Intelligent Transportation Systems in Work Zones

A Cross-Cutting Study

Integrated Work Zone Systems for Improving Travel Conditions and Safety

November 2002

Foreword

Dear Reader,

We have scanned the country and brought together the collective wisdom and expertise of transportation experts implementing Intelligent Transportation Systems (ITS) projects across the United States. This information will prove helpful as you set out to plan, design, and deploy ITS in your communities.

This document is one in a series of products designed to help you provide ITS solutions that meet your local and regional transportation needs. The series contains a variety of formats to communicate with people at various levels within your organization and among your community stakeholders:

- **Benefits Brochures** let experienced community leaders explain in their own words how specific ITS technologies have benefited their areas;

- **Cross-cutting Studies** examine various ITS approaches that can be taken to meet your community's goals;

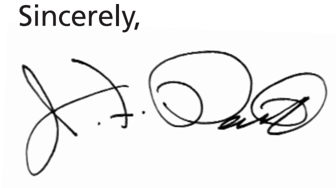
- **Case Studies** provide in-depth coverage of specific approaches taken in real-life communities across the United States; and

- **Implementation Guides** serve as "how to" manuals to assist your project staff in the technical details of implementing ITS.

ITS has matured to the point that you are not alone as you move toward deployment. We have gained experience and are committed to providing our state and local partners with the knowledge they need to lead their communities into the next century.

The inside back cover contains details on the documents in this series, as well as sources to obtain additional information. We hope you find these documents useful tools for making important transportation infrastructure decisions.

Sincerely,



Jeffrey F. Paniati
Acting Associate Administrator for Operations
Acting Director, ITS Joint Program Office
Federal Highway Administration

Contents

Contents

LIST OF FIGURES

LIST OF TABLES

Executive Summary

Everyone knows how frustrating it is to be caught in a long traffic backup due to road construction. In addition, work zones present safety challenges to both travelers and road workers. Using Intelligent Transportation Systems in work zones, however, can help ease the frustration and prevent crashes.

This cross-cutting study examines the real-world experiences of using ITS in work zones in four locations across the U.S. In addition, this study profiles new ITS work zone products that are under development or just now coming to market and new analytical tools that can be used to assist in work zone planning.

The evaluation results from these projects are positive. ITS technologies do make a difference in reducing crashes, reducing delays, and reducing costs when used in work zones. For example:

- ITS helped the Michigan Department of Transportation to **issue real-time information on problem areas for travelers**, respond to incidents more quickly, and communicate more effectively with local agencies during a full closure that reduced construction time from two seasons to one.
- ITS was one of the factors that enabled the Illinois Department of Transportation to undertake a 40-mile bridge reconstruction and pavement resurfacing project with **no significant traffic backups**, a reduced rate of speeding citations, and only two crashes, both of which were caused by impaired drivers.
- ITS helped the New Mexico State Highway and Transportation Department to **significantly reduce the time it takes to identify and clear incidents**, resulting in better maintenance of traffic flow and safety. The use of ITS has earned praise from both travelers and the public safety sector.
- ITS enabled the Arkansas State Highway and Transportation Department to **provide delay information at strategic locations** so that travelers may choose an alternate route. It has also enabled the Department to reduce delay through better construction-traffic coordination.

Finally, this study identifies lessons learned from the four sites, including the following key strategies for success:

- It is vital to **address communications issues early** in the process, as communications are the linchpin of ITS work zone systems. What may seem like a trivial issue at the outset of a project may evolve into an intractable problem when deploying or operating the system.

- It is important to **allow start-up time when deploying a system**. Problems will arise – such as the operation of sensors, communications (wireless or wireline), applying for licenses, calibration, or software – and take time to address.
- It is important to **use a proactive approach for building public awareness** of the project and the information that the ITS work zone system will provide. Successful techniques include holding press conferences, issuing news releases, and keeping local media up-to-date on project developments.
- It is vital to **deliver accurate information to the public**. If inaccurate information is provided, the public can quickly lose confidence and negative public relations can result.
- The more successful projects **involve a wide range of stakeholder agencies**, such as those responsible for incident management. It is important to determine how the ITS work zone system can work within each agency's existing procedures.
- It is important to **carefully consider how to set up automated information delivery and sharing with other agencies**. Particularly with an automated system, it is possible to deliver too much information for the agency and its partner agencies to effectively process.

The purpose of this study is to enable other regions to benefit from the hard-earned experience gained by state departments of transportation that have been early deployers of ITS in work zones. Following these lessons learned increases the likelihood of reaping similar benefits of fewer crashes, better informed motorists, shorter backups, and lower costs.

Introduction

It's an irrefutable fact — work zones cause congestion, and they result in more than 800 fatalities and 37,000 injuries in the U.S. every year. However, as our infrastructure ages, there is an increasing need for the maintenance and rehabilitation of our roadways, which means more work zones. At the same time, travel and congestion on our roads keeps growing. Between 1980 and 1998, vehicle miles traveled increased 72 percent while the number of lane miles increased only 1 percent.[1] These factors combine to produce an increasing amount of exposure of vehicles in work zones. This increased risk creates challenges to moving traffic smoothly and safely through work zones and heightens the need for finding new ways to enhance mobility and safety in work zones.

Forward-looking transportation agencies across the country are using Intelligent Transportation Systems in their major work zones to make travel through and around the work zones safer and more efficient. ITS involves the use of electronics, computers, and communications equipment to collect information, process it, and take appropriate actions.

Rhonda Faught, the Adjutant Secretary of the New Mexico State Highway and Transportation Department, noted, "We have received scores of thank you letters and e-mail from the public. Our colleagues in the public safety sector have been generous in their praise of our ITS activities. We are able to contact them immediately and they can respond immediately to incidents. It has really worked out well."

"This is just the beginning of ITS in Arkansas. Our limited use of ITS in the work zone has already helped us identify other areas of our activities where the public could benefit from further ITS deployment."

– Robert Walters
Chief Engineer
Arkansas State Highway and Transportation Department

Purpose

The purpose of this document is to raise awareness among maintenance and construction engineers and managers of the applications and benefits of ITS in work zones. ITS technology can be applied in work zones for:

- Traffic monitoring and management
- Providing traveler information
- Incident management
- Enhancing safety of both the road user and worker
- Increasing capacity
- Enforcement
- Tracking and evaluation of contract incentives/disincentives (performance-based contracting)
- Work zone planning.

Many ITS applications in work zones serve a combination of the above purposes.

[1] FHWA (2000). *Highway Statistics 2000*. http://www.fhwa.dot.gov/ohim/hs00/index.htm.

To better identify and document uses and benefits of ITS in work zones, the following four sites were visited. These sites used ITS for road rehabilitation projects:

- Springfield, Illinois I-55
- Lansing, Michigan I-496
- Albuquerque, New Mexico I-40/I-25
- West Memphis, Arkansas I-40.

These sites all used ITS for traffic monitoring and management and providing traveler information, while one site also used the system extensively for incident management. This report documents the findings from those site visits, and also contains a section that provides examples of other uses of ITS in work zones based on a literature review.

Benefits

Traffic monitoring and management and traveler information systems monitor traffic conditions and provide delay and routing information to drivers and key agency personnel. Benefits of using these systems include improved mobility, increased safety, and cost savings. The four sites visited experienced benefits in each of these areas, as well as improved communication with the public and other agencies. A summary of benefits is provided in Figure 1.

Mobility — ITS applications in work zones contribute to improved mobility by providing drivers with traffic condition information so that drivers can adjust routes or travel times. ITS applications may also improve mobility by smoothing traffic flow through a work zone. Mobility is measured in terms of the absence or decrease of observed or reported traffic backups or delays at the work zone.

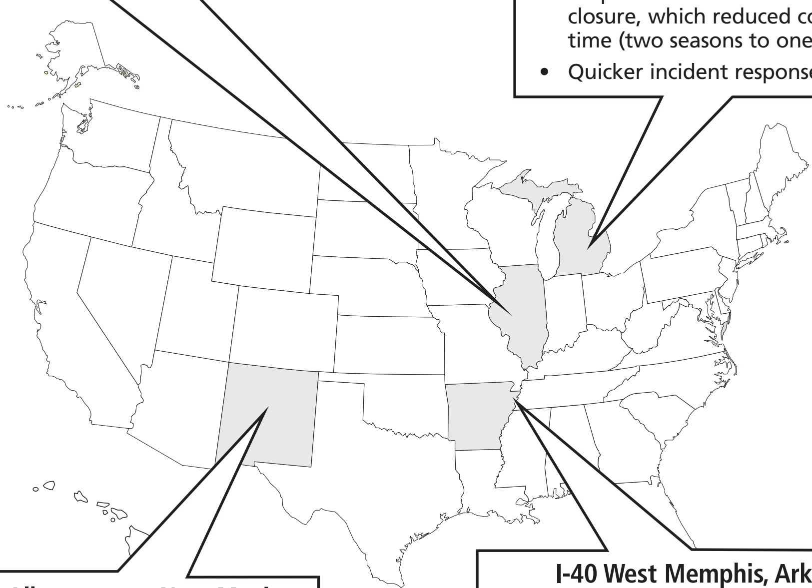
Safety — ITS work zone applications contribute to increased safety by providing drivers with advance notice of the presence of work zones and associated traffic conditions, such as slowed or stopped traffic ahead. Safety is measured in terms of the number and severity of vehicle crashes in the work zone that are attributable to the presence of construction or maintenance activities, as opposed to a crash attributed to a driver falling asleep at the wheel. Another factor used to measure the safety of work zones is the number of citations issued. Decreasing numbers of citations indicates improved safety conditions in the work zone.

I-55 Springfield, Illinois

- No significant traffic back-ups
- Reduced rate of traffic citations
- 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 effective communications with local agencies
- Helped enable use of full road closure, which reduced construction time (two seasons to one)
- Quicker incident response



I-40/I-25 Albuquerque, New Mexico

- 44 percent reduction in incident response and clear time
- Fewer secondary accidents
- Better maintenance of traffic flow
- Praise from travelers and the public safety sector
- 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
- Reduced delay through better construction traffic coordination

Figure 1 – Summary of Benefits by Site

Cost Savings — ITS work zone systems reduce operating costs by automating functions that heretofore were performed manually and could be expensive and time-consuming. Cost savings are measured in terms of savings derived from automation of systems or processes based on the number of staff required to operate the system. For example, some ITS work zone systems do not require full- or part-time commitment of agency staff.

