Intelligent Transportation Systems in Work Zones

A Case Study

Dynamic Lane Merge System

Reducing Aggressive Driving and Optimizing Throughput at Work Zone Merges in Michigan

October 2004

Notice

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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.

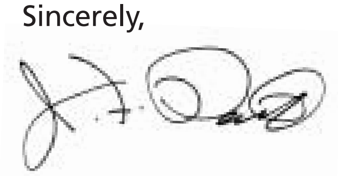
- **Case Studies** provide in-depth coverage of specific approaches taken in real-life communities across the United States.

- **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 future.

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,



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Preface

This case study is one in a series of documents that examines the use of Intelligent Transportation Systems (ITS) in work zones. More information on applications of ITS in work zones is available in the companion document, *Intelligent Transportation Systems in Work Zones – A Cross-Cutting Study* (Report No. FHWA-OP-02-025, EDL# 13600).

This case study presents information gathered during interviews with key personnel involved with an Interstate 94 (I-94) reconstruction project in Detroit, Michigan, as well as information and photos obtained during a site visit. Interviewees were involved in the deployment of the dynamic lane merge ITS application on I-94, and were also involved with other recent deployments of the system. The authors greatly appreciate the cooperation of the Michigan Department of Transportation, along with their partners, which made the production of this document possible.

Contents

Project and System Background

The Michigan Department of Transportation (MDOT) rebuilt a large section of I-94 in Clinton Township (a suburb of Detroit) during the 2002 and 2003 summer construction seasons. The improvements were necessary to upgrade roadway geometry and roadside hardware, to enhance safety and efficiency, and to rehabilitate deteriorating pavement. This section of I-94 provides access to and within the eastern portion of the state. The road parallels the Detroit River, a natural boundary between the United States and Canada. The work zone on I-94 extended from Michigan Route 102 (M-102) to Masonic Boulevard, a distance of about 13 miles, and involved both directions of traffic.

The two-season construction project began on April 1, 2002, and ended on September 30, 2003. The project involved 13.5 lane-miles of construction, including bituminous resurfacing, concrete pavement repair, bituminous freeway and concrete ramp reconstruction, lighting installation, traffic signal installation (at the end of ramps), water main alteration, and rehabilitation of 18 bridge structures. The total project cost was $46 million.

For the I-94 project, MDOT deployed a work zone Intelligent Transportation System (ITS) to help smooth traffic flow and reduce aggressive driving just prior to the transition into the construction area. MDOT selected a dynamic lane merge (DLM) system that uses electronics and communications equipment to monitor traffic flow and, as queuing increases at approaches to lane closures, to regulate merge movements and require early merging. The system, developed by International Road Dynamics Inc., used microwave radar sensors installed on five DLM trailers to detect traffic volume, vehicle speed, and detector occupancy.[1] The system then used the data to calculate an Activity Index (a function of volume, speed, and occupancy). When the detected conditions surpassed the pre-set thresholds established by MDOT, the system would automatically activate flashing "Do Not Pass" signs. A schematic of the I-94 DLM layout, including the five DLM trailers with sensors and flashing signs, is shown in Figure 1. When traffic conditions no longer warranted activation, the system remained active for five minutes and then automatically switched to inactive mode. MDOT spaced the trailers 1,500 feet apart. The closer the trailer was to the merge point, the lower the Activity Index was for activation. The trailer closest to the merge point was always on. A close-up of an activated (flashing) "Do Not Pass" sign at the I-94 site is shown in Figure 2.

This ITS application was deployed on westbound I-94 in September and October 2002, and August and September 2003. MDOT decided not to deploy the system on the eastbound direction because the higher traffic volumes in that direction would have made the system operate in active mode almost all of the time. These conditions would have caused the system to display the same messages most of the time and decreased the value of using a dynamic ITS technology. MDOT planned to use the

"The use of ITS on the I-94 reconstruction project has improved driving conditions in our area."

– Robert J. Cannon
Supervisor
Clinton Township
Michigan

[1] Detector occupancy is a measure of traffic density.

