

## **Chapter 3.0 Real-Time Advanced Warning And Traffic Control Systems For Highway Work Zones**

### **3.1 Need for Real-Time Systems**

Traffic volumes on highways are increasing rapidly, especially in urban areas. High construction costs, environmental concerns, and difficulties and costs involved in right-of-way acquisition have practically ruled out the option of building new highways as a means of accommodating growing traffic needs. Several DOTs are thus focusing on efficiently using the existing facilities, increasing their capacity to accommodate additional traffic. Intelligent Transportation Systems (ITS) play an important role in efficiently managing traffic. ITS subsystems such as Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), and Advanced Public Transportation Systems (APTS) are innovative and efficient means of increasing capacity without building new highways. Additionally, the increasing growth in traffic and the aging of the highway system has necessitated reconstruction and regular maintenance of most highways and freeways.

In recent years, several DOTs have shifted their focus to methods of carrying out reconstruction and maintenance activities without disrupting traffic and drastically reducing capacity. Construction and maintenance work zones are characterized by features such as reduced capacity, congestion, and delays, thereby representing bottlenecks in the highway system. The high increase in traffic demand and reduced capacity conditions at highway work zones present a very hazardous scenario, making them prone to accidents. Studies have shown that there is an increase in accident rate due to the presence of construction and maintenance zones. Studies on the location of accidents show that most accidents occur at the taper, buffer, and advance zones. The accidents occurring at the taper zone may be attributed to improper merging maneuvers, whereas those in the buffer and advance zones may be due to driver inattention, excessive speed, following too close, or simply not knowing what to expect ahead in the work zone. The argument may be

further strengthened by the fact that the most predominant type of accident experienced at work zones is rear-end collisions. These accidents may be caused due to either a single reason or a combination of reasons including excessive speed, not knowing what to expect ahead, driver inattention, and following too close. Other predominant accident types include fixed-object off road-type collisions and sideswipe. These accident types correlate with the location of accidents within the work zone. For example, sideswipe-type accidents may be expected to occur at taper zones due to improper merging maneuvers. Fixed object off road-type collisions may also be seen as a subset of rear-end type collisions. The reasoning behind this is that a driver may swerve, deciding that it is safer to collide with a fixed object rather than another vehicle. Additionally, these types of accidents may logically seem to occur in the advance and buffer zones of the work area. The following bulleted list summarizes the problems encountered at work zones and their probable causes:

- Work zones are more prone to accidents than non-work zones. Higher accident rates have been observed at work zones as compared to non-work zones
- Rear-end collisions are the most predominant type of accidents experienced at work zones, followed by fixed object off road and sideswipe. Together, these collision types claim 60-80 % of all work zone accidents.
- A high percentage of collisions take place in the taper, advance, and buffer zones of the work area.
- The major causes for accidents include driver inattention, exceeding safe speed, following too close, and not knowing what to expect ahead at the work zone.

The facts mentioned above depict the work zone safety issues currently experienced by most DOTs. The Manual for Uniform Traffic Control Devices (MUTCD) explains in detail the safety measures that need to be taken and the traffic control devices that need to be used for efficient management of traffic within the work zone. Every state must comply with the basic criteria set forth by the MUTCD. Besides the traffic control devices mentioned in the MUTCD, several innovative technologies and devices have been

developed to enhance work zone safety and facilitate traffic control. These include portable rumble strips, work zone intrusion alarm, lightweight changeable message signs, unmanned radars, safety warning systems, truck-mounted attenuators, solar-assisted arrowboards, flashing stop/slow paddles and barrier lighting units. The devices used and developed for work zone safety and traffic control provide for static means of information dissemination to motorists. The information lacks the dynamic quality that renders it less credible to motorists. Motorists are thus confused when they encounter a sign, not knowing for sure whether the information given to them is current, or obsolete and not applicable to them. Thus, motorists tend to ignore many warning signs, which leads to accidents as reported earlier in this section.