Update to the National ITS Architecture

The use of ITS in work zones has grown to the point that steps have been taken towards its inclusion in the *National ITS Program Plan* and the National ITS Architecture. The Maintenance & Construction Operations (MCO) User Service Description has been developed, and features work zone management and safety as one of its main functional areas. The MCO User Service underscores the value of work zone information and smart work zones when states and regions establish regional ITS architectures for ITS deployment. For more information about the National ITS Architecture, access the website address http://www.its.dot.gov/arch/arch.htm.

Study Site Summary Descriptions

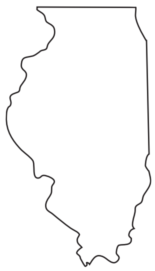
This section describes the four ITS work zone applications examined in detail. While each of these sites used or is using an ITS application that supports traffic monitoring and management, the characteristics and capabilities vary from system to system. Table 1 shows selected characteristics of the ITS work zone applications at each of these sites. Following the table are more detailed descriptions of each site, the ITS application, and the reasons for using ITS technology on the project.

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 am to 7:00 pm)	Yes (5:00 am to 8:00 pm)	No
Temporary or Permanent Deployment	Temporary	Temporary	Parts of system permanent	Temporary
Lease or Purchase	Lease	Lease/Purchase	Purchase	Lease

Table 1 – Site Overview

Springfield, Illinois

Project/Work Zone Overview



The Illinois Department of Transportation (IDOT) reconstructed the Lake Springfield Bridges on I-55 south of Springfield, resurfacing sections of I-55 south of Springfield, and improving Toronto Road and Southwind Road. In total, the work zone encompassed over 40 miles of I-55. Reconstruction of the Lake Springfield Bridges involved closing the southbound bridge and diverting southbound traffic onto the northbound bridge. During construction, traffic on the bridge was separated by a barrier wall, requiring motorists to reduce speed to 55 mph or 45 mph, depending on whether or not workers are in the area. Once the new southbound bridge was complete, the process was reversed.

Why Use ITS?

Use of ITS for the Lake Springfield Bridges project offered a number of benefits to operators as well as travelers. This construction effort, part of Illinois Governor George Ryan's Illinois First project, required the use of systems or methods to minimize the negative impact of the project on the traveling public.

The ITS application provided travelers with information on traffic conditions in the work zone while providing IDOT and contractors with real-time information regarding these conditions. Additionally, ITS offered potential savings to Illinois taxpayers through automation by eliminating the need to have full-time IDOT staff or state employees constantly monitoring conditions.

System Goals

The main goals of the Springfield Automated Portable Real-Time Traffic Control System (RTTCS) were to provide traveler information and to enhance traveler safety.

System Description

The Real-Time Traffic Control System included 17 remotely controlled portable dynamic message signs (DMSs), 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.

System Operations

The system consisted of data collection devices electronically linked via wireless communications to a central base station server. The base station server processed data collected by system sensors and then disseminated appropriate information to travelers and IDOT staff. IDOT staff were automatically updated via e-mail based on pre-defined parameters established by the agency. For example, the system would contact higher-level IDOT staff as longer queue lengths were detected. Real-time traffic condition information was conveyed to motorists via the system's DMSs. In addition, the system displayed congestion levels of roads in the region on the Internet (see Figure 2) for pre-trip planning (http://www.dot.state.il.us/i55/i55.html — under Traffic Information). Congestion levels on the website were updated every five minutes.

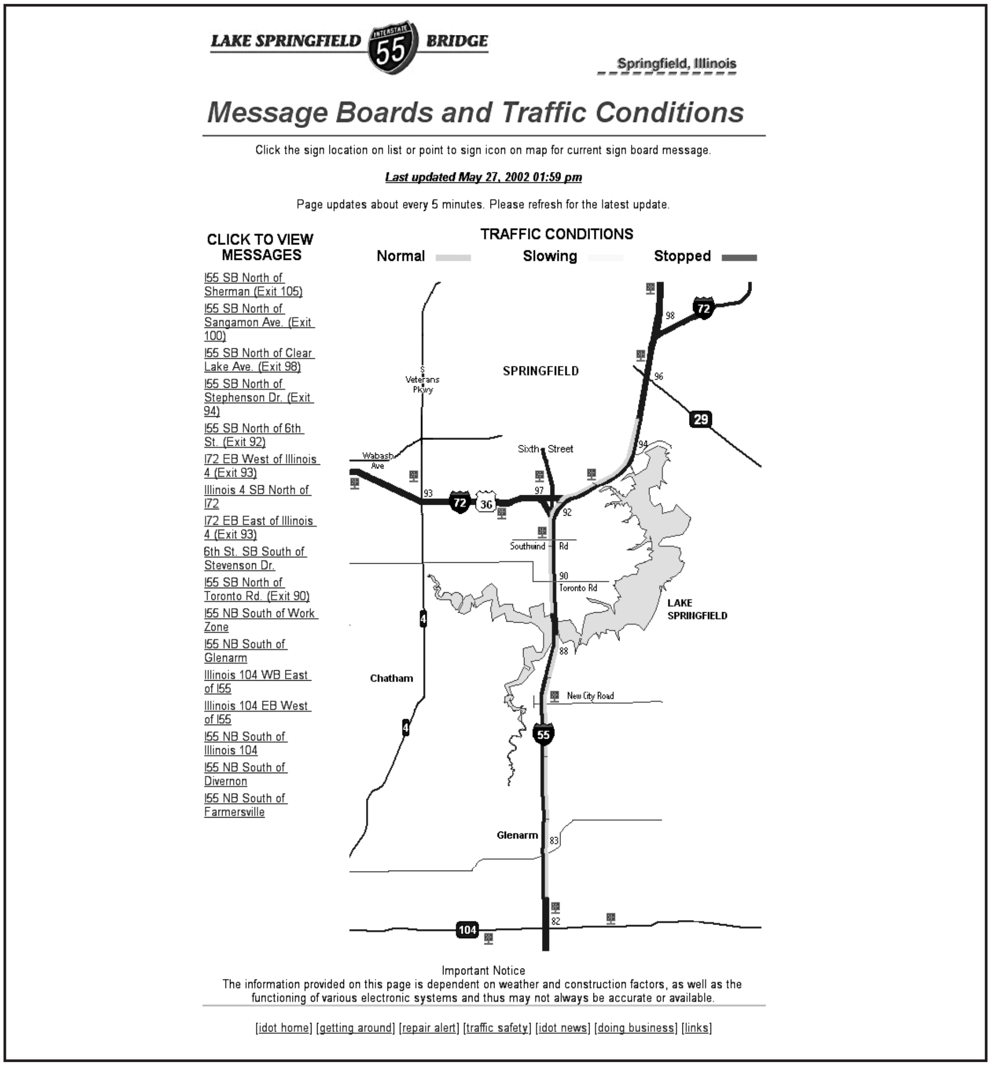


Figure 2 – Traffic Information Map from IDOT I-55 Work Zone Website[2]

IDOT leased the RTTCS from United Rentals for the duration of the Lake Springfield Bridge reconstruction project. Included in the lease were personnel assigned to monitor the system. The system ran continuously on an automated basis, with one person making periodic checks of system performance during weekdays. After hours and on weekends, someone was on-call via a pager in the event of any problems.

The concept of operations is summarized in Figure 3.

"An integral part of Governor Ryan's Illinois First initiative to improve the state's infrastructure is to minimize delay and disruption to public travel – ITS applications such as the Real-Time Traffic Control System, which provides congestion information to travelers via the Internet and dynamic message signs located over 40 miles away from potential traffic backups, epitomize the state's commitment to improving travel conditions, even in the midst of significant construction activity."

– James Slifer
Director
Division of Highways
Illinois Department of Transportation

[2] IDOT (2002). *Illinois Department of Transportation Lake Springfield Bridge Message Boards and Traffic Conditions*. http://64.225.254.208/springfield/i55springfield.htm.

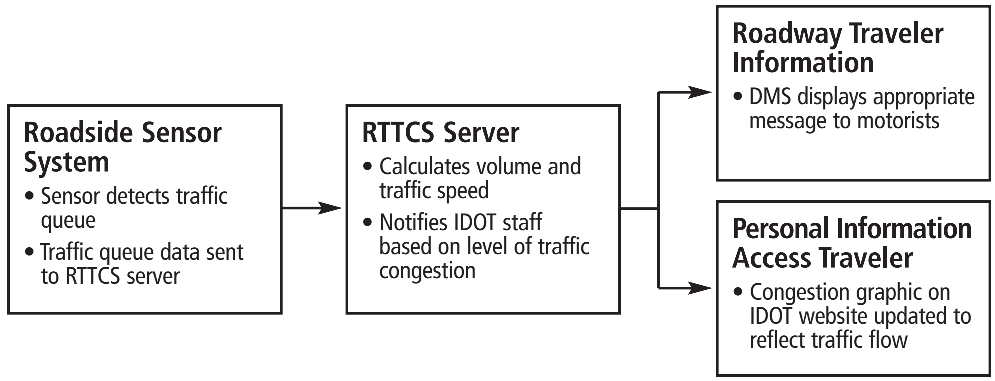


Figure 3 – Springfield, Illinois ITS Work Zone Concept of Operations

System Selection

In the past, IDOT staff had had favorable experiences with similar systems in other areas of the state that required the provision of traveler information due to traffic congestion, especially in the Chicago area. The overall concept for this system was, therefore, familiar to IDOT district staff responsible for the Lake Springfield reconstruction project.