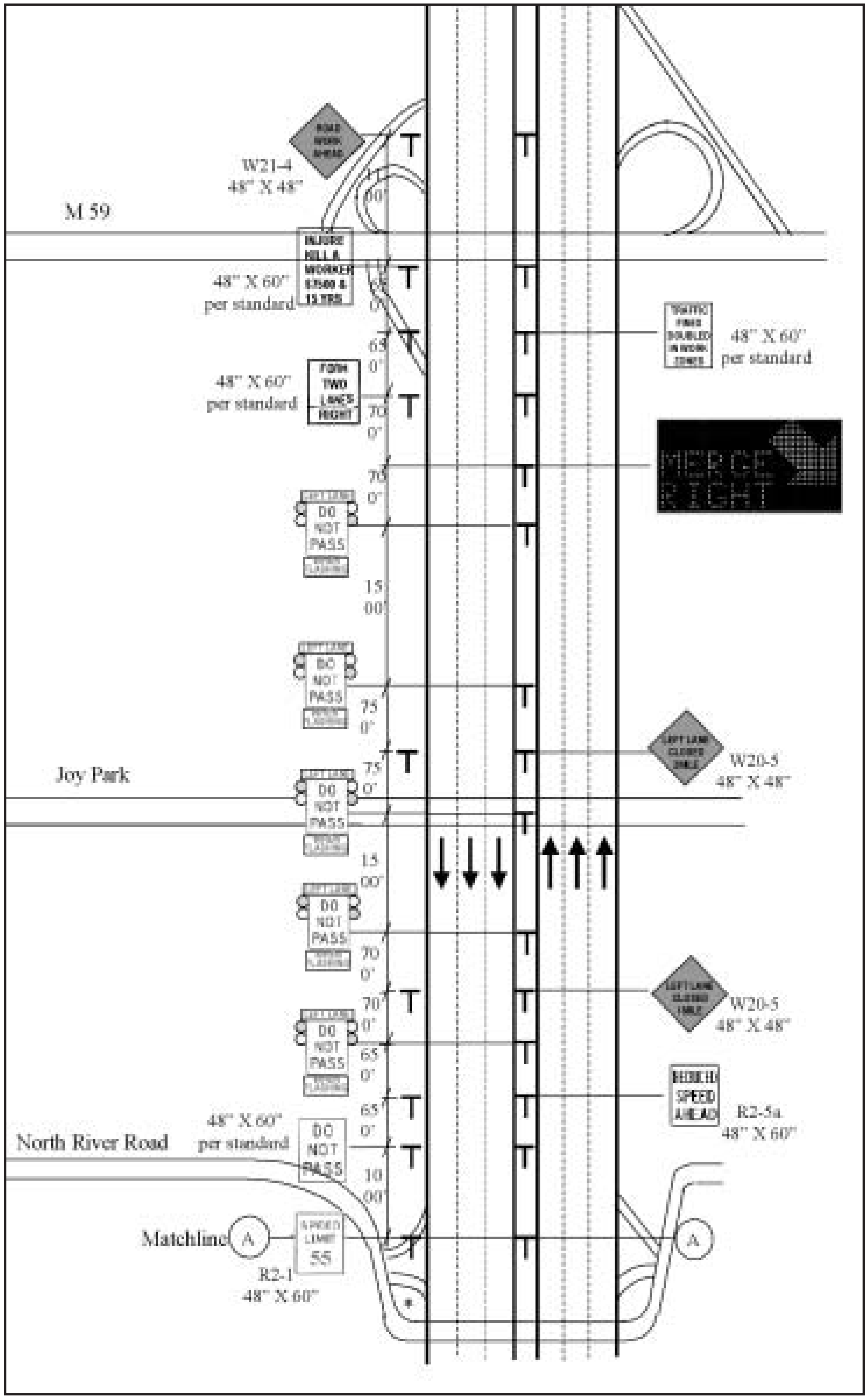

Figure 1 – DLM Layout on I-94[2]

[2] Michigan Department of Transportation (2004). *Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control System for 3 to 2 Lane Transition Areas in Work Zones.*

Figure 2 – Activated “Do Not Pass” Sign at the I-94 Dynamic Lane Merge Site

system during the entire 2003 construction season, but experienced some circuit-related electrical problems that caused deployment delays. MDOT had used DLM previously on several other sites that included two-to-one lane drops, while the I-94 site was the first DLM deployment in Michigan that involved a three-to-two lane drop.

