Deployment and Evaluation of ITS Technology in Work Zones

Rob Bushman, P. Eng.
Department of Civil Engineering
University of Saskatchewan
Saskatoon, SK, Canada

Curtis Berthelot, Ph. D., P. Eng.
Department of Civil Engineering
University of Saskatchewan
Saskatoon, SK

Rod Klashinsky
International Road Dynamics Inc.
Saskatoon, SK

Paper prepared for presentation

at the Work Zone Safety Session

of the 2003 Annual Conference of the
Transportation Association of Canada
St. John’s, Newfoundland and Labrador

ABSTRACT

Traffic safety and mobility is a concern to transportation agencies throughout North America, evidenced by the aggressive goals for reduced accidents and congestion set by Transport Canada, the Canadian Council of Motor Transport Administrators, and the Federal Highway Authority. Work zones often act as a compounding factor to intensify issues of safety and congestion on the highway system. Recent advances in the use of Intelligent Transportation Systems (ITS) and the application of ITS to work zones are providing new tools that can be used for management of traffic in and around work zones.

This paper will examine several recent field applications of ITS in work zones, providing a description of the operation of the systems, results of evaluations that have been conducted, and identification of current and future research.

One application of ITS in work zones has been dynamic lane merging. Dynamic lane merging creates a dynamic “No Passing” zone in advance of the construction area that advises motorists to merge early, rather than wait until reaching the final taper area. The system changes as traffic condition changes so that it is always relevant to the current driving conditions. A study recently completed by Wayne State University in Michigan showed that the Lane Merger was beneficial in reducing aggressive driving, reducing travel time delay, and decreasing traffic stops and duration of stops. It was also shown to have a favorable benefit to cost comparison.

Dynamic lane merging is just one example of ITS in work zones that has been developed, deployed, and proven successful. Other applications have also emerged such as variable speed limit and travel information systems that provide regulations and information that are based on the current conditions and are relevant and believable to drivers.

DEPLOYMENT AND EVALUATION OF ITS TECHNOLOGY IN WORK ZONES

INTRODUCTION

Significantly improving traffic safety has been identified as an important goal for the Canadian transportation community. Road Safety Vision 2010 adopted by the Canadian Council of Motor Transport Administrators (CCMTA) targets a 30 percent reduction in the number of road user fatalities over a 10 year period. If the targets are achieved, road user fatalities will be reduced to 2100 per year in 2010 (1). In it's strategic plan "Straight Ahead – A Vision for Transportation in Canada", Transport Canada identifies several areas of focus including congestion, environmental pressures, and safety and security (2). Achieving the goals and vision of CCMTA and Transport Canada will require the cooperation, initiative and innovation of many people and agencies in many areas of the transportation industry. The use of intelligent transportation systems (ITS) has been identified as one of the ways that improved safety and efficiency of the transportation system can be achieved.

The challenge of safety and mobility is particularly acute in work zone areas as road repair and construction intensify traffic issues and concentrate them in specific locations and at specific times. A stretch of highway, either in urban or rural areas, that is normally safe and relatively free of congestion can experience severe congestion when construction work is taking place. Safety is also affected by the presence of work zones. Experience in the United States indicates that approximately 2.5 percent of all accidents that occur on the highway system occur in or around work zones (3). In terms of total highway miles traveled this is a disproportionately high number and reflects the concentration of safety issues at construction sites.

ITS technology has been developed and is being deployed to improve the safety and mobility of traffic in and around work zones. This paper will highlight three unique systems that have been developed for work zones in terms of their operation, performance, and current and future research. The three systems that will be discussed are dynamic lane merge, variable speed limit and traveler information.

MERGING TRAFFIC AT WORK ZONES

A high percentage of work zone related accidents occur in the transition area prior to the actual construction area. In the transition area traffic must change from multi-lane free flow conditions to restricted speeds and reduced lanes. Difficulties in making this transition result in a higher distribution of rear end and side swipe occurrences in work zone accidents than non-work zone accidents (4).

