful and useful.

*Missouri IntelliZone Study*

Researchers at the University of Missouri and University of Nebraska completed two evaluations of the IntelliZone system under the MwSWZDI in 2003 (MWSWZDI, 2003). The system deployed in Missouri and tested by the University of Missouri, consisted of three mobile count stations, two CMSs, and one mobile command unit

located between the sensors and signs. The mobile command unit collected information on average speeds from sensor units and then sent appropriate messages to the CMSs. The study site was on I-70 eastbound just west of St. Louis, Missouri. CMSs were located 2 and 5 miles in advance of the work zone taper. Four objectives for the evaluation included determining whether the system:

1. performed as described,
2. affected the speed pattern positively,
3. reduced traffic conflicts, and
4. was understood and accepted by the traveling public.

Driver surveys administered downstream of the work zone allowed for the evaluation of driver understanding and acceptance. Detectors located upstream of the work zone measured speeds, speed variances, and headways for analyzing performance and changes in speed. The researchers did not evaluate a reduction in traffic conflicts (as originally proposed) due to inconclusive video footage. Researchers had a difficult time obtaining data during congested periods due to nighttime construction practices. In some instances, delays did occur and reached beyond the CMSs, therefore drivers were reacting to the queues and not to the CMSs.

Approximately 1.5 hours of dynamic operations showed positive changes in speeds approaching the work zone. However, researchers noted no changes in speed in the left-most lane and changes in the right-most lane occurred only 2 miles prior to the work zone with modest reductions of 1-2 mph. The IntelliZone system had a continuous effect on traffic patterns with reductions in speed variance between the travel lanes even during uncongested periods.

A convenience sample of survey drivers indicated that 66.3% of drivers slowed down after seeing the message signs. Only 16.9% said the signs had no effect on their driving. Although the researchers were not able to interview drivers who were likely to have changed their route choice significantly due to the signs, 3.6% of the interviewed drivers (all under the age of 25) said that they did make some changes to their route as a result of the signs. This younger group also indicated that they did not slow down in response to the signs. While almost all drivers said they could read and understand the signs (90%), a small percent (4.1%) indicated that they could not read the entire message, but still understood the meaning.

*Wisconsin IntelliZone Study*

The IntelliZone system deployed in Wisconsin on US 41 incorporated 3 sensors, 3 CMSs and a Mobile Control Unit. Based on data from the RTMS sensors, the system computed a “decision speed” based on a volume-weighted average of speeds over all lanes for the previous three minutes. The decision speed was posted at 10 mph increments. The sign was blank when speeds were greater than 50 mph. “STOPPED TRAFFIC” messages were displayed when speeds were less than 10 mph. Speeds between 10 and 50 mph triggered speed advisory messages alternated

with the phrase “ACTUAL SPEEDS AHEAD” (see Figure 15) so that the driver knows what actual speeds to expect downstream. Researchers chose the construction site due to heavy volumes from urban peak traffic conditions. The section of road was two lanes in each direction reduced to one during active construction.

**Figure 15.** IntelliZone Enhanced CMSs

*Source: MwSWZDI, 2003*

The analysis data set included a driver questionnaire and IntelliZone data files paired with queue observations. Drivers exiting to go to the gas stations downstream of the construction were administered the questionnaires. The majority of the drivers were passing through Green Bay, Wisconsin. Approximately 73% of respondents were male, and the majority of the respondents were between the ages of 25 and 45. Around 16% stated that they normally traveled through the work zone, but avoided it on this occasion. When asked about the accuracy of the speed advisory signs, only 12 out of 122 drivers rated the signs as inaccurate. Most drivers who could rate the signs indicated that they were satisfied with the system.

Based on queuing observations during data collection, queues only extended one mile upstream of the taper, well downstream of the two other IntelliZone sensors. The two upstream signs remained blank during the data collection. The lack of sensors within the work zone did not allow drivers to be warned of stopped conditions upstream of the work zone. Researchers recommended that the system developers revise the decision speed formula because speeds in different lanes can vary greatly. Additional detectors placed in the work zone and between the signs would enhance the systems ability to display the most appropriate speed reductions. Finally, the decision on the number of signs to deploy and the location of the signs should be based on queue length estimates and probability of incidents.

### 2.4.4. Video Detection and Portable Traffic Management Systems

#### *2.4.4.1. Technology Description*

The final category of technologies encompasses those technologies using *Video Detection* as well as those systems that require minimal to more involved human intervention during normal operations. These systems are usually classified as *Portable Traffic Management Systems (PTMS)* and may contain any number of technologies coordinated into a comprehensive system. These systems tend to be somewhat automated, but also tend to include such things as verification by human inspection, and incident specific messages posted by system managers. Three of the four system deployments (Springfield, Illinois; Lansing, Michigan; and Albuquerque, New Mexico) identified in Table 2 would be classified in this category.

#### *2.4.4.2. Sample Applications and Results*

**Table 6.** Video Detection and Portable Traffic Management Systems Summary

| Sponsor / Research Agency | Location | Road Name (Length) | System | Reference |
|---|---|---|---|---|
| PTMS Smart Work Zone Operational Test (FHWA) MN DOT | Minneapolis, MN | I-94 & I-35 | (Video detection, Control Center, Driver Info, Radio Comm., ISDN) ADDCO, Inc. | SRF Consulting, 1997 |
| RTCMSC (MWSWZDI) Brown Traffic Products | Lincoln, NE | I-80 (2.7 mi.) | (Video detection, CMS, NDOR Radio) Brown Traffic Products | MWSWZDI, 2000 |

**Figure 16.** PTMS Skid Deployment

*Source: SRF Consulting, 1997*

*Minnesota Study*

Beyond the deployments covered in the state-of-the-art review section, this section identifies two additional studies. The Minnesota Department of Transportation conducted one of the first PTMS studies (SRF, 1997). The portable traffic management system had been developed previously for implementation at non-recurring sporting events and other traffic generators. The current test included an implementation of this same system in a highway work zone application. The goal of the study was to provide real-time information to motorists as they approach and pass through the work zone. The objectives for providing such information are improved safety for motorists and workers, as well as reduction in delays experienced by motorists. The test was federally funded and independently evaluated.

The PTMS work zone application was comprised of four subsystems:

- Vehicle detection / surveillance (video detection with machine vision capability),
- Traffic control center (system operators review information from detection system and post messages),
- Driver Information (Messages from traffic control center posted to CMSs and internet), and
- Communications (Spread spectrum radio and cellular digital packet data using Integrated Services Digital Network format).

The major field components of the system were deployed on portable skids. The skids housed cameras, communications hardware, central processing units, and message boards as shown in Figure 16. The skids were placed at strategic locations in the area of the work zone. Through wireless communications, the skids became nodes in the portable traffic management system.

Machine vision cameras allowed the skids to report traffic volumes and speeds as well as to provide incident detection services directly to the TMC. The cameras also allowed TMC operators to verify incidents and deploy appropriate traffic controls, including messages posted on the CMSs attached to the skids. Highly accurate pan, tilt, and zoom mounts allowed the cameras to be returned to appropriate machine vision settings automatically. However, the cameras were susceptible to issues of wind and settling of the skid and require slightly higher maintenance.

Utilizing various sources of wireless communications and TCP/IP protocols, the system allowed for ease of integration with existing TMC functions. The skids pass information over spread spectrum or digital wireless data channels between one another. Communications with the TMC were handled via phone lines. The cost of a basic PTMS with all communications equipment was $78,850, and additional nodes were $59,850.

The system was evaluated based on traffic operations benefits; functional characteristics; operator, worker and motorist perceptions; and overall costs. Traffic counts, volumes, and speeds from the PTMS as well as from the permanent TMC stations were used in the evaluation of the benefit of traffic operations. A telephone survey of motorists and interviews with system operators and construction workers comprised the data sources for the user perception evaluation.

The PTMS was deployed at two construction work zones. The first location, I-94 between downtown Minneapolis and St. Paul, was chosen for its high volumes, complex geometry, lack of full TMC surveillance, and its proximity to the existing TMC facility. The ADT at this site was 141,000 and two travel lanes were required to remain open throughout the construction period. The deployment of the PTMS occurred in the last two months of the construction.

The second test was located on I-35 in Lakeville, MN and included the reconstruction of 2.5 miles of rural mainline concrete interstate and a new folded half diamond interchange. This site was chosen because of its rural nature, high traffic volumes (58,000 ADT), extended lane closure from two to one lane, and construction schedule. Again, the system was deployed in the latter stages of the construction project for a one month test.

Measures of effectiveness (MOEs) for traffic operation included: average speeds, average travel time, accident reduction, consistency of speed in and approaching the work zone, and change in volumes or diversion of traffic. The analysis of the data from I-94 showed an increase in traffic volume entering the work zone after the deployment of the PTMS. It was assumed that these increases occurred due to added capacity under more orderly traffic conditions. There was a 3.6% increase in the AM peak and a 6.6% increase in the PM peak. These changes were significant at the 90% and 99% confidence intervals respectively. The research team also noted a reduction in the use of the alternate routes, and this observation was assumed to be related to increased confidence on the part of the motorists resulting from having real-time information about traffic conditions in the work zone. By analyzing speeds from the I-35 site, researchers found that the variability in speeds within the work zone decreased by more than 70%. Therefore, speeds were much more uniform within the work zone. While no significant speed decreases were noted in the work zone, the research team did observe a decrease in speeds of 9 mph in the approach area.

Drivers passing through the I-94 site were identified by license plate and contacted in a telephone survey. Approximately 66% of those surveyed remember seeing the PTMS messages, and 79% of those remembering the messages actually remembered specific message content. Approximately 61% said they were ‘much’ more or ‘somewhat’ more informed than in other work zones, and 90% said they received the information that they needed. The survey also determined that the messages were easy to read (96%), easy to understand (99%), displayed far enough in advance

(83%), correct (76%), and useful (60%). Overall the PTMS was well received by the public.

*Nebraska Study*

As part of the MWSWZDI (MWSWZDI, 2000), Nebraska developed and deployed the Real-Time CMS Control System (RTCMSC). The research team tested the system on a section of interstate where speed monitoring displays and ADAPTIR technologies were also tested. The section of I-80 near Lincoln, NE was a four-lane divided highway with two-lane head to head operations on each end of the work zone and an ADT of 38,000. The system provides real-time traveler information on changeable message signs located in advance of diversion points. The objective was to provide the motorist with information on congestion within the work zone so that diversions were possible. The system was comprised of a video detection system and a portable CMS.

The video detection was used to measure speeds of traffic entering the work zone. A default message "RIGHT LANE CLOSED, 2 MILES AHEAD" was normally displayed on the CMS. However, when congested conditions were detected, the message "DELAYS!! CONSIDER ALT. RTE." was posted. Congested conditions were equated with three or more consecutive vehicles with entry speeds less than 20 mph. The special message would display for 13 minutes before defaulting back to the normal message. The camera was placed at the entrance of the work following the lane closure taper. The CMS was located approximately one mile in advance of the Highway 6 interchange. Highway 6 provided an alternate route to I-80 via Highway 31.

The objective of the study was to divert traffic and was not expected to affect speeds. The RTCMSC was evaluated purely on its effectiveness in diverting traffic. Entry and exit ramp counts were collected as well as volume data from the video image processing system. The time periods when special messages were displayed were extracted from the system log files. Exiting traffic volumes for the congested periods were also identified. The diversion message increased the percentage of traffic on the exit ramp and decreased the traffic on the mainline by 4.5%. Researchers noted that providing further information on the alternate route may have increased the diversion percentages.

There are a broad range of deployments within this technology area. While the latter system was fully automated, the location of the CMS was meant not to act as an immediate traffic control, but rather as a source of traveler information. The use of video detection also requires additional set up and maintenance that other systems do not. Thus the complexity of the system and its intended purpose direct its inclusion in the video detection and PTMS section.

## 2.5. General Guidelines for Application of Portable Work Zones

Where formal traffic management systems do not exist, several states have used portable Work Zone Intelligent Transportation Systems (WZITS). Several manufacturers as reviewed in the section on Speed/Queue Detection and Alert Systems have developed systems requiring little or no day-to-day human intervention. Faced with increased congestion and increasing construction and maintenance on the nations interstate system, many more DOTs will be considering the use of these systems based on manufacturer claims. Fontaine (2003) documented general guidelines that can be used in deciding if these systems are appropriate and for what types of activities. By reviewing studies and interviewing DOT personnel, Fontaine discovered that many evaluations of the previous deployments have not conclusively proven their benefit. This lack of proof is traced to several factors:

- Technological problems with early deployments precluded operational data from being collected,
- Sites were not conducive (i.e., congestion was not present)
- Research was focused on functional aspects, not on operational effects.

Given this information, Fontaine et al. suggests that further deployments with well-planned evaluations need to be conducted. However, based on the lessons learned to date, they suggested several application guidelines as follows:

- Presence of congestion – this is the most basic pre-requisite. If there is no congestion, no messages will be displayed and the system will not be beneficial. Capacity analysis of work zones should be performed and operations for the entire day should be examined (not just the peak hour). The percentage of commuter traffic should also be taken into consideration. When congestion occurs at the same time of day and there is a large percentage of commuter traffic, drivers become to expect the situation and expensive WZITSs will not be of much added benefit. However, if congestion is maintained, and travel speeds and times are variable, then a system may be worthwhile.
- Duration of work activities – WZITSs should only be used on long-term (several month) construction and maintenance projects. The expense and set up time are prohibitive for short-term projects at current.
- Speed Advisory Messages (SAM) – SAMs only appear to be effective in congested periods (density > 40 vpm).
- Delay, travel time, and alternate route messages – Provide drivers with information that potentially allows them to choose a new route to avoid delays. Alternate routes imply improved travel times – this should be analyzed under diversion scenarios. Viable alternate routes must also exist if this message is given. In general with all of these messages, an alternate route should be conceived by the DOT with considerations for local operations.

Pearce (2000) wrote a short article for Traffic Technology International entitled, "Filtering Through." The article discusses the problems facing the nation's interstate

system as it undergoes significant amounts of maintenance and reconstruction. Pearce recognizes ITS as the core of a program to manage traffic conditions during roadway construction. He defines several objectives which influence the decision for determining which ITS alternative configurations should be considered for deployment; these include:

- Protecting the roadway construction workers,
- Protecting motorists passing through the work zone,
- Maintaining as much workable traffic capacity in the work zone, and
- Reducing demand for capacity.

He goes on to provide consequences if these objectives are not met:

- Unsafe working and driving conditions,
- Economic damage to adjacent areas,
- Congestion, including worsened noise and air quality, and
- Self-diversion through sensitive areas.

ITS components alone cannot handle these objectives, but when paired with traditional methods offer significant opportunities. Pearce suggests various elements including traveler information, alternative route development, transit, creative contracting, and construction scheduling combinations for optimal benefit.

## 2.6. Recent Developments in Portable Changeable Message Signs

"In the last 15 years, the ability to provide real-time information to motorists through changeable message signs has assisted in efforts to improve roadway safety and operations" (Dumke, 2002). By providing information, motorists can make informed choices based on their individual goal system, thereby reducing the strains on the overall transportation network. The key word here is in the provision of 'information'. To assure the effectiveness of CMSs, the information they display must deliver the appropriate messages in a clear and precise manner. Over the last few years, several papers have addressed the effectiveness of CMS message formats. Since CMSs are key to most of the technologies reviewed herein, a few new developments in this area are presented here.

The first paper by Dudek (2000) reviews appropriate formats for work zone message signs regarding the delivery of time of day, day of week, and month dates in sign messages. The New Jersey Department of Transportation initiated the laboratory research to deliver shorter alternative messages for time information than those previously used. Among numerous findings, Dudek found that a dash can be used in place of "THRU" to indicate construction over successive days. The term "WEEKEND" is not a good descriptor for work beginning on Friday evening and ending on Monday morning. The terms "DAY" and "NIGHT" did not connote specific daytime or nighttime periods for work. The term "NIGHT" is acceptably shortened to "NITE". Drivers did not easily interpret calendar dates to specific days of the week, and therefore dates should

not be used. Dudek's paper is a good resource for questions regarding the delivery of time/date information.

Trout et al. (2002) followed up the work conducted by Dudek for New Jersey and studied driver reaction to CMS messages in the Texas driver population. Laboratory studies proved to have results similar to those reported by Dudek. In addition, these researchers added a test of motorist understanding of travel time messages. Test messages provided travel times with and without the time of day included the following:

| MESSAGE #1 | MESSAGE #2 |
|---|---|
| TRAVEL TIME | TRAVEL TIME |
| TO DOWNTOWN | TO DOWNTOWN |
| 20 MINUTES | AT 7:20 AM |
| | 20 MINUTES |

The majority (80%) of all drivers perceived both messages to mean that travel time to downtown would take 20 minutes. Thus, no significant difference between the formats existed. When asked if they thought it would take less than 20 minutes, exactly 20 minutes, about 20 minutes, more than 20 minutes, or whether the driver was unable to discern the travel time, 76% of participants indicated that the message without the time stamp means that the travel time would be "about 20 minutes". Little perceived difference was found for the message displaying the additional time stamp. From this, approximately 90% of the drivers understood that travel time is an approximation. Only 10% of the drivers interpreted the message to mean exactly 20 minutes.

In 2003, the Federal Highway Administration released the *Portable Changeable Message Sign Handbook*. This document covers topics from what is a portable changeable message sign (PCMS) to placement and maintenance of the signs. Sections include:

- What is a PCMS?
- When should a PCMS be used?
- PCMS screen characteristics,
- PCMS Message Design Process (including abbreviations and content),
- Placement of PCMS,
- When to discontinue PCMS or Alter Message, and
- Operational Issues.

This document should be available to all offices that use PCMSs. While the document is by no means all encompassing, the contents provide sufficient general guidelines and information for successful deployment of PCMSs.

Finally, Wardman et al. (1997) completed a stated preference study regarding driver response to CMSs in the United Kingdom. The findings of this study showed that information on delay was valued at 1.3 to 1.7 times more than travel time depending on the cause of delay. Drivers valued the term "LONG DELAY" at between 35 and 47 minutes, while "DELAYS LIKELY" was valued at between 10 and 31 minutes. Delays attributed to accidents had the biggest impact on route choice, while no cause produced relatively little effect. These findings suggest that information portrayed on the CMSs

can have a profound effect on a driver's route choice. The fact that quoting or not quoting a cause can influence a driver's response could be employed to influence diversion. Lastly, researchers noted that a blank CMS is interpreted differently from a positive ALL CLEAR message – with driver's second guessing the motives of the operators.

### 2.7. Summary of Literature Review

This review demonstrates that the use of ITS technologies in highway work zones is a promising area with a wide variety of available and evolving technologies. The current "Smart Work Zone" projects also are subject to many targeted objectives.

Common ITS work zone applications include speed monitoring displays, changeable message signs with radar, queue or speed detection and alert systems, and video detection and portable traffic management systems. Implementation goals for these technologies include providing drivers accurate information, encouraging alternative routes during congested conditions, modifying vehicle operations such as reducing speeding, and monitoring queue conditions adjacent to the work zone to help better manage work activities.

A frequent observation by researchers for the previous ITS studies is that these new technologies are still evolving and, as a result, deployment of these technologies may include hardware configuration malfunctions. With each new deployment, however, these configuration difficulties are minimized and should eventually be addressed so that this issue is no longer an obstacle for implementation of ITS technologies.

For previous ITS studies where driver surveys were performed, a common observation by researchers is that the survey respondents are very appreciative of the new technologies. There did appear to be some concerns by drivers regarding the accuracy of the displayed information, and drivers tended to comment that messages suggesting that drivers seek alternative routes are not helpful unless they also include route options.

In general, the evaluators of "Smart Work Zone" ITS technologies focused on system performance and the influence of the technology on adjacent traffic conditions. Previous researchers have extensively tested sign messages, triggers for these messages, system communication strategies, and sign message visibility. In addition, common operational evaluations included work zone and upstream speed evaluations.

Though the conclusions by previous researchers for various technologies are mixed regarding operational effects, it appears that in no case did the deployment of these technologies worsen operational conditions. In addition, the reception by the driving population has been overwhelmingly positive. As a result, the application of "Smart Work Zone" technology appears to be promising; however, it is clear that there is a need to define the specific benefits of each system and better identify when each unique ITS technology should be used to help maximize the benefits and minimize the expense for unique work zone scenarios.

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# CHAPTER 3. CMR DATA COLLECTION PLAN

As previously indicated, this study examines the effects of CMRs and portable ITS systems on Georgia highway construction zones. Due to the extreme differences in facility type (two-lane rural highway for CMR and freeway for ITS) as well as the different data collection techniques needed for the varying technologies, this chapter reviews only the CMR data collection plan. The portable ITS systems data collection summary is included in Chapter 6.

The GA Tech team tested the CMR influence on operating speed using a before-after study approach. The following sections review the specific location and data collection performed for the CMR evaluation.

## 3.1. Site Selection

In the previous GA Tech work zone study (Dixon & Wang, 2002), the CMR evaluation occurred at a rural two-lane tapering to one-lane (in each direction) transition area at the upstream end of a work zone. For the CMR analysis summarized in this report, the research team worked with Mr. Russell Merritt, GDOT District Two Construction Engineer, to locate a suitable evaluation site where the CMR could be tested adjacent to the work activity area. The site selected had to operate, in general, under free-flow traffic conditions (to assure the perceived changes in speed are due to the CMR and not work zone congestions).

The site selected was State Highway 88 located in Jefferson and Washington Counties. The construction zone extends from County Road 106 (in Washington County) to State Route 171 (in Jefferson County). Figure 17 depicts the limits of the State Highway 88 construction project. The CMR was evaluated at two sites within this construction zone. The first site (Site A) permitted evaluation of the influence of the CMR on the westbound traffic. The CMR was positioned at construction station 16+740 (located in Jefferson County approximately 0.5 miles east of the Washington County line) for Site A. [The construction stationing is in meters extending from west to east.] The second site (Site B) permitted evaluation of the CMR influence on the eastbound traffic. The CMR was located at construction stationing 1+460 (located in Washington County approximately 3.4 miles west of the Jefferson County line) for Site B. The CMRs were not present at the same time, and Sites A and B were separated by a distance of approximately 3.9 miles (6,280 meters).

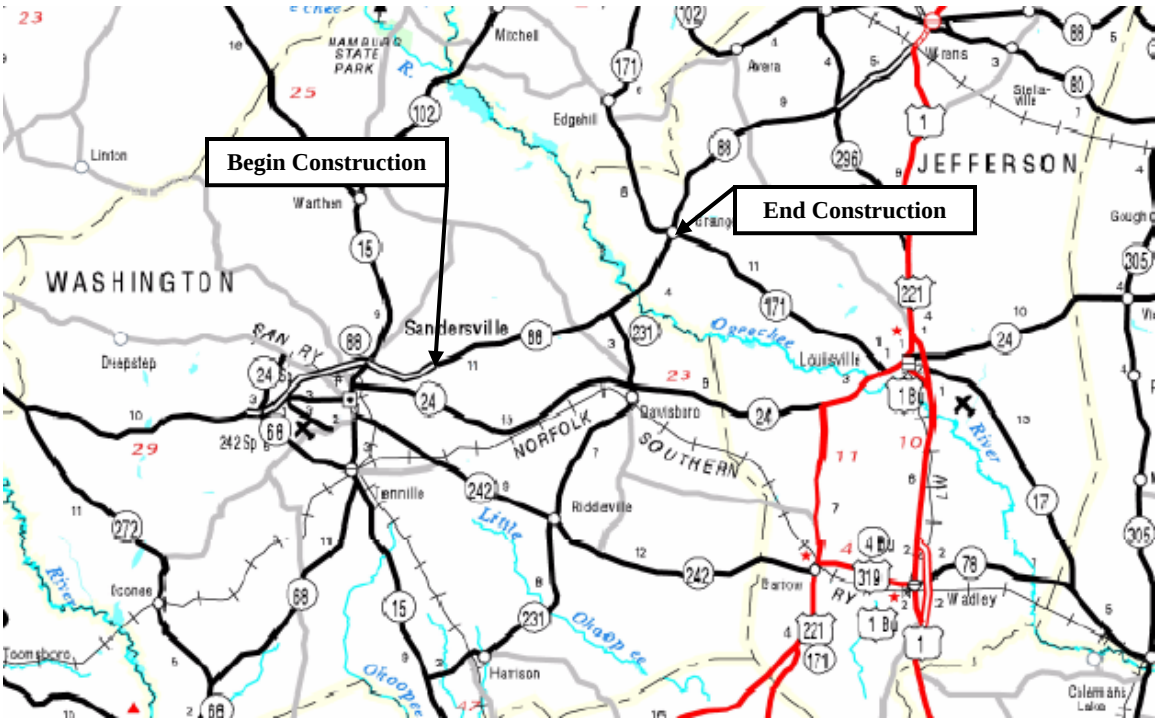


**Figure 17.** State Highway 88 Work Zone Project Limits

## 3.2. Data Collection

The objective of the CMR data collection effort was to evaluate traffic speed and volume as well as changes in speed prior to the placement of the CMR, immediately after CMR placement, and two to three weeks following CMR placement (to determine if drivers relaxed speed modifications over time). The GA Tech team collected volume, speed, vehicle length, and time headway data for periods ranging from 24 to 48 continuous hours. Data collection occurred on Tuesdays, Wednesdays, and Thursdays. The GA Tech team did not collect data on Friday through Monday at this site due to the atypical traffic patterns and reduced construction activity associated with weekends at the site.