There were a number of reasons why MDOT used ITS for this major construction project, including the following:

- MDOT anticipated aggressive driving at the merge point. As queues build on the approach to work zone lane closures, drivers try to avoid these queues by using storage space upstream of the closed lane prior to the merge point. This situation is known as a “late lane merge” phenomenon, and can create safety and mobility concerns when drivers attempt to forcefully merge into the through lane at the last minute.
- MDOT expected speed variability to increase as queues formed in the through lanes, and that this could decrease traffic safety and create a higher risk for crashes.
- MDOT identified a need to provide for smoother flow through the merge point at the work zone approach. MDOT believed that the traffic volumes on westbound I-94 were in a suitable range for traffic flow to benefit from the DLM system.

The main goals of the ITS system were to:

- Reduce aggressive driving at the merge point
- Maximize available capacity at the merge point just prior to dropping one lane out of three
- Reduce capacity losses due to increased headways at the work zone taper
- Enhance traveler safety.

System Design, Selection, and Implementation

This section provides information on MDOT's experience in bringing the system from the concept stage to fully operational.

In-House or Contractor Design

- MDOT added specifications for the DLM system components as pay items in the prime construction contract after award, as a modification to the contract.
- The prime construction contractor hired two subcontractors to design, install, and integrate the system components based on the specifications that MDOT provided in the contract modification.

System Selection and Procurement

- The construction contract called for the leasing, installation and calibration, and as-needed maintenance of all components of the ITS system.
- MDOT included specifications in the contract for trailers, signs, and microwave sensors.

Lease Versus Purchase

- The subcontractor leased all of the system components, as MDOT specified in the prime construction contract. The period of performance for the subcontractor was approximately six months during each of two years, and included installation, testing, and operation time.
- MDOT's total cost for deployment of the DLM system was $120,000.
- MDOT wrote the specifications for temporary use of the system so that they could deploy DLM without having to perform equipment maintenance or store the system after construction was completed. MDOT continues to use the lease option to benefit from the latest in rapidly changing technology.

System Implementation

- The subcontractor developed a safety plan for placement of the DLM system on I-94. The safety plan specified several procedures that were used, including implementation during off-peak hours to minimize exposure to traffic.
- Electrical problems with sensor power sources delayed deployment early in the 2003 construction season. Sensor circuit boards were ultimately replaced to resolve the problem.

- The project special provision for the DLM system called for wireless communications between sensors. The specification required the ability to communicate between sensors over a minimum distance of five miles on an unlicensed transmission band.
- Following a one-day installation and testing period, the subcontractor requested approval to turn the system on to traffic.

Testing

- Traffic sensor equipment required testing and calibration to ensure adequate wireless communication between trailers in a closed loop setting. Each trailer required access to the operational status of the other trailers in the loop, since they operated as one system.
- The subcontractor performed preliminary testing that focused on sensor operations and communication among sensors.

Training

- The subcontractors were responsible for all technical aspects of the system, including equipment installation, maintenance, and operation. MDOT did not specify any requirements for formal training of MDOT employees on these aspects of the system as part of the contract.

"We are pleased that this enforceable system is being implemented to help reduce aggressive driving and improve mobility at work zone merge areas."