All of the facts on work zone accidents, their characteristics and probable causes combined with the lack of dynamic information dissemination to motorists entering the work area, define the need for a real-time or dynamic work zone system. The primary objective of deploying a real-time system is to encourage motorists to obey work zone signage, thereby enhancing safety and facilitating traffic control. It can be safely said that real-time systems definitely are a step forward in enhancing safety and the existing traffic management capabilities at work zones.

### **3.2 Review of Currently Available Real-Time Work Zone Systems**

Initially, several DOTs started using special equipment like VMS, sensors, and CCTV as stand-alone devices to monitor traffic in work zones. Gradual development led to the integration of these components into a comprehensive system to enhance traffic safety and control. The general idea was to have one or more sensors monitor traffic within the work zone, have this data analyzed and interpreted, and send out this information to travelers in real-time using various output devices. In order to determine the current status of development and deployment of real-time work zone traffic control applications, the Center for Transportation Research (CTR) contacted the state DOTs. Three states are currently testing such systems, and five others plan on developing such systems in the near

future. FHWA is also planning on developing a similar system as part of the national study on rural applications of Advanced Traveler Information Systems. These four systems are described below.

### **3.2.1 Condition-Responsive Work Zone Traffic Control System**

The Condition Responsive Work Zone Traffic Control System is a real-time work zone system developed by the Scientex Corporation for the Maryland State Highway Administration (MSHA). It is a portable, modular, and autonomous system that may be used at all types of work zones. The system provides real-time information regarding current traffic status to motorists, forewarning them of congestion and changes in roadway geometry such as closed lanes and lane shifts. The system also provides advisory messages advising drivers of operating traffic speeds within and around the work zone. The system also provides alternate route messages in the event of congestion. Additionally, the system alerts workers of work area intrusions, thereby increasing worker safety.

The basic components of this system are: (a) sensors, (b) output devices, (c) roadside remote stations (RRS), (d) central system controller (CSC), and (e) communication links (The Scientex Corporation, 1996). The data acquisition is performed using non-pavement intrusive radar sensors located within and upstream of a work zone. This acquired data is retrieved by the Central System Controller (CSC) using a radio modem from the network of data collection devices called Roadside Remote Stations (RRS). The communication link used is Ultra High Frequency (UHF), which facilitates the use of the system in areas not yet supported by cellular service. It also insures operation of the system during periods of heavy cellular phone usage. The CSC analyzes the traffic data to predict delays and detect traffic conditions upstream of the work zone. In the event of deteriorating traffic conditions, the CSC selects appropriate messages to warn drivers of delays, low traffic speeds, and other hazardous conditions. The output devices used include Variable Message Signs (VMS), Traveler Advisory Radio (TAR), and Lane Control Signals. Based

on the commands received from the CSC, the RRSs, which control the VMS and the TAR, update the messages and provide real-time information on current traffic conditions to the motorists approaching the work zone. The messages displayed on VMS are reinforced by time stamps to improve motorist compliance with speed reduction and lane change messages. The condition-responsive work zone traffic control system can be monitored locally from the CSC, and remotely using a modem. The system portability is maximized by mounting all units on trailers. The low power requirements of the system hardware make the use of solar-powered operations feasible, thus reducing maintenance costs.

The system as a whole aims to benefit motorists through improved safety and smoother traffic flow in highway construction zones. The basic system functions include (The Scientex Corporation, 1996):

- Providing reliable real-time information on current traffic conditions
- Forewarning travelers of closed lanes or hazardous traffic conditions
- Advising drivers of operating traffic speeds within the work zone and downstream of the work zone
- Providing adequate alternate route signage, encouraging diversion to alternate routes to reduce traffic congestion, and
- Alerting workers from possible hazardous work area intrusions

The reported advantages of the system are (The Scientex Corporation, 1996):