### *3.2.1. 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 18 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. GA 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 19 shows two adjacent Nu-Metric classifiers and their tape coat cover.

**Figure 18.** Sample Nu-Metrics Classifier (Model No. NC-97)

*Source: http://www.nu-metrics.com*

**Figure 19.** Deployed Classifiers at Work Zone Advance Warning Area

GA 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.

*3.2.2. Traffic Speed and Volume Data Collection*

As previously indicated, immediately following placement of an "attention getting" device, drivers may 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 behavior. With this possible *novelty effect* in mind, the GA Tech 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 7 summarizes the various data collection dates for CMR evaluation.

**Table 7.** Summary of CMR Data Collection Time Periods

| Site | Date | | Phase |
|---|---|---|---|
| | From | To | |
| Site A (Westbound) | 8/3/2004 | 8/5/2004 | Before |
| | 8/24/2004 | 8/26/2004 | After (Immediate) |
| | 9/14/2004 | 9/16/2004 | After (Novelty) |
| Site B (Eastbound) | 8/3/2004 | 8/5/2004 | Before |
| | 9/21/2004 | 9/23/2004 | After (Immediate) |
| | 10/5/2004 | 10/7/04 | After (Novelty #1) |
| | 10/12/2004 | 10/14/2004 | After (Novelty #2) |

Figure 20 depicts the device placement specifications as included in the project work plan. The entire work plan is included in Appendix 2. As shown, the GA Tech researchers directed CMR placement on the right side of the road (in direction of travel) so that the radar could be aimed at approaching vehicles and then display the appropriate message to the drivers of those vehicles. Within the lanes adjacent to the activity area, the roadway had two travel lanes (one westbound and one eastbound) available to active traffic. The work plan schematic (prepared prior to data collection implementation) depicts the activity area to the left of the active travelway; however, at both sites the active work area (upon final CMR device placement) occurred to the right of the studied lanes and the CMR was positioned in the future median area at the top of an erosion

control dam (to assure placement did not conflict with drainage and to provide a level placement of the sign).

The manufacturers of the Nu-Metric traffic classifiers advertise ± 4.2-percent vehicle speed accuracy and ± 8-percent vehicle length accuracy; 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. In the previous Georgia work zone study (Dixon & Wang, 2002), the research team performed a test to identify the relative recording error of the study devices. Devices were separated into two evaluation groups (six classification devices per group). This evaluation of the classifiers indicated that the same classifier is dependable for repetitive use, but that the speed variation between one classifier and another could be different enough to provide false readings of a few miles per hour. As a result, speed changes at a specific location are the target of this analysis and the same devices were used at the same locations to assure removal of any device variation errors.

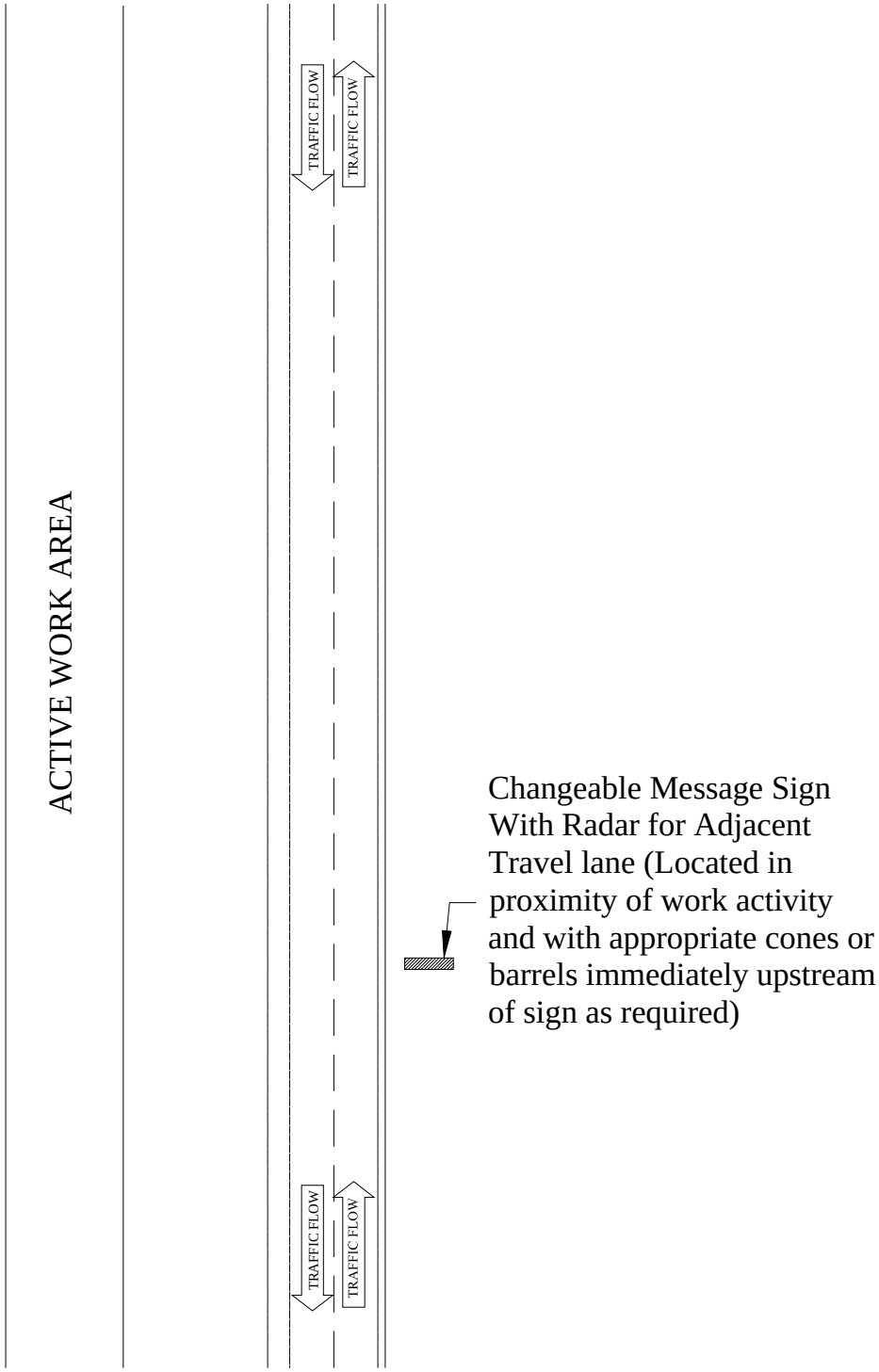


**Figure 20. CMR Device Placement (per Work Plan)**

# CHAPTER 4. CMR DATA SUMMARY, EVALUATION, AND FINDINGS

The GA Tech research team collected speeds and headways for a period of seven weeks; however, due to equipment malfunctions, the final analysis data set includes six weeks (see Table 7) for the State Highway 88 site. This site is characterized by periodic increases in truck traffic due to mining activities along the corridor. As a result, evaluation of vehicle type (based on length information) is important. One worker at the highway construction site shared anecdotal information that the truck drivers are paid based on the number of truck loads they deliver each day, so the influence of a speed reduction strategy at a work zone may not have the same affect on a local truck driver as it would on the driver of a different vehicle.

While all vehicle speeds were monitored by the Nu-Metric classifiers, only the speeds of free flow vehicles (defined for the purposes of this study as vehicles with time headways of 5 seconds or more) were used in the analysis. Following the collection of traffic speed and volume data, the GA Tech research team identified the free flow speed vehicles for each analysis period and tested the significance of changes of vehicle speeds upon CMR deployment.

## 4.1. 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 8 shows a sample of raw data downloaded from the traffic counter located adjacent to Site "A" on August 24, 2004. The "Speed" column is the operating speed of each vehicle in mph. The "Length" column depicts the length of the vehicle in feet. The "Seconds" column is the headway in seconds between two adjacent vehicles (except for the value for the first vehicle 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.

## 4.2. 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 the date and time information into an Access database. In addition, the database included a table with the exact time of sunrise and sunset for the data collection days. Table 9 shows the data summary file for the same 40 observations depicted in Table 8. The exact time of day is important so that the research team could distinguish between daytime and night time lighting conditions.

**Table 8.** Sample Raw Data from Nu-Metric Classifier

| *Speed* | *Length* | *Seconds* | *Offset* | *Speed* | *Length* | *Seconds* | *Offset* |
|---|---|---|---|---|---|---|---|
| 60 | 32 | 7 | 7 | 59 | 31 | 33 | 1303 |
| 58 | 29 | 5 | 12 | 60 | 32 | 22 | 1325 |
| 57 | 28 | 13 | 25 | 58 | 28 | 30 | 1355 |
| 58 | 13 | 19 | 44 | 57 | 13 | 186 | 1541 |
| 60 | 32 | 77 | 121 | 60 | 17 | 11 | 1552 |
| 58 | 70 | 81 | 202 | 57 | 35 | 35 | 1587 |
| 52 | 19 | 14 | 216 | 57 | 30 | 146 | 1733 |
| 63 | 36 | 69 | 285 | 56 | 28 | 28 | 1761 |
| 57 | 29 | 176 | 461 | 56 | 10 | 75 | 1836 |
| 58 | 10 | 5 | 466 | 47 | 15 | 8 | 1844 |
| 68 | 14 | 152 | 618 | 54 | 21 | 1 | 1845 |
| 63 | 15 | 23 | 641 | 61 | 34 | 45 | 1890 |
| 63 | 16 | 28 | 669 | 49 | 14 | 65 | 1955 |
| 55 | 17 | 154 | 823 | 58 | 31 | 26 | 1981 |
| 61 | 13 | 68 | 891 | 55 | 29 | 9 | 1990 |
| 61 | 10 | 118 | 1009 | 58 | 32 | 39 | 2029 |
| 52 | 14 | 98 | 1107 | 59 | 51 | 15 | 2044 |
| 52 | 32 | 135 | 1242 | 54 | 34 | 71 | 2115 |
| 59 | 29 | 19 | 1261 | 62 | 31 | 64 | 2179 |
| 56 | 26 | 9 | 1270 | 58 | 20 | 33 | 2212 |

### 4.3. Data Reduction

In the previous GDOT work zone research project, members of the research team developed a computer program (the GDOT Work Zone Data Analysis Tool) to enable quick and consistent speed data evaluation for varying headway, vehicle length, and lighting conditions. 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.)

**Table 9.** Sample Data Used for Analysis after Data Reduction

| *ID* | *Date* | *Speed (mph)* | *Length (ft)* | *Headway (sec)* | *Offset (sec)* | *Time* | *Hrs* | *Min* | *Sec* |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 24-Aug-04 | 60 | 32 | 7 | 7 | 12.00194 | 12 | 0 | 7 |
| 2 | 24-Aug-04 | 58 | 29 | 5 | 12 | 12.00333 | 12 | 0 | 12 |
| 3 | 24-Aug-04 | 57 | 28 | 13 | 25 | 12.00694 | 12 | 0 | 25 |
| 4 | 24-Aug-04 | 58 | 13 | 19 | 44 | 12.01222 | 12 | 0 | 44 |
| 5 | 24-Aug-04 | 60 | 32 | 77 | 121 | 12.03361 | 12 | 2 | 1 |
| 6 | 24-Aug-04 | 58 | 70 | 81 | 202 | 12.05611 | 12 | 3 | 22 |
| 7 | 24-Aug-04 | 52 | 19 | 14 | 216 | 12.06000 | 12 | 3 | 36 |
| 8 | 24-Aug-04 | 63 | 36 | 69 | 285 | 12.07917 | 12 | 4 | 45 |
| 9 | 24-Aug-04 | 57 | 29 | 176 | 461 | 12.12806 | 12 | 7 | 41 |
| 10 | 24-Aug-04 | 58 | 10 | 5 | 466 | 12.12944 | 12 | 7 | 46 |
| 11 | 24-Aug-04 | 68 | 14 | 152 | 618 | 12.17167 | 12 | 10 | 18 |
| 12 | 24-Aug-04 | 63 | 15 | 23 | 641 | 12.17806 | 12 | 10 | 41 |
| 13 | 24-Aug-04 | 63 | 16 | 28 | 669 | 12.18583 | 12 | 11 | 9 |
| 14 | 24-Aug-04 | 55 | 17 | 154 | 823 | 12.22861 | 12 | 13 | 43 |
| 15 | 24-Aug-04 | 61 | 13 | 68 | 891 | 12.24750 | 12 | 14 | 51 |
| 16 | 24-Aug-04 | 61 | 10 | 118 | 1009 | 12.28028 | 12 | 16 | 49 |
| 17 | 24-Aug-04 | 52 | 14 | 98 | 1107 | 12.30750 | 12 | 18 | 27 |
| 18 | 24-Aug-04 | 52 | 32 | 135 | 1242 | 12.34500 | 12 | 20 | 42 |
| 19 | 24-Aug-04 | 59 | 29 | 19 | 1261 | 12.35028 | 12 | 21 | 1 |
| 20 | 24-Aug-04 | 56 | 26 | 9 | 1270 | 12.35278 | 12 | 21 | 10 |
| 21 | 24-Aug-04 | 59 | 31 | 33 | 1303 | 12.36194 | 12 | 21 | 43 |
| 22 | 24-Aug-04 | 60 | 32 | 22 | 1325 | 12.36806 | 12 | 22 | 5 |
| 23 | 24-Aug-04 | 58 | 28 | 30 | 1355 | 12.37639 | 12 | 22 | 35 |
| 24 | 24-Aug-04 | 57 | 13 | 186 | 1541 | 12.42806 | 12 | 25 | 41 |
| 25 | 24-Aug-04 | 60 | 17 | 11 | 1552 | 12.43111 | 12 | 25 | 52 |
| 26 | 24-Aug-04 | 57 | 35 | 35 | 1587 | 12.44083 | 12 | 26 | 27 |
| 27 | 24-Aug-04 | 57 | 30 | 146 | 1733 | 12.48139 | 12 | 28 | 53 |
| 28 | 24-Aug-04 | 56 | 28 | 28 | 1761 | 12.48917 | 12 | 29 | 21 |
| 29 | 24-Aug-04 | 56 | 10 | 75 | 1836 | 12.51000 | 12 | 30 | 36 |
| 30 | 24-Aug-04 | 47 | 15 | 8 | 1844 | 12.51222 | 12 | 30 | 44 |
| 31 | 24-Aug-04 | 54 | 21 | 1 | 1845 | 12.51250 | 12 | 30 | 45 |
| 32 | 24-Aug-04 | 61 | 34 | 45 | 1890 | 12.52500 | 12 | 31 | 30 |
| 33 | 24-Aug-04 | 49 | 14 | 65 | 1955 | 12.54306 | 12 | 32 | 35 |
| 34 | 24-Aug-04 | 58 | 31 | 26 | 1981 | 12.55028 | 12 | 33 | 1 |
| 35 | 24-Aug-04 | 55 | 29 | 9 | 1990 | 12.55278 | 12 | 33 | 10 |
| 36 | 24-Aug-04 | 58 | 32 | 39 | 2029 | 12.56361 | 12 | 33 | 49 |
| 37 | 24-Aug-04 | 59 | 51 | 15 | 2044 | 12.56778 | 12 | 34 | 4 |
| 38 | 24-Aug-04 | 54 | 34 | 71 | 2115 | 12.58750 | 12 | 35 | 15 |
| 39 | 24-Aug-04 | 62 | 31 | 64 | 2179 | 12.60528 | 12 | 36 | 19 |
| 40 | 24-Aug-04 | 58 | 20 | 33 | 2212 | 12.61444 | 12 | 36 | 52 |

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 program user then identifies the source database (comprised of the summary data files for each site in a format similar to the example shown in Table 9) in the text box labeled “Database Name” as shown in Figure 21.

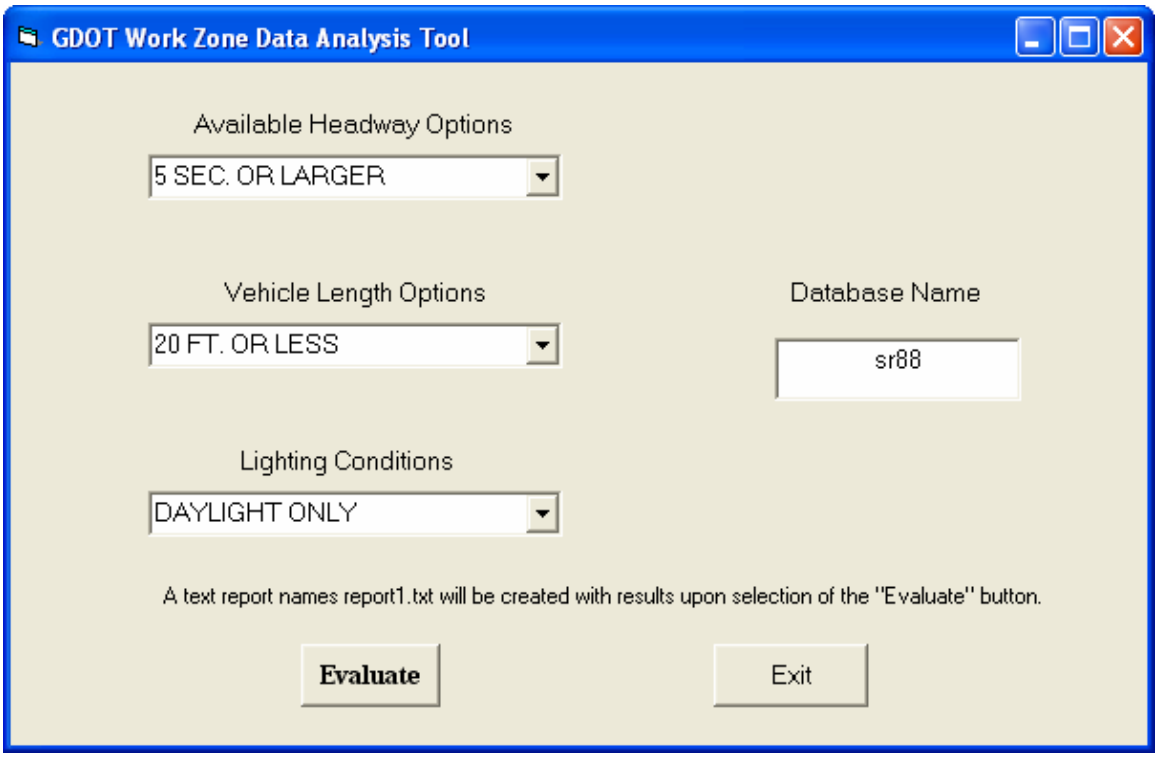


**Figure 21.** Interface of Data Summary Program

GDOT Work Zone Summary File

File Name: sr88 Headway Condition: 5 SEC. OR LARGER
Vehicle Type: 20 FT. OR LESS Lighting Condition: DAYLIGHT ONLY

| Location | Avg. Speed | Sample Size | Std.Dev. | Description |
|---|---|---|---|---|
| 0803_1_wb | 60.8 | 712 | 9.94 | WB Upstream |
| 0803_2_eb | 47.0 | 963 | 14.93 | EB Downstream |
| 0803_3_wb | 60.0 | 755 | 9.63 | WB Site A |
| 0803_4_eb | 58.9 | 849 | 9.62 | EB Site A |
| 0803_5_wb | 63.2 | 735 | 8.48 | WB Site B |
| 0803_6_eb | 58.0 | 950 | 8.94 | EB Site B |
| 0803_7_wb | 57.2 | 838 | 9.00 | WB Downstream |
| 0803_8_eb | 60.4 | 909 | 8.49 | EB Upstream |
| 0824_1_wb | 59.7 | 648 | 10.65 | WB Upstream |
| 0824_2_eb | 46.5 | 934 | 14.57 | EB Downstream |
| 0824_3_wb | 56.9 | 682 | 7.83 | WB Site A |
| 0824_4_eb | 55.1 | 789 | 12.68 | EB Site A |
| 0824_5_wb | 61.3 | 654 | 9.90 | WB Site B |
| 0824_6_eb | 56.9 | 900 | 8.82 | EB Site B |
| 0824_7_wb | 54.9 | 774 | 10.79 | WB Downstream |
| 0824_8_eb | 58.4 | 853 | 9.54 | EB Upstream |
| 0914_1_wb | 60.6 | 631 | 10.43 | WB Upstream |
| 0914_2_eb | 64.2 | 734 | 10.49 | EB Downstream |
| 0914_3_wb | 58.0 | 671 | 10.58 | WB Site A |
| 0914_4_eb | 57.7 | 746 | 11.92 | EB Site A |
| 0914_5_wb | 63.5 | 681 | 7.82 | WB Site B |
| 0914_6_eb | 57.3 | 877 | 8.58 | EB Site B |
| 0914_7_wb | 56.8 | 790 | 9.85 | WB Downstream |
| 0914_8_eb | 59.4 | 854 | 8.16 | EB Upstream |
| 0921_1_wb | 60.3 | 579 | 11.17 | WB Upstream |
| 0921_2_eb | 62.5 | 688 | 10.78 | EB Downstream |
| 0921_3_wb | 59.7 | 615 | 9.47 | WB Site A |
| 0921_4_eb | 57.0 | 700 | 12.53 | EB Site A |
| 0921_5_wb | 62.7 | 568 | 8.58 | WB Site B |
| 0921_6_eb | 56.1 | 814 | 8.58 | EB Site B |
| 0921_7_wb | 57.3 | 636 | 9.92 | WB Downstream |
| 0921_8_eb | 60.2 | 780 | 7.99 | EB Upstream |
| 1005_1_wb | 58.1 | 618 | 12.49 | WB Upstream |
| 1005_2_eb | 59.9 | 770 | 12.78 | EB Downstream |
| 1005_3_wb | 58.7 | 671 | 9.99 | WB Site A |
| 1005_4_eb | 56.6 | 794 | 11.74 | EB Site A |
| 1005_5_wb | 62.3 | 636 | 8.45 | WB Site B |
| 1005_6_eb | 56.8 | 908 | 7.98 | EB Site B |
| 1005_7_wb | 56.7 | 706 | 9.66 | WB Downstream |
| 1005_8_eb | 60.5 | 850 | 7.14 | EB Upstream |
| 1012_1_wb | 59.2 | 598 | 10.68 | WB Upstream |
| 1012_2_eb | 62.4 | 663 | 11.25 | EB Downstream |
| 1012_3_wb | 58.7 | 614 | 9.41 | WB Site A |
| 1012_4_eb | 57.9 | 712 | 11.44 | EB Site A |
| 1012_5_wb | 63.0 | 598 | 8.57 | WB Site B |
| 1012_6_eb | 57.7 | 787 | 8.67 | EB Site B |
| 1012_7_wb | 55.5 | 669 | 10.65 | WB Downstream |
| 1012_8_eb | 61.5 | 753 | 8.11 | EB Upstream |

**Figure 22.** Sample Output for Data Summary Program

After a click on the "Evaluate" button, a text report named report1.txt will be created as illustrated in Figure 22. This report is a summary of data collected that 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); the standard deviation of the observed speeds; 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.

### 4.4. Statistical Tests

The Georgia Tech research team used a paired t-test to evaluate the significance of observed average speed changes. For further information, the specific results of each test are depicted in Appendix 1.

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 hypotheses:

Hypothesis 1: The placement of the CMR does not change average speeds at (a) upstream locations, (b) lanes immediately adjacent to the sign, and (c) downstream locations.

Hypothesis 2: After a period of approximately three weeks, the placement of the CMR does not change average speeds at (a) upstream locations, (b) lanes immediately adjacent to the sign, and (c) downstream locations.

