Smarter Work Zones Webinar Series

Webinar #6: Technology Application Case Studies: Variable Speed Limit and Dynamic Lane Merge

Todd Peterson, Josh Van Jura, and Chris Brookes

November 12, 2015
12:30-2:00pm EST

Efficiency through technology and collaboration

innovation ingenuity imagination invention
Every Day Counts

U.S. Department of Transportation
Federal Highway Administration

Smarter Work Zones

Introduction and Today's Speakers

Today's Speakers

Todd Peterson, P.E., PTOE
Transportation Specialist
FHWA Office of Operations

Josh Van Jura
Project Controls Engineer
Utah Department of Transportation

Chris Brookes
Work Zone Delivery Engineer
Michigan Department of Transportation

Smarter Work Zones Webinar Series

- This is the sixth in a series of bi-weekly SWZ webinars
- Topics based on **what matters most to you!**
- Previous Webinars include:
  - Webinar #1: A Comprehensive Overview of the SWZ Initiative (9/9/2015)
  - Webinar #2: Implementing Technology Application Solutions (9/29/2015)
  - Webinar #3: SWZ Corridor-Based Project Coordination (10/15/15)
  - Webinar #4: SWZ Technology Showcase – Queue Warning Systems (10/26/15)
  - Webinar #5: SWZ Program-Based Project Coordination (11/2/15)
- Recordings and materials for previous webinars are available on The National Work Zone Safety Information Clearinghouse website: https://www.workzonesafety.org/swz/webinars
- Coming Up:

December	12/2	Webinar #7: Work Zone Project Coordination Guide and Examples
	12/15	Webinar #8: TA/PC Showcase: Corridor Traffic Management

Purpose of Today's Webinar

Provide an overview of Variable Speed Limit (VSL) and Dynamic Land Merge (DLM) and discuss real-world examples of VSL and DLM that have been used to reduce congestion or delay and ease traffic through a work zone.

Topics include:

1. SWZ Technology Application Initiative
   - Show how the SWZ Technology Application initiative can be used by agencies to enhance their current work zone management practices
2. Variable Speed Limit and Dynamic Lane Merge Examples
   - Provide real-world examples of the successful use of Variable Speed Limit and Dynamic Lane Merge, which can result in:
     - Improved Safety
     - Reduction in congestion or delay

Smarter Work Zones
SWZ Overview &
Technology Application Initiative

What are Smarter Work Zones (SWZ)?

Innovative strategies designed to optimize work zone safety and mobility

- Policies and practices used to incrementally and continuously improve WZ operations
- Tools to reduce WZ crashes and delays
- Tools to enhance WZ management strategies

Two Identified SWZ Initiatives:

Project Coordination

Coordination within a single project and/or among multiple projects within a corridor, network, or region, and possibly across agency jurisdictions

Technology Application

Deployment of Intelligent Transportation Systems (ITS) for dynamic management of work zone traffic impacts, such as queue and speed management

Today's Focus of Discussion

SWZ Technology Application Goals:

Goal 1A

By December 2016, 35 State DOTs have implemented business processes for work zone ITS technologies as identified in the Work Zone ITS Implementation Guide

- **What does this mean?**
  - Well-documented agency policies and processes to streamline consideration and use of work zone ITS technologies to minimize traffic impacts

SWZ Technology Application Goals:

Goal 1B

By December 2016, 35 State DOTs have utilized at least one work zone ITS technology application for dynamic management of work zone impacts

- **What does this mean?**
  - Consideration of the six step process explained in the WZ ITS implementation guide to plan and implement ITS strategies
  - Identify and use ITS strategies such as speed and/or queue management on at least one project for dynamic management of work zone impacts

Smarter Work Zones

Overview of Variable Speed Limit & Dynamic Lane Merge

Variable Speed Limit (VSL)