One of the reasons for the increase in side swipe incidents is the lane change and merge that must occur when a lane is closed. As traffic approaches an area with a lane restriction, some vehicles will merge into the single continuous lane and proceed in an orderly fashion through the work zone. However, aggressive drivers will frequently stay in the dropped lane until the last moment in an attempt to get further ahead in the queue. They must then perform a dangerous merge maneuver in congested traffic with limited time and space available.

There are at least three problems that arise from this kind of action. First, there is the risk of accident during the actual lane merge itself since there are few openings in the continuous lane for a vehicle to merge and aggressive driving is often involved. Secondly, if the lane merge is successfully completed, it has likely disrupted the flow of traffic. Someone has had to slow down or stop in order to create an opening for the incoming vehicle, forcing all vehicles behind to adjust speed as well. As the number of traffic disruptions increases, so does the potential for rear-end accidents and other incidents. The third aspect is the perception and attitudes of drivers. Drivers who pass a waiting line of traffic in the continuous lane and then make a merge into the front of the line obtain an unfair time saving over those who stay in the continuous lane. This increases the impatience, anxiety, and anger level of many who must now wait longer. These feelings will linger and may affect the driving habits and aggressiveness of drivers further down the road and divert their focus away from safe driving.

DYNAMIC LANE MERGING

A dynamic lane merging system has been used on a number of projects to address safety and mobility concerns related to aggressive driving and late lane merges. Motorists are discouraged from attempting to enter the continuous lane at the taper location by creating a no-passing zone in advance of the taper area. This encourages all vehicles to move into the continuous lane before the final merge point, avoiding many of the problems discussed earlier. However, the traffic volumes and congestion will vary greatly throughout the day at the construction zone. As a result, the point at which vehicles can be moved smoothly into a single lane will also vary greatly during the day. As congestion increases and the queue in the continuous lane lengthens, the opportunity for smooth lane changes moves further back from the taper area. Static signing can not cover the variety of conditions that exist and risks being perceived as irrelevant by drivers.

The dynamic lane merge system is designed to automatically react to the changing queue length and flow conditions and adjust the length of the no passing zone. As congestion occurs at a specific point, the no passing zone must be moved upstream of this point to provide vehicles with time and space to merge while traffic is still moving and there are sufficient openings. The dynamic no passing zone is created by using a series of trailer mounted traffic signs with flashing beacons. These signs contain the message “LEFT LANE - DO NOT PASS WHEN FLASHING”. The entire sign and message is in conformance with the MUTCD standards. By turning the beacons on or off, the length of the no passing zone can be adjusted to match the traffic flow characteristics so that it is meaningful and relevant to the motorist and appropriate for the conditions.

The equipment for each control station is mounted on a small trailer so that it is portable. This allows the system to be moved at a site as construction progresses or moved to another site with relative ease. Each control station is equipped with a static sign and flashing beacons. Each station, except the one furthest upstream, is also equipped with a non-intrusive traffic monitoring device to detect vehicle volume, occupancy, and speed.

The information from the sensor is processed to determine the congestion level at that particular point. If congestion is detected a signal will be relayed by radio frequency (RF) communication to the next upstream station. The sign at the upstream station will be activated to extend the no passing zone.

CURRENT AND FUTURE RESEARCH: DYNAMIC LANE MERGER SYSTEM

In December 2001 the final report of an evaluation of the use and effectiveness of the Dynamic Lane Merger system was released by Wayne State University and the Michigan Department of Transportation (5). The Dynamic Lane Merger was deployed at six different locations through the 2000 and 2001 construction seasons. In Phase I of the study which took place in 2000, the focus was deployment issues and approaches to determine an effective configuration to provide clear and positive guidance to motorists. In 2001 the second phase of the project was conducted to determine the effectiveness of the system in improving traffic flow and reducing aggressive driving.