– Robert J. Cannon
Supervisor
Clinton Township
Michigan

System Description and Operations

System Description

- The system consisted of five trailers, spaced 1500 feet apart, upstream of the work zone.
- Each trailer included a flashing “Do Not Pass” sign, communications equipment, and a power source. All the trailers except the one furthest from the work zone also contained a Remote Traffic Microwave Sensor (RTMS).
- Components relied on solar, rechargeable systems for power.
- The system used wireless radio communication equipment to allow for communication and data sharing between trailers.
- For the DLM deployment, the only communications requirement was to allow the sensors to communicate with each other. In addition, the contractor was able to dial up the system from a remote area to check the status of the system.
- In addition to the DLM system components, MDOT installed two signs on highway entrance ramps near the work zone to alert drivers of the no passing zone ahead. MDOT also deployed two “Form Two Lanes Right” signs approaching the merge area, one message board, and six static “Do Not Pass” signs as part of the system. The message board included a script message and visual arrow as shown in Figure 3.

Figure 3 – Westbound I-94 Message Board

System Operations

- The sensors on the DLM system trailers detected occupancy, which is a measure of traffic density. As congestion increases, density increases and thus occupancy increases. The DLM system calculated an Activity Index based on volume, speed, and occupancy. When preset Activity Index levels were met, the system sent a signal to the next upstream dynamic sign to be activated. The greater the sign/trailer number, the further upstream it was from the lane closure. The further upstream a sign was from the merge point, the higher the activity index to trigger activation. This concept is a result of the changes in traffic conditions, including driver behavior, forced merges, and associated impacts to traffic flow and queuing potential. The sign on the trailer closest to the merge point (sign 1) was always activated.
- Activity Index thresholds are shown in Table 1. When the average Activity Index exceeded the high threshold based on data at a sensor, the system activated the next upstream sign and that sign stayed on until the Activity Index at the next downstream sensor fell below the low threshold. For example, when sensor 1 reached an Activity Index of 15 percent or higher, the sign on trailer 2 activated until the Activity Index for sensor 1 fell below 10 percent. Once activated, each sign remained activated for a minimum of five minutes.

Sensor at Sign Number	Activity Index Threshold (%)		Update Period (minutes)
	Low	High	
1 (Base Trailer) Closest to the Merge	10%	15%	1 minute
2	15%	20%	1 minute
3	20%	25%	1 minute
4	25%	30%	1 minute
5	N/A*		

Table 1 – Sensor Settings

- Michigan State Police (MSP) personnel were able to enforce the no-passing zone as needed through a light on the back of each sign panel as shown in Figure 4. When alerted by the light, officers were aware that the sign was active and no passing was allowed.

* This sign does not transmit signals because there are no signs upstream of it.