- Uses sensors, portable changeable message signs (PCMS), and a processing system
- Calculates speeds limits to be displayed on PCMS based on measured speed and/or volume data
- Provides drivers with a safe speed limit to drive through a work zone and minimize braking as they approach the queue

- VSL Considerations
  - Advisory versus Enforceable
    - Legislative Policy (allowing enforceable VSLs)
    - Law Enforcement involvement (active vs. visibility)
  - Pre-determined, fixed time VSL versus fully automated VSL
    - During active work zone (workers present)
    - Changing congestion conditions

Source: Minnesota DOT

Variable Speed Limit Benefits

- Reduction of potential crashes as drivers approach back of queue
- Reduction of congestion and ease traffic through work zone depending on current conditions
- Reduction in travel time through uniformity in traffic speeds

Source: Virginia DOT

Source: Virginia DOT

Dynamic Lane Merge

- Uses sensors and Portable Changeable Message Signs (PCMS) placed in advanced of a lane closure
- Provides lane use instructions to drivers
  - USE BOTH LANES, TAKE YOUR TURN – MERGE HERE
- Two strategies
  - Early Lane Merge
  - Late “Zipper” Lane Merge

Early Lane Merge

- Advises drivers to move out of closed lane well before the forced merge point
- Works best when there is a low traffic volume combined with high average speeds

- Benefits:
  - Reduction of aggressive driving and unsafe merge maneuvers
  - Provide significant advanced warning to allow drivers adequate distance to merge
  - Gives positive instructions on lane usage

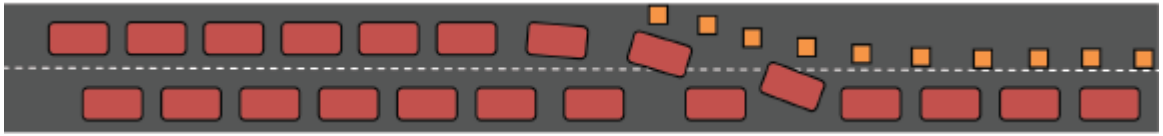
Source: https://www.workzonesafety.org/fhwa_wz_grant/atssa/atssa_dynamic_lane_merging

Source: Minnesota DOT

Late Lane Merge

- Advises drivers to use both lanes up to the merge point
- Works better for high traffic volumes, situations where queueing upstream of work zone is expected to occur.

- Benefits:
  - Maximize available storage upstream of work zone for reducing total queue length.
  - Reduces confusion between drivers who think they should merge early vs. drivers that use open lanes as far as possible.
  - Clarifies right-of-way at merge point ("alternate merge")



Source: https://www.workzonesafety.org/fhwa_wz_grant/atssa/atssa_dynamic_lane_merging

Source: Hallmark, Mudgal, Stout, & Wang, 2011

Smarter Work Zones

Utah DOT Statewide VSL Deployment

Example #1: Utah Variable Speed Limits in Work Zones – Where Are We and Where We Are Going

- Goal: Improve safety for the construction personnel and traveling public within construction work zones through significant reduction in traveler speed within the boundary of Active Work Zone.

Concerns

- Traffic Queueing
  - Preliminary traffic modeling predicted no queueing
  - 1800 vehicle/hour/lane and relatively flat = Low risk
- Speed Harmonization
  - Little concern until deviation greater than 15 mph from median speed
- Enforcement
  - System logs time that speed changed
  - Document location of device

Current Projects

- I-70 Slab Replacement
- Pine Creek Climbing Lane
- Beaver Ridge Climbing Lane
- Spotted Wolf
- R4 Maintenance Project

Source: Utah DOT

Success Stories

- Beaver Ridge Climbing Lane
  - Original Posted 80 mph
  - Drop to 65 at front of work zone
    - 85th percentile of 67 mph and 70 mph
  - 45mph allowed structure work
    - 85th percentile of 51 mph
  - Speed Harmonization +/- 12 mph