System Functions

Springfield, Illinois ITS Work Zone Functions

- Acquires and processes data and automatically selects motorist information messages for display on DMS without human intervention
- Operates continuously (24/7) for duration of work project
- Allows agency staff to manually override motorist information messages for a user-specified time, after which the system returns to automated function
- Protects critical functions with a password system
- Provides current traffic condition information via the Internet on a full-color map that utilizes color-coding to depict traffic conditions
- Archives camera imagery
- Displays sensor data along with imagery at locations equipped with sensors and CCTV cameras
- Detects stopped traffic and determines traffic volume in all kinds of weather and visibility conditions
- Calculates traffic speed in the work zone in all kinds of weather and visibility conditions
- Displays independent advisory messages on each DMS based on conditions near specific DMSs
- Allows adjustment of thresholds for advisory message selection or staff notification

Lansing, Michigan

Project/Work Zone Overview

The Michigan Department of Transportation (MDOT) used a Temporary Traffic Management System (TTMS) during a construction project that involved a total closure of I-496 in downtown Lansing, Michigan. The ITS system included traffic detection and surveillance equipment along with message signs and a website in an effort to help guide motorists to alternate routes and alleviate traffic congestion on those surrounding roads while the major freeway was closed. The $40 million, single-season construction project involved rebuilding 32 bridges, reconstructing one mile and repairing seven miles of freeway, and adding a third lane/merge weave in each direction for a section of the freeway. The system was deployed in March 2001 and was used throughout the construction project, ending in October 2001. The system was removed at the end of construction.

Why Use ITS?

If performed using the traditional construction approach, MDOT's rehabilitation work on I-496 would have taken two construction seasons and would have had significant productivity impacts on the local economy. MDOT decided to use a full closure approach to reduce the construction time from two seasons to one to lessen the extended impacts to the public and nearby businesses. Full closure of the affected miles of I-496 required that all traffic be diverted from the freeway at those points and that additional traffic management and traveler information be provided.

MDOT realized that the use of available state-of-the-art technology was important to increasing the efficiency and expediency of relaying information to the public. The use of ITS in and around work zones allows the automation of functions that would have been performed by maintenance personnel. What normally would have been accomplished by a field visit from a technician could now be accomplished remotely or automatically. ITS allowed MDOT to inform motorists about changes in traffic conditions while reducing the demands on their staff.

System Goals

MDOT's 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.

System Description

MDOT used its mobile traffic monitoring and management system as a virtual traffic management center. The system included 17 cameras, 12 DMSs, six queue detectors, and National Sign and Signal's ITSworkzone™ software package to gather and process data on current conditions and display advanced traveler information to the public.

System Operations

In this application, the TTMS consisted of data collection devices electronically linked via wireless radio frequency (RF) communications equipment to a server at the Construction Traffic Management Center (CTMC). The ITSworkzone™ software processed data collected by system sensors and then informed CTMC operators of problem areas where queues were building. The software automatically updated the signs depending on the time of day and current stage of construction. MDOT staff members had the ability to manually update the messages displayed. The software had a bank of pre-determined messages that could be displayed on each DMS, and operators also had the option of creating a new message for use.

Real-time traffic condition information was conveyed to motorists via the system's DMSs. In addition, the system displayed a map with color-coded average roadway speeds on the Internet for pre-trip planning (http://www.fix496.com). The website also allowed motorists to view camera images of several roadways within the network.

MDOT leased most of its system and hired a private contractor, URS Corporation, to serve as the system development contractor. Another private company, AVD, staffed the center, under the supervision of MDOT engineers. The traffic management center operated 24 hours a day, and was staffed by contractor staff on weekdays from 5:00 am to 7:00 pm.

The concept of operations is summarized in Figure 4.

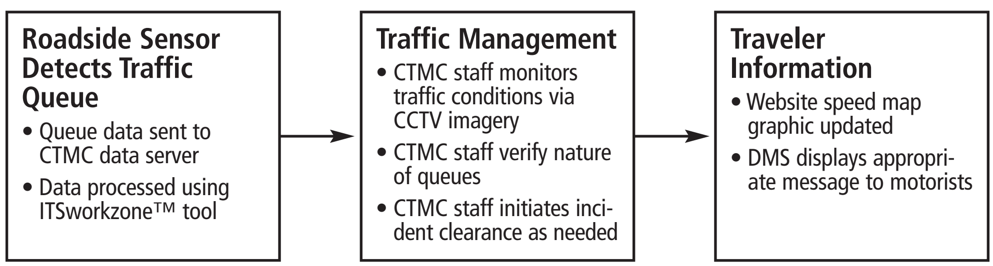


Figure 4 – Lansing, Michigan ITS Work Zone Concept of Operations

System Selection

MDOT staff had not used a similar system in the past. However, MDOT was motivated to seek more aggressive solutions to work zone traffic congestion because the I-496 project was much larger in scope than other work zones deployed in the area. URS introduced the ITSworkzone™ system to MDOT and developed project specifications that included the use of the system.

Lansing, Michigan ITS Work Zone Functions

- Acquires and processes data, and automatically selects an appropriate motorist information message for display on a DMS, leaving the option for human intervention if needed
- Allows agency staff to manually override motorist information messages for a period of time specified by the user, after which the system returns to automated function
- Protects user-defined messages with advanced word filters
- Provides current traffic speed information via the Internet on a map that utilizes color-coding to depict traffic conditions
- Displays camera images via the Internet
- Archives speed, volume, and occupancy at locations equipped with Remote Traffic Microwave Sensors (RTMS)
- Detects queued traffic and determines traffic volume in all kinds of weather and visibility conditions
- Calculates traffic speed in the work zone in all kinds of weather and visibility conditions
- Displays independent advisory messages on each DMS based on conditions at pre-defined locations
- Allows for the use of existing DMS equipment, even if an agency already owns several different types

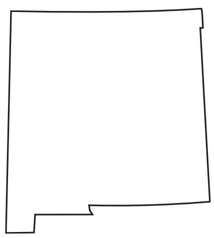
System Functions

"During construction projects, it is important to provide the most up-to-date information to motorists. By allowing the average citizen to access ITS technology through a video network, roadside kiosks and the World Wide Web, Michigan is allowing the daily commuter to make informed, educated choices regarding their travel plans."

– Terry L. Anderson
Manager
Lansing Transportation Service Center

Albuquerque, New Mexico

Project/Work Zone Overview



The New Mexico State Highway and Transportation Department (NMSHTD) is rebuilding "The Big I" interchange in Albuquerque to make it safer and more efficient and to provide better access. The Big I is where the Coronado Interstate (I-40) and the Pan American Freeway (I-25) intersect in Albuquerque. The original Big I was designed to support an average daily traffic (ADT) of only 40,000 and was severely over capacity, experiencing an average of 1.7 crashes per day that were estimated to cost about $12 million annually. ADT in the interchange was approximately 300,000 vehicles per day prior to its redesign; the redesigned Big I will have a design capacity of 400,000 ADT. The two-year project began on June 30, 2000 and involved 111 lane-miles of construction and 45 new and 10 rehabilitated bridges. The observations noted in this report are based on ITS use in the first year of the project.

Why Use ITS?

Albuquerque employed ITS to help move the large number of vehicles through the extensive construction area. The ITS application was installed in 2000 for use throughout the work zone duration (two years). Following project completion, the system will become part of a permanent system for freeway management. Construction generally occurred six days a week, two shifts per day. During daylight hours at least two lanes were open to traffic in each direction on both interstates, while at night the core of the Big I was typically closed to all traffic. The daytime lane closures changed frequently, so traffic flow patterns changed regularly. These changes in traffic patterns, the nighttime closures, and pre-determined alternate routes required that travelers be provided with high-quality real-time information on travel route availability.

NMSHTD determined that traffic volume needed to be reduced by at least 20 percent to keep traffic moving through the Big I area. Any incidents in the roadway, such as crashes, cars running out of gas, or flat tires, caused further capacity decreases, thus increasing the demand for faster response. NMSHTD decided that ITS could help achieve its goals of communicating with motorists and more promptly removing incidents to maintain capacity.

System Goals

The main goals of the ITS portion of the Big I reconstruction 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.

System Description

The Big I ITS 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 traffic management center (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.

System Operations

System cameras were electronically linked via wireless communications to a central base station server in the traffic management center. The base station server processed and displayed the images collected by system cameras. A NMSHTD staff person monitored the camera images continuously from 5:00 am to 8:00 pm. Problems such as incidents were identified manually by the staff person based on observation of these images. When a camera image showed an incident in the roadway, the NMSHTD staff radioed a Highway Emergency Lender Program (HELP) safety service patrol vehicle to go to the location to offer assistance. Information from both the camera images and the HELP vehicle staff observations assisted emergency response teams in gauging what vehicles they needed to send for the incident, eliminating excessive responses that could unnecessarily tie up roadway capacity and increase costs. To assist in handling incidents, NMSHTD staff maintained close coordination with emergency service providers. The ITS application also assisted in tracking incidents. Whenever an incident was within view of one of the cameras, a picture of the incident was recorded and stored in an incident database along with the incident report.

The central base station server software held a set of scenarios for the DMSs. These scenarios were not set to activate automatically, although they could be. The scenarios enabled the staff to activate a pre-defined message scenario for all the DMSs with "one click" access. Because the core of the Big I was entirely closed most nights, a whole series of detour messages needed to be displayed each night. The pre-defined scenarios made this task a simple one. During incidents, NMSHTD could also manually activate DMS messages indicating the accident location, lanes affected, and whether delays were occurring. The extent of delay and length of queue were not displayed.

In addition to any messages displayed on the DMSs, current information on conditions in the Big I was available via the Big I website, highway advisory radio, facsimile and e-mail updates, and pager. The camera images were typically available to the public in real-time on the Big I website (http://www.thebigi.com). The camera images on the website were updated automatically every three minutes or less, and much of the website's contents were refreshed manually on a weekly basis. Weekly reports and other bulletins were made available online at http://members.aol.com/nmroads immediately upon distribution of notices, and this information was used to regularly update the Big I website. The Big I website typically received 2,000 to 3,000 hits per day. NMSHTD staff knew that travelers frequently used the website because they received complaints if there was a problem with even one camera. Website data also were transmitted to a commercial paging service that reformatted the information and made it available to approximately 30,000 subscribers. The four HAR broadcast messages were updated manually at least daily, and more frequently as needed. "Interstate Ernie" traffic reports that include traffic updates on the Big I project were sent via facsimile and/or e-mail to more than 1,600 recipients. Faxes were sent out weekly, or more frequently as needed, to inform the media and affected agencies about road closures, detours, schedule changes, and major incidents that constrained the roadway for more than three to six hours. In an interview survey of 1000 travelers conducted between April and June, 2001, 60.2 percent of respondents believed that NMSHTD had provided them with accurate and timely information on the Big I project.