Data was collected for each test condition using the floating car method where a driver and a timer travel through the work zone with at least 15 runs conducted under each condition. In addition, the location and duration of any stopped time delay through the advanced warning area were recorded along with any observations of aggressive driver behavior.

The general conclusion of the evaluation was that the Dynamic Lane Merger “Can be very helpful in reducing aggressive driver behavior, increasing safety and reducing delay at work zones where lane closures are necessary.”

Specific findings of the evaluation included the following:

- The average peak period travel time decreased by over 30% resulting in time savings for drivers.
- The average number of stops and duration of stops were decreased, reducing fuel consumption and emissions.
- The number of aggressive driver maneuvers (late merges) during peak hours were reduced by 50-75%, reducing the potential for accidents and road rage
- Driver understanding through education and awareness, supplementary signing, and enforcement is important for overall effectiveness. Police enforcement has a positive impact on reducing aggressive driving.
- Deployment of the Lane Merger will be economically beneficial and achieve B/C ratios greater than one, if a value of time of $3.80 per person hour is assumed for travel time savings.

- The Lane Merger has been shown effective for reduction from two lanes to one lane with either a right lane or left lane closure, and may also be applicable for reductions from three lanes to two lanes.

In 2002, further research was undertaken to study the application of dynamic lane merging to locations where the closure reduces a highway from three lanes to two lanes. This research will continue in 2003, so results are not yet available on this application. Some work is also underway to determine if work zone situations, and particularly the use of dynamic lane merging, can be accurately reproduced using traffic simulation software. If work zones can be simulated then various operating scenarios can be tested to determine their impact on traffic flow and traffic safety. The Wayne State study indicated a significant decrease in aggressive lane changes and stops. It may be possible to use these as surrogate measures of safety by relating the frequency of aggressive lane changes and stops to side swipe and rear-end accidents. Simulation of traffic could then be used to determine relative safety of various approaches by determining the expected frequency of indicator events.

VARIABLE SPEED LIMIT SYSTEM

The variable speed limit (VSL) system is designed to manage the speed of traffic approaching and traveling through work zones based on the current traffic conditions as well as the current status of the construction site. Static speed reduction signs are often ignored by drivers because they are seen as irrelevant, either because traffic volumes are low and traffic is flowing freely, or because there is no construction activity occurring at the site. An Oregon survey which found the number one driver complaint related to work zones was “signs up and nobody home” confirms the need for relevant signing (4). When drivers get in the habit of ignoring advanced signing, the transition from high speed free flow traffic conditions to slowed or stopped traffic can be a potentially dangerous situation.

The VSL consists of a series of portable trailers with traffic detection capabilities similar to the lane merge system. However, rather than directing vehicles to change lanes, the VSL displays the current posted speed limit for that section of highway. The speed limit to be displayed is automatically determined by the system based on the activity level of the work zone, current traffic characteristics, and road conditions such as rain or ice. A VSL trailer in operation in Michigan is shown in Figure 2.

The Federal Highway Administration has initiated a project to examine the effectiveness of VSL systems in work zones. In 2002 Michigan DOT and Michigan State University deployed a VSL system under various work zone configurations to gather data that is being used in the evaluation of the effectiveness of this approach to work zone traffic management. Some of the measures used to determine the effect of the system on traffic flow include speed, speed variance, speed limit violation, and travel time. Analysis is still underway to determine the significance of results, but there is indication that the system may reduce travel time and may reduce the percentage of vehicles exceeding 60 mph and 70 mph.

REAL TIME INFORMATION SYSTEM

Work zones can be the cause of unexpected delays to motorists and the amount of delay can vary significantly depending on the traffic volumes, intensity of construction work, type of lane closure and many other variables. The uncertainty of the length of delay and the loss of control over their situation can cause frustration and anxiety to motorists.