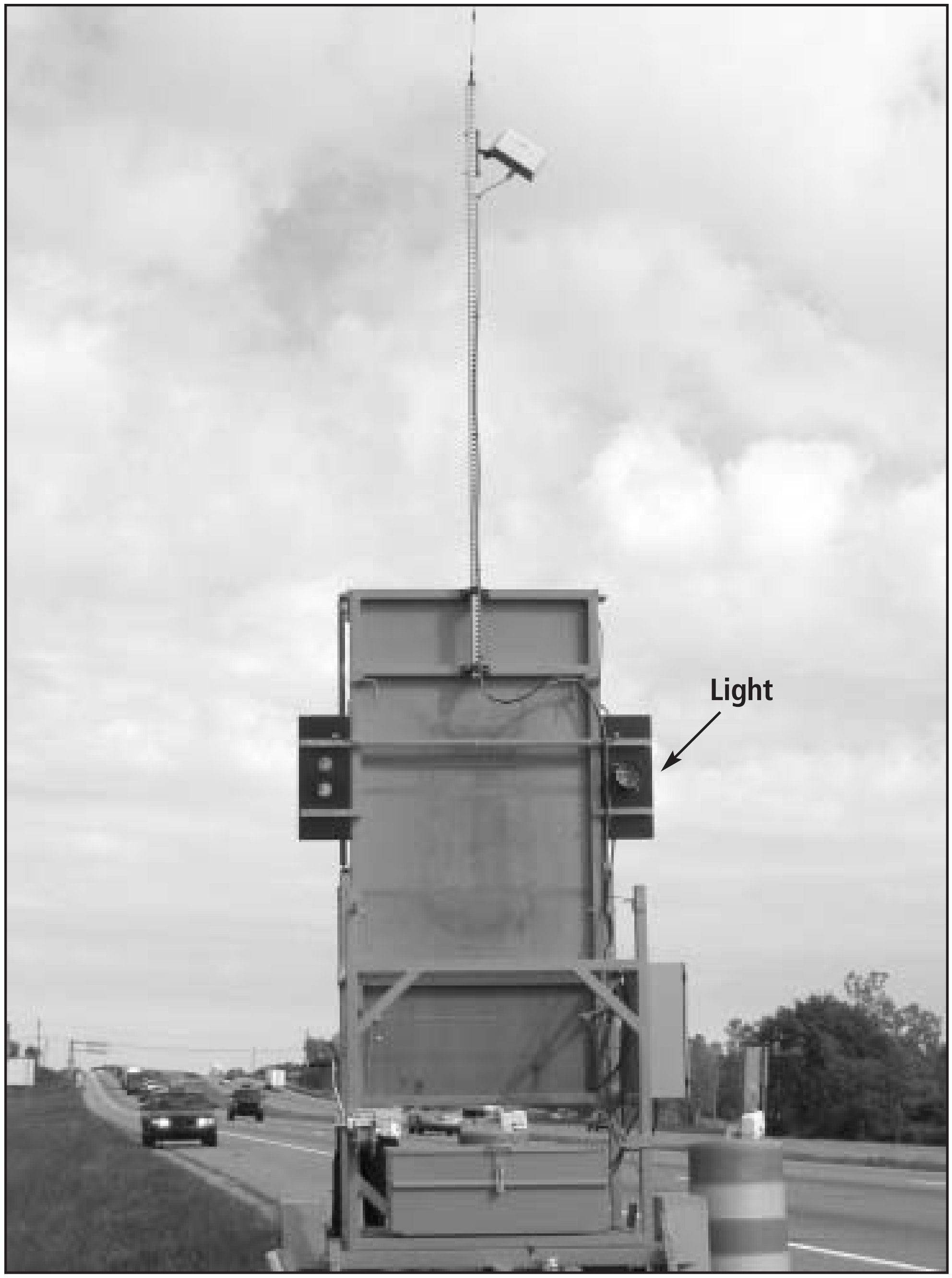

Figure 4 – Back Side of Dynamic Lane Merge Trailer

- The MSP assigned an officer to the I-94 work zone throughout construction. The MSP cited active police presence as the main deterrent to potential violators. At the I-94 work zone, officers focused their time on monitoring traffic and responding to traffic incidents and crashes in the work zone. No citations were written on this project, but on other projects using the DLM system many citations were written. Resource limitations required the officers to focus on other areas of this construction project. Active police presence and enforcement support successful operation of the system.

- The Concept of Operations diagram for the MDOT system is presented in Figure 5.

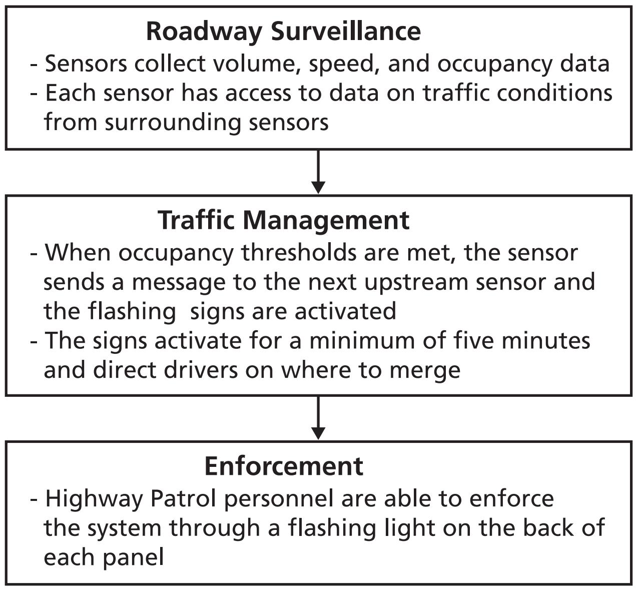

Figure 5 – Dynamic Lane Merge System Concept of Operations

Contractor or Agency Staff

- The subcontractors were responsible for operating and maintaining the system.