"ITS has been a very essential and integral part of the Big I Construction Project."

*– Rhonda Faught
Adjutant Secretary
New Mexico State Highway and Transportation Department*

NMSHTD purchased the system and intended to leave many of the ITS components in place to become part of a permanent freeway management system. NMSHTD operated the system after receiving training from the vendor.

The concept of operations is summarized in Figure 5.

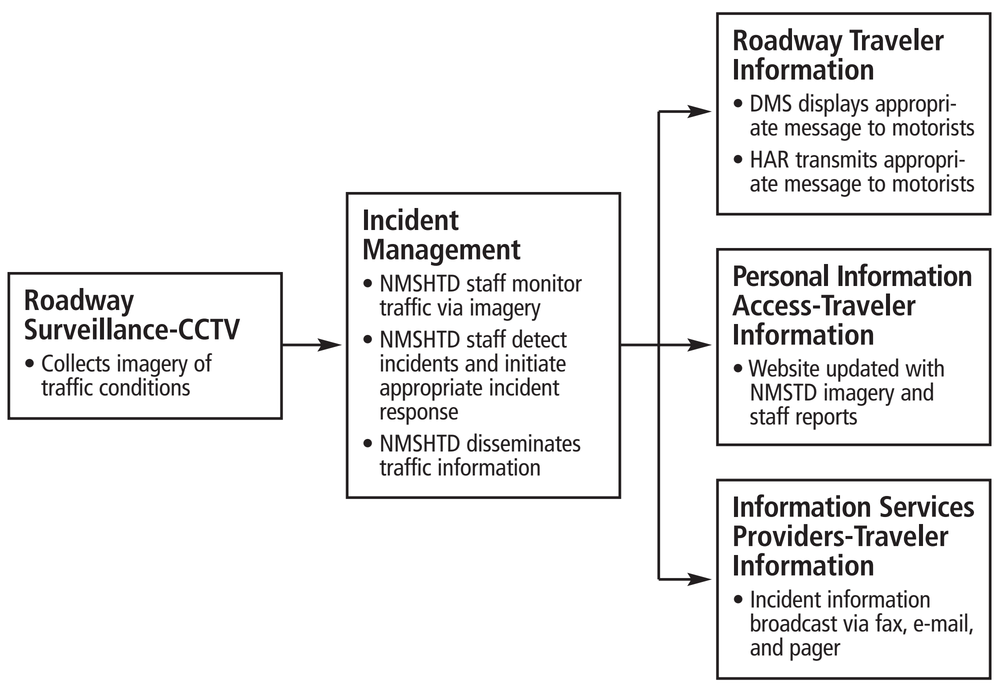


Figure 5 – Albuquerque, New Mexico ITS Work Zone Concept of Operations

System Selection

It was important to NMSHTD to identify an ITS work zone system that had been used not only for a single freeway corridor but also in more complex situations involving the intersection of two interstates. NMSHTD had contracted with URS Corporation to serve as the design contractor for the entire Big I reconstruction project. URS selected the ITS work zone system used in Albuquerque based upon the requirements identified by the NMSHTD.

System Functions

Albuquerque, New Mexico ITS Work Zone Functions

- Acquires data on traffic conditions via roadside cameras and transmits the data to the TMC
- Operates continuously (24/7) for the duration of the work project
- Displays messages about detour routes and major incidents
- Allows for development of pre-set scenarios of DMS motorist information messages that can be activated for display either manually or automatically
- Provides current traffic condition information via the Internet using camera images and staff reports
- Archives camera imagery and creates electronic incident reports
- Enables direct communication between ITS staff and police through a police substation in the TMC
- Provides traffic and construction reports to businesses, emergency services personnel, and the media via an automated fax and e-mail system

West Memphis, Arkansas

Project/Work Zone Overview

In 2000, the Arkansas State Highway and Transportation Department (AHTD) embarked on a project to reconstruct three miles of concrete pavement on I-40, near its intersection with I-55 in West Memphis, Arkansas. The work zone area began near a bridge across the Mississippi River to Memphis, Tennessee and abutted a Tennessee work zone on the bridge. The work zone was expected to be in place for 12 to 18 months for the duration of the $13.8 million project.

Why Use ITS?

AHTD decided to use ITS on this project because the state believed that it needed to go beyond traditional traffic control in addressing the impacts of the reconstruction project. Because West Memphis, Arkansas is a border city and close to Memphis, Tennessee, AHTD knew that the construction for this project would affect its larger neighbor. The two cities are on opposite sides of the Mississippi River, so drivers traveling in the area have limited options for travel. They must take one of two bridges, either the bridge on I-40 or the one on I-55. AHTD was aware that, in the past, incidents such as crashes on the bridges and construction resulted in significant backups and bad publicity. AHTD also knew that any delays arising from its construction project might be amplified by the adjacent Tennessee work zone. As a result, AHTD looked for ways to better communicate with the public in both Arkansas and Tennessee about what delays to expect from the construction. The improved information would allow travelers to make choices about alternate travel times and routes and experience less stress from unexpected delays.

The AHTD District Office initially considered using only highway advisory radio for the West Memphis work zone. However, after meeting with the AHTD Research Division, the AHTD District Office decided to use a more expansive system. The research division had been interested in increasing the use of ITS in the state. AHTD patterned its system requirements after those used by other states and then tailored the requirements to meet the needs of this particular project.

System Goals

The main goals of the Automated Work Zone Information System (AWIS) 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, AHTD hoped that the system could provide faster incident response, thereby restoring capacity and reducing the opportunity for secondary crashes.

System Description

The West Memphis AWIS was deployed in October 2000. 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 highway advisory radio. 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.

System Operations

Data collection devices were electronically linked via wireless communications to a central base station server. Each sensor had a modem to convert from computer signal to radio waves, which were then sent from the sensor site to the command center. A modem at the command center then converted the radio waves back to computer signal for processing by the base station server. The base station server processed data collected by the 12 system queue detectors and then, based on pre-programmed scenarios of conditions, disseminated appropriate information to travelers, AHTD staff and Tennessee DOT staff, construction contractors in both Arkansas and Tennessee, traffic reporters, and media outlets. Real-time traffic condition information was conveyed to motorists via the system's DMSs and HAR. The other personnel were automatically updated via e-mail or by pagers based on pre-defined scenario parameters established by AHTD.

AHTD leased the AWIS system from Protection Services, Inc. for the duration of the West Memphis I-40 reconstruction project. Included in the lease were personnel to monitor the system, which typically entailed one person for periodic system maintenance and to be on-call in the event of any problems after hours. In addition, ASTI supported Protection Services in monitoring the system.

The concept of operations is summarized in Figure 6.

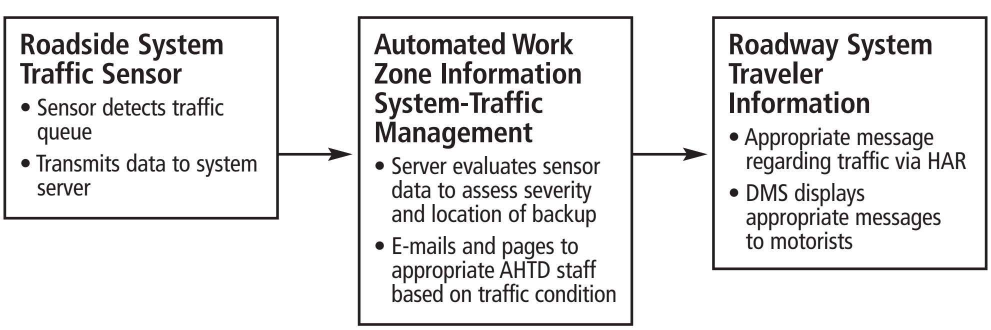


Figure 6 – West Memphis, Arkansas ITS Work Zone Concept of Operations

System Selection

In the contract put out for bid, AHTD required the use of ITS and offered contractors two systems from which to choose. The contractor selected by AHTD chose CHIPS. The other system option offered by AHTD had been used in other work zones in the state. For this project, AHTD decided to use a system that could provide information to travelers on the length of queues. AHTD decided not to provide estimated delay times because this information would be indirectly calculated, not measured directly. AHTD wanted to tell the public what they did know (how far the backup was), instead of trying to estimate something they did not know directly (amount of delay in minutes).

System Functions

"Prior to reaching the construction area, motorists have a choice of routes to take, either I-40 or I-55. The ITS advises travelers of any problems on the routes and helps them make the most informed decision possible at the time. Local residents are familiar with alternate routes and the ITS information can help them readily decide which route to take. Motorists traveling cross-country, however, may not readily know alternate route options, but the ITS tells them what they can expect in terms of traffic backups and delays."

– Robert Walters
Chief Engineer
AHTD

West Memphis, Arkansas ITS Work Zone Functions

- Acquires and processes data and automatically selects motorist information messages for display on DMS without human intervention
- Operates continuously (24/7) for duration of work project
- Protects critical functions with a password system
- Provides current traffic condition information via HAR
- Displays sensor data on a map and in separate windows at the command center computer and via secure remote dial-in access
- Detects stopped traffic in all kinds of weather and visibility conditions
- Calculates traffic speed in work zone in all kinds of weather and visibility conditions
- Displays independent advisory messages on each DMS based on conditions at sensors nearby
- Allows adjustment of thresholds for advisory message selection or staff notification
- Allows re-programming of scenarios, such as DMS messages and HAR broadcasts, for different sensor conditions

Cross-Cutting Findings

This section presents the findings from the four sites visited. The findings are presented below, organized into the following subsections:

- **Benefits —** presents the benefits of using ITS applications in the four study site work zones, organized into three broad benefit categories of mobility, safety, and cost savings.
- **System Costs —** presents the costs associated with the four ITS applications, in terms of capital costs, long-term operational costs, and costs for the project, and discusses whether the system was leased or purchased.
- **Use of Analytic Tools for Project Planning —** discusses analysis performed at the study sites in planning for their ITS applications in work zones.
- **Institutional/Implementation Issues —** identifies issues encountered during implementation of ITS applications in work zones and their impact on the study sites.