Real time information systems have been developed to provide messages to motorists of traffic conditions ahead. The system includes a number of data collection trailers using non-intrusive traffic sensors to measure traffic flow approaching and traveling through a work zone. Based on the measured conditions estimated travel times are determined and displayed for motorists on portable changeable message signs in advance of the work zone. Also displayed to the motorist is the physical distance to the end of the work zone. In addition advice on alternate routes can be provided when congestion is causing significant delays. Some systems also support a publicly accessible information web-site where current conditions can be checked. A message sign in operation at a project in Michigan and a screen shot from a project in North Carolina are shown in Figure 3.

By providing this type of information to motorists, some of the anxiety and impatience caused by work zone delays may be reduced. The information also gives back to motorists a small measure of control over their situation so they can make an informed decision on whether to continue through the work zone or choose an alternate route. By reducing anxiety and increasing driver control, the information system facilitates motorists focusing their attention on driving safely.

In addition to the driver benefits the travel information system may also have a direct impact on congestion and delay. Informing motorists in advance of the work zone of the delays ahead, especially long delays, will result in some of the motorists choosing alternate travel routes, thus reducing demand through the work zone and decreasing the delay for subsequent motorists through the work zone.

Much of the research conducted so far has been inconclusive due to technical difficulties, unsuitable test locations, and a focus on the ability of systems to meet functional requirements rather than the operational effectiveness. A Nebraska study showed that the use of alternate routes increased from eight percent to 11 percent with the use of a delay advisory system that only informed of delay ahead without suggesting alternate routing (6). Similar research in Wisconsin determined that diversion rates of 10 percent were achievable during peak hour traffic (7). In Arkansas the rate of fatal and rear-end accidents at a site with an information system was compared to two similar sites. The number of fatal accidents was 2.2 per 100 million vehicle miles traveled at the site with the information system, compared to 3.2 and 3.4 at the comparison sites, an average reduction of 33 percent. Rear end accidents occurred at a rate of 33.7 per 100 million vehicle miles traveled compared to 29.5 and 43.2 at the comparison sites, an average reduction of seven percent (8).

More research is underway and planned at a number of locations for the evaluation of real time information systems in work zones. Some of the research focuses on quantifying the benefits of these systems in terms of reduced traveler delay, reduced accidents, and reduced emissions, both theoretically using modeling software and with actual field measurements. More research is also needed to determine driver use and acceptance of the system and the effect of the system on changes in specific driver behavior such as aggressive braking, speed variations, and stops.

CONCLUSION

As traffic continues to increase on the highway system and maintenance and construction activities are needed to ensure a reliable highway infrastructure, safety and mobility in work zone areas will continue to be a concern. The cost of maintaining the highway infrastructure in terms of delay costs, injuries and deaths warrant continued attention to finding new and better ways to manage traffic through work zones.

Just as ITS technology is being applied in many urban freeway settings to address traffic concerns there are technologies emerging that can be applied specifically to work zone situations. The dynamic lane merger system has been evaluated in Michigan and has been shown to reduce traffic delay time, reduce traffic stops, and reduce aggressive lane change maneuvers. Other systems such as variable speed limit and real time information also show promise to improve the safety and efficiency of traffic flow through work zones.

Based on the positive results obtained from the use of ITS in work zones thus far, research should continue in this area, including the following issues:

- Trends in work zone safety on a national level in Canada.
- Benefits of ITS in terms of safety and mobility under various application and operational scenarios.
- The application of modeling and simulation to analyze and design various implementation scenarios.
- The use of surrogate measures from the field or from simulation as predictors of safety performance.

