Iowa Department of Transportation Intelligent Work Zone Deployments

SMARTER WORK ZONES TECHNOLOGY APPLICATIONS CASE STUDY

The Every Day Counts Initiative (EDC-3) aims to accelerate the deployment of identified, but underutilized innovative practices that focus on reduced project delivery schedules, increased roadway safety, reduced congestion, and/or enhanced environmental sustainability. Smarter Work Zones (SWZ) is one of three EDC-3 initiatives focused on safety and mobility, and was developed to promote safe and operationally efficient work zones through project coordination and technology application strategies.

This case study focuses on technology applications called Intelligent Work Zone (IWZ) systems that are deployed by the Iowa Department of Transportation (DOT). The IWZ deployments focus on expanding current traffic management and incident response technologies, and providing queue detection systems on freeways and divided highways.

Background

To address traffic safety and mobility challenges in work zones, the Iowa DOT initiated the Traffic Critical Projects (TCP) program in 2014. The purpose of the program was to identify key construction work zones that required enhanced Transportation Management Plan (TMP) components in order to achieve well-defined, measurable goals for improved mobility and safety. One approach to minimize work zone mobility and safety impacts in TCPs was to deploy IWZ systems. Iowa DOT followed a systems engineering process, such as that outlined in the Federal Highway Administration's (FHWA's) *Work Zone ITS Implementation Guide* (FHWA-HOP-14-008), to successfully deploy IWZ systems to mitigate impacts during the 2014 construction season, as presented in this case study.[1]

Figure 1: The Work Zone ITS Implementation Guide six-step process. *Source: Battelle*

The primary goal of the TCP program is to develop and implement a comprehensive strategy for improved traffic safety and mobility through construction and maintenance work zones across the state of Iowa.

Assessment of Needs

The TCP program brings together several stakeholder groups, including personnel from various Iowa DOT offices, support consultants, and equipment vendors. The stakeholders work cohesively to develop, improve, and accomplish the goals and objectives of the program. Iowa DOT defines a TCP as any project that may cause significant safety or mobility issues during a construction or reconstruction event. Specifically, a work zone that meets any of the following criteria set by the Iowa DOT qualifies as a TCP:

- The Average Annual Daily Traffic (AADT) volume is over 17,000 vehicles per day (vpd) on freeways or divided highways;
- The AADT volume is over 4,000 vpd on two-lane, two-way primary highways;
- The project impacts traffic on a border bridge over the Mississippi or Missouri Rivers; or
- Other projects identified by district personnel where congestion and travel delays are expected.

1 This case study is largely derived from: "Traffic Critical Projects Program 2014 Evaluation Final Report." Iowa Department of Transportation; January 14, 2015.

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Based on the specific safety and mobility concerns of a given TCP, a variety of mitigation strategies were available for implementation. These included: work day restrictions (day of week / seasonal), night work / limited work hours, innovative contract provisions such as lane rental, traffic incident management plans, and an IWZ system.

In 2014, 18 work zones were initially identified as TCPs, with 11 of those initially planned to receive IWZ treatments. Over the course of the construction season, two of the locations were dropped and five new IWZ deployments were added, resulting in 14 IWZ locations, as shown in Figure 2.

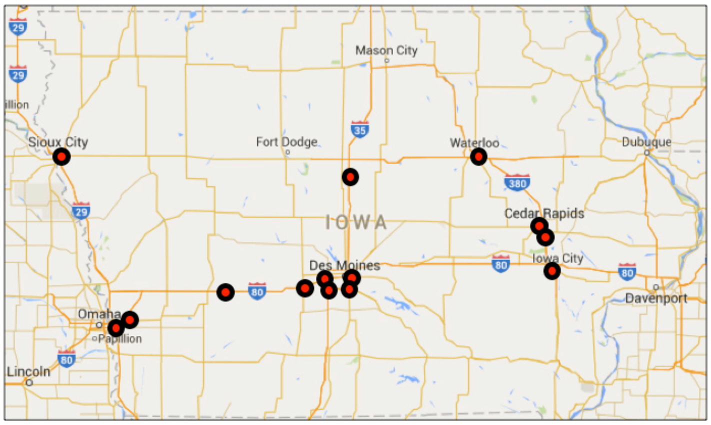

Figure 2: Map of 2014 IWZ Deployments in Iowa. *Source: Iowa DOT*

Concept Development and System Design

A general IWZ system was developed based on discussions with each Iowa DOT district. The general concept developed for the IWZ system included traffic surveillance, incident warning and notification, and end-of-queue warnings to drivers, but was flexible based on the specific needs at each work zone. To facilitate these capabilities, the IWZ system consisted of the following components:

- Side-fire radar traffic speed and volume sensors
- Closed circuit television (CCTV) cameras
- Portable changeable message signs (PCMS)

When the identified needs for a TCP warranted an IWZ technology application, Iowa DOT undertook a system design process for implementing the necessary components based on the specific work zone area and existing technology infrastructure. This involved reviewing staging plans and developing preliminary IWZ concepts using geographic information systems (GIS) or other mapping tools with input from traffic operations and district staff. The IWZ system was designed for each site to expand on the site's existing traffic management capabilities and incident response technologies. In addition, all of the IWZ deployments in 2014 were designed to be integrated into the statewide Traffic Operations Center (TOC) via existing traffic management software to better utilize existing resources and combine efforts.

Every IWZ integrated temporary sensors and equipment with the Iowa DOT statewide advanced traffic management system (ATMS) software. Despite some associated challenges, Iowa DOT found this to be very beneficial. The seamless integration of cameras, sensors, and CMS, regardless of whether they are permanent, rented, or contractor-provided, allowed all equipment and data to be accessible to the Traffic Operations Center staff and the traveling public via the 511 website and mobile application.

Although most IWZ devices supported an end-of-queue warning system, some devices were deployed solely for traveler information purposes or for expanded visibility of the project at the TOC. The end-of-queue warning systems operated using both permanent and temporary traffic sensors, and permanent changeable message signs (CMS) or PCMS, as illustrated in Figure 3.

A user-defined alert processing system (APS) logic was developed for each queue detection system based on speed or volume thresholds for that particular TCP to post "SLOW TRAFFIC AHEAD" or "STOPPED TRAFFIC AHEAD" messages[2] to specific PCMS and send e-mail alerts to TOC staff.

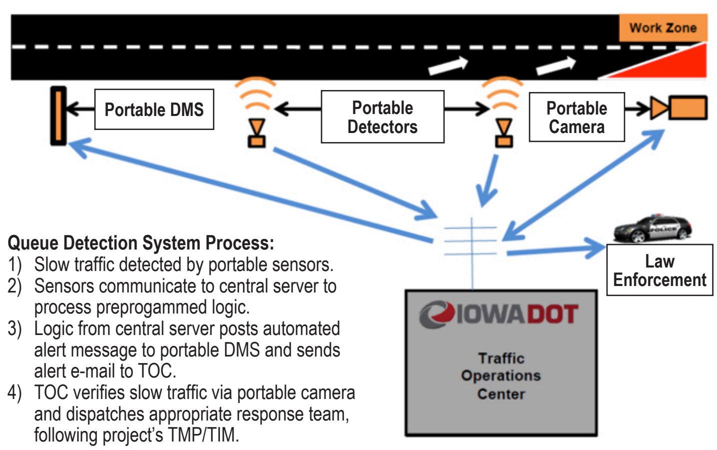

Figure 3: General queue detection system layout. *Source: Iowa DOT*

2 In addition to APS logic, a secondary logic in the existing traffic management software was used for one TCP in 2014 to automatically display "SPEED AHEAD XX MPH" messages on specific PCMS when sensors detected speeds below set thresholds (note that this logic was later determined to be less effective as APS messages).