The Ga Tech researchers conducted the two-sample t-test to determine if the implementation of the speed reductions resulting from placement of the CMR 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 $\sigma_A^2$ and $\sigma_B^2$ 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: $H_0$: $\mu_A - \mu_B = 0$

$H_A$: $\mu_A - \mu_B \neq 0$

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

Size $\alpha$ hypothesis tests: Accept $H_0$, if $|t| \le t_{\alpha/2,\nu}$

Reject $H_0$, if $|t| > t_{\alpha/2,\nu}$

Where:

- $H_0$ is null hypothesis which states that two population means are equal,
- $\mu_A$ is mean of population A,
- $H_A$ is alternative hypothesis which states that two population means are not equal,
- $\mu_B$ 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 $\nu$

The researchers applied the two-sample t-test for each of the two travel directions.

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.

### 4.5. Data Validation

To assure consistent evaluation for comparable traffic conditions, the graph shown in displays a representative sample depicting the number of vehicles at the westbound CMR location 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.

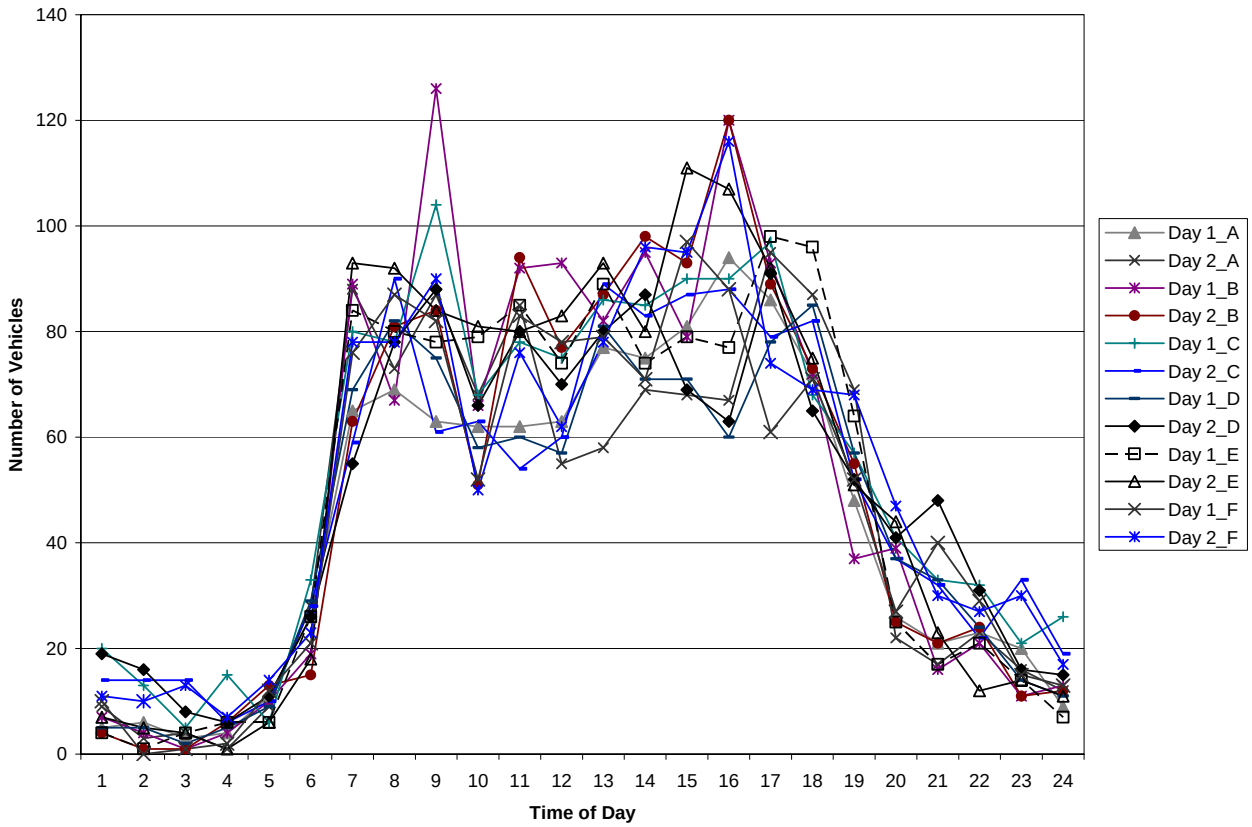


**Figure 23.** Vehicles at Site A for Each Data Collection Day

### 4.6. Changeable Message Sign with Radar Speed Evaluation Results

The GA Tech research team collected traffic data for a minimum of three weeks (before deployment, immediately after deployment, and a few weeks following deployment) at two locations. The researchers performed analysis using a paired t-test (see Appendix 1 for additional information) in an effort to determine what significant speed changes occurred at the site.

Table 10 shows the average free flow (headway equal to or greater than 5 seconds) speed change for the westbound lane (where the CMR was visible to the driver) and the upstream and downstream speeds for the westbound configuration. The table also similarly depicts the eastbound speeds and their significance. In general, immediately following sign implementation, the vehicles adjacent to the CMR reduced their average speed 2.0 to 2.4 mph for all vehicles and 1.7 to 2.5 mph downstream of the CMR; however, the upstream traffic also demonstrated a slight speed reduction of 0.6 to 1.0 mph indicating that the prevailing traffic may have been driving at a slightly reduced speed independent of the CMR deployment. **This finding indicates a possible reduction of speed solely due to the CMR of 1.0 to 1.8 mph.**

**Table 10.** Speed Changes for Before versus Immediately following CMR Placement

| | Upstream | | Adjacent to CMR | | Downstream | |
|---|---|---|---|---|---|---|
| | Average Speed Change (mph) | Statistically Significant Change*? | Average Speed Change (mph) | Statistically Significant Change*? | Average Speed Change (mph) | Statistically Significant Change*? |
| Traffic Condition | | | | | | |
| Site A (WB): | | | | | | |
| All Free Flow Vehicles | -1.0 | Yes | -2.0 | Yes | -1.7 | Yes |
| Passenger Vehicles, Day | -1.1 | No | -3.1 | Yes | -2.3 | Yes |
| Passenger Vehicles, Night | +2.3 | Yes | -1.5 | No | -1.0 | No |
| Trucks, Day | -0.8 | Yes | -0.8 | Yes | -1.7 | Yes |
| Trucks, Night | -0.9 | No | -3.5 | Yes | -0.6 | No |
| Site B (EB): | | | | | | |
| All Free Flow Vehicles | -0.6 | Yes | -2.4 | Yes | -2.5 | Yes |
| Passenger Vehicles, Day | -0.2 | No | -1.9 | Yes | -1.9 | Yes |
| Passenger Vehicles, Night | -3.0 | Yes | -5.1 | Yes | -4.5 | Yes |
| Trucks, Day | -0.9 | Yes | -2.2 | Yes | -1.7 | Yes |
| Trucks, Night | -0.8 | No | -2.2 | Yes | -4.4 | Yes |

* Statistically significance refers to a 95% confidence level.

Evaluation of the influence of the sign on passenger cars during daytime hours shows speed reductions ranging from 1.9 to 3.1 mph adjacent to the sign and sustained speed reductions of 1.9 to 2.3 mph downstream of the sign (indicating drivers or passenger cars reduced speed and maintained this speed reduction). The upstream speed variations were not significant indicating that the traffic speeds for passenger cars prior to and immediately after sign implementation were not substantially different. Similar speed reductions occurred for passenger vehicles at night; however, the upstream speed varied significantly from the "before" observation resulting in effective speed changes for passenger cars at night ranging from no speed reduction to approximately a 2.1 mph speed reduction.

As previously indicated, there is a substantial heavy vehicle population at this site due to the construction activity itself as well as regional mining activities for which State Route 88 is the primary corridor from the mines (east of the region) to the factory (west of the construction site). Since a truck driver is paid for the individual load, it is a high priority for the driver of a loaded truck to quickly deliver his or her load and return for another load. The CMR sign (once upstream traffic variations are considered) did not significantly affect the daytime truck traveling in the westbound direction (the loaded truck), but the returning (eastbound) trucks did slightly reduce their speeds adjacent to the

sign. At nighttime when presumably the mining activities have ceased, the trucks reduced their speed from 2.2 to 3.5 mph adjacent to the sign and maintained a speed reduction downstream ranging from 0.6 mph to 4.4 mph.

As previously indicated, it is important to determine if speed changes are short term and subject to a novelty effect where once frequent travelers are accustomed to the sign, they may begin to return to speed behaviors prior to sign placement. The speed before CMR deployment can be compared to the speed a few weeks following deployment to see if speed reductions continue at a constant rate. The results of this novelty effect evaluation are depicted in Table 11.

As shown in Table 11, even after the CMR was in place for a few weeks the drivers continued to reduce speeds slightly. For the eastbound direction of travel, the upstream traffic conditions again fluctuated significantly. Correcting for the increase in the upstream speed of +0.8 mph, the average speed reduction adjacent to the CMR ranged from 0.7 to 1.4 mph with a continued speed reduction effect downstream. For nighttime conditions, however, the results varied dependent upon vehicle type and travel direction. The overall speed reductions were present at the downstream location with a corrected speed reduction ranging from 0.6 to 2.4 mph.

Figure 24 shows the observed passenger car daytime speeds. For the westbound direction of travel, the CMR was present from August 24, 2004 through the morning of September 24, 2004. The sign was then relocated to the eastbound direction of travel and remained at this location from the afternoon of September 24, 2004 until October 15, 2004. Similarly, Figure 25 depicts the observed heavy vehicle daytime speeds. Similar graphics for all vehicles and for nighttime conditions are included in Appendix A.

### 4.7. Summary of CMR Results

Though speed reductions are small, the placement of a CMR sign adjacent to work zone activity area traffic will result in an average speed reduction ranging from 1.0 to 1.8 mph for all vehicles. This speed reduction does not substantially diminish over time, so the CMR can be expected to provide reasonably consistent results for all vehicles for a sustained period of deployment at two-lane, two-way rural work zone locations. The influence of the sign varies between daytime and nighttime lighting conditions as well as for passenger cars compared to trucks. Finally, the speed reductions were observed an approximately 3-mile distance downstream of the device, so the CMR appears to remind drivers of the reduced work zone speeds and any adjustments they make are still present downstream.

**Table 11.** Speed Comparison for Novelty Effect Evaluation

| | Upstream | | Adjacent to CMR | | Downstream | |
|---|---|---|---|---|---|---|
| | Average Speed Change (mph) | Statistically Significant Change? | Average Speed Change (mph) | Statistically Significant Change? | Average Speed Change (mph) | Statistically Significant Change? |
| Traffic Condition | | | | | | |
| Site A (WB): | | | | | | |
| All Free Flow Vehicles | 0.0 | No | -0.7 | Yes | -0.6 | Yes |
| Passenger Vehicles, Day | -0.2 | No | -2.0 | Yes | -0.4 | No |
| Passenger Vehicles, Night | +0.2 | No | -1.1 | No | -3.0 | Yes |
| Trucks, Day | +0.4 | No | 1.0 | Yes | 0.0 | No |
| Trucks, Night | +0.4 | No | -2.4 | Yes | -0.5 | No |
| Site B (EB): | | | | | | |
| All Free Flow Vehicles | +0.8 | Yes | -0.6 | Yes | -1.6 | Yes |
| Passenger Vehicles, Day | +1.1 | Yes | -0.3 | No | -1.0 | No |
| Passenger Vehicles, Night | -1.6 | No | -2.6 | Yes | -4.9 | Yes |
| Trucks, Day | +0.7 | No | 0.0 | No | -0.3 | No |
| Trucks, Night | -0.6 | No | -0.6 | No | -3.5 | Yes |

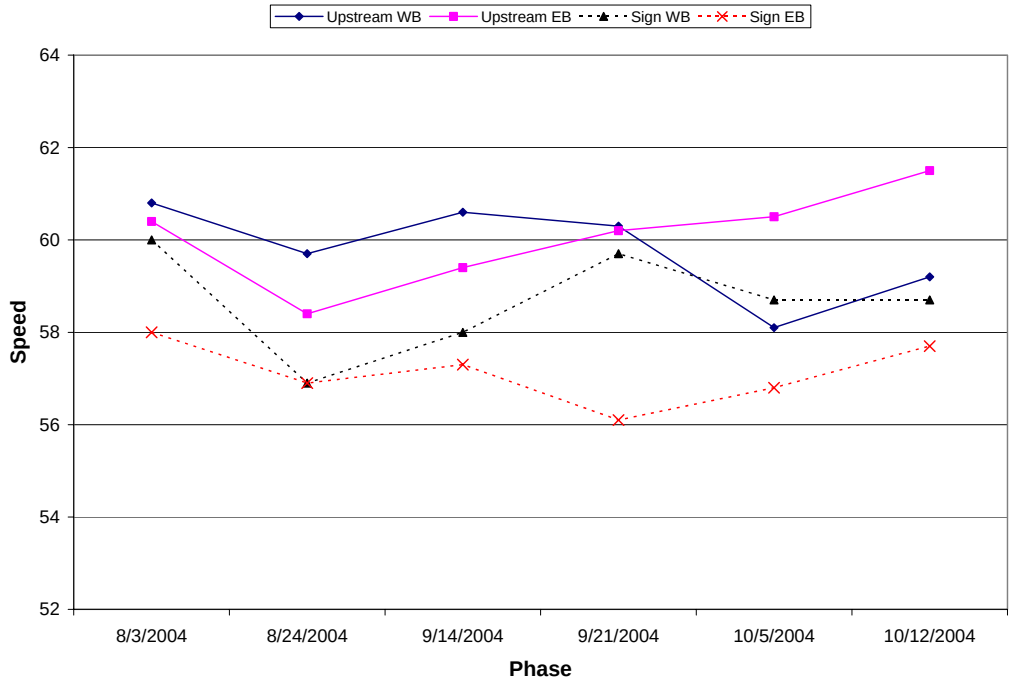


**Figure 24.** Average speeds for Passenger Vehicles, Day

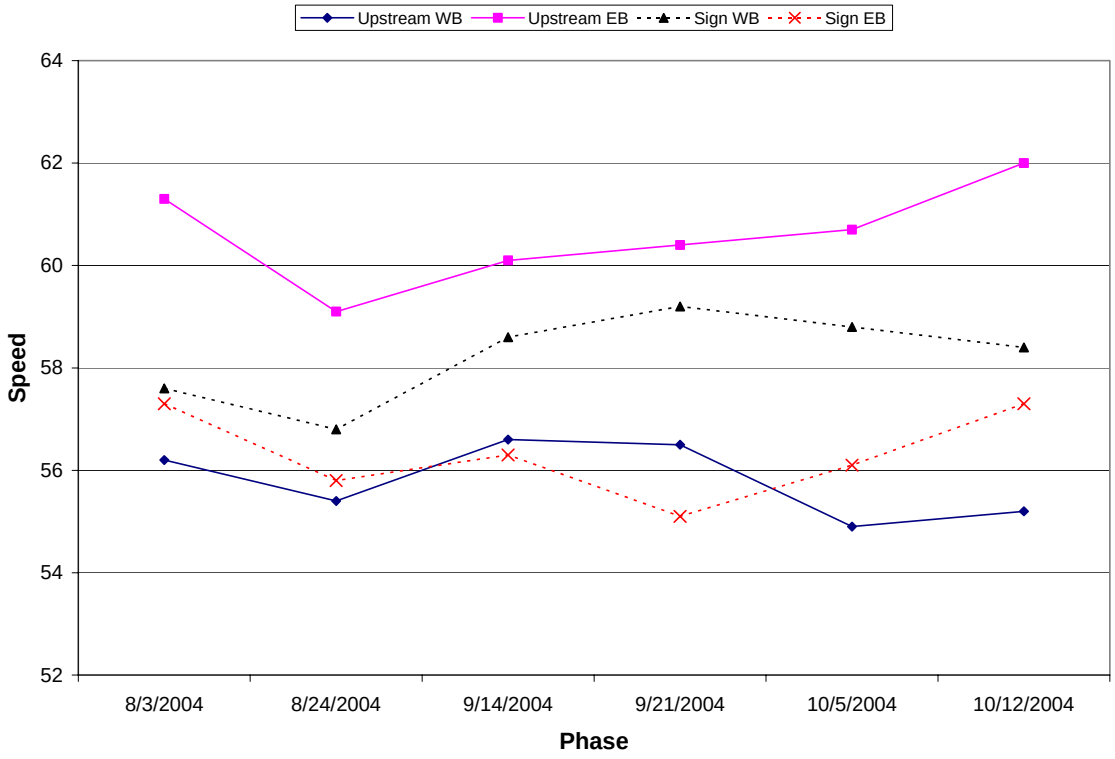


**Figure 25.** Average Speeds for Heavy Vehicles, Day

# CHAPTER 5. PORTABLE ITS DATA COLLECTION PLAN

## 5.1. Site Selection

The GDOT identified three freeway construction sites as candidates for evaluation of various portable ITS configurations. The three corridors selected included:

- I-20 near Augusta,
- I-75 south of Atlanta, and
- I-75 adjacent to and north of Tifton.

Each site was characterized by a unique ITS system, site-specific features and limitations, and varying operations including 24-hour law enforcement presence at one site and virtually no law enforcement at another site. The following sections review each candidate freeway site and the portable ITS system located at the site.

### *5.1.1. I-20 in Richmond County near Augusta*

GDOT located a TIPS system (developed by PDP Associates and discussed in more detail in the literature review section beginning on page 23). This system used six sensors, a central computer (located in the GDOT construction trailer), and changeable message signs that provided travel time information to the traveling public. Only travel in the eastbound direction received benefit of the TIPS system. At this site, law enforcement was present for 24-hours a day and construction occurred from late 2002 until mid-2003. Construction extended from milepost 198 to milepost 201 (see Figure 26 for a site map). Construction activity was present during daytime and nighttime hours when required; however, during the two weeks of the Masters Golf Tournament all construction activity stopped and the TIPS system was completely removed from the corridor. The data work plan for this project is included in the appendix of this document.

Ideally an analysis of new technology should include evaluation of the site prior to deployment of the technology (to evaluate the before-after benefits); however, due to delays in contract execution for this research project, the research team was not able to collect data at the site prior to deployment of the TIPS system. In addition, the research team met with the president of PDP Associates and he assured them that all volume, occupancy, and sign message data collected by the on-site sensors and stored on the central computer would be provided to the research team to include with evaluation (though he was not contractually obligated to provide this data). Unfortunately, for this site the vendor was ultimately not able to supply all this information for reasons unknown to the research team.

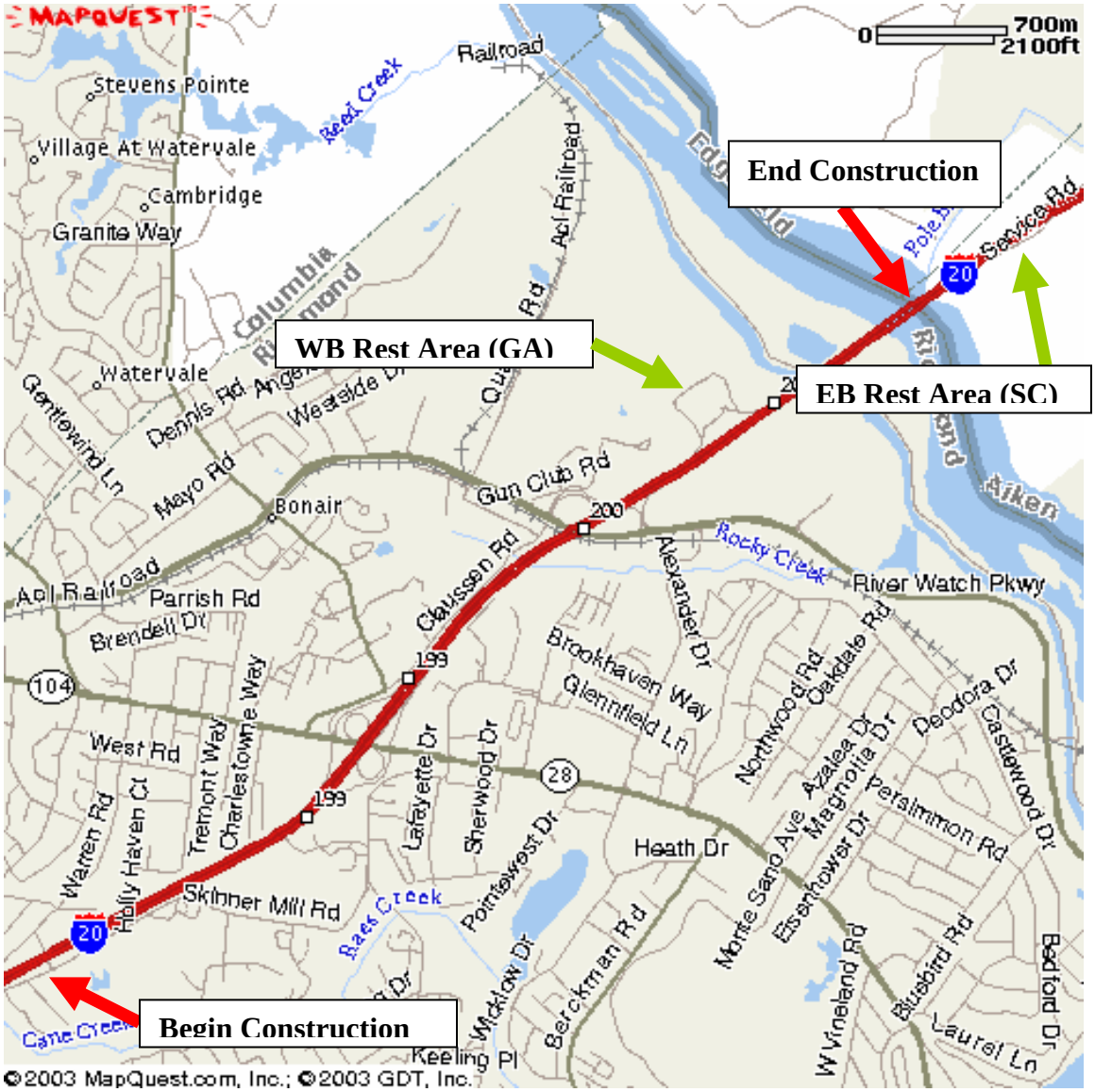


**Figure 26.** Augusta Work Zone Project Limits

### *5.1.2. I-75 South of Atlanta*

The I-75 construction work zone south of Atlanta extended from Walt Stephens Rd. Milepost 226.3 to Exit 205 (see Figure 27 for location). At this site, GDOT deployed the IntelliZone system (previously discussed in Chapter 2). This 23-mile work zone included portable ITS equipment for both the northbound and southbound directions of travel. This work zone was characterized by commuter traffic (northbound to Atlanta in the morning and southbound leaving Atlanta in the evening). As a result, work activity at this site generally occurred during weekends and weeknights. There was occasional law

enforcement present at this site. GDOT elected to use the IntelliZone system as a mobile deployment strategy as a contrast to the static deployment at the Augusta site.

The identification and selection of alternative routes for this project proved to be challenging. GDOT's senior management determined that when a 45 minute travel time threshold in the 23-mile work zone was exceeded, the Department would provide alternative routes. This decision required supplementing the IntelliZone equipment with GDOT owned and operated changeable message signs, highway advisory radio systems, Highway Emergency Response Operators (HEROs), and two-way radio communication between the Atlanta and Macon Traffic Management Centers. Due to time and fiscal constraints, these supplemental devices could not be integrated into the overall ITS system.

Alternate routes were delineated as detours corridors. These detour corridors were restricted in length to enable traffic to re-enter I-75 downstream of the active work zone and to avoid adversely affecting the traffic in several small towns along the alternative route corridor. Due to the limited capacity of available alternative routes, GDOT accepted that the detour options would provide only limited benefits.