Benefits

The mobility, safety, and cost savings benefits experienced by the four sites are described below. In addition to these benefits, the sites evaluated in this study developed improved relationships with the public and other agencies as a result of their use of ITS. For example, NMSHTD noted its improved relations with the incident response community, resulting from their cooperative efforts in both planning and operating the Big I ITS work zone application. AHTD noted how the West Memphis ITS work zone application not only aided public relations with its own residents by keeping them informed, but also helped better its interstate relationship with neighboring Tennessee and its residents that were affected by the West Memphis work zone just over the border in Arkansas. At some sites, the improved relationship with the public was documented through numerous positive letters and e-mails, and through survey responses.

Selected Mobility Benefit Highlights

Illinois — IDOT staff reported no significant traffic backups since implementation of the Real-Time Traffic Control System, despite its location on a busy interstate between Chicago and St. Louis, and near the location of a busy airport serving southern Illinois and eastern Missouri.

Michigan — The ITS application allowed MDOT to better manage traffic conditions while implementing a full-closure scenario during Phase I of construction. Motorists received information in advance of the work zone to allow them to make more informed route decisions. MDOT staff used video cameras to identify and verify the location of an incident or crash. Once a situation was verified, MDOT staff alerted the appropriate agency such as law enforcement or emergency response agencies. MDOT also worked closely with these and other agencies during the planning phase.

New Mexico — A 1996 study that included the Albuquerque area was conducted by the Middle Rio Grande Council of Governments to assess the needs for a freeway management system. That report quoted an average time of 45 minutes for clearing incidents. This average time for responding to and clearing an incident dropped to 25 minutes in the work zone area with the use of ITS. Delay savings were achieved through improved incident response that removed obstructions from traffic lanes as quickly as possible. The ITS work zone application also helped NMSHTD better determine the appropriate response to an incident, so that extra emergency services and motorist assistance vehicles were not sent, thereby saving money and minimizing the decrease in road capacity.

Arkansas — The AHTD used the ITS application to inform travelers about any queues ahead and the length of queues as they approached the work zone on I-40. This real-time information was displayed on dynamic message signs and updated automatically by the system as conditions changed. The readings transmitted to the control center by the system of sensors indicated that certain traffic flow conditions were present and triggered the automatic display of messages to travelers based on pre-programmed scenarios. Because these message boards were strategically placed before key alternate routes, their information enabled drivers to choose alternate routes that may have had less delay. The ITS application automatically paged the Arkansas Motorist Assistance Patrol when certain queue conditions formed. The Patrol could go to the area and verify the nature of the incident, and either clear it or notify the resources needed to clear the incident and restore normal traffic flow. The sensors helped AHTD personnel to determine whether a backup was likely to be short-lived or would require intervention. Traffic data provided by the system also gave AHTD staff a more accurate understanding of daily traffic patterns so that contractors could avoid or minimize operations during peak periods.

Selected mobility benefits are summarized in Table 2.

Benefits	Illinois	Michigan	New Mexico	Arkansas
Traffic Delays	No significant delays.	Has the ability to reduce delays through recommendation to drivers to seek alternate route.	Average time required to respond and clear incident reduced from 45 minutes (historically) to 25 minutes with ITS. More appropriate level of incident response. Safety service patrol trucks aided 1600 drivers in first year.	Delay data provided to drivers upstream enabled selection of alternate route. Improved incident response noted. ITS provided more accurate data on peak periods, enabling AHTD to improve project scheduling.
Public Perception of Benefit	No data available.	Public perception survey conducted in 2001; results were positive.	60 percent of survey respondents found the data to be accurate and timely.	Improved public relations.
Pre-trip Traveler Information Available	Congestion information updated every five minutes via the Internet.	Information available via the Internet.	Information available via the Internet and pager service.	No pre-trip traveler information available.
Advanced Warning of Work Zone	Message signs warned drivers up to 40 miles upstream of work zone.	Message signs warned upstream of work zone.	Message signs and HAR warned drivers upstream of work zone and any major incidents.	Message signs and HAR warned drivers upstream of work zone and queues.

Table 2 – Selected Mobility Benefits

Selected Safety Benefit Highlights

Illinois — IDOT staff responsible for operations in the Lake Springfield Bridges work zone reported only two crashes in the construction area since implementation of the Springfield ITS. One of the crashes was attributed to driver fatigue and the other to driving while impaired. IDOT staff attribute this low number of crashes to the absence of backups and ample driver warning to drivers via dynamic message signs, some of which are located 40 miles upstream of the work zone.

The DMSs notified drivers as they approached the work zone of the number of speeding citations issued in the work zone. IDOT staff reported a significant downward trend in the number of violations since the system began displaying the messages. The frequency of speeding violations is often used as a safety surrogate measure. A reduction in the number of violations suggests a positive impact on safety.

Michigan — The DMSs displayed real-time information on traffic conditions around the work zone, thus allowing motorists to avoid hazards by taking an alternate route. Although MDOT did not recommend alternate routes, motorists adapted to caution messages and diverted from the main detour route when necessary. The ITS system helped MDOT to successfully implement a full closure, which reduced traffic exposure to the work zone and worker exposure to traffic, surrogate measures for safety.

New Mexico — The ITS application reduced the overall number of incidents from what Albuquerque would have expected. During the first three months of the work zone, there was a crash reduction of 32 percent in that area compared to the previous year when the work zone was not in place. This reduction in crashes was partly due to a public information campaign that encouraged travelers to use alternate routes, partly due to additional enforcement measures early in the project, and partly attributed to the use of ITS. With Albuquerque's reduced time for clearing incidents as a result of its ITS, there were many fewer secondary incidents in the work zone. Over the entire first year of the work zone, crashes were 7 percent higher in the work zone area versus the year before without the work zone. This increase is smaller than what was expected, particularly given the complex work zone with many lane shifts and regular (sometimes daily) changes in configuration. The change from the significant initial decrease in the number of crashes to a small increase is in part attributed to drivers who had been using alternate routes returning to the Big I, as well as less intensive enforcement.

Information provided by the ITS application helped agency personnel identify the location of problems with merges, ramps, or work zone configuration, such as areas where high levels of incidents were occurring or the camera images showed drivers having difficulty navigating the work zone. Agency personnel were then able to suggest changes in the work zone, such as striping or geometry, aimed at improving traffic flow and safety.

Arkansas — The Arkansas State Highway and Transportation Department personnel did not cite any specific safety benefits; however the information provided to travelers about queues in advance of the work zone is likely to have reduced the occurrence of rear-end collisions. A much higher portion of crashes in work zones are rear-end collisions when compared to those in areas not related to work zones.

Selected safety benefits are summarized in Table 3.

Benefits	Illinois	Michigan	New Mexico	Arkansas
Crash Risk	Only two crashes in the work zone–one attributed to fatigue, the other to alcohol.*	No data available.	32 percent reduction in crashes initially.+ Reduction in secondary crashes.** No fatalities in the work zone.	Anecdotal data suggest a reduction in the number of certain types of crashes typically associated with work zones.
Speed Reduction	Significant reduction in number of speeding citations since system development.	Average speed of traffic reduced; caution messages assumed to be the cause of the reduction.	No data available.	No data available.

Table 3 – Selected Safety Benefits

Selected Cost Savings Highlights

Illinois — The Real-Time Traffic Control System is designed to automatically alert the appropriate personnel when human intervention is needed, based on parameters defined by IDOT. This function eliminates the need to have staff monitor CCTV displays or patrol the work zone.

Michigan — The Temporary Traffic Management System is designed to automatically update each DMS message, thus eliminating the need for maintenance personnel to go out to the field to change the signs manually.

New Mexico — Traffic flow through the Big I work zone was changed on a regular basis, and the core of the work zone was entirely closed five to seven nights a week. For the nighttime closures, alternate routes were often the same from one night to the next. The system design allowed pre-programming of scenarios of messages to display on each DMS, and activation of a set of messages each night with a few key strokes without having to leave the control center. Operations in the work zone could be monitored and information disseminated to the public via DMSs or HAR, or to incident response personnel by one person at the control center.

The police department, fire department, and emergency services agencies all experienced cost savings related to the ITS application. When personnel detected an incident using the images transmitted back to the control center by the ITS cameras, a HELP truck was

* A similar system in Philadelphia, the Traffic and Incident Management System (TIMS), helped decrease freeway incidents by 40 percent.

\+ Reduction was for the first three months of the project. the overall rise in the crash rate during the first year was much smaller (7 percent) than expected.

** Attributed to reduced incident clearance time.

dispatched. Information from the camera images and the HELP truck assisted police, fire, and emergency services personnel in assessing the severity of an incident and determining whether to send one vehicle instead of two to respond. When the incident was determined to be minor enough to be handled by only one vehicle, costs were reduced and other units were then free to respond to other incidents.

Arkansas — The system is designed to automatically alert the appropriate personnel when human intervention is needed, based on parameters defined by AHTD. These alerts were sent in real-time by both e-mail and pager, and eliminated the need to have staff constantly patrol the work zone.

Selected cost savings benefits are summarized in Table 4.

Benefits	Illinois	Michigan	New Mexico	Arkansas
Staff Hours Required to Operate System	Automatically updated message boards based on real-time traffic inputs without human intervention. Staffing provided by contractor.	Automatically updated message boards based on real-time traffic inputs without human intervention.	System designed to allow on-duty staff to update and monitor system with minimal effort.	Automatically updated message boards based on real-time traffic inputs without human intervention. Staffing provided as needed by contractor.
Ability to Automatically Notify Multiple Agencies	System had capability to notify different levels of staff based on severity of congestion without human intervention.	Not applicable. The system was monitored. Disseminated information was aimed at motorists.	Not applicable. Staff operated the control center, and dispatched incident response personnel and changed DMS messages as needed.	System automatically disseminated information to AHTD staff, contractors, and media outlets.
Required for Additional Personnel	No additional agency personnel required.	No additional agency personnel required. Construction Traffic Management Center already in place.	No additional agency personnel required.	No additional agency personnel required.