Procurement

To best facilitate IWZ deployments on selected TCPs, Iowa DOT determined that a standalone, qualification-based procurement contract for an IWZ device vendor would provide the greatest benefit at lowest cost to meet TCP program goals. Iowa DOT utilized a support consultant to help develop a request for proposals for three regional contracts to select vendors to provide IWZ equipment throughout the state. Three separate contracts allowed for smaller geographic area and reduced equipment needs than a single statewide contract. Contract language for the IWZ vendor responsibilities included:

- Coordinating IWZ integration with existing advanced traffic management system (ATMS) software;
- Monitoring the health of IWZ systems to provide uninterrupted service;
- Maintaining and updating IWZ equipment;
- Coordinating with project and construction personnel;
- Deploying, troubleshooting, and relocating equipment, as requested.

A standalone IWZ vendor contract separate from construction contracts was employed to ensure the vendor had the required technical expertise, to allow quicker and easier response to system operations, and for flexibility to add or remove IWZs to projects not initially identified on the original TCP list.

The IWZ vendor contracts utilized per-device pricing schedules. Each contract assigned an initial placement cost and daily operational and maintenance cost to each device deployed. A relocation fee was also established for requests to move equipment within a project. The 2014 IWZ vendor contract also specified that devices must be functional and providing accurate data 92 percent of the time during each day to receive payment for a given device on that day.

Through the selection process, a single vendor was awarded all three contracts for 2014, with up to five optional one-year extensions. The 2014 IWZ vendor per-device costs are in Table 1. The 2014 IWZ deployments for all 14 TCPs included 60 traffic sensors, 44 PCMS, and six cameras, with the rental cost for all deployed IWZ systems totaling approximately $775,000.

System Deployment

For system deployment, planned IWZ device locations were first verified and marked in the field for optimal visibility and to maintain state and federal sign spacing recommendations. The IWZ vendor would then bring the equipment on site, placing devices at the marked locations in the corridor, and provide device details for software integration. Software integration involved entering the IWZ equipment into the existing traffic management software and incorporating alert processing logic required for end-of-queue warning systems. This also included adding the IWZ PCMS and cameras to the public 511 website and mobile application.

System Operation and Maintenance

When messages were posted on PCMS about stopped traffic conditions, TOC staff received e-mail alerts. TOC staff then verified slow traffic using cameras, speed probe data (INRIX and Google Traffic) and TOC software to identify queues, as shown in Figure 5. When an incident was identified, the TOC dispatched a response team, as needed per the project TMP and traffic incident management plan. TOC staff also had the ability to

Table 1: Schedule of 2014 Costs per Device. *Source: Iowa DOT*

Device	Cost Item	Contract #1 (Western Iowa)	Contract #2 (Eastern Iowa)	Contract #3 (Council Bluffs)
PCMS	Daily Cost (per day)	$20	$22	$23
	Deployment	$2,600	$2,900	$3,200
	Relocation	$480	$480	$480
Traffic Sensor	Daily Cost (per day)	$18	$23	$25
	Deployment	$2,200	$2,600	$2,800
	Relocation	$480	$480	$480
CCTV	Daily Cost (per day)	$20	$22	$23
	Deployment	$2,600	$2,900	$3,200
	Relocation	$480	$480	$480
Cell Modem in Traffic Sensor	Daily Cost (per day)	$4	$4	$4
	Deployment	$300	$300	$300
	Late Deployment	$500	$500	$500

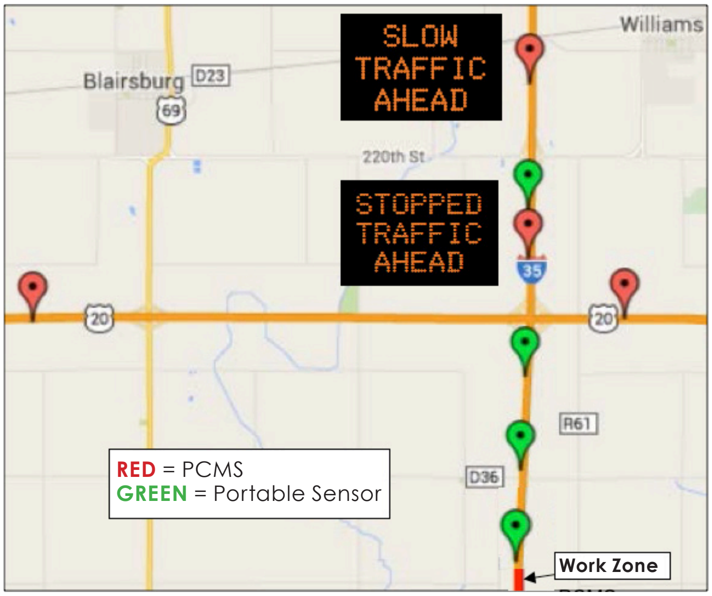

Figure 4: Queue warning system deployed for a work zone on I-35 southbound. *Source: Iowa DOT*