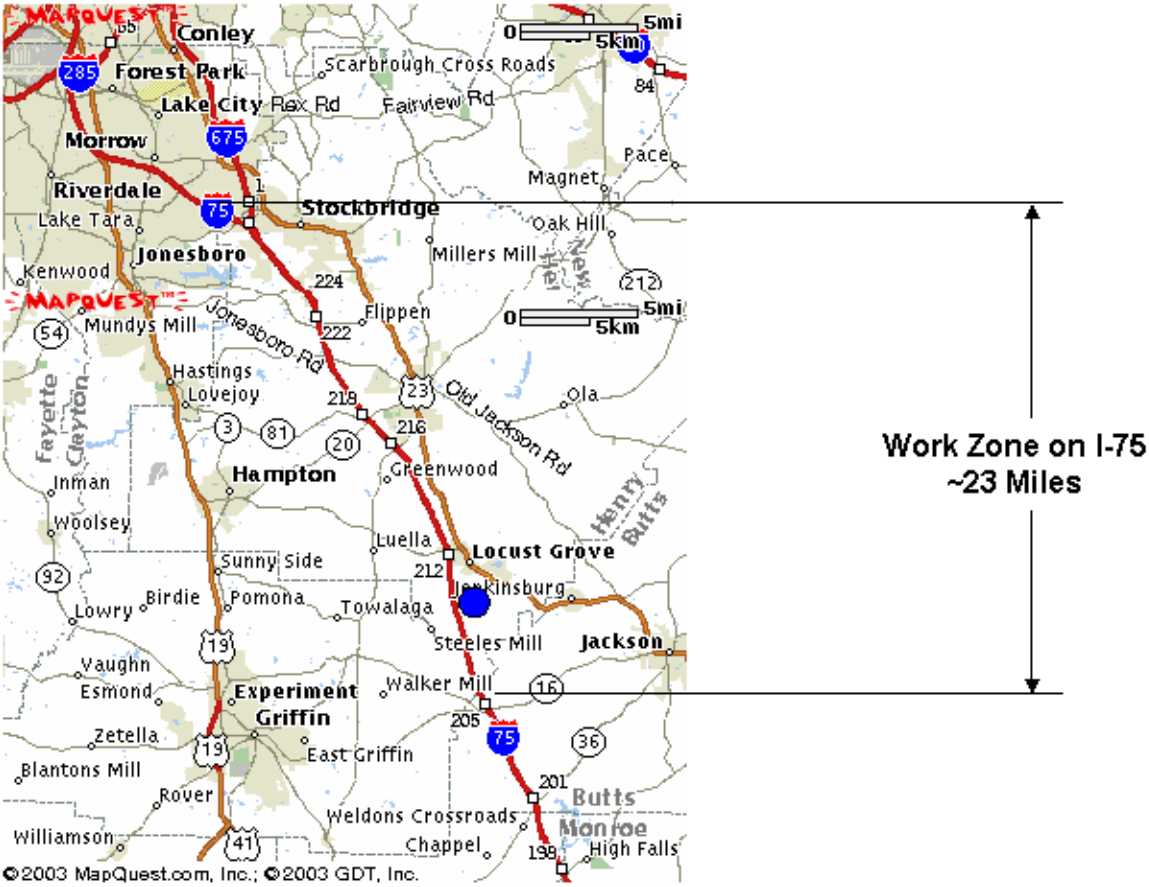


**Figure 27.** I-75 South Atlanta Project Limits

### *5.1.3. I-75 in Tifton*

GDOT selected the I-75 work zone adjacent to and north of Tifton, Georgia to test the ASIS System by PDP Associates (see Chapter 2 for additional information about this system). Figure 28 depicts the I-75 corridor project limits. Whereas the Atlanta I-75 corridor was characterized by heavy commuter traffic and construction activity was scheduled to avoid these time periods, this I-75 corridor is characterized by heavy weekend travel as it is a primary route to and from Florida. As a result, work activity at this site occurred during the standard work week with no weekend lane closures. There was only occasional law enforcement present at the site.

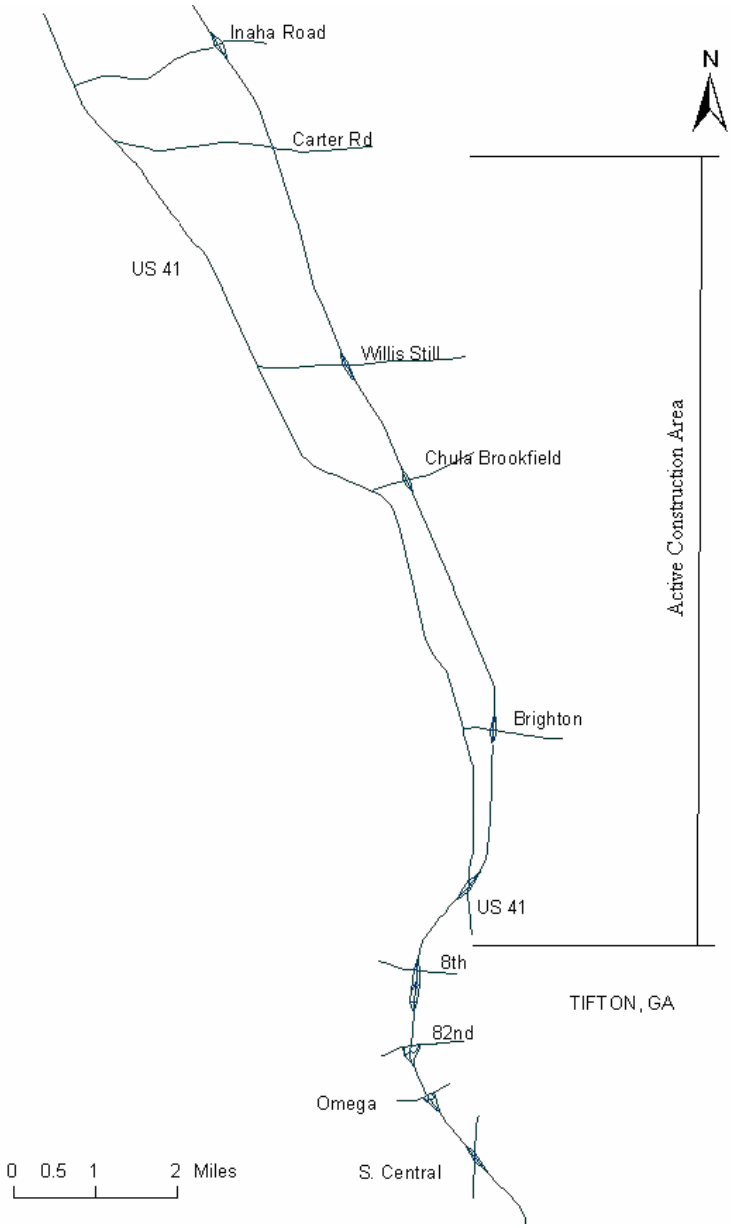


**Figure 28.** Tifton Site Map and Project Limits

## 5.2. Data Collection

The diverse nature of the freeway work zones and the equipment required to monitor such sites required the research team to acquire data from a variety of sources and with varying equipment. Data collection efforts on this project included the collection of operational data (speed, volume, and companion ITS sign messages) as well as driver perception information (in the form of user surveys at two of the sites). In addition, GDOT provided crash records for the Augusta site and a recently completed companion site so as so determine if any safety improvements resulted from the use of the technology. The following section briefly reviews the data collection devices used for the portable ITS evaluation and the data collected for each site.

### *5.2.1. Data Collection Devices*

In addition to data collection using the Nu-Metric devices (discussed previously and as shown in Figure 18), the GA Tech research team selected monitoring equipment compatible with that used by the portable ITS systems. As a result, the research team deployed two Remote Traffic Microwave Sensors (RTMS) mounted on two-wheel trailers. These devices operate using solar batteries and can evaluate mainline traffic, monitoring multiple lanes at a time. Placement of the RTMS devices was typically a minimum of 10 feet from the active travel lanes. No lane closures were required for deployment. See Figure 29 for a picture of the RTMS as deployed. The RTMS is a new technology and the accuracy of this device is unknown. The research team performed field tests prior to deployment and determined that the RTMS data is reasonable for volume and time information, but is easily subject to calibration error for accurate speed information. Subsequent to these tests, the manufacturer upgraded the software to improve speed accuracy but the research team had already elected to discount the RTMS speed and proceeded with data collection before the device upgrade was available.

**Figure 29.** Deployed RTMS Unit

In addition to the traffic sensors (RTMS units and the Nu-Metrics), the research team used laser and video cameras to provide supplemental information regarding prevailing traffic conditions. Both of these data collection methods are well known and discussed in the individual work plans included in the report Appendix B.

### *5.2.2. Traffic Speed and Volume Data Collection*

The following summaries review the traffic speed and volume data collected for the sites.

#### 5.2.2.1. Augusta Operational Data Collected

As previously discussed, the data available for the Augusta site was limited due to a problem retrieving the device data from the vendor. The research plan included deployment of an RTMS to monitor the traffic stream in an effort to validate the data provided by the TIPS system. The research team deployed the RTMS to the site twice. The first deployment was during the period from June 11, 2003 through June 18, 2003. The second deployment occurred in July 2003; however, upon arrival to the site the research team learned that the TIPS system did not appear to be fully functional due to the pending construction completion.

#### 5.2.2.2. I-75 South of Atlanta Data Collected

At the I-75 Atlanta site, the research team acquired operational data using both Nu-Metrics classifiers (for off-ramp observations) as well as the RTMS units supplemented by vendor supplied data from the IntelliZone system. The portable ITS system configuration for this site moved approximately every two weeks due to the dynamic construction activity, so each data collection effort was uniquely designed for the specific construction configuration.

The southbound travel direction included a merging approach of two highways, so at this location the system included duplicate devices for each approach. The work activity at the I-75 Atlanta site was a moving work effort that could progress as much as two miles each evening. As a result, the system had to be moved periodically to coincide with construction activity. The system used five radar sensors and five changeable message signs in conjunction with a control unit to provide traffic information to the traveling public. Figure 30 depicts the proposed northbound deployment configuration for a two-week construction cycle in the northbound direction. Figure 31 demonstrates the initial IntelliZone deployment for the southbound travel direction.

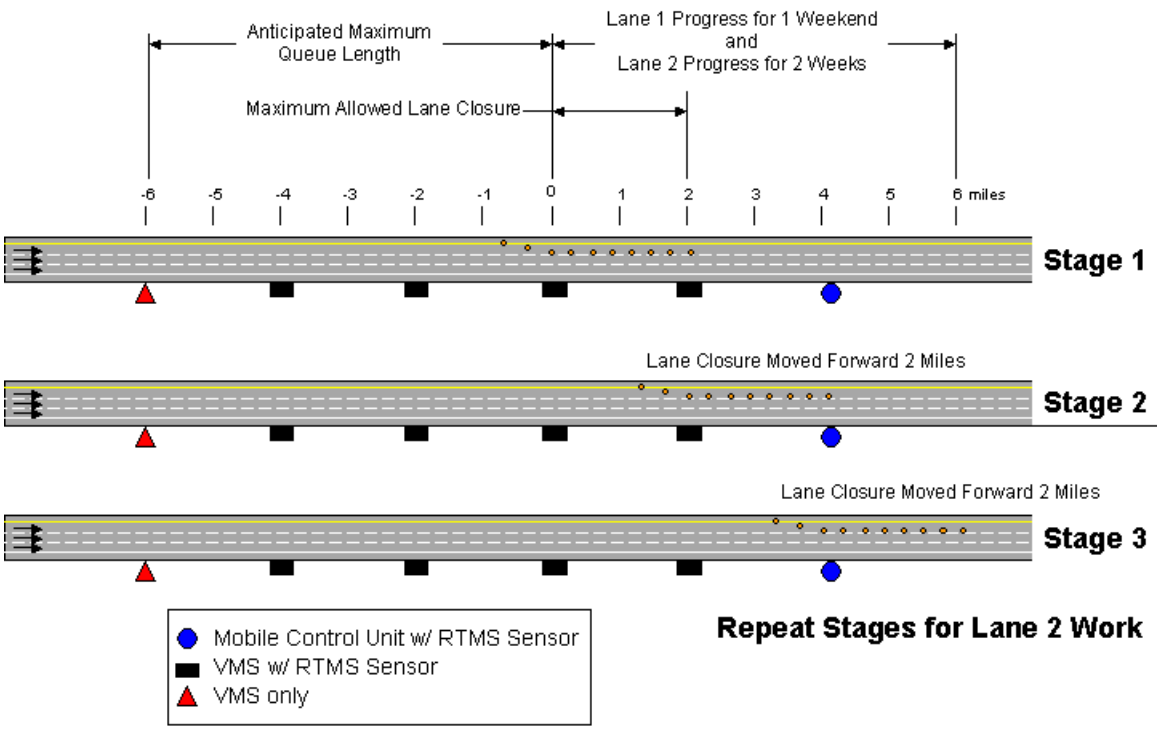


**Figure 30.** I-75 Atlanta Northbound Deployment for a 2-Week Cycle

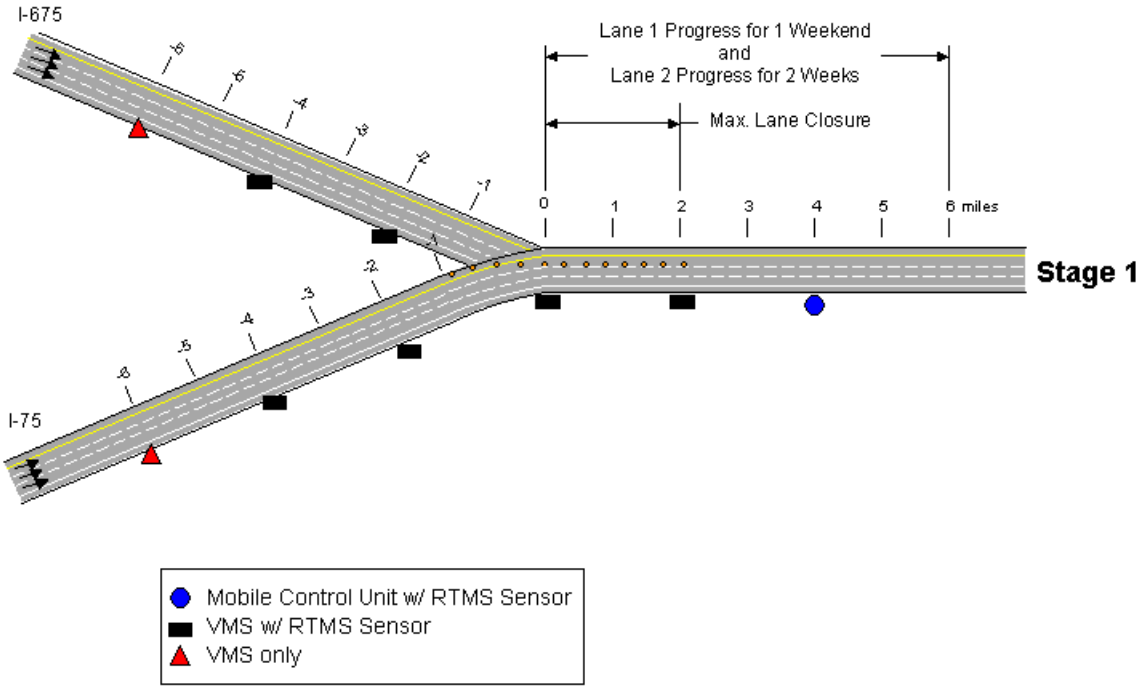


**Figure 31.** I-75 Atlanta Initial Southbound Deployment

The IntelliZone system deployment occurred at the initial stages of this research contract. The GA Tech research team collected data prior to the activation of the IntelliZone system (but with the system sensors present on site and monitoring traffic); however, the retrieval of this data was limited due to technical difficulties by the vendor as they were testing the equipment in preparation for system activation and their focus was not on acquiring data.

Table 12 depicts the data collection dates and location for the IntelliZone site collection effort.

**Table 12.** IntelliZone Site Data Collection

| Location | Direction | Construction Milepost | Date (2003) | Starting Time | Notes |
|---|---|---|---|---|---|
| I-75 | SB | Base-line | 07/09 | 9 pm | Baseline Data |
| I-75 | NB | 220 | 07/24 | 9 pm | |
| I-75 | SB | 226 | 09/03 | 9 pm | Lane 1 |
| I-75 | NB | | 09/09 | 9 pm | Lane 1+2 |
| I-75 | SB | 219 -218 | 09/16 | 9 pm | Lane 1+2 |
| I-75 | SB | 217-216 | 09/18 | 9 pm | Lane 1+2 |
| I-75 | NB | 215.5-216.5 | 11/01 | 2 pm | Lane 1 |
| I-75 | NB | 215.5-216.5 | 11/02 | 2 pm | Lane 1 |
| I-75 | SB | 210.5-209.5 | 11/13 | 9 pm | In zone, Lane 1+2 |
| I-75 | NB | 208-210 | 11/13 | 9 pm | Out of zone, Lane 1+2 |
| I-75 | SB | 210.5-209.5 | 11/15 | 2 pm | Out of zone, Lane 1 |
| I-75 | SB | 210.5-209.5 | 11/15 | 2 pm | In zone, Lane 1 |
| I-75 | SB | 210.5-209.5 | 11/16 | 2 pm | Out of zone, Lane 1 |
| I-75 | NB | 208-210 | 11/16 | 2 pm | Out of zone, Lane 1 |

5.2.2.3. I-75 Tifton Data Collected

The GDOT contractor deployed the ASIS system at the Tifton site a considerable time prior to the development of this research project. As a result, evaluation of a before condition was not a feasible option, so the research team elected to evaluate the influence of the portable ITS on traffic operations when lane closures were and were not present. Table 13 depicts manually collected data (supplemented by mainline RTMS data). The baseline reference in the “Construction Location” column indicates that a lane closure was not present at the time of data collection.

**Table 13.** ASIS Tifton Data Collection Summary

| Location | Direction | Construction Location | Date | Time |
|---|---|---|---|---|
| I-75 | NB | Brighton to Chula Brookfield | 3/3/04 | 2:00 - 4:00 |
| I-75 | SB | Carter to Willis Still | 3/17/04 | 10:45-12:45 |
| I-75 | NB | Baseline | 3/17/04 | 2:30-4:30 |
| I-75 | NB | Brighton to Chula Brookfield | 3/23/04 | 3:00-5:00 |
| I-75 | SB | Baseline | 3/24/04 | 2:45-4:45 |
| I-75 | SB | Baseline | 4/7/04 | -- |
| I-75 | NB | Brighton to Chula Brookfield | 4/7/04 | 10:00-12:00, 2:00-4:00 |
| I-75 | SB | Baseline | 4/14/04 | -- |
| I-75 | NB | Brighton to Chula Brookfield | 4/14/04 | 9:30-12:00, 2:30-4:30 |

*Note: Supplemental mainline RTMS data collected overlapped the above manual data collection time periods.*

A typical data collection configuration is depicted in Figure 32 for the operational analysis at the Tifton site. The location depicted with a large black circle represents a supplemental GA Tech data collection site (for laser and video validation). Hi-Star Nu-Metric classifiers were also positioned on the region off-ramps to determine if changes in sign messages (warning of downstream delays) would influence ramp volume.

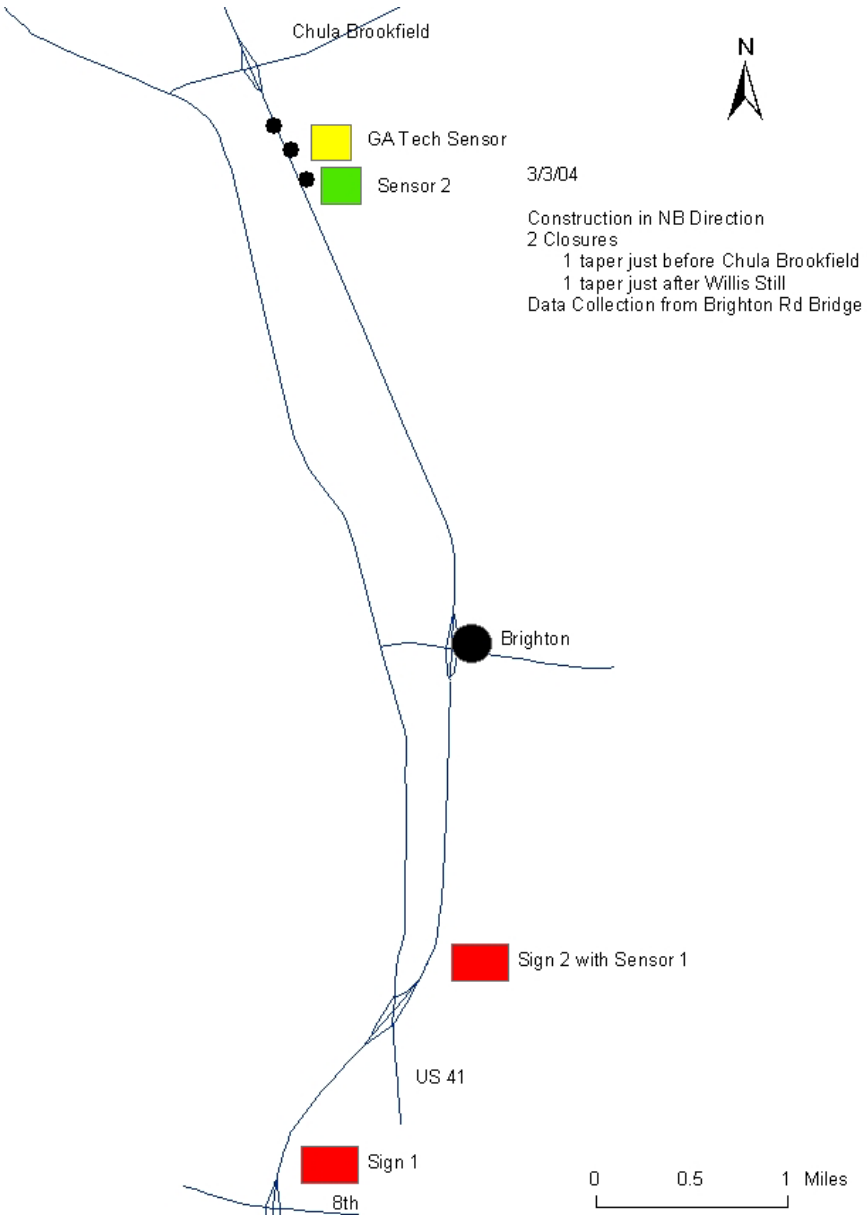


**Figure 32.** Example Tifton Data Collection Configuration

### *5.2.3. Driver Survey Data Collection*

In an effort to determine driver understanding and trust of the portable ITS systems, the research team performed two user surveys. The GA Tech team performed the first survey at the Augusta I-20 site. Since the ITS system was only situated in the eastbound direction of travel and the ideal survey location is immediately downstream of the driver's exposure to the system, the South Carolina Department of Transportation authorized administration of the user survey at the South Carolina welcome center immediately across the state line. Figure 33 depicts the welcome center location and its configuration to the I-20 corridor. As previously indicated, this site is immediately downstream of the work zone.

**Figure 33.** South Carolina Welcome Center and Survey Site

The second site for the user survey was north of the Tifton, Georgia I-75 site. The research team performed this survey at a Georgia rest area. The basic survey questions are shown in Figure 34. Results of the surveys are provided in Chapter 6.

| | |
|---|---|
| **Did you <u>notice</u> the message signs in the work zone?**<br>☐ Yes<br>☐ No<br>☐ Don't Remember<br>☐ Refused<br>☐ Other<br>**NOTICE SIGNS?** | **Was the information provided on the signs <u>useful</u> to you?**<br>☐ Yes<br>☐ Somewhat<br>☐ No<br>☐ Don't Recall<br>☐ Refused<br>☐ Other<br>**INFO USEFUL?** |
| **Did you find the information displayed on the signs to be <u>accurate</u>?**<br>☐ Yes<br>☐ Somewhat<br>☐ No<br>☐ Don't Recall<br>☐ Refused<br>☐ Other<br>**INFO ACCURATE?** | **Were the signs <u>easy to read</u>?**<br>☐ Yes<br>☐ Somewhat<br>☐ No<br>☐ Don't Recall<br>☐ Refused<br>☐ Other<br>**EASY TO READ?** |
| **Did the information on the signs <u>change</u> the way you drove?**<br>☐ Yes<br>☐ Somewhat<br>☐ No<br>☐ Don't Recall<br>☐ Refused<br>☐ Other<br>**CHANGE WAY YOU DROVE?** | **Do you live <u>within 10 miles</u> of the work zone?**<br>☐ Yes<br>☐ No<br>☐ Don't Remember<br>☐ Refused<br>☐ Other<br>**LIVE WITHIN 10 mi?** |
| **<u>How often</u> do you drive eastbound through the work zone each week?**<br>☐ Less than 1<br>☐ 1-2<br>☐ Almost every day<br>☐ More than once per day<br>☐ Don't know<br>☐ Refuse<br>☐ Other<br>**HOW OFTEN?** | **Gender**<br>☐ Male<br>☐ Female<br>**Age**<br>Under 30<br>☐ 30-60<br>☐ Over 60<br>**Thank you for your time!** ☺ |

**Figure 34.** Sample Questions from Driver Survey

### *5.2.4. Augusta Work Zone Crash Data*

During work activity, GDOT acquired copies of crash reports for any crash that may have occurred in the Augusta site work zone. During the previous year, GDOT improved I-20 at a location immediately to the west of this study site. That previous construction zone did not include any portable ITS technology. For the Augusta site, only the eastbound travel direction included portable ITS equipment. As a result, the GA Tech research team have sample crash reports for this companion site, immediately west of the Augusta study site, where similar technology was deployed as well as a directional movement for the specific Augusta study site that did not have this technology. The previous work zone site to the west (the companion site) included a similar widening activity project. Due to the location west of Augusta, the companion site traffic volume may have been slightly less than that at the site immediately adjacent to Augusta. Though it is likely that crashes may occur in the proximity of a work zone (in the upstream queue, for example), these sample crash reports provide a reasonable indication of the type of crashes common to freeway work zone construction projects with and without portable technology. For the companion site, 12 eastbound crashes and 6 westbound crashes are available for this analysis. For the study site, the research team received crash reports for 3 eastbound crashes and 1 westbound crash.