Variable Speed Limit (VSL): Where We Are Going

- FHWA Accelerated Innovation Deployment (AID) Grant
  - Submitted May 2014
  - $775,000 AID Grant Awarded December 2014
- RFP early Spring 2015
- Kimley-Horn NTP June 2015
  - Avenue Consulting

Kimley»Horn

avenue CONSULTANTS

Project Objectives

- Develop a portable and dynamic system
- Test on 2 projects in 2016
- Evaluate results/Revise requirements
- Test on 2 projects in 2017
- Bid into future projects

Goals, Objectives, and Performance Measures (1 of 2)

Category	Goal	Objective	Measure
FIELD	Safety	Safer for field personnel	• Limits exposure to workers for making VSL adjustments (i.e., limits need to go to each VSL) • Speed in work space • Speed compliance within the work space when field personnel are present • Worker satisfaction
	Ease of Use	Ease of deployment and operation	• Time it takes to set up, adjust, or shift the system in a work zone • Time it takes to learn how to operate the Portable VSL (PVSL) • Cost of the system (labor hours and renting devices)

Zero® Fatalities
A Goal We Can All Live With

innovation ingenuity Every Day Counts imagination invention

Goals, Objectives, and Performance Measures (2 of 2)

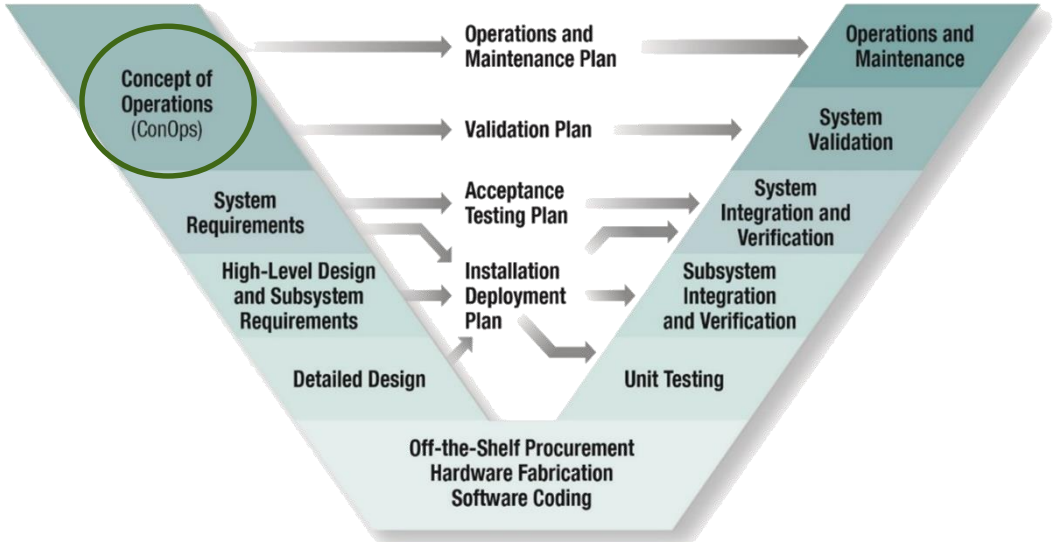
Category	Goal	Objective	Measure
PUBLIC	Safety	Safer for public	• Number of crashes • Customer satisfaction
	Public Trust	Posted speeds comply with work activity	All measures below are measured within the work space: • Speed compliance when workers are present • Percent of drivers that encounter reduced speed limits • The length (distance) for which the speed is reduced • Delay (time it takes to transverse the work space) for when a driver encounters reduced speed limits
		Increased and reliable information	• Travel time through the work space • Uptime of system
	Easy to use	Easy for public to understand	• Speed variation

Needs and Wants of a Portable VSL System

- **Needs:**
  - Adjust speed limits based on detected speeds/queue
  - Provide real-time detection for traffic speed and occupancy (queue):
    - Through ACTIVE work space
    - In advance of the work space
  - Provide advanced notification to drivers about Variable Speed Limits
  - Provide travel time or traffic delay through the work zone
- **Wants:**
  - Provide surveillance/monitoring capability at the work zone
  - Provide real-time weather detection