override the automated queue detection CMS messages if the messages did not match the traffic conditions or if a more informative message could be provided.

In each IWZ deployment, systems were monitored to ensure all deployed equipment was functioning and communicating properly with the traffic management software and that queue detection systems were operating appropriately. Coordination with the IWZ vendor was not a term in the general construction contracts which created a potential challenge. However, good working relationships with the general construction contractors were leveraged to facilitate communications regarding project activities and schedule.

The IWZ vendor, traffic management software integrator/ vendor, and Iowa DOT support consultant all independently verified the condition of each IWZ system for issue resolution and device troubleshooting to ensure all systems and equipment were in proper working conditions at all times.

The statewide TOC provided high-level 24/7 monitoring and operational support for all IWZ deployments. TOC staff actively monitored the IWZ devices and alerted the Project Management Team after identifying any IWZ device that was not functioning properly. Additionally, the IWZ devices were added to the Iowa DOT's intelligent transportation system (ITS) communications monitoring software so alerts were generated when devices did not communicate with the TOC within a set timeframe.

However, TOC involvement was not consistent for each project throughout the construction season because a clear Standard Operating Procedure (SOP) for TOC personnel involvement with IWZ deployments was not established. An SOP was developed for the 2015 TCP program to maximize the benefit of IWZ deployments.

In addition to real-time monitoring of device communications, the support consultant passively monitored sensor data consistency. Reports were created and run daily for the previous day's operations on all IWZ sensors. Using an Iowa DOT program, data sets were analyzed for missing time intervals and operational percentages were created based on these results. Periods when systems were offline were tracked to verify that devices were functional and providing data 92 percent of the day, per the vendor contract. This was done by examining when sensors were not reporting data. This data verification was important because although the DOT and the IWZ vendor each had software to monitor device communications, neither had a tool for monitoring the actual data being reported.

The IWZ vendor was well-equipped for tracking and maintaining deployed equipment. In general, when equipment failures occurred, repairs were made quickly or a new device was placed within the same day as a TOC notification or e-mail alert. The timeliness of the IWZ