Coordination with Key Personnel, Other Agencies, and the Public

- During early predeployment meetings, MDOT, MSP, and local police personnel discussed enforcement issues. These agencies determined that installation of a flashing light on the back of each panel would alert Highway Patrol personnel when the system was activated and adequately allow for enforcement of the system.
- MDOT developed a press release, radio advertisements, and television advertisements for the project to inform the public about the deployment of the DLM system and educate them on how to respond to the signs.
- The public was fairly familiar with the system due to its past use by MDOT on one other project in the Detroit area.

Maintenance

- Because the equipment was leased through the construction contract, MDOT deployed the DLM system without having to maintain equipment or store it after use.
- System maintenance was fairly routine and included verifying that the sensors were operating.

Results

System Performance

- The system accomplished the intended objectives, and MDOT was pleased with its performance. MDOT had several other previous experiences with deploying the DLM system.
- Lessons learned during previous deployments helped MDOT to develop optimal sensor settings, determine the need to increase spacing between dynamic signs, and identify locations where use of the system is warranted by traffic conditions.
- The system was fully operational except for a few days near the end of construction, when a trailer malfunctioned and was permanently in flash mode. There were no impacts to traffic based on this malfunction. Maintenance was completed in about one day and the system was brought back on line.

System Evaluation

MDOT has performed evaluations of selected deployments of the DLM system in Michigan. The three-to-two merge scenario on I-94 was evaluated, as were several previous DLM deployments in two-to-one scenarios:

- Based on observations from the I-94 deployment, MDOT estimated that the DLM system is effective in situations where peak hour traffic volumes are approximately 3,000 to 3,500 vehicles per hour during construction for a three-to-two lane merge. The system is efficient in situations where the peak hour volume ranges from 3,000 to 3,800 vehicles per hour prior to construction. Some drivers will choose to avoid the work zone altogether, reducing the hourly volumes during construction.
- In previous deployments of the two-to-one lane merge, MDOT identified an effective peak hour volume range of 2,000 to 3,000 vehicles per hour.
- If the deployment site experiences higher or lower volumes than mentioned above, the DLM system may not be effective. If volumes are regularly lower than these ranges, a system may not be needed. If volumes are typically higher than these ranges, the system may be ineffective at managing queue lengths, or may be active almost continuously (in which case the same effect could be accomplished using static signs).

Benefits/Impacts

Results from MDOT's evaluation of the 2003 I-94 three-to-two merge project are provided below. The full results of the evaluation are presented in MDOT's report.[3]

Mobility

- The average number of stops (per probe vehicle run) in the construction zone decreased from 1.75 to 0.96 during the morning peak period with the implementation of the DLM system.
- The stopped time delay during both peak periods and the average number of stops during the afternoon peak period (per probe vehicle run) in the construction zone remained relatively unchanged.
- The average morning peak period travel time delay decreased from 95 seconds per vehicle to approximately 69 seconds per vehicle for every 10,000 feet of travel.
- The average number of aggressive driving maneuvers per travel time run decreased from 2.88 to 0.55 during the afternoon peak period and was relatively unchanged during the morning peak period.
- The average travel speed increased from approximately 40 mph to 46 mph during the morning peak period and was relatively unchanged during the afternoon peak period.

Safety

- The DLM system led to a reduction in aggressive driving and aggressive driving maneuvers during the afternoon peak period, therefore improving safety at the merge point.
- Crash data were analyzed for 4.3 months during construction but without the DLM system and 2 months during construction with DLM. Prior to system activation, there was an average of 1.2 crashes per month. For the two-month period after the system was implemented, no crashes were reported. The data included crashes that occurred within the lane merge transition area.
- MDOT observed that traffic flow was disrupted less by queuing, leading to less variance of speeds between the two lanes of traffic, which likely reduced crash risk.