Systems Engineering Process

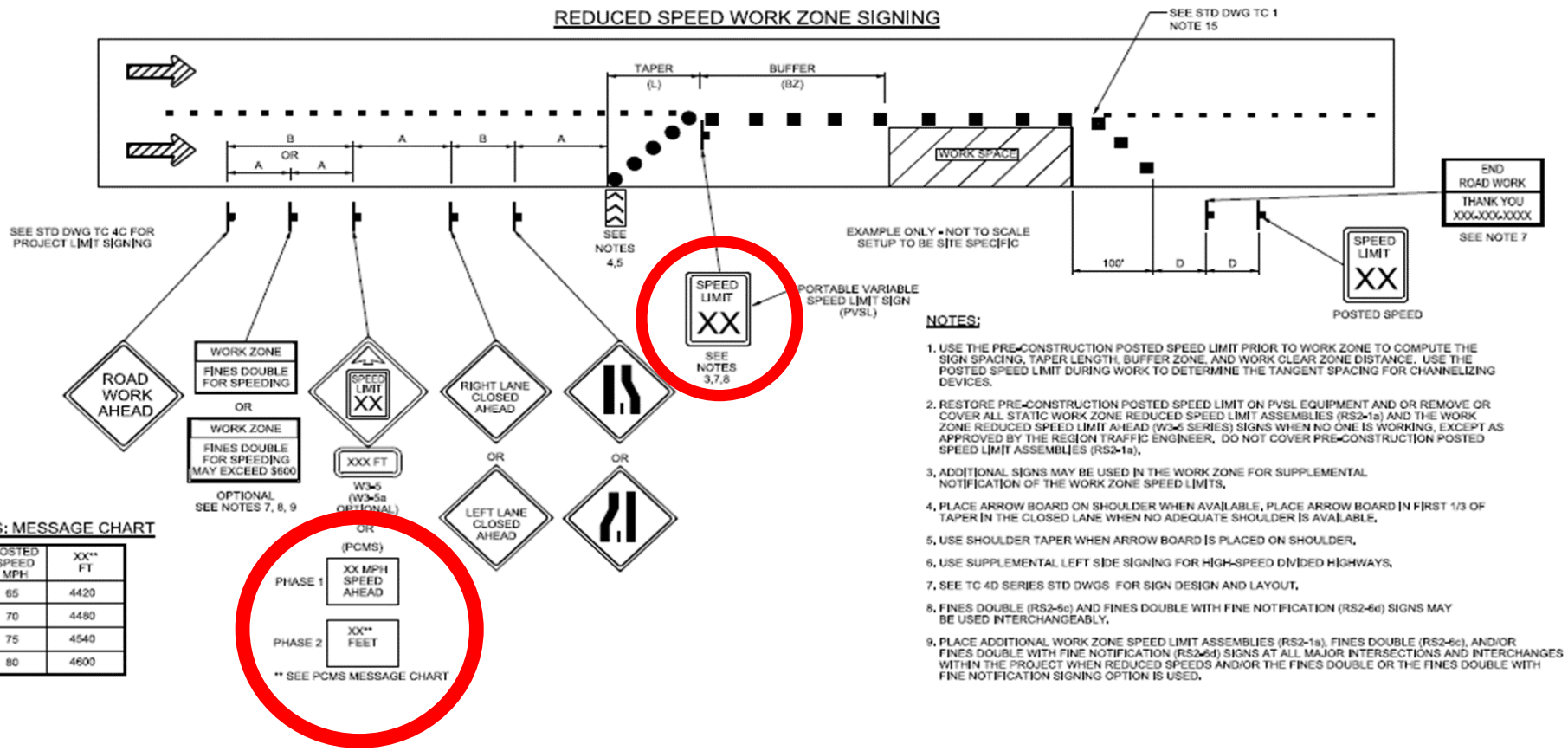
- Concept of Operations (Con Ops) Phase
  - Goals/Objectives/Performance Measures
  - Operational Parameters and Limits
  - Stakeholder Roles and Responsibilities Matrix
  - Operational Scenarios
  - User and System Needs



Parameters and Limits

- Speeds
  - Increments
  - Frequency of posted speed changes
  - Set work zone speed limit based on prevailing conditions
- Spacing
  - Between VSL signs and advanced warning signs
- Variable Message Signs (VMS) Communications
  - Maximum distance away from active work zone to display travel time?