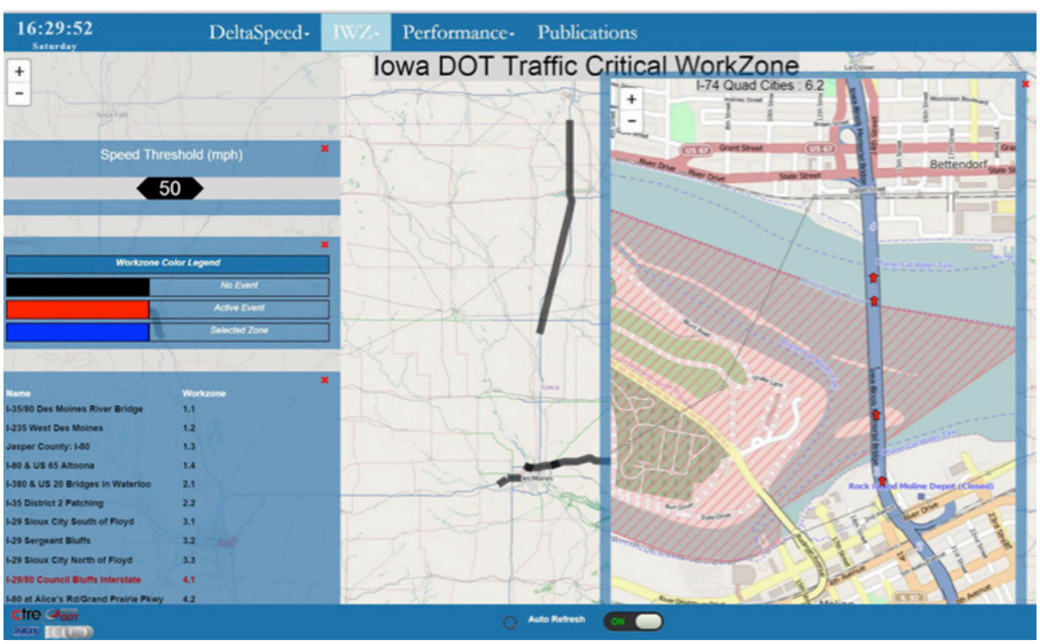

Figure 5: Real-Time IWZ Monitoring at the TOC to Locate Queues. *Source: Iowa DOT*

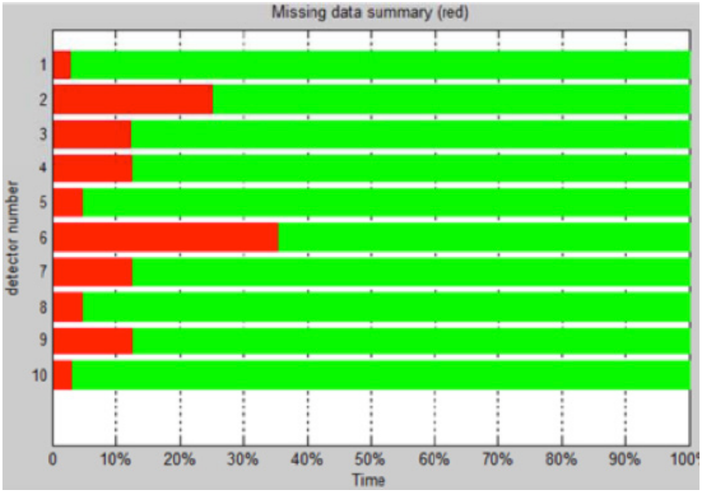

Figure 6: The percentage of missing data was calculated for all IWZ sensors. *Source: Iowa DOT*

vendor was noted to be above expectations given that the contract stated that no additional compensation would be made for device repairs or replacements.

The IWZ vendor was also timely in responding to new equipment requests, relocations, and repairs. The average time between a request and the mobilization of equipment was generally under two business days. The IWZ vendor attributed much of their quick turnaround and responsiveness to having a responsive local subcontractor and a large inventory of equipment.

During the 2014 construction season, Iowa DOT changed the traffic management software alert communications from being displayed on the device map to being sent as e-mail alerts when devices were not functioning properly. These alert e-mails were sent to the IWZ vendor, the Iowa DOT, and the support consultant, and greatly reduced device downtime and facilitated two-way correspondence between the IWZ vendor and the traffic management software vendor/integrator.

System Evaluation

A system evaluation and review was conducted by the Iowa DOT TCP project team and the Institute for Transportation Research (InTrans) at Iowa State University following the IWZ deployments. The ability of the IWZ systems to mitigate work zone mobility and safety impacts was assessed using performance data, and lessons learned were identified to develop efficiencies and new ideas for future deployments and future TCP program goals. The evaluation analyzed performance measures for each IWZ project and summarized for all 2014 deployments in five categories critical to work zones:

- Exposure
- Traffic Queuing
- Traveler Delay
- Travel Time Reliability
- Safety

Available data was limited for the 2014 construction season, which limited analysis efforts and resulted in inconclusive findings. The 2015 TCP program will adapt the 2014 performance measurement approach with significant modifications, and also ensure adequate data collection.