Cost Savings

- For the I-94 deployment, the system evaluator, Wayne State University, determined that the benefits of the system (travel time savings and vehicular fuel savings) outweighed the costs if the value of time for delayed motorists is greater than $3.33 per hour. Wayne State University determined this value by multiplying a monetary value (an iterative process) by the travel time savings, adding in the fuel savings, and then comparing this value to the actual cost of the system. This finding showed that even if a delayed motorist's time was only valued at a rate of $3.33 per hour, which is a low value for

[3] Michigan Department of Transportation (2004). *Development and Evaluation of an Advanced Dynamic Lane Merge Traffic Control System for 3 to 2 Lane Transition Areas in Work Zones.*

user delay time, the system was cost-effective. As the value of a motorist's time is increased from $3.33 per hour, the benefits of the system would increase due to greater travel time savings and would further outweigh the system costs. User delay time is usually valued at a much greater amount than $3.33 per hour. For a relative example of delay analysis, note that the U.S. Department of Transportation uses an average dollar figure of $11.20 per hour for each person in a car and $18.10 per hour for a truck driver when calculating user cost of delay.[4]

Public Reception/ Reaction to the System

- Through informal channels, MDOT recognized a positive perception of the system by the public. Because the system had been deployed previously, the public had become familiar enough with the system to lessen the need for citations to achieve compliance with the no-passing zone.

Obstacles Encountered and Lessons Learned

General

- The DLM system can be helpful in increasing safety and reducing delay near work zones where lane closures are necessary.
- Sites should be wide enough to allow trailers to be moved in and out, and allow for safe placement off the roadway. Site width is also important for enforcement activities.

Relating with Other Agencies

- MDOT held several meetings with key stakeholders, including the law enforcement community, to keep them involved in system planning and design. Identifying stakeholders early in the planning stage is one of the key steps to a successful implementation.

System Features/ Capabilities

- It is better to use the DLM system on construction projects where the work zone geometry and location do not change frequently because such changes often require recalibrating the detectors. Long-term, large projects may have phases that are static, where the system can remain in place for a longer time.
- It is important to give the driving community time to adapt to the system so that they will know how to comply with the regulatory signs in the DLM-controlled area.

Communications

- The system requires line of sight between sensors for adequate communication. MDOT raised antennas on the trailers due to line of sight issues.

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[4] U.S. DOT (2003). *Valuation of Travel Time in Economic Analysis.* http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf

System Deployment

- It is important to use a proactive approach to building public awareness of an ITS deployment. Successful techniques include meeting with stakeholders, holding press conferences, issuing news releases, and keeping local media up to date. MDOT used all of the above-mentioned techniques, and also met frequently with law enforcement early on to avoid miscommunication on overall system objectives.
- It is necessary to allow for access to sensor stations for maintenance.

System Operations

- When changes in work zone roadway geometry are made, it is important to allow time for drivers to learn the new setup.
- Stations may need to be reset manually when there are power interruptions.

Maintenance

- The implementing agency can meet maintenance needs solely through use of the vendor, or the agency can maintain the system with initial help from the vendor. Sensor power issues caused some small delays early on for MDOT. The system will require an adequate system maintenance plan to avoid large amounts of system downtime.

"The public expects us to do everything we can to alleviate the effects of work zones, and innovative solutions like this one are important to achieving that goal."

– Robert J. Cannon
Supervisor
Clinton Township
Michigan

Conclusion

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MDOT has successfully deployed the dynamic lane merge system on several projects, including I-94 in a suburb of Detroit, to help smooth traffic flow and reduce aggressive driving just prior to the construction area. MDOT observed a decrease in aggressive maneuvers and average peak period travel time. These factors influenced both mobility and safety in a positive manner, and ultimately satisfied the goals of the deployment.

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