Special Provisions for VSL (1 of 2)



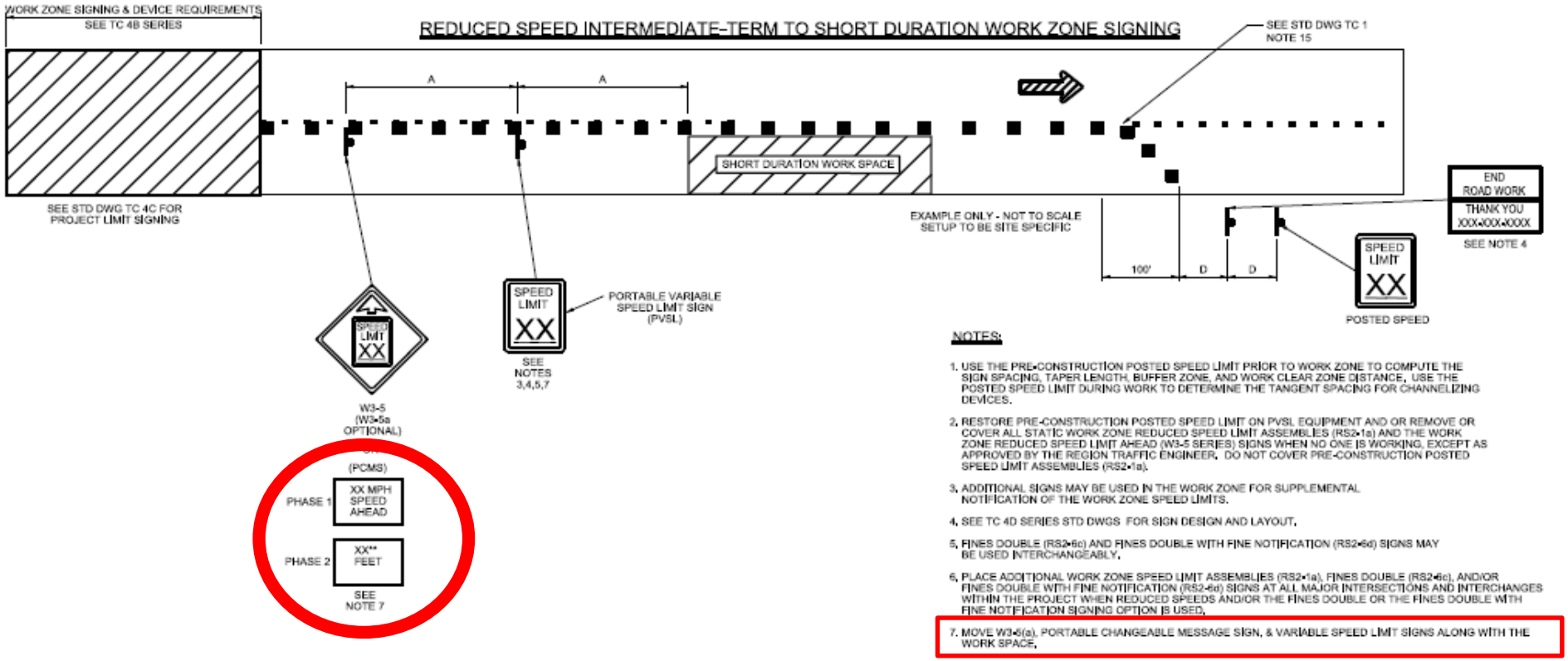
PCMS: MESSAGE CHART

POSTED SPEED MPH	XX** FT
65	4420
70	4480
75	4540
80	4600

NOTES:

1. USE THE PRE-CONSTRUCTION POSTED SPEED LIMIT PRIOR TO WORK ZONE TO COMPUTE THE SIGN SPACING, TAPER LENGTH, BUFFER ZONE, AND WORK CLEAR ZONE DISTANCE. USE THE POSTED SPEED LIMIT DURING WORK TO DETERMINE THE TANGENT SPACING FOR CHANNELIZING DEVICES.
2. RESTORE PRE-CONSTRUCTION POSTED SPEED LIMIT ON PVSL EQUIPMENT AND OR REMOVE OR COVER ALL STATIC WORK ZONE REDUCED SPEED LIMIT ASSEMBLIES (RS2-1a) AND THE WORK ZONE REDUCED SPEED LIMIT AHEAD (W3-5 SERIES) SIGNS WHEN NO ONE IS WORKING, EXCEPT AS APPROVED BY THE REGION TRAFFIC ENGINEER. DO NOT COVER PRE-CONSTRUCTION POSTED SPEED LIMIT ASSEMBLIES (RS2-1a).
3. ADDITIONAL SIGNS MAY BE USED IN THE WORK ZONE FOR SUPPLEMENTAL NOTIFICATION OF THE WORK ZONE SPEED LIMITS.
4. PLACE ARROW BOARD ON SHOULDER WHEN AVAILABLE, PLACE ARROW BOARD IN FIRST 1/3 OF TAPER IN THE CLOSED LANE WHEN NO ADEQUATE SHOULDER IS AVAILABLE.
5. USE SHOULDER TAPER WHEN ARROW BOARD IS PLACED ON SHOULDER.
6. USE SUPPLEMENTAL LEFT SIDE SIGNING FOR HIGH-SPEED DIVIDED HIGHWAYS.
7. SEE TC 4D SERIES STD DWGS FOR SIGN DESIGN AND LAYOUT.
8. FINES DOUBLE (RS2-6c) AND FINES DOUBLE WITH FINE NOTIFICATION (RS2-6d) SIGNS MAY BE USED INTERCHANGEABLY.
9. PLACE ADDITIONAL WORK ZONE SPEED LIMIT ASSEMBLIES (RS2-1a), FINES DOUBLE (RS2-6c), AND/OR FINES DOUBLE WITH FINE NOTIFICATION (RS2-6d) SIGNS AT ALL MAJOR INTERSECTIONS AND INTERCHANGES WITHIN THE PROJECT WHEN REDUCED SPEEDS AND/OR THE FINES DOUBLE OR THE FINES DOUBLE WITH FINE NOTIFICATION SIGNING OPTION IS USED.

Special Provisions for VSL (2 of 2)



NOTES:

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7. MOVE W3-6(a), PORTABLE CHANGEABLE MESSAGE SIGN, & VARIABLE SPEED LIMIT SIGNS ALONG WITH THE WORK SPACE.

Portable VSL Candidate Projects

- Primary Candidate Projects:
  - 4 lane divided/ 3 or 4 lane undivided roads
    - Single or dual lane closure
  - High speed (50 mph +)
  - Project with simple geometries
  - Example
    - Roadway resurfacing
    - Slab replacement
    - Patching