Due to such a small sample size and varying work zone time periods, it is not reasonable to determine crash reduction (if any) due to this new technology. Observations regarding changes in crash type and severity, however, are possible and included in Chapter 6.

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# CHAPTER 6. PORTABLE ITS DATA SUMMARY, EVALUATION, AND FINDINGS

Due to the varying technologies tested during this study as well as different work zone configurations and data collection devices, this chapter first includes a review of the data results and analysis for each of the three portable ITS systems and their perceived affect on the traffic operations of the work zone. Included with this operations evaluation of the ITS equipment is a review of installation, maintenance, and equipment issues that may have influenced system efficiency and recommendations on how to avoid these issues for future deployments. Next, the chapter includes the results of the driver user surveys at the Augusta and Tifton study sites. Finally, this chapter reviews the Augusta crash analysis and observations.

## 6.1. Operational Evaluation of Portable ITS Equipment Configurations

Each of the portable ITS site evaluations are summarized in the following sections.

### *6.1.1. Augusta I-20 TIPS System*

#### 6.1.1.1 Augusta Operational Data Evaluation

As previously indicated, operational analysis at the Augusta site is sparse due to the unforeseen lack of data. Initially, the system developer agreed to provide both the operational data as well as the sign message data for the site; however, PDP Associates (who were not contractually obligated to provide this data) were not able to provide the promised data due to technical difficulties. The GA Tech research team began the study for this site as the project was nearing completion, so full analysis of the operational behavior could not be performed without this supplemental data. The research team did, however, locate a RTMS sensor at the site on two occasions with the intention of using data from the sensor to validate the data that would ultimately be provided by the equipment developer. Figure 35 depicts sample traffic volume from the Augusta site (as collected with the supplemental RTMS device). The TIPS system bases projected travel times on volume/occupancy data within the work zone and does not use the RTMS speed information for system analysis.

Due to the difficulty in acquiring the comprehensive data needed at the Augusta site, the GA Tech research team was not able to perform an operational evaluation for this location. The research team did conduct both a user survey and a crash review for the Augusta site (results in the following section).

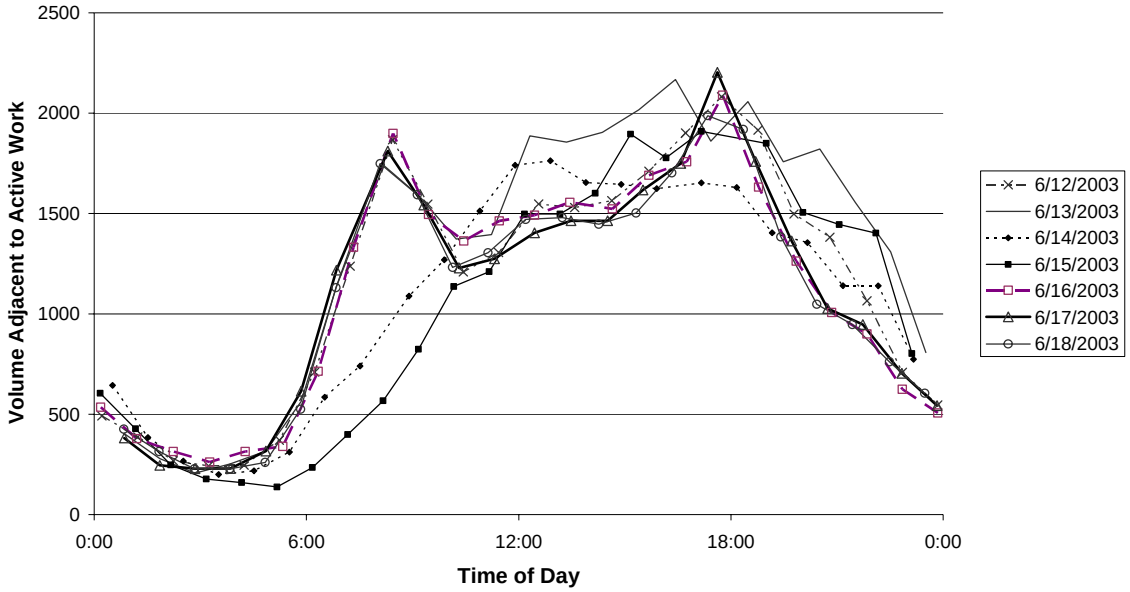



**Figure 35.** Sample Traffic Volume Data at Augusta

6.1.1.2 Augusta Installation, Maintenance, and Equipment Issues

The research team did not have the opportunity to observe the long term operations of the TIPS system; however, upon interviews with the construction management staff, team members were apprised of one issue that is critical to successful system deployment. Due to the high traffic volumes generated by the Masters Golf Tournament each spring, the contractor was instructed by GDOT to halt all construction activity during the two-week window surrounding the tournament. This construction stop required that all traffic control devices be removed from the work zone including the TIPS equipment. When construction resumed, the contractors moved the equipment back to its original location and did not modify any of the system configurations; however, the system did not perform correctly and ultimately the developer of the TIPS system dispatched a technician to the site to re-calibrate the sensors and re-validate the equipment location and operational information.

Though the configuration of the RTMS unit, in particular, as well as placement of devices and their orientation to the travel lanes may be sensitive, a contractor or department of transportation should be aware prior to purchase and deployment of the system what the maintenance issues may be regarding the system as it is very likely that devices will need to be shifted to accommodate construction activity. This maintenance cost should be included in the projected cost of the technology.

*6.1.2. Atlanta I-75 IntelliZone System*

6.1.2.1. Atlanta I-75 Operational Data Evaluation

In contrast to the Augusta site, the Atlanta I-75 site was characterized by a moving work zone with substantial data volumes. The research team evaluated the mainline traffic, the displayed message sign information, and the traffic volume for off-ramps. The mainline data source included the GA Tech deployed RTMS system as well as operational data from the IntelliZone archives. The displayed message history information was provided by the IntelliZone system. The off-ramp information was acquired using Nu-Metric Hi-Star classifiers.

At the IntelliZone site, data collection (for lane closures) occurred during active paving which moved approximately 1.5 to 2 miles per night. As a result, it was difficult to compare data between days due to the moving work zone operation. Most of the supplemental data collection for this site occurred between 9 p.m. and midnight when double lane closures were common. There were also a few single lane closure configurations during weekend supplemental data collection periods.

The northbound direction was rarely subjected to queuing; however, heavy queues occurred for night time data collection in the southbound direction. Figure 36 depicts sample speed data adjacent to and upstream of the southbound work zone. On November 15, 2003, a lane closure was present at the site. The closure was removed for the November 16 date. The upstream, uncongested traffic operating speed for days with and without lane closures averaged approximately 74 mph. Adjacent to the active lane closure, speeds reduced to approximately 55 mph. This type of speed reduction is common when there is an activity such as paving that attracts the attention of the driver. Similar data is available for northbound and southbound data, but the data shown in this figure is a representative sample.

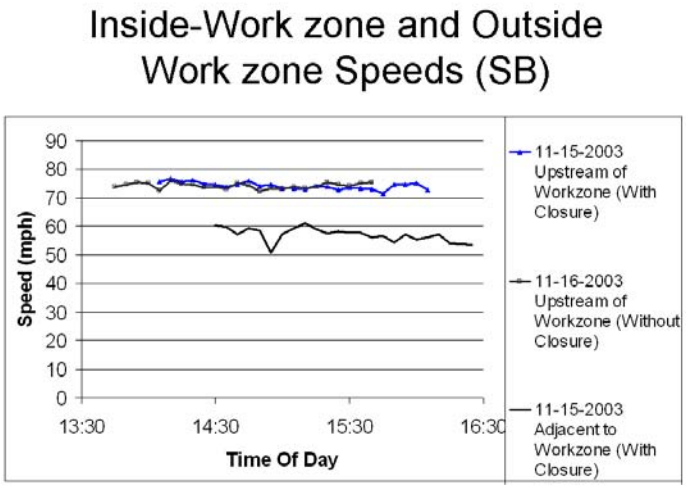



**Figure 36.** I-75 Atlanta Mainline Speeds Sample

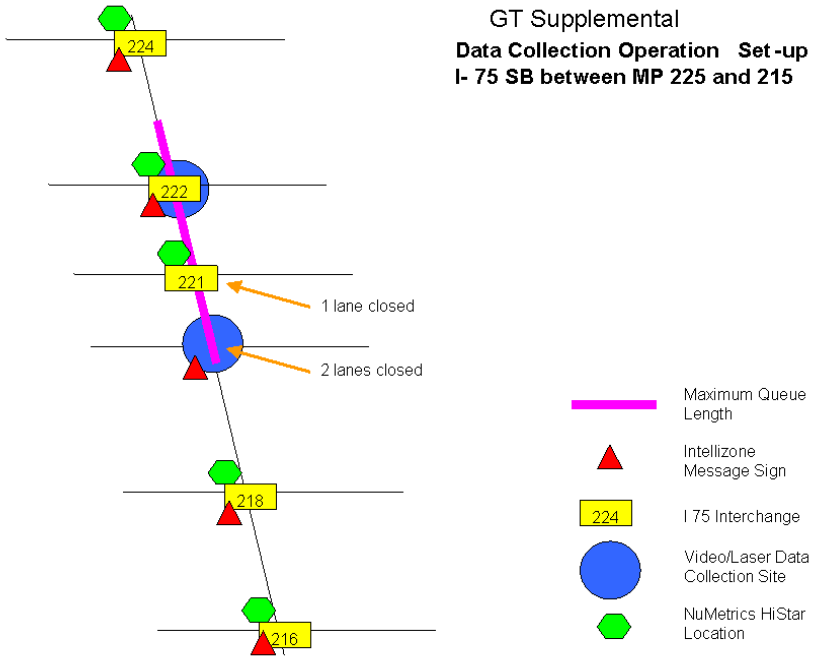



**Figure 37.** I-75 Atlanta Device Configuration

Figure 37 depicts the milepost configuration for this southbound example. At the extreme north off-ramp (Exit 222 as shown in Figure 38), exit volumes are similar for days with and without construction (this example is for the consecutive week nights of September 16 and 17, 2003). As the southbound traffic approaches the construction queuing (see Figure 39 and Figure 40) the number of exiting vehicles increased during active construction. This is a strong indication that drivers were seeking alternative routes to avoid construction queues. This may be due to the IntelliZone messages or driver observation of downstream delays. At milepost 216 (see Figure 41), the exit trend diminishes since this location is south of the southbound construction activity.

One problem encountered with the IntelliZone data (provided by the vendor) was that the sign messages stored by the system did not always reflect those observed in the field. As a result, it was not feasible to evaluate the influence of various signs on traffic operations. This sign message database was provided as a courtesy by the vendor and was not a contractual obligation.

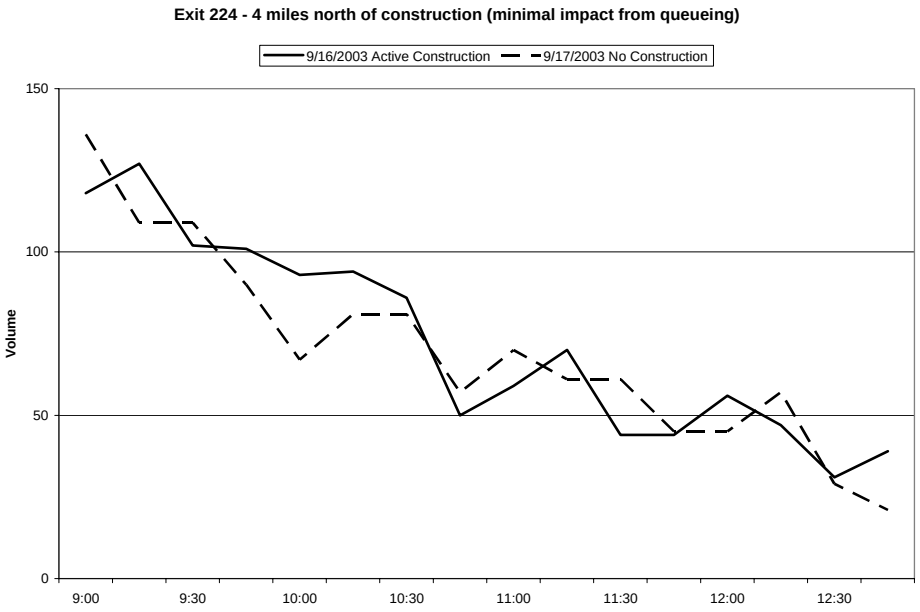



**Figure 38.** Off-Ramp Volumes (Milepost 224)

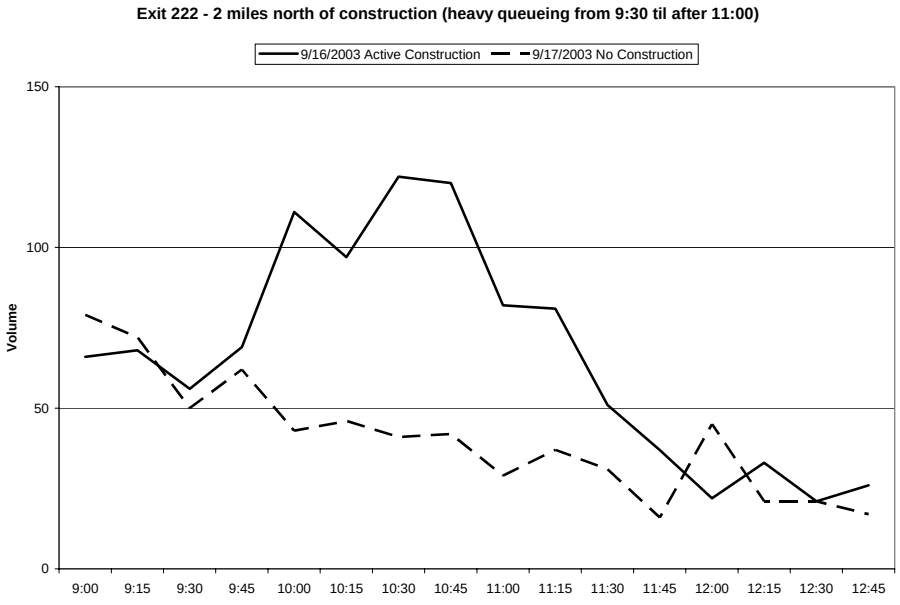



**Figure 39.** Off-Ramp Volumes (Milepost 222)

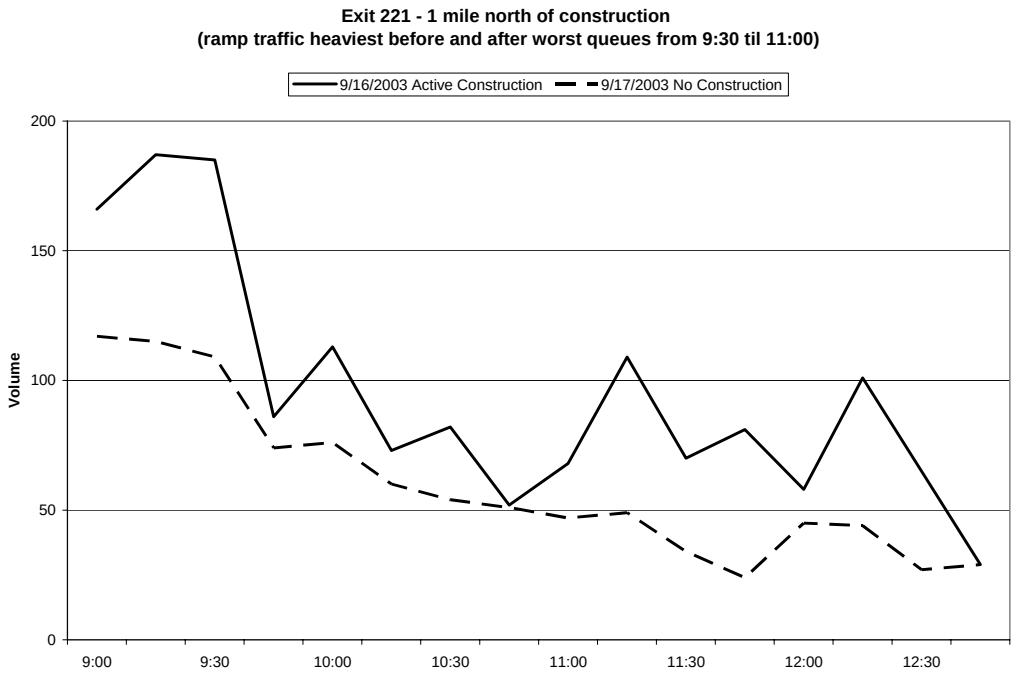



**Figure 40.** Off-Ramp Volumes (Milepost 221)

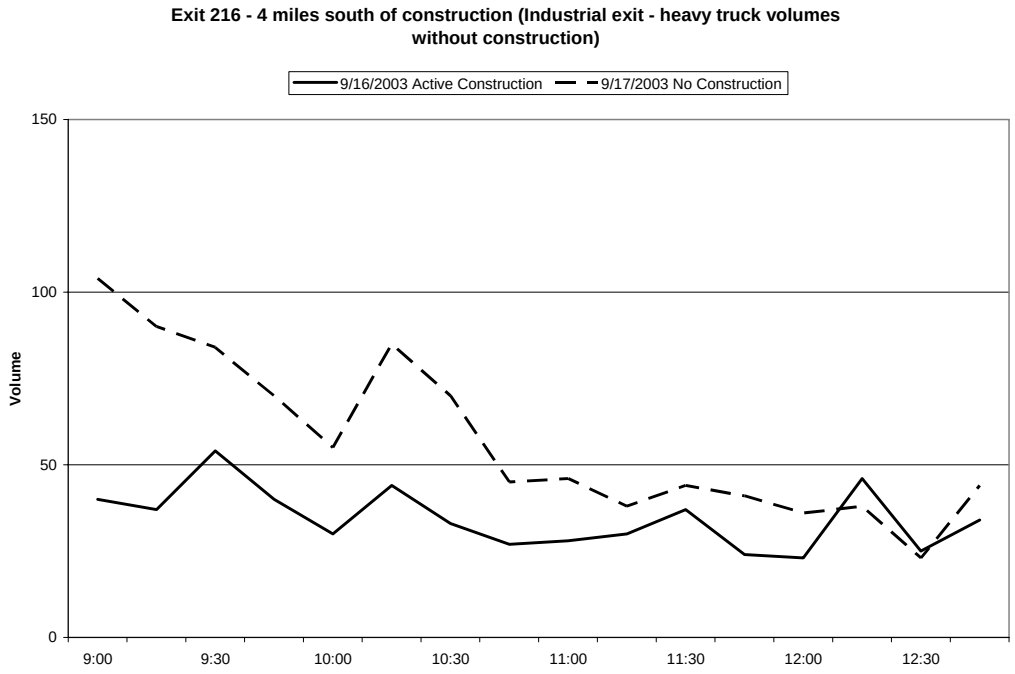



**Figure 41.** Off-Ramp Volumes (Milepost 216)

6.1.2.2. Atlanta I-75 Installation, Maintenance, and Equipment Issues

The initial construction optimization strategy and deployment of the IntelliZone equipment hinged on the assumption that weekend and weekday construction accomplishments would allow a common system placement. The actual construction sequencing, however, was modified to accommodate widely varying asphalt thicknesses and traffic control required to facilitate construction of this type. GDOT therefore elected to focus on continuous 53 hour weekend operations as the critical periods for work zone operations. As a result, the selection of a feasible alternative route for the specific work area during the critical construction periods was restricted to location specific opportunities. In addition, the focus on the 53 hour critical periods resulted in less than optimal device deployment during non-critical time periods.

Due to the dynamic deployment required for the IntelliZone site, the initial equipment design (see Figure 30 and Figure 31) required that sensors and signs be located approximately two miles apart. Since it is desirable to locate message signs on a relatively level platform to enhance their visibility, construction crews proceeded to create crushed stone base platforms at every other milepost location so that there would be a suitable location adjacent to the road every two miles. Unfortunately, these crushed stone base pads were often not at a location that would facilitate the optimal delivery of information to the traveling public. For example, if the purpose of a changeable message sign is to alert the motorist to slow traffic ahead so that he or she may seek an alternative route, it is logical that the sign should be placed upstream of an off-ramp (if one is available in close proximity). The sign location depicted in the photograph in Figure 42 shows one of these sign placements. At this location, the sign is located immediately after (downstream) an off-ramp rather than before (upstream of) the off-ramp.

**Figure 42.** Undesirable Placement of Informational Sign

An additional implementation issue observed with the IntelliZone system at the I-75 Atlanta site was the rigid configuration of the sign and the order in which they were positioned. For example, rather than removing the device furthest upstream of the work

activity (as the activity moved) and locating it downstream of the other devices, the system required that the devices all be deployed in a specific order. So, when one sign was shifted all of the signs had to be shifted at the same time. This deployment strategy caused the system to be taken off-line for up to three days at a time to re-deploy at another downstream location. During that three-day delay, work activity continued without the benefit of the system. A more flexible configuration that does not require this specific sign hierarchy would provide a robust deployment with minimal delays.

It is important to note that the IntelliZone system performed as anticipated throughout the work zone. Limitations to the system were due to site specific issues or deployment strategies that can be refined for future deployments. The purpose of using the IntelliZone for this corridor was to evaluate the differences between static portable ITS systems (such as Augusta) and dynamic deployment ITS systems.

### *6.1.3. Tifton I-75 ASIS System*

#### 6.1.3.1. Tifton ASIS Operational Data Evaluation

The Tifton I-75 corridor included construction activity for both northbound and southbound directions of travel; however, the southbound direction of travel had only one time during active construction when the active construction occurred. Therefore, the northbound direction of travel is the focus of this review.

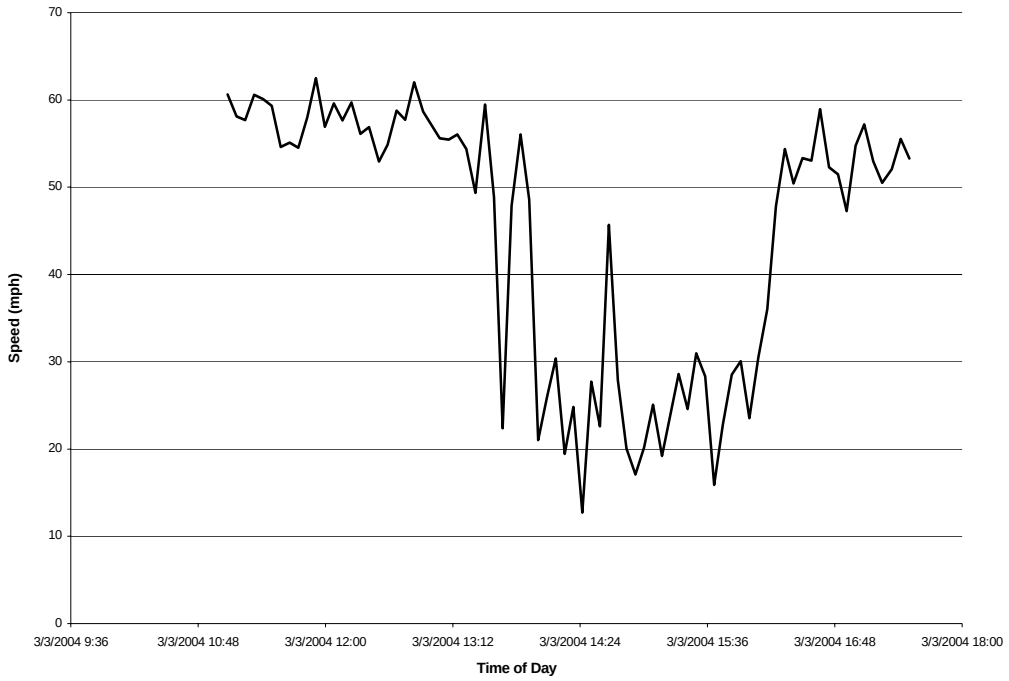



**Figure 43.** Northbound Speeds with Queues Present (3/3/04)

Several data collection days experienced no-construction (baseline) conditions; however, on March 3, 2004, the data collection team observed queues during the afternoon (see Figure 43). The GA Tech data collection team performed floating car studies to evaluate message accuracy for the changeable message signs, and determined the signs were representative of the downstream speeds. At the same time, the research team collected volume data for the adjacent ramps. In general, very little ramp traffic volume increased during downstream delays (as on 3/3/04) compared to non-construction dates (4/7/04 and 4/14/04 as an example). The northbound configuration of I-75 near Tifton is characterized by two off-ramps in close proximity to each other. Figure 44 and Figure 45 demonstrate that drivers elected to take the first exit (at the 82nd Street Ramp) rather than risking further delays and proceeding to the US 41 off-ramp. This demonstrates that either the sign messages or visual identification of downstream queues led drivers to exit upstream of the normal exit and seek alternative surface street routes.