Table 2. Evaluation of Performance Measures for a project on I-35. *Source: Iowa DOT*

I-35 Direction:	North	South
Days active (with sensors, 1 mile spacing)	64	
Work Zone Length	6.1 miles	
Lane closure	1 lane closure	
Total Vehicles	761,577	709,013
Events	100	109
Number of Days with Events	46	42
Average duration (minutes)	28.6	33.4
Median duration (minutes)	5	10
Overall Average (miles)	1.5	1.1
Average Max Queue Length of each event (miles)	0.8	0.2
Median Max Queue Length of each event (miles)	0.4	0
Overall Max Queue Length of each event (miles)	5.5	3.2
Number of Times Queue exceeded farthest sensor	2	2
Percent queues >1 mile	77.9%	74.3%
Traffic encountering a queue	7.23%	10.54%
Time queue present	3.10%	3.95%
Total Delay (vehicle-hours)	58,473	55,917
Average Delay (minutes/vehicle)	0.4	0.4
Maximum Delay	15.3	14.7
% of vehicles experiencing delay >10 minutes	0.2%	0.2%

Iowa DOT was able to reduce costs for many IWZ deployments where existing technology infrastructure was available. Central operations of all equipment at the statewide TOC also provided a major advantage in leveraging existing resources, while the TOC operators' ability to actively monitor traffic vastly increased the IWZ accuracy and value to the traveling public. However, in some cases Iowa DOT found that existing permanent sensors were outdated and unable to provide the high-quality data needed for the APS logic, resulting in a significant delay for providing real-time alerts to drivers.

Generally, the IWZ system deployments were a key contributing element to the success of Iowa DOT's 2014 TCP program, which resulted in substantial improvements in traffic safety and mobility on construction projects across the state. These accomplishments were realized by engaging many stakeholders in implementing traffic safety and mobility mitigation strategies. The experience and lessons learned from the IWZ queue warning system deployments in 2014 will be leveraged to inform the creation of policies and plans regarding work zone technology applications and evaluations in the future to further advance the goals of increasing safety and reducing delay.

Conclusions

This case study illustrates one example of a statewide work zone technology application support contract that can be leveraged on an as-needed basis for projects identified as having critical impacts. As demonstrated by this example, agencies should follow a systems engineering process that considers existing capabilities and resources, identifies the appropriate strategy to design and implement, and then monitor and evaluate that deployment to gather lessons learned for future deployments.

Several specific lessons learned from Iowa DOT experiences on this technology application include:

- A standard operating procedure (SOP) to establish authority, responsibility, and formal processes for device deployment should be developed for performance, reporting, operating, and monitoring the equipment.
- Detailed performance specifications are an absolute necessity for work zone technology applications. Clearly specify required equipment, how the system should operate, and what data are required in deliverables. These specifications are driven by the system requirements, which are derived from the concept of operations.
- The integration of existing technology infrastructure into the temporary work zone system can avoid duplicating roadside equipment and reduce cost. However, existing devices should first be checked to ensure adequate data quality and reliability.
- A statewide work zone technology applications program should engage relevant stakeholders, including DOT offices and district staff, support consulting companies, and equipment vendors.
- Construction project contracts should include provisions to coordinate with other vendors deploying technology applications.
- The location of all deployed devices must be accurate, preferably GPS location information via cellular modems.
- The device vendor should provide communications to facilitate device integration and provide reliable communication for system operations.
- Simulated and actual field testing should be completed on each deployment using set test thresholds and pre-determined test messaging to ensure that the system operates as intended. Test results should be used to modify alert logic, as appropriate.
- Monitoring device health improves overall system performance. Periods when devices were offline were tracked to verify that devices were functional and providing accurate data 92 percent of the day, per the vendor contract for receiving payment.

Additional resources on SWZ technology application strategies can be found at: https://www.workzonesafety.org/swz/main

For additional information, please contact:

Jon Jackels
Iowa DOT TCP Program
Support Consultant
769-249-6722
jjackels@srfconsulting.com

Tim Simodynes
Iowa DOT ITS Engineer
515-239-1606
Tim.Simodynes@dot.iowa.gov

Todd Peterson
FHWA Office of Operations
202-366-1988
Todd.Peterson@dot.gov

Jawad Paracha
FHWA Office of Operations
202-366-4628
Jawad.Paracha@dot.gov

Every Day Counts (EDC), a State-based initiative of FHWA's Center for Accelerating Innovation, works with State, local and private sector partners to encourage the adoption of proven technologies and innovations aimed at shortening and enhancing project delivery.

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