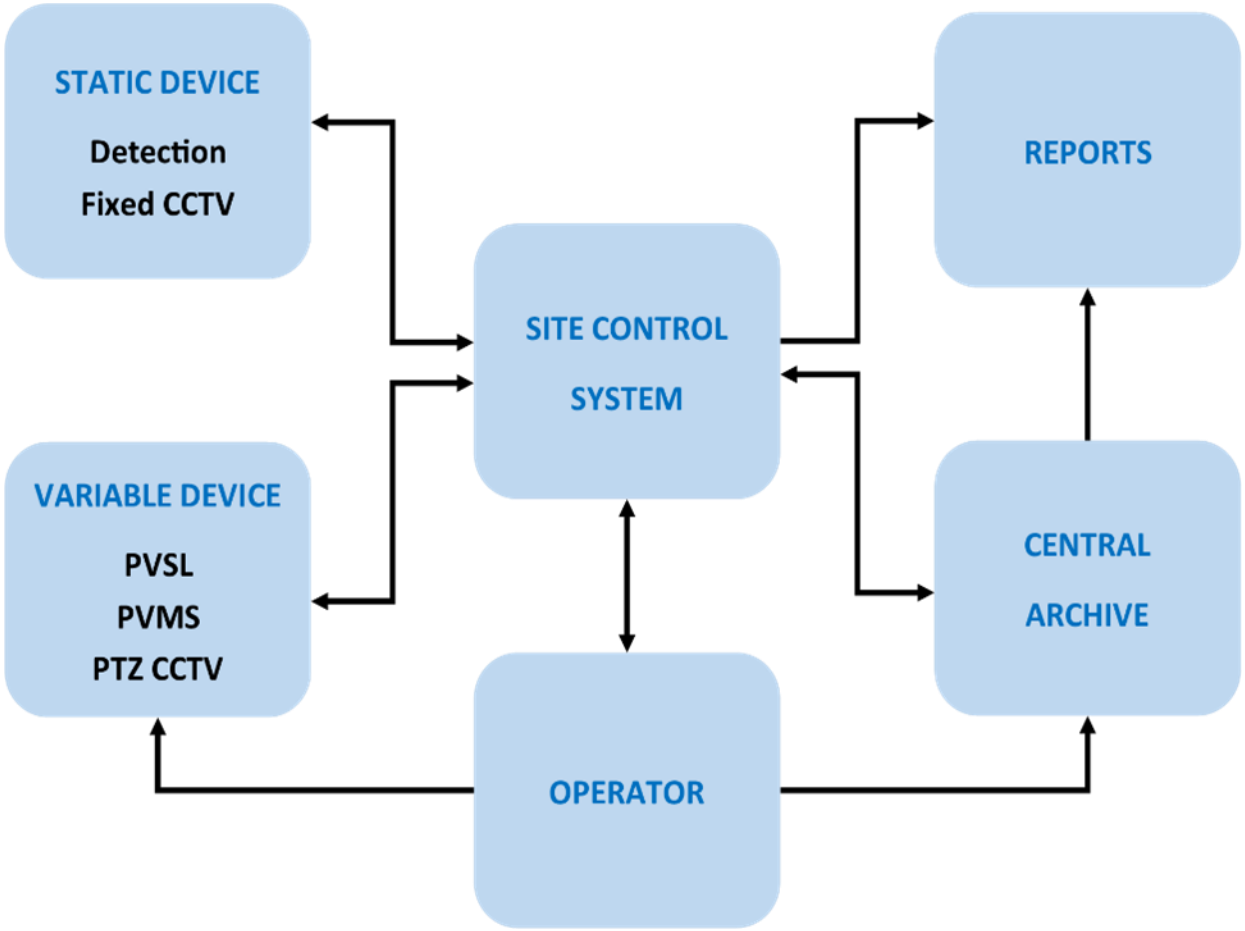
Future Portable VSL Considerations

- Anticipate broadening the circumstances where the system will be deployed
  - Only doing the pilot on these “parameters” for now
- Parameters not in 1st deployment:
  - Higher volume roadways
  - Higher profile roadways (political attention)
  - Variable characteristics (curvature, sight distance, proximity to signals, access, etc.)