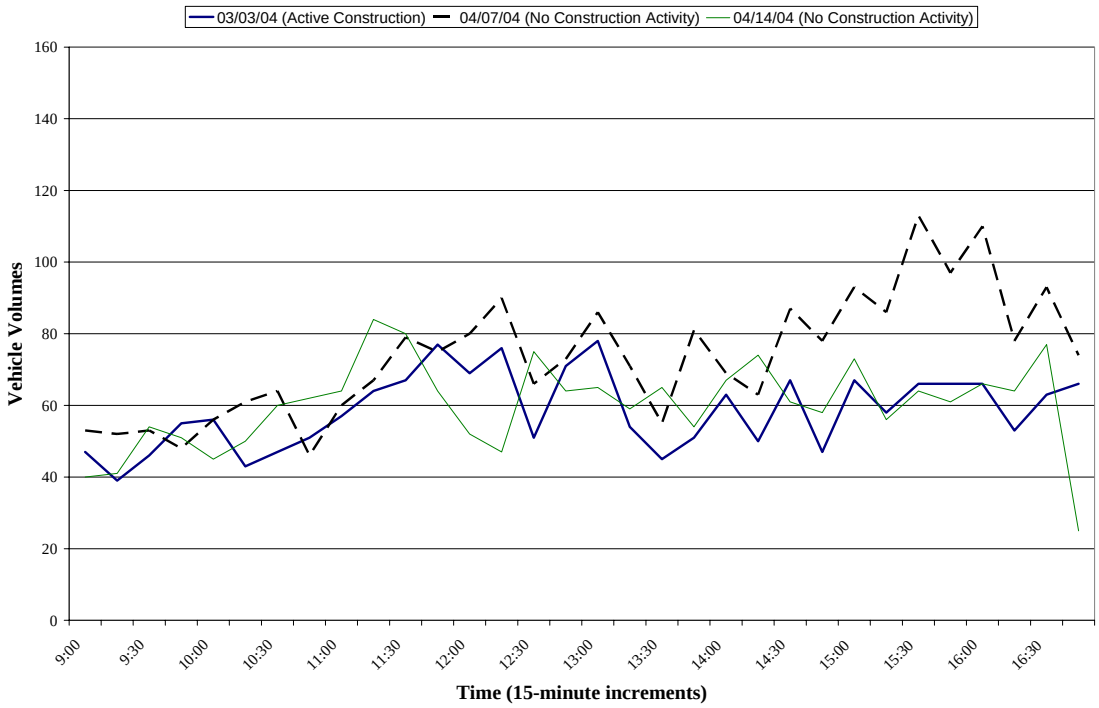



**Figure 44.** Tifton I-75 NB Exit to 82nd Ramp Volumes

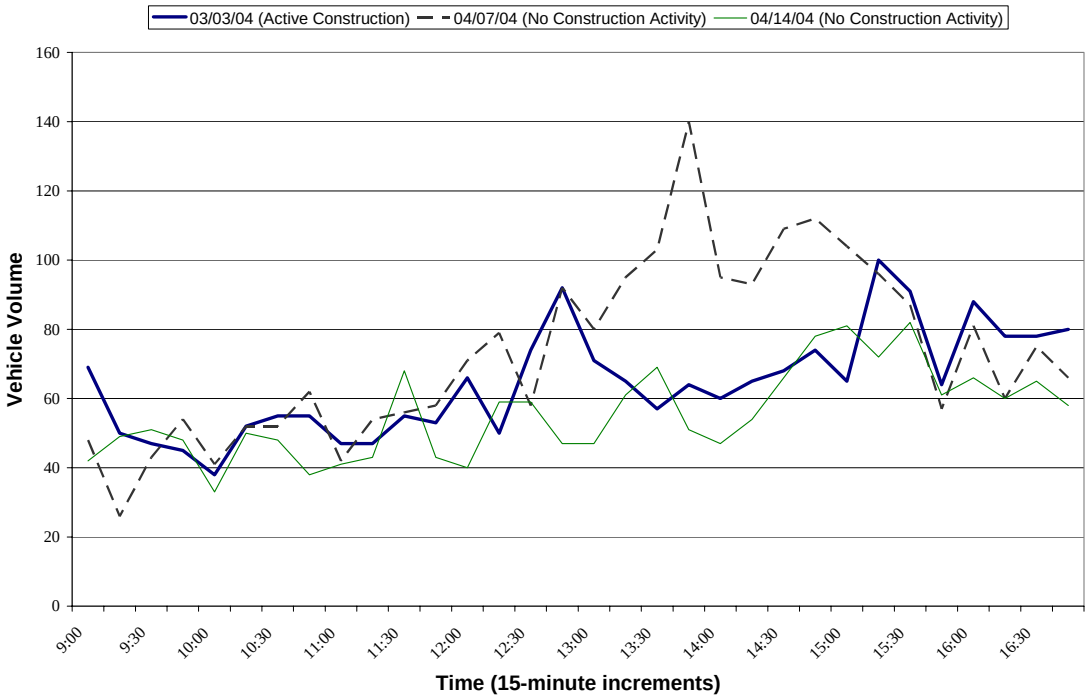



**Figure 45.** Tifton I-75 NB Exit to US 41 Ramp Volumes

Another indication of work zone delays is the percentage of time a low speed or stopped message appeared on the changeable message sign. Figure 46 shows that the most frequent messages at the Tifton ASIS site were for downstream speeds of 55 mph and 60 mph. This demonstrates that the Tifton site overall experienced minimal delays.

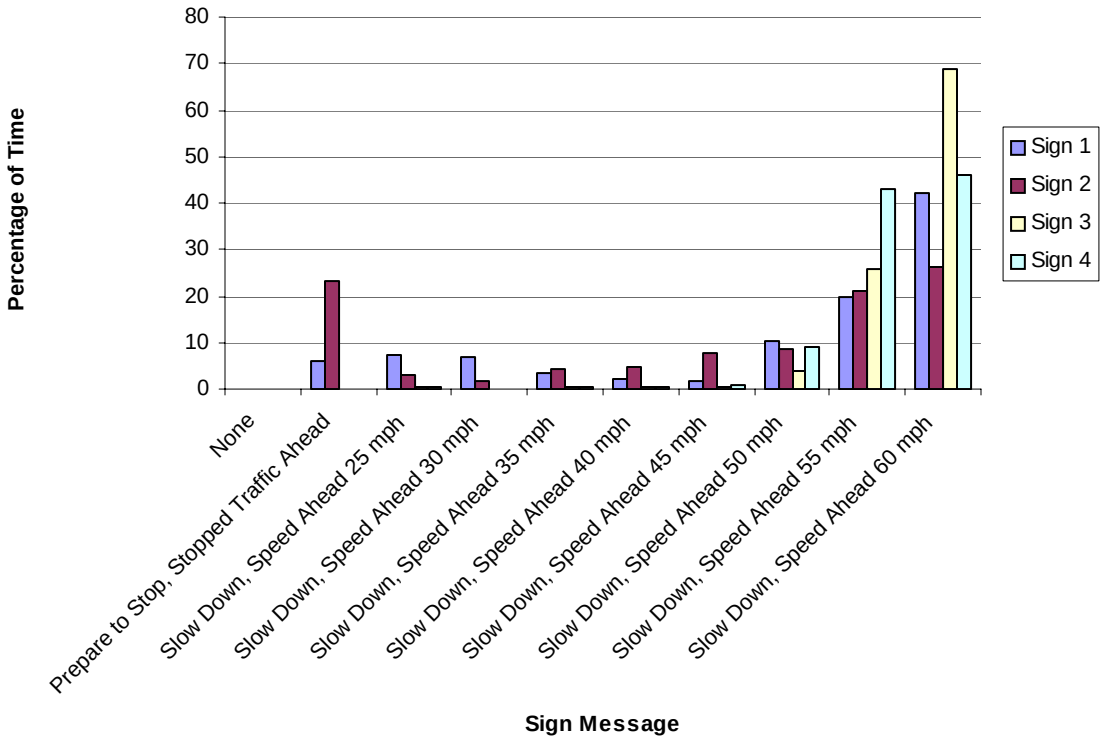



**Figure 46.** Tifton ASIS Sign Message Frequency

6.1.3.2. Tifton ASIS Installation, Maintenance, and Equipment Issues

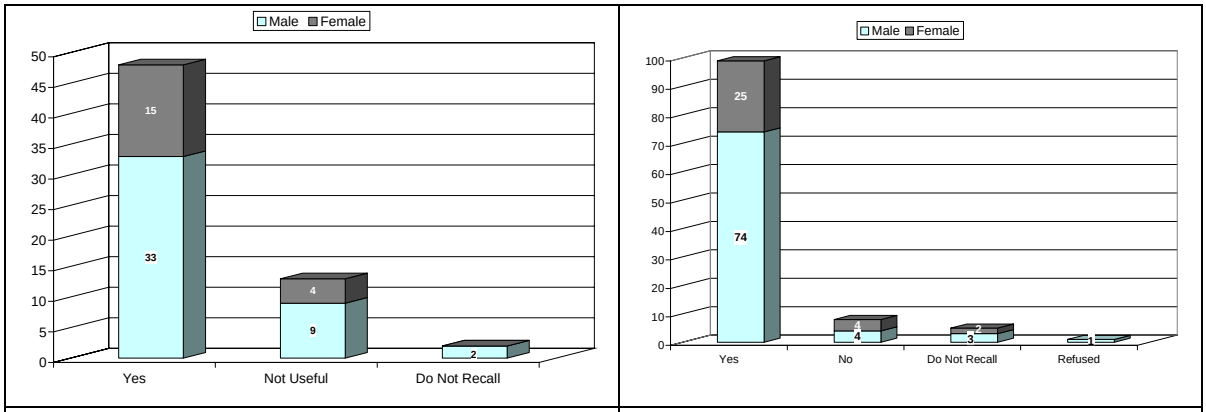
There were very few maintenance issues regarding the ASIS equipment at the Tifton site. For this construction contract, the original contract included a line item for a local ASIS technician to assist the construction staff anytime there was a need to shift the construction activity. As a result, calibration issues such as those that occurred at the Augusta site following the Masters Tournament did not occur.

The data collection team did, however, identify an equipment issue at this site that had a direct influence on system operation. For a period of several days, the construction staff removed one of the operating ASIS system remote sensors from the active work zone and placed this trailer-mounted device adjacent to an off-ramp. Unfortunately, it does not appear that the device was deactivated as it continued to attempt to sense vehicles. Figure 47 shows this device and its temporary location. The result of this sensor placement caused incorrect traffic information to be dispatched to the adjacent ASIS resulting in inaccurate information displayed on the ASIS signs. Since driver confidence is important to the successful use of portable ITS, equipment placement errors such as this could quickly undermine the positive perception by drivers of these systems.

**Figure 47.** Poor Temporary Placement of Active ASIS Remote Sensor

## 6.2. Portable ITS User Surveys

Members of the research team surveyed drivers who stopped at rest areas downstream of the Augusta and Tifton work zones (the Atlanta site did not have a conveniently placed rest area so no survey was performed for that location). Figure 34 shows the entire list of questions included in the survey. A total of 178 drivers (65 at Augusta and 113 at Tifton) responded to the survey. The initial question they were asked was if the drivers noticed the message signs in the work zone. Figure 48 shows the responses at each location. 48 of the Augusta drivers (approximately 74%) and 99 of the Tifton drivers (approximately 88%) noticed the signs. The research team did not anticipate the lower observation rate at the Augusta site; however, one possible explanation is that the Augusta site is adjacent to a busy urban region with many distractions while the Tifton site it primarily a rural freeway configuration.

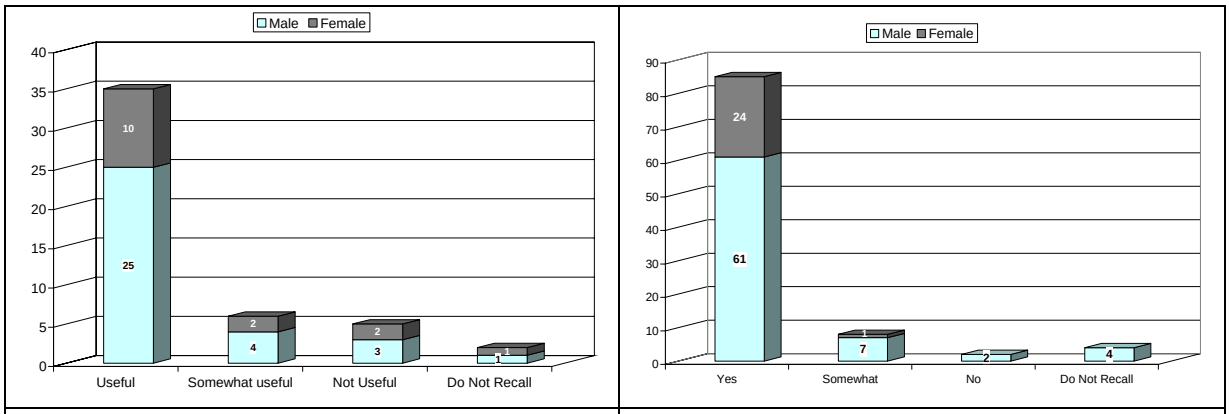



| Augusta | Tifton |
|---|---|

**Figure 48.** Survey Response -- Did You Notice Message Signs in Work Zone?

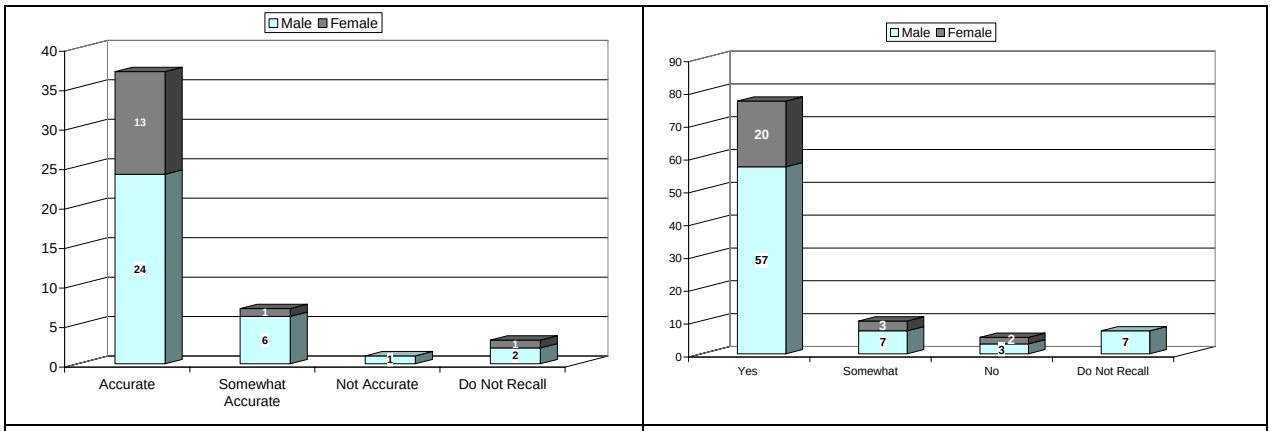
Respondents who answered affirmatively to the initial question were then asked a series of questions regarding their perception of the system. Figure 49 displays the responses to the question that asked if the drivers perceived the information to be useful. Approximately 86% of the remaining Tifton respondents answered yes to this question (11% higher then at Augusta). The drivers were also asked if they perceived the information to be accurate. Figure 50 shows the responses where approximately 78% of drivers at each site responded positively. Finally, when asked if the information changed the way they drove (see Figure 51), 73% of the Tifton drivers indicated they modified their driving with most indicating they drove slower. For the Augusta survey, however, only 46% of the drivers indicated they modified their driving due to the portable ITS system information.

Finally, the research team evaluated the survey response data based on age and gender and did not identify any distinct trends.




Augusta | Tifton

**Figure 49.** Survey Response -- Was the Information on the Signs Useful?




Augusta | Tifton

**Figure 50.** Survey Response -- Did You Find the Displayed Information Accurate?

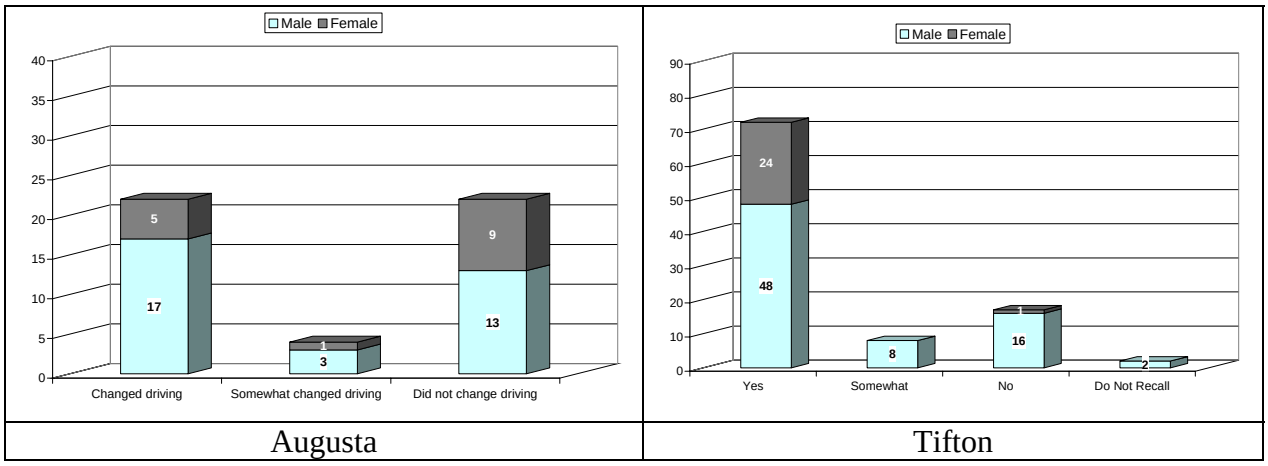



**Figure 51.** Survey Response -- Did the Information Change the Way You Drove?

### 6.3. Portable ITS Crash Analysis (Augusta Site Only)

As indicated in the previous chapter, GDOT provided crash data for the Augusta site as well as for a similar site where the construction had occurred the previous year but for which a portable ITS system did not exist. For the purposes of this evaluation, this information is divided into four location categories: Site A (previous construction site) eastbound travel, Site B (previous construction site) westbound travel, Site C (study site) eastbound travel, and Site D (study site) westbound travel. The portable ITS equipment was only located at Site C (see Table 14).

**Table 14.** Augusta Crash Summary

| Location | Crash Type / Condition | | | | |
|---|---|---|---|---|---|
| | Single Vehicle Crash | | | Multiple Vehicle Crash | |
| | Impact Fixed Object | Overturn | Other | Rear-end | Other |
| Site A | 9 | 1 | 0 | 2 | 0 |
| Site B | 2 | 0 | 0 | 3 | 1 |
| Site C | 2 | 0 | 1 | 0 | 0 |
| Site D | 0 | 0 | 0 | 0 | 1 |

Note: Shaded sites represent eastbound direction of travel.

At least one person was injured fatally in a crash at Site B and Site D (in both cases this was due to speeding and a driver losing control of a vehicle). A common cited crash cause in the accident reports for Sites A and B were that the crashes were due to standing water causing the vehicle to hydroplane. At Site A, 8 of the 12 crashes involved this issue. For Site B, 2 of the 3 crashes may have been due to hydroplaning. There are many causes for hydroplaning; however, the reduced friction of the road surface combined with

higher speeds commonly contributes to this type of crash. Though there were no crashes due to hydroplaning at Site C (the location with the portable ITS system), it is very likely that there were days with rain and standing water. As a result, it is possible that the system helped drivers reduce their speed and may have contributed to safety under these conditions.

The most severe crashes are (1) high-speed single vehicle crashes where the vehicle impacts a rigid object or overturns, and (2) multiple vehicle crashes where the speeds of the involved vehicles are dissimilar. There were no multiple vehicle crashes reported for Site C. Since a perceived benefit of the portable ITS system is to provide advance warning to motorists that there may be stopped conditions downstream, it appears that the portable ITS system did contribute positively to safety by minimizing "surprise" encounters with queued vehicles.

All three of the crashes at Site C were due to poor driver decisions. For one of the crashes at Site C, the driver was simply distracted and impacted a steel guardrail. Upon impact the driver appears to have responded abruptly and ultimately impacted a tree. The second Site C crash involved a driver who was also distracted and abruptly tried to change lanes to avoid hitting another vehicle. Instead, the vehicle impacted a guardrail adjacent to the road.

The third Site C crash may actually be due to the portable ITS system. For reasons unknown (perhaps due to a message on one of the signs), a driver attempted to drive his vehicle across the median to make a U-turn and unfortunately impacted the median ditch.

In general, driver errors due to speeding appear to be reduced with the use of portable ITS equipment. Also, rear-end crashes due to unexpected stopped conditions did not appear to be an issue at the portable ITS site.

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# CHAPTER 7. CONCLUSIONS

This study evaluated the performance of changeable message signs as well as portable message signs for highway work zones. The site selected for CMR evaluation was a two-way, two-lane rural highway. The portable ITS system configurations all occurred at freeway work zones. Three types (TIPS, IntelliZone, and ASIS) of ITS equipment setups were evaluated. The results of this research are summarized in the following paragraphs.

The research team evaluated the use of a CMR adjacent to the work activity area at a two-lane, two-rural highway for potential speed reduction affects. They determined that though speed reductions are small, the placement of a CMR sign adjacent to work zone activity area traffic does result in an average speed reduction ranging from 1.0 to 1.8 mph for all vehicles. This small speed reduction does not substantially diminish over time, so the CMR can be expected to provide reasonably consistent results for all vehicles for a sustained period of deployment. There were varying results when evaluation the influence of the sign for daytime and nighttime lighting conditions as well as for passenger cars compared to trucks. The speed reductions that were observed were maintained an approximately 3-mile distance downstream of the device, so drivers who do adjust their speed due to the CMR retain the speed adjustment as they traverse the downstream work zone region.

This study also evaluated the use of portable ITS systems for operational impacts, system maintenance and deployment issues, user perceptions, and safety implications. Since the systems ranged from a simple 3-device unit (at Tifton) up to a complex configuration with many sensors (I-75 south of Atlanta), direct comparison between the systems proved to be challenging. The research team focused on evaluating operational characteristics available for analysis at each site. The evaluation of the portable ITS system resulted in several conclusions as identified in the following list.

- The use of a portable ITS system does provides work zone operation information to the motorists resulting in increased off-ramp use during downstream queued conditions.
- With appropriate system understanding and a clear idea of all costs including provision of a local technician, a portable ITS system can provide useful information to the traveling public.
- Review of the proposed equipment configuration to assure optimal device placement will significantly enhance the likelihood that the ITS equipment will function well and inform drivers in a timely manner. For example, placement of message signs upstream of exit ramps so that a driver can see the message and respond if necessary will dramatically improve the operations of the system.
- For locations where drivers are not familiar with alternative routes, the portable ITS system may not result in increased exiting.
- The short-term storage of ITS sensors must be evaluated carefully if the unit remains operational as active sensors that are not properly positioned may provide unreliable information to the changeable message signs in the work zone.

- Approximately three-fourths of the drivers notice the ITS system and many of these drivers adjust their driving (usually by reducing speed) as a result of the system.
- The presence of a portable ITS configuration appears to have a positive influence in improving safety. Alerting the driver of downstream queues helps prevent rear-end crashes due to unexpected "surprise" stopped traffic. In addition, single vehicle crashes due to speeding may be reduced as a result of a portable ITS system.