- Portability
- Modular construction
- Autonomous operation
- Credible signage due to time stamps on messages
- Automatic logging of all traffic conditions data and algorithm parameters to DOS text file
- Adaptable system which may be used for general traffic control purposes

### **3.2.2 Travel Time Prediction System (TIPS) for Work Zones**

The University of Cincinnati is presently developing an Intelligent Traffic Control system for highway work zones. This new system, called the Travel Time Prediction System (TIPS), is designed to provide motorists with advanced real-time work zone information. The basic objective is to provide motorists with travel time information to traverse the work zone. The information is provided in advance of and through the work zone. The system is portable and relies on non-contact sensors, wireless communications, variable message signs, and a software capable of predicting travel time. The basic components of this travel time prediction system are: (a) traffic detectors, (b) micro controller, (c) personal computer, (d) spread spectrum communication device, and (e) variable message signs (Pant and Polycarpou, 1997).

The system collects traffic flow data, such as volume and occupancy, every 30 seconds using several non-contact, side-fired, microwave radar detectors mounted on portable aluminum mini-towers and located at selected points along the side of the highway. Each of the mini-towers also has a micro-controller and a spread-spectrum radio communication device attached to it. The traffic data collected by all stations (mini-towers) is transmitted to a personal computer using the spread spectrum radio communications device. The computer is housed in a construction trailer at the work area. A special software within the computer is used to collect all the traffic flow data, estimate travel time, and communicate with the VMS. Based on the travel time predictions, appropriate messages are displayed on the VMS. The software employs cellular telephone connections to perform this operation. The software is developed using Visual C++ and works on a Windows NT operating system. The unique feature of this system is that the information provided is an estimate of the travel time the motorist will require to traverse the work zone when he/she reaches the work zone from the location of the VMS.

The anticipated benefits of the TIPS system are reduced motorist frustration, improved safety, and reduced congestion and delays (Pant and Polycarpou, 1995). The TIPS is

planned for deployment on a six-mile-long work zone on I-70 in Ohio during the summer of 1997.

### **3.2.3 Advanced Portable Traffic Management System**

The Advanced Portable Traffic Management System (APTMS) for work zones is a real-time traffic management system (Nookala et al., 1996). The basis of this system is the compilation of real-time traffic data from the work zone and surrounding roadway system, and transmission of that data through the work zone and to a traffic control center where the traffic information is reviewed before it is disseminated to motorists via suitable output devices. This system is basically an integration of both existing and newly-created technologies into a comprehensive portable traffic management system. The APTMS project is being conducted under a public-private partnership, including

- The Minnesota DOT
- ADDCO Manufacturing, Inc.
- Federal Highway Administration, and
- The University of Minnesota, Center for Transportation Studies

The APTMS consists of five sub-systems: (a) vehicle detection/surveillance, (b) traffic control center, (c) driver information systems, (d) communications, and (e) guidance. The traffic data collection is done by the vehicle detection/surveillance subsystem. It consists of several different components including video cameras, machine vision devices, and magnetic sensors. The video cameras are placed at strategic locations in the work zone to record and provide real-time information on traffic flow and incidents. The portable machine vision devices gather and record information, such as traffic volumes and speeds within the work zone. Magnetic sensors are used to collect volume and speed data in areas that cannot be observed by cameras. The collected information is transmitted to a traffic control center located within a construction trailer in the work zone. From there, it is sent to the main MnDOT Traffic Management Center via ISDN lines. The basic equipment used at the traffic control center is a Pentium P60 computer running Windows 95. Using

this CPU, the operator can view all the video images and traffic data from the work zone. This may be done on-site or remotely from the traffic management center. The data aggregated is analyzed, and decisions are made regarding the changes needed to improve traffic flow through the work zone. These changes are made via the Driver Information subsystem, which consists of full-size portable VMS and smaller work zone changeable message signs. This may be done either from the traffic control center or the MnDOT traffic management center. The information is also made available on the Internet, and kiosks may be employed to extend this facility to non-Internet users. The communication subsystem relies on spread spectrum radio, cellular links, and ISDN. Each of these communication devices are used for specific links within the system. The guidance subsystem is a moving light setup on a portable concrete barrier. This will be used in areas where lanes are tapering in order to enhance lane visibility and improve the motorist's visual comprehension of the roadway geometry. This subsystem will also include a master controller and a radio link to the traffic control center.