REFERENCES

1. Road Safety Vision 2010 – 2001 Update, Canadian Council of Motor Transport Administrators and Transport Canada, Ottawa, Canada.
2. Straight Ahead - A Vision for Transportation in Canada, Transport Canada, Ottawa, Canada, February 2003.
3. Fatality Analysis Reporting System, National Center for Statistics and Analysis, National Highway Traffic Safety Administration, US Department of Transportation
4. Work Zone Facts at a Glance, Oregon Department of Transportation, www.odot.state.or.us/transafety/Workzone.htm
5. T. Datta, K. Schattler, C. Hill, Development And Evaluation Of The Lane Merge Traffic Control System At Construction Work Zones, Wayne State University Department of Civil and Environmental Engineering, Research Report RC-1409, December 2001.
6. Fontaine, M., Guidelines for the Deployment of Portable Work Zone Intelligent Transportation Systems, Transportation Research Board 82nd Annual Meeting Compendium of Papers, Washington, D.C., January 2003.
7. Horowitz, A., Weisser, Ian, Notbohm, T., Diversion From a Rural Work Zone Owing to a Traffic Responsive Variable Message Signing System, Transportation Research Board 82nd Annual Meeting Compendium of Papers, Washington, D.C., January 2003.
8. Tudor, L., Meadors, A., Plant, R., Deployment of Smart Work Zone Technology in Arkansas, Transportation Research Board 82nd Annual Meeting Compendium of Papers, Washington, D.C., January 2003.

FIGURES

Figure 1: Dynamic Lane Merger Deployed On I-69 Near Lansing, Michigan

Figure 2: Variable Speed Limit system in operation

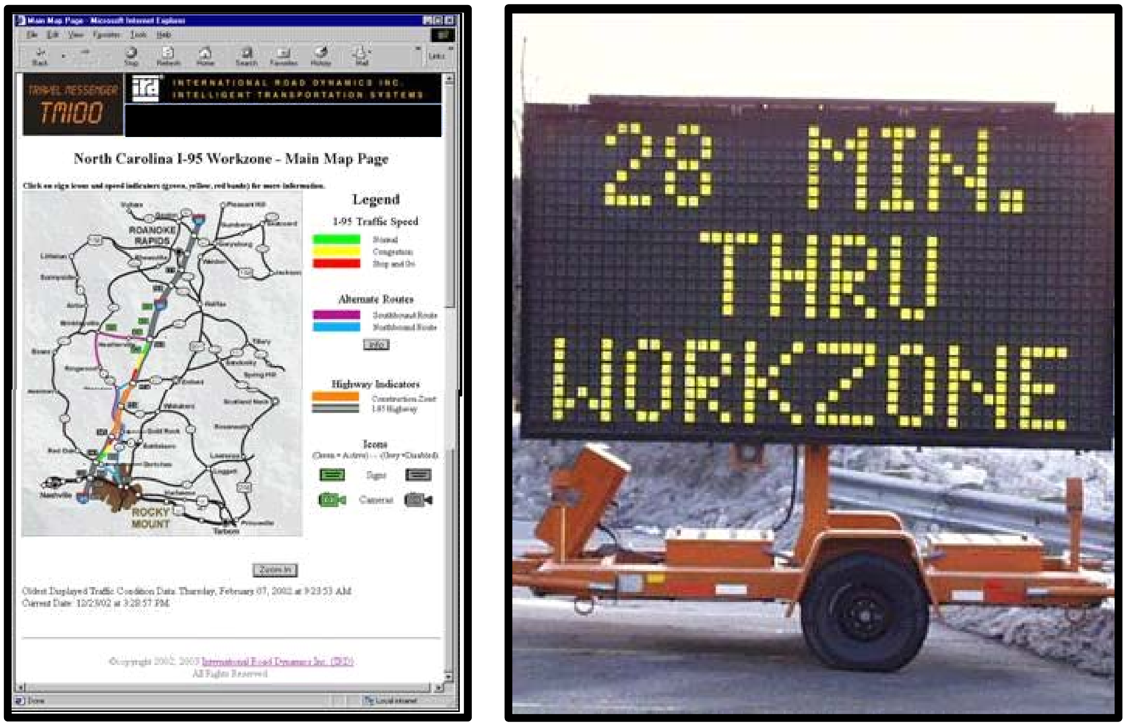

Figure 3: Travel information system in provides information via web-site and road-side signing