In conclusion, both the CMR and the portable ITS systems appear to have a positive influence on traffic operations. Though the speed reduction is minor for the CMR condition, a common problem in the work activity area is a speed increase so this result should not be discounted. The portable ITS systems do appear to provide some operational smoothing; however, the results of this research indicate that perhaps the biggest benefit of the portable ITS systems were the driver informational benefit and its application to work zone safety. The research team evaluated three different portable ITS systems that range from a simple three-device configuration (ASIS) up to a complex configuration that requires as many as six sensors for travel direction. The selection of the simple versus more complex ITS system should depend upon the traffic volume (for more vehicles have more sensors and message signs available to address driver decision issues) and the type of construction activity. The complex system with multiple sensors is better suited for a "permanent" configuration rather than a moving construction operation, while a system with as few as three sensors can be easily shifted provided that a technician is included in the equipment price.

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# APPENDIX A. SUPPLEMENTAL TABLES AND FIGURES

## CMR Testing Results

### Hypothesis 1 : Test Speed Reductions Immediately After CMR Deployment

The following tables summarize the upstream speed changes in different data collection phases.

**Table 15.** Westbound Upstream Speed Changes (8/3/04 to 8/24/04)

| | 08/03/04 | 08/24/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 58.7 | 57.7 | -1.0 | 3.47 | Yes |
| Passenger vehicles, Day | 60.8 | 59.7 | -1.1 | 1.96 | No |
| Passenger vehicles, Night | 59.5 | 61.8 | 2.3 | -2.22 | Yes |
| Trucks, Day | 56.2 | 55.4 | -0.8 | 2.46 | Yes |
| Trucks, Night | 58.1 | 57.2 | -0.9 | 1.04 | No |

**Table 16.** Eastbound Upstream Speed Changes (8/3/04 to 9/21/04)

| | 08/03/04 | 09/21/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 60.9 | 60.3 | -0.6 | 2.45 | Yes |
| Passenger vehicles, Day | 60.4 | 60.2 | -0.2 | 0.50 | No |
| Passenger vehicles, Night | 62.8 | 59.8 | -3.0 | 3.12 | Yes |
| Trucks, Day | 61.3 | 60.4 | -0.9 | 2.67 | Yes |
| Trucks, Night | 61.4 | 60.6 | -0.8 | 0.86 | No |

The following tables summarize the speed changes at the CMR immediately after deployment.

**Table 17.** Westbound CMR Speed Changes (8/3/04 to 8/24/04)

| | 08/03/04 | 08/24/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 59.1 | 57.1 | -2.0 | 7.51 | Yes |
| Passenger vehicles, Day60.0 | 60.0 | 56.9 | -3.1 | 6.72 | Yes |
| Passenger vehicles, Night | 60.0 | 58.5 | -1.5 | 1.38 | No |
| Trucks, Day | 57.6 | 56.8 | -0.8 | 2.12 | Yes |
| Trucks, Night | 60.5 | 57.0 | -3.5 | 4.61 | Yes |

**Table 18.** Eastbound CMR Speed Changes (8/3/04 to 9/21/04)

| | 08/03/04 | 09/21/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 58.1 | 55.7 | -2.4 | 9.30 | Yes |
| Passenger vehicles, Day | 58.0 | 56.1 | -1.9 | 4.55 | Yes |
| Passenger vehicles, Night | 60.2 | 55.1 | -5.1 | 4.89 | Yes |
| Trucks, Day | 57.3 | 55.1 | -2.2 | 6.73 | Yes |
| Trucks, Night | 58.0 | 55.8 | -2.2 | 2.30 | Yes |

The following tables summarize the speed changes downstream of the CMR immediately after deployment.

**Table 19.** Westbound Downstream Speed Changes (8/3/04 to 8/24/04)

| | 08/03/04 | 08/24/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 57.7 | 56.0 | -1.7 | 6.36 | Yes |
| Passenger vehicles, Day60.0 | 57.2 | 54.9 | -2.3 | 4.63 | Yes |
| Passenger vehicles, Night | 60.2 | 59.2 | -1.0 | 1.09 | No |
| Trucks, Day | 57.3 | 55.6 | -1.7 | 5.01 | Yes |
| Trucks, Night | 59.3 | 58.7 | -0.6 | 0.90 | No |

**Table 20.** Eastbound Downstream Speed Changes (8/3/04 to 9/21/04)

| | 08/03/04 | 09/21/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 59.1 | 56.6 | -2.5 | 7.28 | Yes |
| Passenger vehicles, Day | 58.9 | 57.0 | -1.9 | 3.29 | Yes |
| Passenger vehicles, Night | 60.5 | 56.0 | -4.5 | 4.34 | Yes |
| Trucks, Day | 58.5 | 56.8 | -1.7 | 3.04 | Yes |
| Trucks, Night | 57.8 | 53.4 | -4.4 | 3.31 | Yes |

**Hypothesis 2 : Test Speed Reductions a Few Weeks After CMR Deployment**

The following tables summarize the upstream speed changes in different data collection phases.

**Table 21.** Westbound Upstream Speed Changes (8/3/04 to 9/14/04)

| | 08/03/04 | 09/24/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 58.7 | 58.7 | 0.0 | 0.00 | No |
| Passenger vehicles, Day | 60.8 | 60.6 | -0.2 | 0.36 | No |
| Passenger vehicles, Night | 59.5 | 59.7 | 0.2 | -0.20 | No |
| Trucks, Day | 56.2 | 56.6 | 0.4 | -1.18 | No |
| Trucks, Night | 58.1 | 58.5 | 0.4 | -0.48 | No |

**Table 22.** Eastbound Upstream Speed Changes (8/3/04 to 10/12/04)

| | 08/03/04 | 10/12/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 60.9 | 61.7 | 0.8 | -3.22 | Yes |
| Passenger vehicles, Day | 60.4 | 61.5 | 1.1 | -2.69 | Yes |
| Passenger vehicles, Night | 62.8 | 61.2 | -1.6 | 1.70 | No |
| Trucks, Day | 61.3 | 62.0 | 0.7 | -1.92 | No |
| Trucks, Night | 61.4 | 60.8 | -0.6 | 0.62 | No |

The following tables summarize the speed changes at the CMR immediately after deployment.

**Table 23.** Westbound CMR Speed Changes (8/3/04 to 9/14/04)

| | 08/03/04 | 09/14/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 59.1 | 58.4 | -0.7 | 2.52 | Yes |
| Passenger vehicles, Day60.0 | 60.0 | 58.0 | -2.0 | 3.72 | Yes |
| Passenger vehicles, Night | 60.0 | 58.9 | -1.1 | 1.15 | No |
| Trucks, Day | 57.6 | 58.6 | 1.0 | -2.69 | Yes |
| Trucks, Night | 60.5 | 58.1 | -2.4 | 3.68 | Yes |

**Table 24.** Eastbound CMR Speed Changes (8/3/04 to 10/12/04)

| | 08/03/04 | 10/12/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 58.1 | 57.5 | -0.6 | 2.37 | Yes |
| Passenger vehicles, Day | 58.0 | 57.7 | -0.3 | 0.71 | No |
| Passenger vehicles, Night | 60.2 | 57.6 | -2.6 | 2.73 | Yes |
| Trucks, Day | 57.3 | 57.3 | 0.0 | 0.00 | No |
| Trucks, Night | 58.0 | 57.4 | -0.6 | 0.63 | No |

The following tables summarize the speed changes downstream of the CMR immediately after deployment.

**Table 25.** Westbound Downstream Speed Changes (8/3/04 to 9/14/04)

| | 08/03/04 | 09/14/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 57.7 | 57.1 | -0.6 | 2.35 | Yes |
| Passenger vehicles, Day60.0 | 57.2 | 56.8 | -0.4 | 0.85 | No |
| Passenger vehicles, Night | 60.2 | 57.2 | -3.0 | 3.75 | Yes |
| Trucks, Day | 57.3 | 57.3 | 0.0 | 0.00 | No |
| Trucks, Night | 59.3 | 58.8 | -0.5 | 0.76 | No |

**Table 26.** Eastbound Downstream Speed Changes (8/3/04 to 10/12/04)

| | 08/03/04 | 10/12/04 | T statistics | | |
|---|---|---|---|---|---|
| | Mean | Mean | Average speed change | t-value | Statistically significant change |
| All Vehicles (Headway >=5) | 59.1 | 57.5 | -1.6 | 4.93 | Yes |
| Passenger vehicles, Day | 58.9 | 57.9 | -1.0 | 1.85 | No |
| Passenger vehicles, Night | 60.5 | 55.6 | -4.9 | 5.24 | Yes |
| Trucks, Day | 58.5 | 58.2 | -0.3 | 0.54 | No |
| Trucks, Night | 57.8 | 54.3 | -3.5 | 2.81 | Yes |

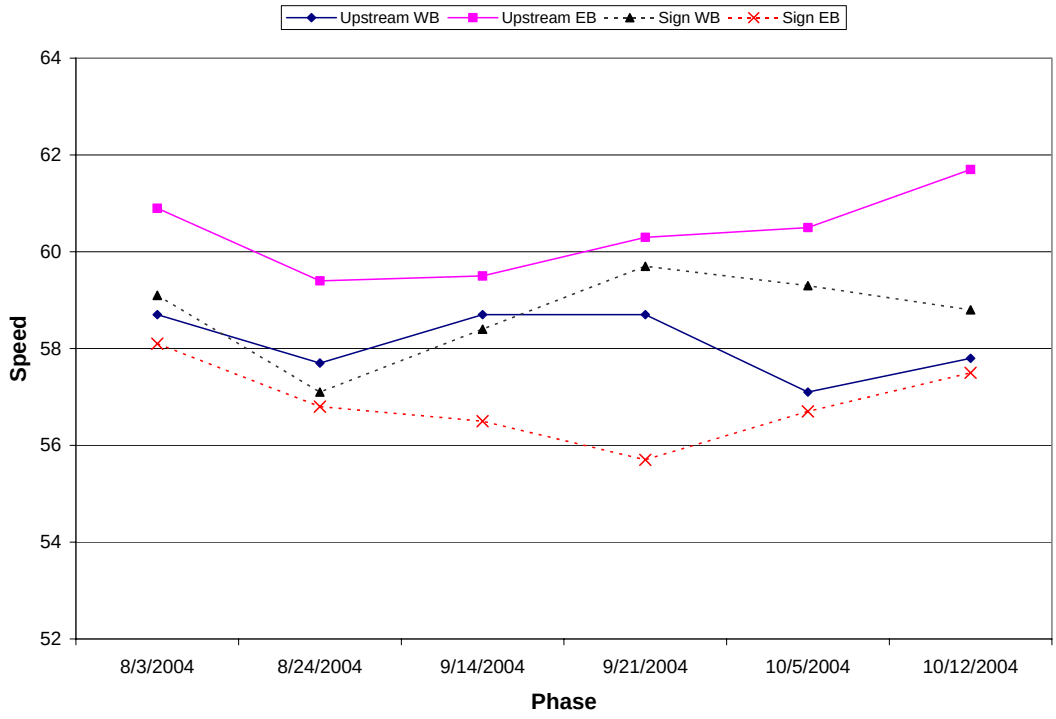


**Figure 52.** Average Speeds for CMR Study (All Free flow Vehicles)

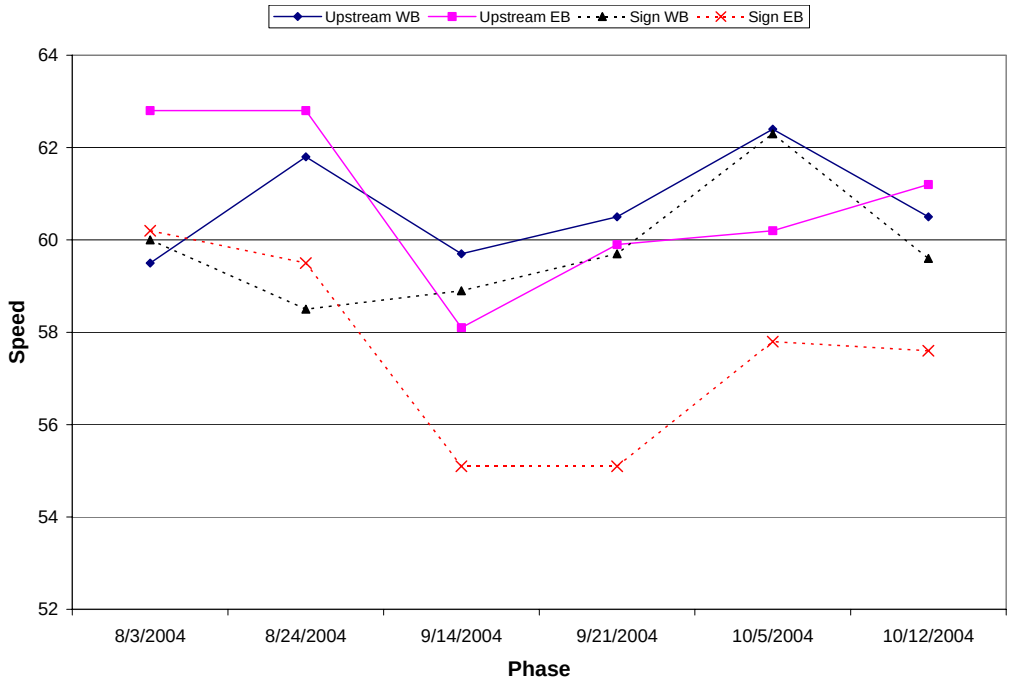


**Figure 53.** Average Speeds for CMR Study (Passenger Cars, Night)

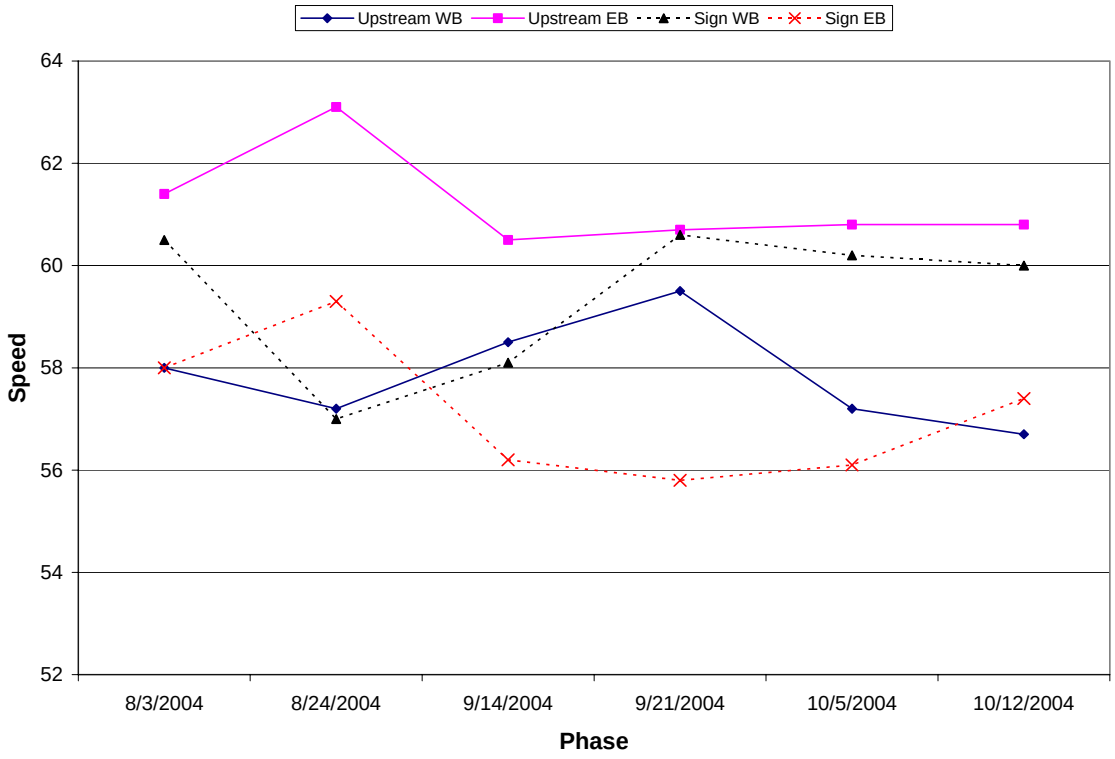


**Figure 54.** Average Speeds for CMR Study (Heavy Vehicles, Night)

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# APPENDIX B. WORK PLANS

GDOT Project 2031
(Georgia Tech Project E-20-J40)
Evaluating Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
S.R. 88 in Washington and Jefferson Counties

The Georgia Institute of Technology research team for the above project would like to initiate data collection and device testing at S.R. 88 in Washington and Jefferson 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 active work zone configuration in the westbound direction of travel. Next, a changeable message sign with radar (CMR) will be placed adjacent to the westbound lane (on the right in direction of travel) as shown in Figure 1. Sign placement will be adjacent to the two-lane, two-way configuration in the activity area of the work zone. 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). The sign may be tested at more than one activity area locations, but only one sign will be active at any given time.

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 so drivers can easily view the message as they approach the CMR.

The CMR will have two 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 to 10 miles per hour above the work zone speed limit the CMR message will read: "ACTIVE WORKZONE, REDUCE SPEED." For vehicles travelling between 10 miles per hour or more above the posted speed limit the CMR will display a message that indicates: "YOU ARE SPEEDING, SLOW DOWN NOW."

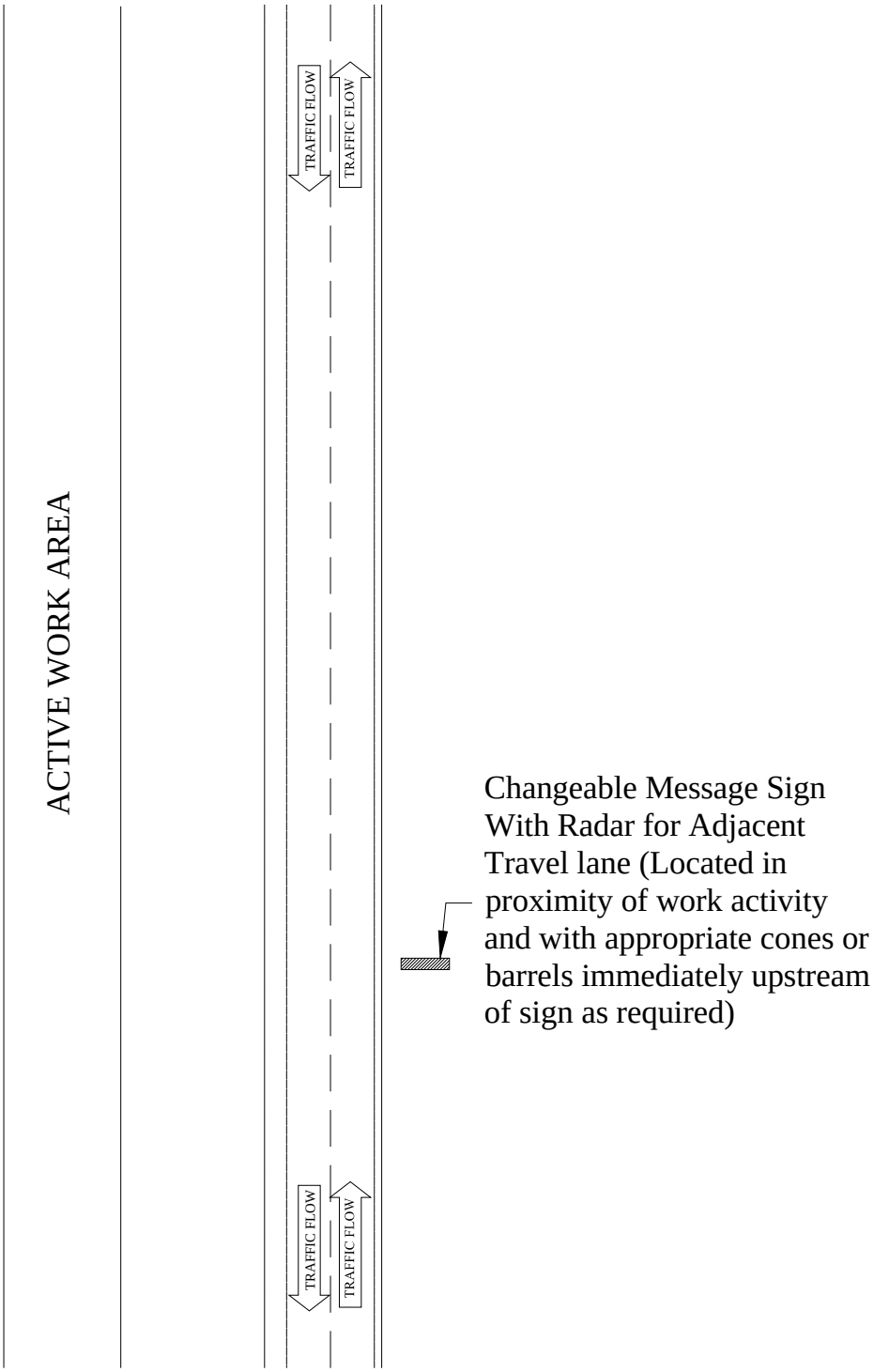


FIGURE 1. SIGN PLACEMENT ADJACENT TO WORK ACTIVITY
SR 88 in WASHINGTON & JEFFERSON COUNTY

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.

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, Georgia Tech 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 Shepherd Construction Company, Inc. 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.

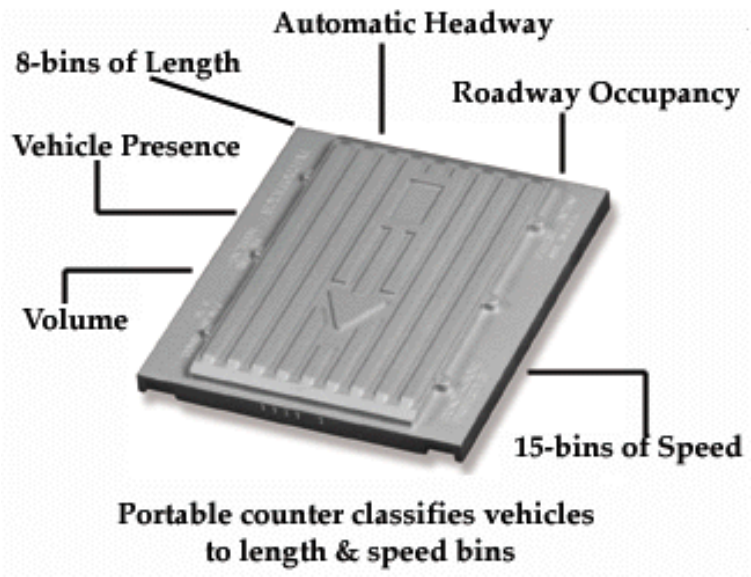


FIGURE 2. SAMPLE NU-METRICS CLASSIFIER (MODEL NO. NC-97)

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 may supplement the speed and volume data acquired from the Nu-Metric devices with sample laser speed data collection (if an unobtrusive location can be identified). The purpose of this supplemental data is to assure that the speed data collected by alternative devices is accurate.

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:

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 CMR,
3. 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.

GDOT Project 2031
(Georgia Tech Project E-20-J40)
Evaluating Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
I-20 from milepost 198 to milepost 201 in Richmond County

The Georgia Institute of Technology research team would like to initiate data collection along I-20 for the above project. In addition to data already collected from the Smart Work Zone technology already deployed, traffic speed and volume data collection is also necessary to complete this project. Data will be collected for both directions of travel. This work plan summarizes data collection tasks for the proposed project corridor.

## Traffic Speed and Volume Data Collection

Two sites will be used for each direction of travel, one approximately one-half mile upstream from the work zone's advance warning signs (see Figures 1 and 2) and another within the work zone where queuing of vehicles is likely to occur (see Figures 3 and 4). In the eastbound direction, it is preferable to take measurements within the work zone at a location where a sensor in the Smart Work Zone system is simultaneously collecting data in order to evaluate the accuracy of the data used by the system. Neither site should be near an interchange as weaving traffic could influence speeds. Both sites should also be readily accessible for the data collectors to safely set up equipment while minimizing driver distractions and interruption of traffic flow. The final locations for data collection may be changed upon field evaluation should a more suitable location be identified. All locations and times selected for data collection will be subject to approval by GDOT.