Table 4 – Selected Cost Savings

System Costs

The cost of the ITS applications developed and deployed at the four sites visited was examined in terms of capital costs, long-term operational costs, and ITS costs relative to the overall cost of the project. An agency's decision to lease or purchase its system and whether the system was temporary or permanent affected overall system costs. For example, much of the Albuquerque, New Mexico ITS work zone application will become part of a permanent ITS installation that will monitor 44 miles of the metropolitan area's highway network. NMSHTD purchased its system, thereby incurring greater capital costs than if it had chosen the leasing option. However, some of the long-term costs will be reduced because the system will be used on a permanent basis following completion of the Big I work zone project. In contrast, the other three sites planned to use the ITS work zone application for the duration of the construction project, and then remove the system.

Illinois — IDOT avoided large capital costs by leasing major hardware components of its ITS work zone application. Operating costs were minimized by using a system design that focused on automation.

- Capital Costs – None. The system was leased for the duration of the project.
- Long-Term Operational Costs – None. The system lease expires upon completion of the project.
- Project Cost – The ITS work zone system cost represented less than 10 percent of the total project cost annually for the two-year project.

Michigan — MDOT purchased some of the hardware components of its system and a license for the software. However, the majority of the system was leased. System hardware included a communications tower, antenna, queue detectors, and cameras.

- Capital Costs – There were some capital costs for the purchased components. The majority of the system was leased for approximately $2.4 million.
- Long-Term Operational Costs – The system is portable, but no plans have been made for use after the project’s completion.
- Project Cost – The ITS work zone system cost represented approximately 6 percent of the total project cost.

New Mexico — Selected parts of Albuquerque’s ITS work zone application will remain in place after the Big I construction is completed and will become an integral part of Albuquerque’s ITS infrastructure and freeway management system. The portable aspects of

Albuquerque's ITS will be removed after the Big I project is completed and used in other future work zones.

- Capital Costs – The system was purchased for $1.5 million. Parts of the system will remain in place and become part of a permanent system following completion of reconstruction, thereby reducing overall capital costs for the permanent freeway management system.
- Long-Term Operational Costs – No data available.
- Project Cost – The ITS work zone system cost represented less than 1 percent of the total project cost. Parts of the system will remain in place after project completion, reducing project costs by spreading costs beyond the reconstruction phase. Other parts of the system will be used in future work zones.

Arkansas — AHTD paid a contractor a daily fee for the ITS application, and paid a lump sum amount for the highway advisory radio. The daily fee was assessed each day the system was operational, so the state did not pay for any down time. The system design focused on automation, minimizing operating costs for personnel.

- Capital Costs – None. The system was leased for the duration of the project.
- Long-Term Operational Costs – None. The system lease expired upon completion of the project.
- Project Cost – The cost for the leased system is estimated at $495,000, including the lump sum payment for the HAR. This amount is less than 4 percent of the total project cost.

For more information and resources on the unit costs of ITS technologies, refer to the ITS Unit Cost Database (http://www.benefitcost.its.dot.gov).

Use of Analytic Tools for Project Planning

For the ITS work zone applications examined in depth in this study, agencies generally did not use advanced analytical tools to plan for their ITS work zone projects. Agencies relied primarily on their own previous experience with similar ITS applications or on ITS requirements used by other states. However, for the Big I project in New Mexico, NMSHTD analyzed past peak hour traffic flow values against the estimated Big I traffic capacity that would be available during construction to determine the reduction in ADT that would be needed to maintain traffic flow through the work zone. NMSHTD determined that during peak hours, traffic volumes would need to decrease by approximately 20 percent to the estimated capacity of 25,000 vehicles per hour. Based on these data, NMSHTD determined that it was important to preserve the remaining capacity of the work zone. NMSHTD decided to use ITS to facilitate rapid identification and clearing of incidents to preserve capacity.

Institutional/ Implementation Issues

Institutional and implementation issues identified in planning, deployment, and implementation of the ITS applications for work zones at the four sites are summarized in Table 5. Each of the four lead agencies spent time coordinating and working with other agencies involved in public safety, emergency services, the media, and other government agencies. As noted above, the study sites frequently experienced better relationships with other agencies as a result of using ITS to share information and coordinate resources.

Benefits	Illinois	Michigan	New Mexico	Arkansas
Institutional Issues	None encountered.	None encountered.	NMSHTD needed to share data with emergency and incident response services to facilitate quick incident response. NMSHTD also needed to educate these partners on the system and include them in decisions.	No data available.
Inter-Agency Agreements	None required.	Construction took place on state right-of-way, so no formal agreements required. However, MDOT involved local jurisdictions in the project.	Formal agreements were not recommended for determining operating procedures with outside agencies such as emergency medical services.	Work zone was located near the border with Tennessee. Some parts of the ITS work zone system (DMS, HAR) were located in Tennessee.
Available Staff with Appropriate Areas of Expertise	Not an issue. Contractor support included in agreement.	Not an issue. Contractor support included in agreement.	NMSHTD staff received training from the system vendor and became able to operate the system with periodic vendor support.	Not an issue. Contractor support included in agreement.

Table 5 – Institutional/Implementation Issues

Lessons Learned

Common Lessons Learned

Although site characteristics varied, there were a number of lessons learned that were common to most, if not all, of the systems.

- **Systems need to have reliable communications.** The communications network for an ITS application is vital to the operation of the system and must be reliable. Issues that may impact communications need to be addressed early in the system development and deployment process. What may seem like a trivial issue at the outset may evolve into a more difficult problem when deploying or operating the system. Such issues include whether adequate cellular capacity is available and whether there are obstructions to signal transmission due to geography or terrain.
- **It is important to allow start-up time when deploying a system.** Problems will arise – such as the operation of sensors, communications (wireless or wireline), applying for licenses, calibration, or software – and will take time to address.
- **It is important to use a proactive approach in building public awareness of the project and the information that the ITS application will provide.** Successful techniques include holding press conferences, issuing news releases, and keeping local media (especially those the public turns to for traffic information) up-to-date.
- **It is vital to deliver accurate information to the public.** If inaccurate information is provided, the public can quickly lose confidence and negative public relations result. For example, some agencies have decided not to display travel time or length of delay in minutes on DMSs because it can be more difficult to ensure the accuracy of this information. In addition, motorists may be more likely to submit complaints when their experience differs from the displayed estimate.
- **Other stakeholder agencies, such as those responsible for incident management, need to be involved early.** One step is to determine how the system can work within each agency's existing procedures. Coordination with other agencies is a primary issue that agencies should consider both in developing and implementing an ITS work zone system.
- **It is important to carefully consider how to set up automated information delivery and sharing with other agencies.** Particularly with an automated system, it is possible to deliver too much information for the agency and its partner agencies to process effectively. The frequency, usefulness, and volume of information delivered to managers and partners need to be appropriate or the information will likely be discarded or ignored. Many ITS applications can be set to automatically deliver e-mail, faxes, or pages to the agency or partners such as the media and public safety agencies. If the thresholds for delivery of these messages are not carefully considered, a recipient may be inundated with information and unable to sort out what is useful.

Site Specific Lessons Learned

Lessons learned that were specific to a site have been categorized into five areas: planning and system development, communications, system deployment, system operations, and legal issues.

Planning and System Development

Relating with Other Agencies

- **Illinois —** It is important to involve agencies responsible for 911 and other emergency response operations.
- **Michigan —** It is important to involve other stakeholder agencies, such as those responsible for incident management, early on. The next step is to determine how the ITS work zone system can work within each agency's existing procedures.
- **New Mexico —** State departments of transportation need to "sell" ITS to the incident management community and let them dictate how to use the system to coordinate with incident response.

Relating with the Public

- **Michigan and Illinois —** It is important to use a proactive approach to building public awareness of the project. Successful techniques include holding press conferences, issuing news releases, and keeping local media up-to-date.

System Features/Capabilities

- **Illinois —** It is important to ensure common terminology use between software/systems engineers and transportation engineers during the requirements definition process.
- **Illinois —** System features and capabilities include the vendor's engineering staff, in addition to vendor marketing staff. Early discussions of vendor capabilities is important.
- **New Mexico —** Portability of the ITS units is key in the core of the work zone because the work zone configuration changes frequently and requires that the units be moved.
- **Arkansas —** The overall system would benefit from an override for times when major incidents occur such as a crash that will take a long time to clear. Without the override function, the system has the potential to send out e-mail alerts that are excessive, and the base computer at the command center is more likely to malfunction because of the hyperactivity. AHTD has asked for this capability on the next job where the system will be used.
- **Arkansas —** When possible, it is helpful to include a video capability into the design of the system that will allow traffic management staff to view a backup on camera in order to help them determine the appropriate response. AHTD noted that they would have liked to have this capability in their system.

Communications

- **Michigan —** It is sometimes necessary to apply for a licensed communications frequency to avoid problems with high-usage cellular telephone towers.
- **Michigan —** It is important to ensure that a thorough cellular coverage survey is conducted, as signal coverage can vary significantly over relatively short distances.
- **Michigan —** Obtaining a Federal Communications Commission license for the HARs can be difficult because there are few available radio frequencies.
- **Michigan —** Communications are the linchpin of ITS work zone systems. What may seem like a trivial issue at the outset may evolve into a difficult problem when deploying or operating the system.
- **Michigan —** Radio frequency coverage can vary seasonally in heavily foliated areas.
- **New Mexico —** For wireless communications, it is important to ensure that the system Internet address has enough priority so that information gets through the network.

System Deployment

Start-Up

- **Illinois —** It is necessary to allow significant time for initial system calibration for queue length detection systems during initial implementation. One suggestion is to add 5 percent to the best estimate of the time required.
- **Arkansas —** Start-up time is needed for getting the system into place and fully operational. In Arkansas, the construction project itself was delayed because it could not begin until the ITS system was operational and unanticipated delays were encountered in bringing the system online.
- **Arkansas —** Snags in system deployment may include traffic condition scenarios that were not anticipated in pre-programming of scenarios. In Arkansas, the timing of some sensors had to be lengthened because the system was interpreting slow moving traffic as stopped vehicles.
- **All sites —** It is important to use a proactive approach to building public awareness of the project and the information that the ITS application will provide. Successful techniques include holding press conferences, issuing news releases, and keeping local media up to date.

Terrain

- **Michigan —** It is important to plan around rolling terrain to avoid difficulties in placing cameras where obstacles may be present.
- **Michigan —** The line-of-sight for cameras needs to be tested to be sure that the entire network is within the field of view.