An evaluation of the APTMS system is currently being performed by SRF, Inc. at the I-94 Dartmouth River Bridge construction project. The main goals of the evaluation are to (Nookala et al., 1996):

- evaluate system benefits on traffic operations
- evaluate system costs
- evaluate system functionality characteristics
- evaluate perceived benefits of the system, and
- evaluate the effectiveness of public/private partnerships

### **3.2.4 Portable Surveillance and Delay Advisory System**

Rural work zones are continuously facing extensive traffic delays and congestion. Every year, thousands of miles of rural roadways experience construction and maintenance work zones. As part of the rural advanced traveler information system study, the Federal Highway Administration (FHWA) selected the Portable Surveillance and Delay Advisory

System (PSDAS) as a concept for testing. As the name suggests, the main objective of this system will be traffic surveillance and dissemination of delay advisory information at rural highway work zones to help motorists make judicious travel decisions (Zarean et al., 1996).

The PSDAS consists of the following four components: (a) data collection devices, (b) roadside data processor, (c) traveler interface, and (d) communication links. Traffic information within the work zone is collected using traffic data collection devices and is transmitted to the roadside data processor. The data collection devices to be used for the system are undecided. The device(s) selected should be able to collect speed and/or vehicle identification data. Three methods are proposed to be used for data collection: passive AVI, active AVI, and spot speed (Zarean et al., 1996). Passive AVI uses a method that recognizes license plates and records time to move from upstream to downstream of the work zone, calculating travel time. Active AVI uses automatic vehicle identification upstream and downstream of the work zone via radio frequency signature matching to calculate travel time. Spot speed detection calculates travel time by adding link travel times between strategically-located stations along the length of the work zone. The roadside data processor receives the data collected and transmitted by the data collection devices and analyzes it to calculate meaningful information like travel time, speed, and delays expected in the work zone. The roadside data processor then selects the appropriate sign or message to be displayed or sent out to the motorists via the traveler interface. The traveler interface consists of several information dissemination channels, such as VMS, HAR, and information kiosks. The traffic information is relayed to the motorists via one or more of the above output devices. The type of communication link to be used to transmit information between the data collection devices and roadside data processor, and from the roadside processor to the traveler interface has not yet been decided. There are several systems under consideration, including low power radio frequency, cellular, microwave, and spread spectrum. The Portable Surveillance and Delay Advisory System (PSDAS) is still in the planning stages and will eventually be used at rural highway work zones.

### **3.3 Need for Real-Time Systems on I-81 in Virginia**

By reviewing the work zone accident experience on the I-81 Corridor in Virginia (section 2.3.2), it may be observed that there is indeed a growing problem of work zone safety and traffic control. It may be seen that together, rear-end collisions and fixed-object off road type collisions claim over 75% of the total work zone related accidents (1991-1994) on I-81. Major accident causes include driver inattention, exceeding safe speed, and following too close. Additionally, the traffic volumes on I-81 are growing and their characteristics changing with the increase in percentage of truck traffic. For the next twenty years, I-81 will experience a huge number of construction and maintenance activities totaling approximately two billion dollars. The nature of traffic, past accident records, and the planned construction activities for the future bring forth concerns in terms of work zone safety and traffic control. New strategies need to be examined and implemented to help combat the pending work zone safety issues which may arise on I-81. Real-Time Advanced Warning and Traffic Control Systems may provide new dimensions to enhance work zone safety via dynamic information dissemination and advanced warning techniques.