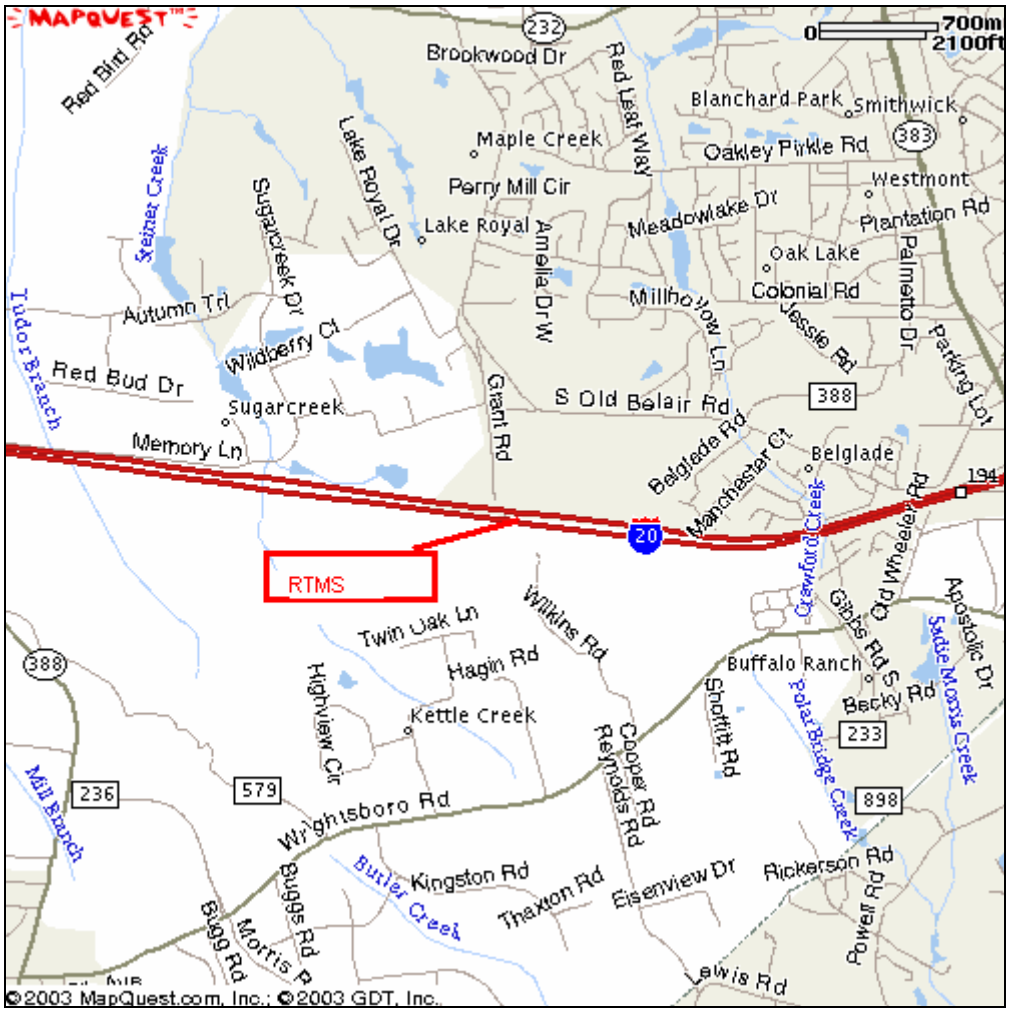


Figure 1 – Eastbound upstream data collection point near milepost 193.

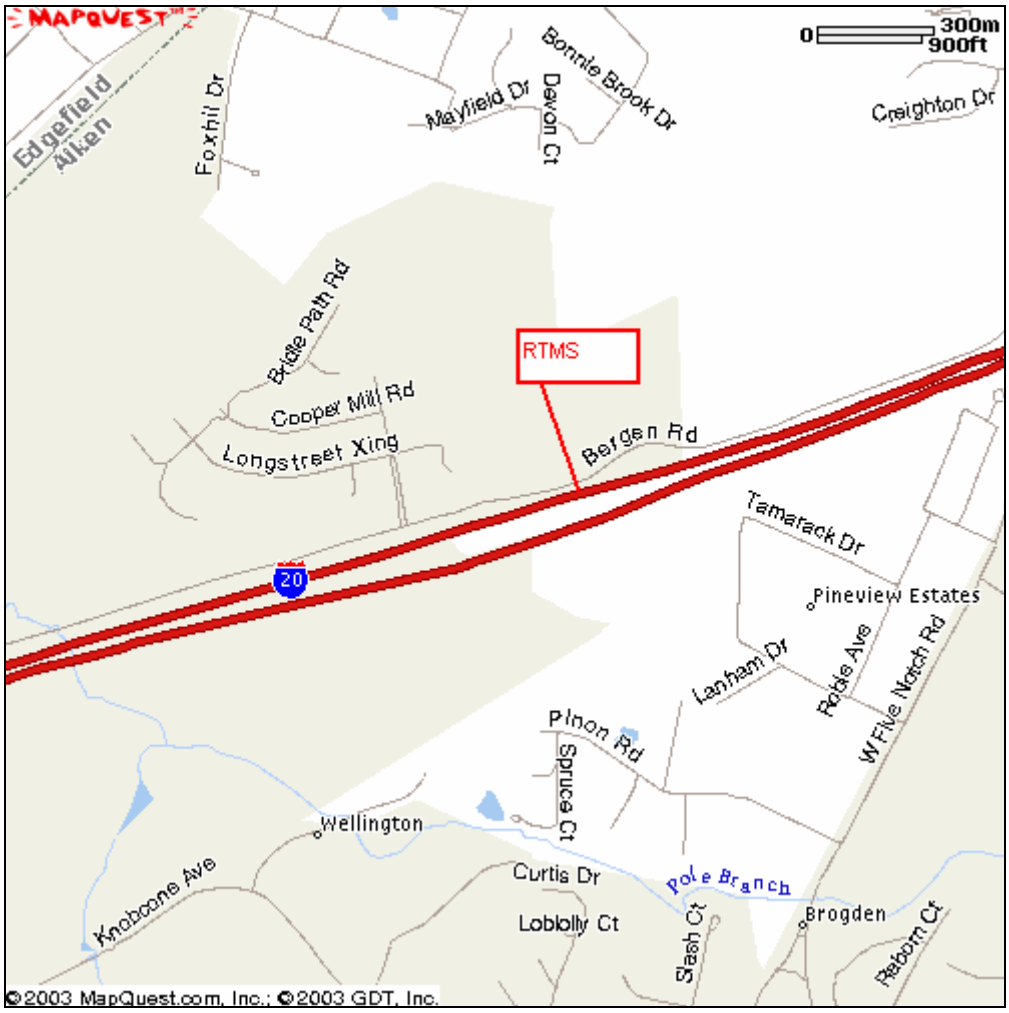


Figure 2 – Westbound upstream data collection point near milepost 2 in South Carolina.

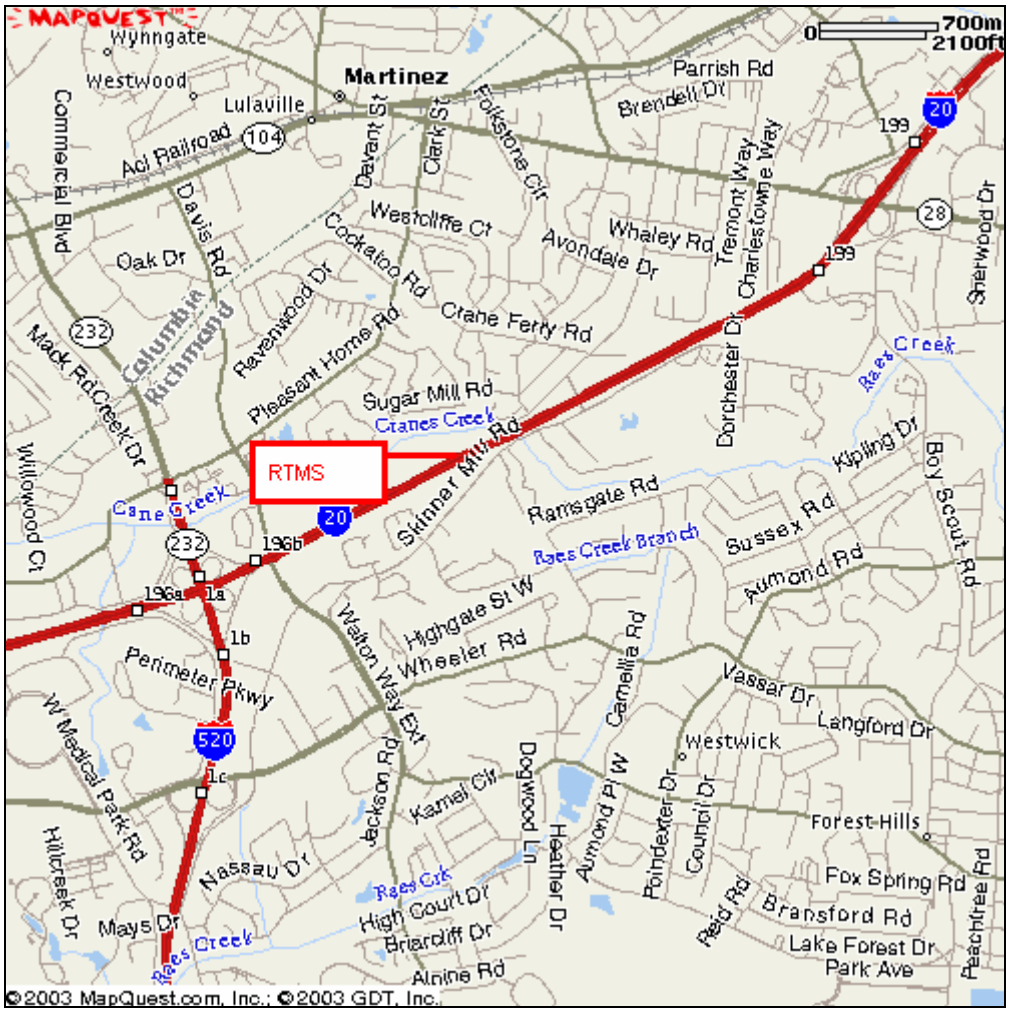


Figure 3 – Eastbound work zone data collection point at CMS with sensor.

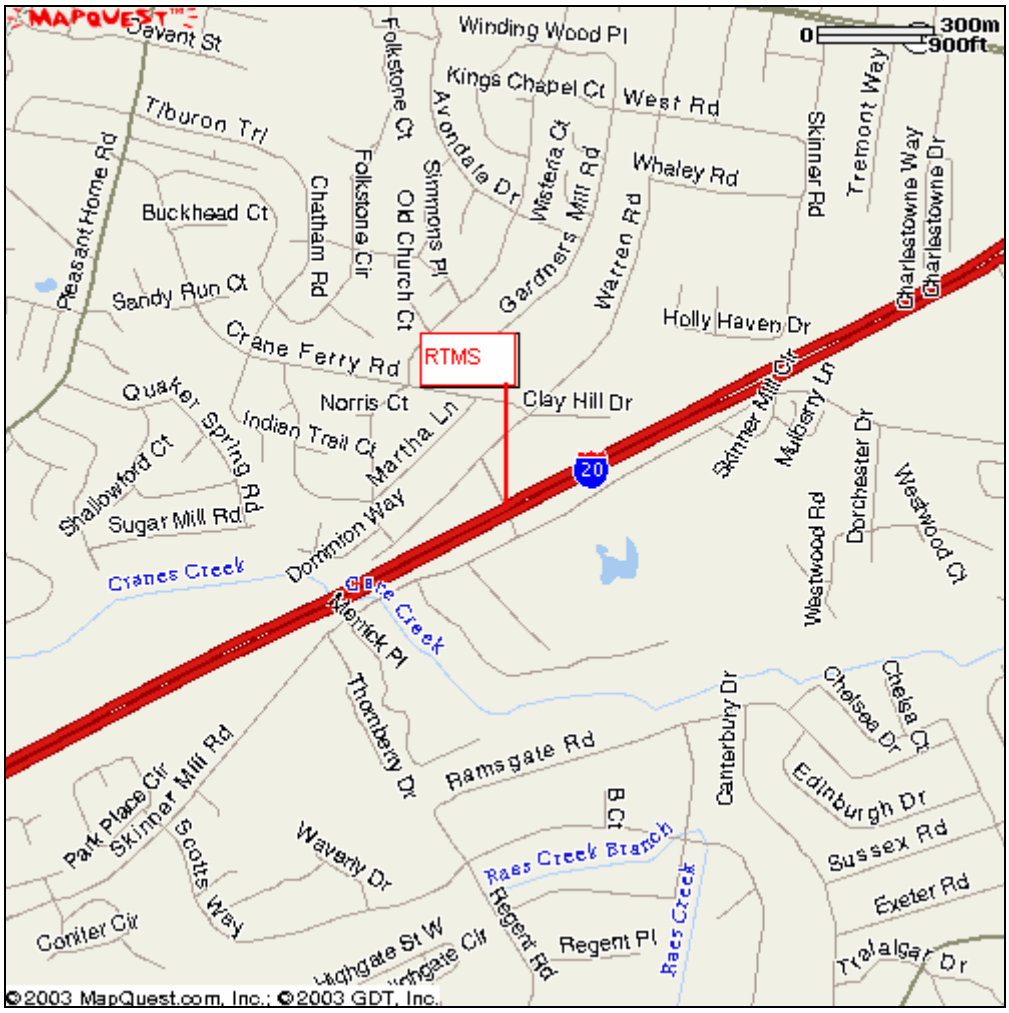


Figure 4 – Westbound work zone data collection point near the Warren Rd. overpass.

Two RTMS sensors mounted on trailers will be used to collect traffic data for each travel direction. These sensors will need to be calibrated each time they are moved to a new location. The researchers will set up one unit upstream from the work zone. The unit will be located on the right shoulder of the travel way at least 6 feet from the rightmost traveled lane. Appropriate demarcation for the unit, including the use of construction barrels, will be used. The unit will be set up to conform to MUTCD guidelines for temporary placement of roadside equipment. See Figure 5 for a schematic of the RTMS sensor location with respect to the direction of travel. Within the work zone, it is assumed that sufficient barriers and demarcation are already in place to safely locate the RTMS devices.

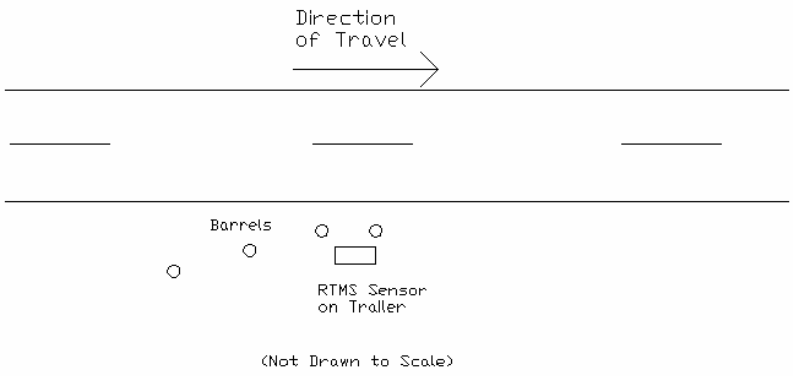


Figure 5 – General setup of RTMS sensor on trailer outside work zone.

The researchers will also collect supplemental data manually within the work zone using laser speed guns and a video camera for a period of time when the RTMS units are functioning. The entire data collection process described above will be repeated for the opposite direction of travel. However, the use of laser speed detection and video may be used exclusively within the work zone for the eastbound direction, as RTMS data from the Smart Work Zone itself should be readily available.

Georgia Tech data collectors will wear safety vests while working along active lanes. The researchers will always coordinate data collection efforts with the contractor. There will be two data collection periods, each lasting one night, one for eastbound travel and one for westbound travel.

GDOT Research Project 2031, Task Order 02-03
(Georgia Tech Project E-20-J40)
Evaluating Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
I-75 Construction Work Zone from Walt Stephens MP 226.3 to Exit 205

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 on I-75 South of Atlanta. The research team will work with Highway Information Systems, systems integrator for the Intellizone System, to collect data from the intelligent work zone system, but will also require additional data from independent sources to validate and evaluate the system performance and effects. This work plan summarizes the data collection tasks for the proposed project corridor.

## Traffic Speed and Volume Data Collection

A three-phase analysis is proposed for this project.

1) Collect speed and volume data upstream of the work zone to evaluate changes attributable to the work zone and information systems.
2) Validate Intellizone system equipment
3) Evaluate dispersion effects after the Intellizone system is activated.

Each phase will be described in more detail in the following sections.

1) The upstream data collection will be completed using Remote Traffic Microwave Sensors (RTMS) mounted on two-wheel trailers manufactured by AMSIG. The trailers are similar to those currently deployed by HIS, with the exception of the message boards, these will not be found on the research trailers. The trailers will be placed prior to the entrance of the work zones, approximately 1/2 mile upstream. The research team will work with GDOT and the project contractor to acquire appropriate traffic control devices (barrels) prior to deploying the devices. A minimum of 3 barrels will be used on diagonal in front of the sensor. The RTMS devices will be placed a minimum of 10 feet from the active travel lanes. No lane closures are expected for deployment. See Figure 1 for a picture of the RTMS as deployed.

**Figure 1. General setup of RTMS sensor on trailer outside work zone.**

2) Validation of the Intellizone Equipment will involve multiple data collection efforts. The first type of validation will require an RTMS device to be placed adjacent to one of the intellizone RTMS/CMS trailers for simultaneous data collection. It is expected that the traffic control used for the Intellizone device will also encompass the research device deployment given that the research RTMS will be placed immediately downstream and adjacent to the Intellizone trailer. The second type of data collection activity will include video and laser data collection. 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 and laser radar devices may also be utilized on a limited basis to observe driver reaction to the lane closure or traffic control device placement. Multiple overhead bridge crossings within the extents of the work zone have been identified for static video and laser data collection. The research team prefers to use those that do not have interchanges due to the weaving operations in those areas. However, in certain circumstances, the team may not have any other viable options. No lane closures will take place for these data collection activities and all equipment and personnel will use sidewalk/roadside areas for data collection activities. Advance cones will be used to denote the sidewalk obstacles. Data collection will take place with traffic moving away from the bridge to minimize driver distraction when possible. Figure 2 shows an example of these data collection activities along a bridge.

**Figure 2  Video and Laser Equipment on Overhead Bridge**

3) The last data collection effort will encompass the capture of potential dispersion effects of traffic onto alternative routes by monitoring exit ramp volumes before and after the Intellizone system is installed. This activity will require the use of NuMetrics HiStars on the Exit ramps. Up to thirteen ramps may be monitored at one time. Nu-Metrics traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the exit ramp lane. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). 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 GDOT for appropriate times to deploy the devices. Nu-Metric devices can be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Figure 3 shows the schematic of a typical classifier.

**Figure 3. Sample Nu-Metrics Classifier (MODEL NO. NC-97)**

Safety is paramount for all research activities. 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 chosen GDOT respresentative. Data collection efforts may range from one day to several consecutive days. These discrete time periods are:

4. Prior to implementation of the Intellizone system (this data set will function as a baseline for future data collected),

5. Immediately following implementation of the Intellizone system

6. A few weeks following implementation of the Intellizone system

7. At other interesting changes in lane closures and traffic scenarios.

Please contact Jennifer Ogle at Georgia Tech 404-385-0694 or the Principal Investigator, Karen Dixon, at 404-894-5830 if you have any questions regarding this proposed work plan.

GDOT Research Project 2031, Task Order 02-03
(Georgia Tech Project E-20-J40)
Evaluating Speed Reduction Strategies for Highway Work Zones

Research and Data Collection Work Plan
I-75 Construction Work Zone North of Tifton, Georgia

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 on I-75 just north of Tifton, Georgia. The research team will work with the local GDOT project and contractor representatives to coordinate data collection for the site currently instrumented with ASIS intelligent work zone system. Since the ASIS system does not store data for the traffic condition, the research team will collect additional data from supplemental sources to validate and evaluate the system performance and effects. This work plan summarizes the data collection tasks for the proposed project corridor.

Traffic Speed and Volume Data Collection

A three-phase analysis is proposed for this project.

4) Collect speed and volume data upstream of the work zone to evaluate changes attributable to the work zone and information systems.
5) Validate accuracy of ASIS sign messages
6) Evaluate any diversion effects if appropriate.

Each phase will be described in more detail in the following sections.

4) The upstream data collection will be completed using Remote Traffic Microwave Sensors (RTMS) mounted on two-wheel trailers manufactured by American Signal. The trailers are similar to those currently deployed as part of the ASIS system but do not include the message boards. The trailers will be placed prior to the entrance of the work zones, approximately 1/2 mile upstream. The research team will work with GDOT and the project contractor to acquire appropriate traffic control devices (barrels) prior to deploying the devices. A minimum of 3 barrels will be used on diagonal in front of the sensor. The RTMS devices will be placed a minimum of 10 feet from the active travel lanes. No lane closures are expected for deployment. See Figure 1 for a picture of the RTMS as deployed.

**Figure 1. General setup of RTMS sensor on trailer outside work zone.**

5) Validation of the accuracy of the ASIS sign messages. It is important to understand the accuracy of the information conveyed by the ASIS system to the traveling public. This analysis is also helpful in determining the influence of the ASIS system on traffic conditions. To accomplish this effort, the research team will include several data collection variables.

   The first type of validation will require an RTMS device to be placed adjacent to one of the ASIS trailers while a second RTMS device will be positioned upstream for simultaneous data collection. The second type of data collection activity will include video and laser data collection. 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 and laser radar devices may also be utilized on a limited basis to observe driver reaction to the lane closure or traffic control device placement. Ideally this data will be collected from overhead bridge crossings in the vicinity of the work zone so as to be unobtrusive. No lane closures will take place for these data collection activities and all equipment and personnel will use roadside areas for data collection activities. Data collection will take place with traffic moving away from the bridge to minimize driver distraction when possible. Figure 2 shows an example of these data collection activities along a bridge.

**Figure 2  Video and Laser Equipment on Overhead Bridge**

6) The last data collection effort will encompass the capture of potential diversion effects of traffic onto alternative routes by monitoring exit ramp volumes in the vicinity of the work zone and coordinating these volumes with time of day and traffic control operations. This activity will require the use of NuMetric HiStar classifiers on the Exit ramps. NuMetric traffic classifiers that measure speed, volume, and approximate vehicle length will be positioned in the center of the exit ramp lane. These devices monitor the earth's magnetic field and register disruptions to that field (indicating vehicle behavior). 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 GDOT for appropriate times to deploy the devices. Nu-Metric devices can be placed using a tape coat product that resembles an asphalt "patch" from a driver's perspective. Figure 3 shows the schematic of a typical classifier.

**Figure 3. Sample Nu-Metrics Classifier (MODEL NO. NC-97)**

Safety is paramount for all research activities. 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 chosen GDOT representative. Data collection efforts may range from one day to several consecutive days. At the construction project is nearing completion, the research team would like to deploy to the site as soon as possible.

Please contact Karen Dixon at 404-894-5830 or Jennifer Ogle at 404-385-0694 if you have any questions regarding this proposed work plan.

# APPENDIX C. ACRONYM DEFINITIONS

## Acronym Definitions

| Acronym | Definition |
|---|---|
| ADAPTIR | Automated Data Acquisition and Processing Traffic Information in Real-Time |
| ADT | Average Daily Traffic |
| ASIS | Advance Speed Information System |
| ATIS | Advanced Traveler Information System |
| AWIS | Automated Work Zone Information System |
| CCTV | Closed Circuit Television |
| CHIPS | Computerized Highway Information Processing System |
| CMR | Changeable Message Sign with Radar |
| CMS | Changeable Message Sign |
| CRWZTC | Condition Responsive Work Zone Traffic Control |
| DMS | Dynamic Message Sign |
| GDOT | Georgia Department of Transportation |
| GA Tech | Georgia Institute of Technology |
| HAR | Highway Advisory Radio |
| ISTEA | Intermodal Surface Transportation Efficiency Act |
| ITS | Intelligent Transportation System |
| LED | Light-Emitting Diode |
| MOE | Measures of Effectiveness |
| MUTCD | Manual of Uniform Traffic Control Devices |
| MWSWZDI | Midwest Smart Work Zone Deployment Initiative |
| PCMS | Portable Changeable Message Sign |
| PTMS | Portable Traffic Management Systems |
| RTMS | Remote Traffic Microwave Sensors |
| RTTCS | Real-Time Traffic Control System |
| SAM | Speed Advisory Messages |
| SMD | Speed monitoring displays |
| TIPS | Traffic Information Prediction System |
| TMC | Traffic Management Center |
| VMS | Variable Message Sign |
| WZITS | Work Zone Intelligent Transportation Systems |