Access/Security

- **New Mexico —** It is necessary to allow for access to sensor stations because they may need to be reset manually when there is a power interruption, such as a lightning storm.
- **Arkansas —** Vandalism can be a problem. Although securely locked, the control center trailer in Arkansas was broken into and the vandals ripped the system wires from their connections and destroyed the monitor for the computer. The system was down for several days while waiting for shipment of a replacement computer and then reconnection of all the wiring.

System Operations

- **Illinois and Arkansas —** Recalibration of detection systems should be expected during the course of the project. At the Arkansas site, the sensors that were originally procured sent an infrared beam across all the lanes of traffic to a receiver and reported the presence of a queue any time that beam was interrupted for more than a few seconds. The sensors worked well initially, but over time dirt, film, rain, ice, and fog formed on the lens, causing the sensors to transmit signals to the control center that traffic was backed up when it was not. The sensors also had to be realigned periodically. These problems led the agency to switch to another type of sensor.
- **New Mexico —** When changes in work zone roadway geometry are made, it is important to allow time for drivers to learn the new traffic pattern before reporting problem spots to the contractor based on observations from the system's cameras.
- **New Mexico —** Stations may need to be reset manually when there are power interruptions, such as lightning storms.
- **Arkansas —** At the Arkansas site, battery acid produced fumes that caused some connections in the control center cabinet to rust out. There was also a series of bad modems, so the supplier had to be changed, which required reprogramming for compatibility.

Legal Issues

- **Michigan —** Archiving of certain data such as imagery may have legal implications, because video of crashes could be requested for use in litigation. MDOT concluded that it would be better not to have any archived video data.

Other ITS Applications

In addition to the four mobile traffic monitoring and management systems highlighted previously, there are many other existing and potential applications of ITS in work zones. This section provides an overview of a few examples of ITS applications and advanced technology approaches aimed at improving safety, capacity, enforcement, performance-based contracting, and work zone planning. These applications of ITS in work zones were identified through a literature search.

Safety

With more than 800 people killed in US work zones annually, ITS applications capable of enhancing safety in work zones are a key priority for agencies responsible for work zone operations. ITS work zone applications for safety generally fall into the following categories or approaches:

- Traffic queue detection and alert systems
- Speed management systems
- Intrusion alarms
- Automated work zone functions
- Automated enforcement.

The safety functions of most of the systems previously described rely on traffic queue detection sensors and traveler information approaches to alert drivers of conditions ahead. Other safety-focused work zone applications are described below. Two of these systems, ADAPTIR and Wizard CB Alert System, use advanced warning to drivers to improve safety. A third system, the Dynamic Work Zone Safety System (DWZSS), adjusts no passing zones based on traffic backups approaching work zones. Examples of speed management systems include SPEEDGUARD, which uses ITS to inform individual drivers of their current speed, and variable speed limit (VSL) systems that adjust speed limits based on current roadway conditions. Although these applications can increase safety among construction workers, they primarily focus on protecting road users. Conversely, intrusion alarms emphasize protecting workers from errant vehicles, although they may also protect road users. Examples of automated work zone functions are included in the Increased Capacity section, which follows, because these ITS applications can enhance both mobility and safety. Similarly, automated enforcement applications are discussed in the Enforcement Support section.

ADAPTIR

The ADAPTIR system, similar to the mobile traffic monitoring and management systems described above, has been used to address safety in work zones. The system was used in a work zone on I-80 in a rural area in Nebraska to advise drivers of slowing traffic speeds downstream.

Information was provided to drivers by four DMSs. Speed advisory messages were presented to drivers in a two-phase format. The first phase provided the location, the word "ADVISORY" and the time of the message. The second phase stated "REDUCED SPEED AHD xx MPH". The logic used to select whether a message should be displayed and the speed to be displayed was based on the speed differential, measured in eight- or four-minute intervals depending on time of day. Speed differentials greater than 10 mph at locations downstream from the DMS caused messages to be displayed at the upstream location.

Teams evaluating the effectiveness of the system noted that the system was not effective in reducing speeds during periods of uncongested flow. However, when traffic flow approached congested levels, the team found that the signs were effective in reducing speeds.[3]

In addition to the potential safety benefits, the system may provide cost savings by automating functions that would otherwise be performed manually.

Wizard CB Alert System

The Wizard CB Alert System automatically broadcasts advisory messages to warn drivers of traffic or road conditions/hazards ahead and is primarily targeted at truckers. The system broadcasts a pre-recorded message of approximately seven to ten seconds duration warning drivers over a citizens band (CB) channel, usually Channel 19. The message contains information about downstream construction activities or other conditions associated with reduced traffic speeds. The system was evaluated in Iowa for one month during a striping operation on a rural section of I-35.

Teams evaluating the system found a high percentage (75 percent) of truckers surveyed had heard the message. All of the drivers who reported hearing the message thought this approach was worthwhile; 89 percent of the drivers thought the message to be effective. Nearly all (98 percent) stated that they did not consider the message obtrusive or annoying.[4]

Dynamic Work Zone Safety System

The Dynamic Work Zone Safety System is designed to prevent dangerous merging in the tapered approach to work zones by creating a dynamic no-passing zone. The length of the no-passing zone depends on the length of the traffic backup. The coverage area of the no passing zone is depicted by a series of signs. The trailer-mounted, portable signs

[3] Maze, T., et al. (2000). *Midwest States Smart Work Zone Deployment Initiative: Technology Evaluations – Year 1.* http://www.matc.unl.edu/project.

[4] Maze, et al. (2000).

consist of flashing lights, a "DO NOT PASS" sign, and a "WHEN FLASHING" sign. As sensors detect that traffic is backing up, the next upstream sign begins to flash. The signs are regulatory, and thus, the "DO NOT PASS" message is enforceable. Components of the system include non-intrusive traffic sensors, interface controllers, communication devices, regulatory signboard with flashers and trailer, and solar power equipment and batteries.[5] The system has been used in work zones in Indiana and Michigan.

SPEEDGUARD

SPEEDGUARD is a portable system designed to enhance safety by informing drivers of their speed. The system is expected to reduce both the average speed of vehicles and speed variations. The system consists of a portable trailer unit that uses radar to measure vehicle speed and a panel with 24-inch light-emitting diode (LED) numerals on which vehicle speeds are displayed. The system was deployed on I-70 in a rural section of Kansas and on a rural stretch of I-80 in Nebraska, upstream from a work zone where the speed was reduced from 75 mph to 55 mph. The system in Nebraska was designed to display the vehicle's speed under a sign stating "SPEED LIMIT 55". Although reliability was an issue for the system in Nebraska because the unit malfunctioned after seven hours and had to be removed from the site, evaluation teams were able to collect limited data on the system.

Evaluation teams found that, in Kansas, the speed display resulted in a significant reduction in mean speeds, 85th percentile speeds, the percentage of drivers exceeding the posted limit, and speed variation. Even with the limited data in Nebraska, evaluation teams found the system to be effective in reducing speeds by approximately 5 mph, decreasing speed variation, and increasing driver compliance with the posted limit. However, the evaluation team recommended further study of the system in Nebraska given the short data collection period.[6]

Variable Speed Limit Systems in Work Zones

There is increasing interest in deploying Variable Speed Limit systems in work zones. One such system has been demonstrated by the Minnesota Department of Transportation (Mn/DOT). The objective of the system is to make work zone speed limits on high-volume urban freeways easier to sign and enforce. The system incorporates two BRICK™ modular message blocks on each speed limit sign placed in a work zone. The signs are easily moved because they are mounted on U-channel supports. While construction workers are not present, the speed limit continues to be 65 mph. When construction workers arrive, a designated worker changes the speed limit to 45 mph. The displayed speeds are enforceable.[7] In 2000, Mn/DOT deployed one sign for the demonstration.

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5 International Road Dynamics, Inc. *Dynamic Work Zone Safety System*.

6 Maze, et al. (2000).

7 Dumke (1999). "The Signs They Are A Changin'". *Traffic Technology International*. June/July 1999. pp. 100-102.

The results of this demonstration led Mn/DOT to conduct an additional evaluation the following year. This additional evaluation included as many as eight VSL signs.

The Federal Highway Administration supports additional development of variable speed limits in work zones, as reflected by the award in autumn 2001 of field tests to Michigan, Maryland and Virginia. These field tests will deploy a VSL system that measures real-time traffic conditions in the work zone, and then computes and posts a speed limit that reflects the safe speed at which drivers should be traveling given the measured conditions. It is hoped that by implementing such a system, both mobility and safety in work zones will be improved.

Intrusion Alarms

Intrusion alarms detect vehicles entering the buffer area between work crews in the work space and vehicles driving past the work zone, and provide a warning to alert workers. Although the time for a worker to move out of the path of an incoming vehicle is very short, the jarring alarm can provide workers with an estimated four to seven seconds of warning to provide some ability to avoid the intruder. Intrusion alarms employ various technologies, such as infrared, ultrasonic, microwaves, or pneumatic tubes, to detect the intruding vehicle. When the system detects an intrusion, it sounds a loud siren to warn the workers in the area. Transmission mechanisms include radio and hard-wired systems. The Strategic Highway Research Program (SHRP) tested several of these technologies.[8] In addition, the Pennsylvania Department of Transportation (PennDOT) deployed an infrared intrusion alarm to protect workers in its rehabilitation of eight miles of pavement and several bridges on U.S. Route 22. The intrusion alarms were used in combination with a traffic monitoring and management system that provided traveler information. PennDOT selected these ITS technologies for use in the U.S. Route 22 work zone because of their ability to protect workers and motorists and minimize traffic disruptions. The U.S. Route 22 work zone presented particular safety and mobility concerns due to the large volume of traffic and the blind corners that make it difficult to see slowed or stopped traffic on this highway segment.[9]

[8] Canadian Strategic Highway Research Program (1995). "Strategic Highway Research Program, Maintenance Work Zone Safety Devices – Development and Evaluation." *Technical Brief*, February 1995.

[9] FHWA (1998). "Queue Length Detector Reduces Risk of Rear-End Accidents in Work Zones." *FOCUS*. April 1998.

Increased Capacity

One approach to improving capacity in work zones is to reduce the amount of delay associated with work zone set-up and take-down as well as work zone configuration shifting. These operations, especially in urban areas with high ADT, can have a negative impact on overall capacity approaching and in the work zone. Applications of advanced technology that can reduce the time required for these operations provide contractors with more time for actual construction activities, as hours of construction are often restricted to non-peak traffic periods. Two such applications, the Advanced Cone Machine and the Quick Change Moveable Barrier,™ are profiled below. While these systems may not fit a strict definition of ITS, they will be of interest to agencies responsible for work zone operations.

Mobile traffic monitoring and management systems such as those used by the four sites profiled in detail above, as well as similar systems, can also increase effective capacity by:

- Providing delay information on DMS messages, thus enabling drivers to select alternate routes that may be faster
- Actually suggesting the use of alternate routes, perhaps even particular routes, in DMS messages displayed
- Providing pre-trip information via the media, the Internet, or other communication media, so that drivers can make informed choices of routes and times of travel.

Advanced Cone Machine

The Advanced Cone Machine automatically lays down cones at regular intervals, and removes them when the work zone is taken down. A single operator can safely and quickly open and close busy lanes during construction or maintenance. The Advanced Cone Machine utilizes robotics, automation, and advanced computer control to place and retrieve cones around highway work zones. Use of the advanced cone machine improves safety and efficiency of cone placement and retrieval operations. The use of the new technology provides operational flexibility with a simple operator interface.[10] Figure 7 shows the Advanced Cone Machine placing cones.

Figure 7 – Advanced Cone Machine Placing Cones[11]

[10] SAIC (2000). "State-of-the-Art Work Zone Technology Inventory" Report submitted to FHWA under contract DTFH61-96-C-00047, Task Order 0002.

[11] University of California – Davis (2002). *Automated Highway Cone Placement and Retrieval Vehicle*. http://www.ahmct.ucdavis.edu/cone/cone_mn.htm.

Quick Change Moveable Barrier

The Quick Change Moveable Barrier is made up of two parts: safety-shaped concrete barriers connected to form a continuous wall, and a transfer machine that moves the wall. A barrier is 32 inches high, 24 inches wide at the base, and 3.28 feet (1 meter) long, and weighs approximately 1500 lbs. Barrier sections are connected by heavy steel pins that engage specially designed hinges attached to both ends of the barrier. The cross section of the barrier is similar to that of a standard safety-shaped barrier except for its "T"-shaped top. An inverted conveyor system on the self-propelled Transfer and Transport Machine (TTM) uses the underside of the "T" top of the barrier as a lifting surface to pick up and move the wall across the roadway. The barrier wall can be moved at speeds of up to 5 mph, meaning that a mile of barrier can be moved in under 20 minutes. This system offers both safety and mobility benefits by reducing worker exposure to traffic while increasing the speed at which barriers can be put into place, thereby reducing associated traffic delays.[12]

Enforcement Support

A growing consideration for enhancing safety in work zones is incorporation of enforcement into work zone traffic management or near work zone sites. One approach involves the use of automated enforcement of speed limits. In automated enforcement of speed limits, cameras are set to photograph any vehicle that exceeds the posted speed limit by a certain pre-determined threshold. The vehicle caught speeding is cited and a ticket is automatically issued. Signs can be set up prior to work zones to warn approaching drivers that photo surveillance is in use. The use of these systems or any similar automated enforcement system has the potential to increase safety through greater compliance with speed limits, improve both mobility and safety by decreasing the need for enforcement personnel to stop vehicles in and around work zones, and provide cost savings for enforcement personnel.

While the equipment for automatically ticketing speeders in work zones exists, there are significant legislative issues involved in deploying such systems. However, with the increased deployment of red light enforcement camera systems, use of automated speed enforcement systems in work zones is becoming a greater possibility.[13]

[12] SAIC (2000).

[13] Turner, S., et al. (1999). *Automated Enforcement in Transportation*.

Performance-Based Contracting

The use of ITS to assess performance-based contracting conditions is relatively new in the U.S. However, a few agencies are starting to apply these systems. In the reconstruction of State Route 68 in northeast Arizona, the Arizona Department of Transportation (ADOT) turned to ITS to minimize the delays motorists experience on a day-to-day basis while traveling through the work zone. ADOT decided to use ITS in an innovative way to measure travel times related to a contract incentive/disincentive clause. The ITS application involved measuring speed consistency and performance through a 13-mile work zone. Prior to construction, travel time through the area averaged 17 minutes. The contract for the project included a provision requiring that, during construction, travel time through the work zone could not exceed an average of 27 minutes. This figure was calculated using the work zone's reduced speed limit. If the average travel time was not kept as specified, the contractor had to pay for the delay. Cameras were located at the beginning and end of the work zone and were used as part of a license plate reader system to measure average speeds. The system required adjustments to the cameras and lights as construction progressed and travel lanes were shifted because these movements affected the visibility of vehicle license plates. The license plate reader system required high-speed data connections and incurred electricity costs. ADOT had the option of paying $700 per month for a T1 line or $200 per month for a wireless data connection. ADOT incurred about $100 per month in additional electricity costs to operate the license plate reader system.[14] A similar type of system that employed contracting incentives and disincentives based on travel time was used in Massachusetts for a project on the Coolidge Bridge.[15]

Analytical Tools for Work Zone Planning

Microcomputer tools and models can assist in the development and analysis of work zone layouts. Large amounts of data can be stored and analyzed to determine the scenario that has the least impact on the traveling public. As part of the application of computer technology to help relieve the burden of road construction, several advanced analytical tools have been developed for use in evaluating work zone traffic control strategies.

[14] Hansen, Alan (2001). *Work Zone Operational Enhancements, State Route-68*.

[15] Computer Recognition Systems, Inc. (2002). *Real-Time Travel Information Website*. http://crs-its.com/Coolidge/coolidge.shtml.

QUICKZONE

The Federal Highway Administration is currently developing a traffic impact analysis spreadsheet, known as QuickZone, which provides a general and quick work zone traffic impact analysis capability. The overall goal is to provide a tool that requires less than one hour to input and check a QuickZone network, and less than three minutes to analyze the data and produce delay profiles over the project duration. For example, if a highway agency were widening a lane of traffic, QuickZone could estimate the impacts of doing work at night instead of during the day or diverting the traffic to various detour routes during different phases of the construction, thus allowing the agency to select the solution best-suited for its particular needs.

The target users of QuickZone are state and local traffic construction, operations, and planning staff, and construction contractors. The tool is suitable for application in both urban and inter-urban settings. For more information about QuickZone, access the website address http://www.tfhrc.gov/its/quickzon.htm.

QUICKZONE
A NEW WORK ZONE DELAY ESTIMATION TOOL

QUEWZ

The Texas Transportation Institute, in cooperation with the Texas Department of Transportation, has developed a tool that estimates traffic impacts and road user costs associated with short-term lane closures in work zones. The Queue and User Cost Evaluation of Work Zones (QUEWZ) tool is currently being used by several state agencies to assist with planning and scheduling of work zone activities.

The QUEWZ tool can be applied to freeway facilities or multilane divided highways with as many as six lanes in each direction and can analyze 24 consecutive hours of operation. This tool is designed to analyze the effects of lane closures within work zones, and therefore is often used in conjunction with other analysis tools. For example, QUEWZ can be used to analyze the effects of closing one lane of freeway for several hours during the day, and another tool can supplement this analysis by estimating the effects of the same lane closure occurring at night.

Conclusion

Agencies across the country are successfully deploying ITS in work zones. This cross-cutting study has examined some applications of ITS in work zones – mobile traffic monitoring and management, traveler information, and incident management systems – in detail, and has provided highlights of a few other successful applications of ITS and advanced technologies in work zones. These systems have the capability to provide significant benefits to agencies and to those affected by the mobility and safety impacts of road construction and maintenance work zones – road users, nearby businesses, and construction workers. Many agencies have already begun to experience benefits and pass those benefits on to others.

While an ITS application may not be appropriate for every work zone, there are many situations where transportation agencies can effectively use ITS in work zones. Although the need exists for more data collection to better quantify benefits, the qualitative benefits are already apparent. Several sites using ITS work zone applications indicated that, at present, the most effective gauge of the value of a system can be found in the comments and feedback received from the public. Using ITS in work zones has resulted in better communications and coordination between stakeholder agencies and groups, and, for the agencies, a better relationship with the traveling public.

Selected Resources

Federal Highway Administration's Work Zone Technical Assistance Program

Federal Highway Administration's *Work Zone Website.*
http://ops.fhwa.dot.gov/wz/workzone.htm

Work Zone Operations Best Practices Guidebook. Washington, DC: U.S. Department of Transportation (Publication Number FHWA-OP-00-010), April 2000. http://ops.fhwa.dot.gov/wz/bestprac.htm

Professional Associations Committees and Task Forces

American Association for State Highway and Transportation Officials (AASHTO) Standing Committee on Highways Subcommittee on Construction and Subcommittee on Maintenance.
http://www.transportation.org

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http://www.ahmct.ucdavis.edu/cone/cone_mn.htm

Federal Highway Administration Resource Centers

Eastern Resource Center
10 S. Howard Street
Suite 4000 – HRC-EA
Baltimore, MD 21201
Phone 410-962-0093

Southern Resource Center
61 Forsyth Street, SW
Suite 17T26 – HRC-SO
Atlanta, GA 30303-3104
Phone 404-562-3570

Midwestern Resource Center
19900 Governors Highway
Suite 301 – HRC-MW
Olympia Fields, IL 60461-1021
Phone 708-283-3510

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201 Mission Street
Suite 2100 – HRC-WE
San Francisco, CA 94105
Phone 415-744-3102

FHWA Metropolitan Offices

New York Metropolitan Office
1 Bowling Green, Room 429
New York, NY 10004-1415
Phone 212-668-2201

Philadelphia Metropolitan Office
1760 Market Street, Suite 510
Philadelphia, PA 19103-4124
Phone 215-656-7070

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"Since the Real-Time Traffic Control System has been in place on I-55, there have been no significant backups during reconstruction of the bridge spanning Lake Springfield – thereby improving safety and mobility for the traveling public."

–James Slifer, Director, Division of Highways, Illinois Department of Transportation

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