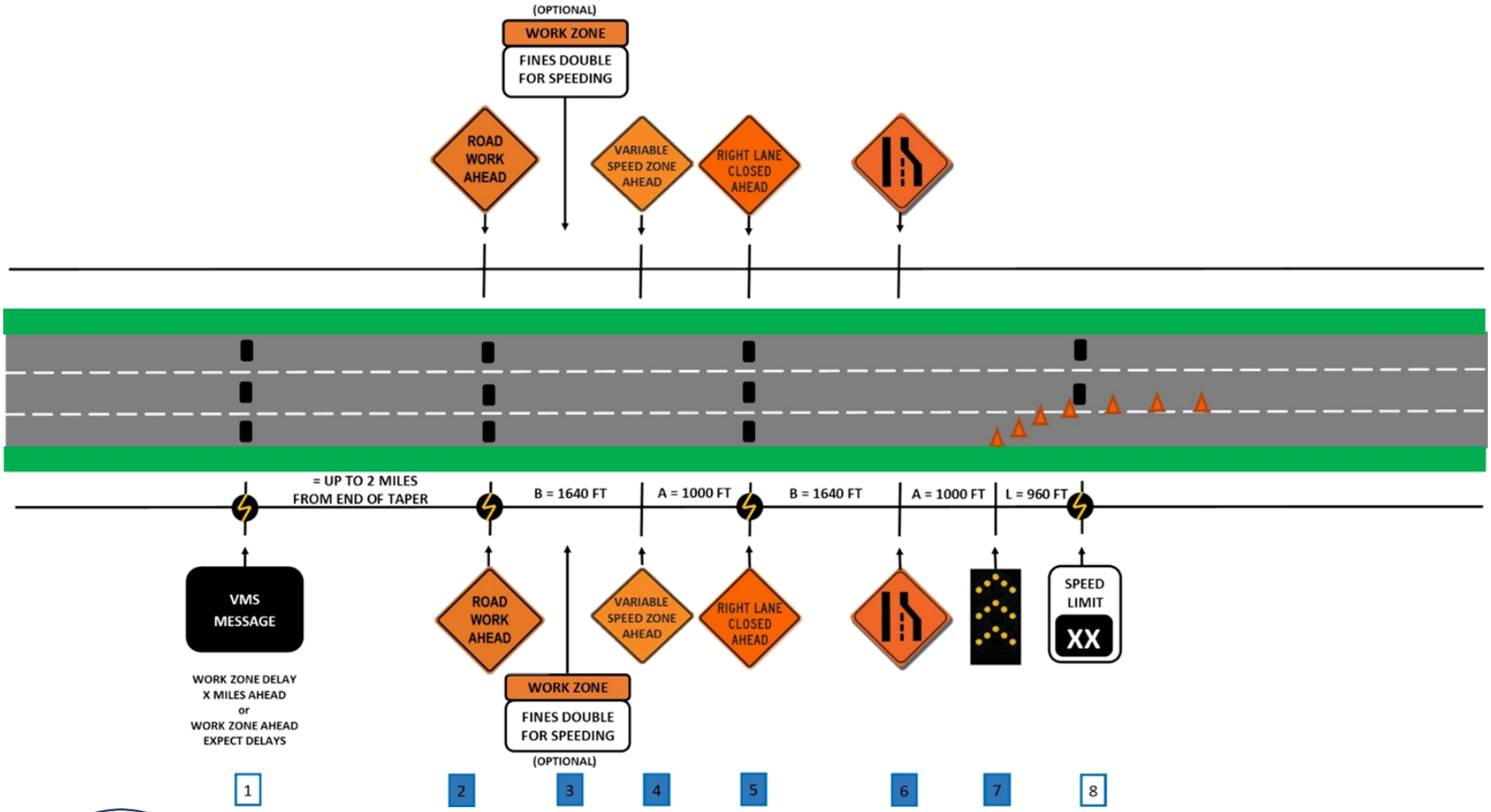
Technologies

- Portable VSL (PSVL) Signs
- Portable Variable Message Sign (PVMS)
- Mainline detection by lane
- Wireless communication
- RWIS and CCTV – not included

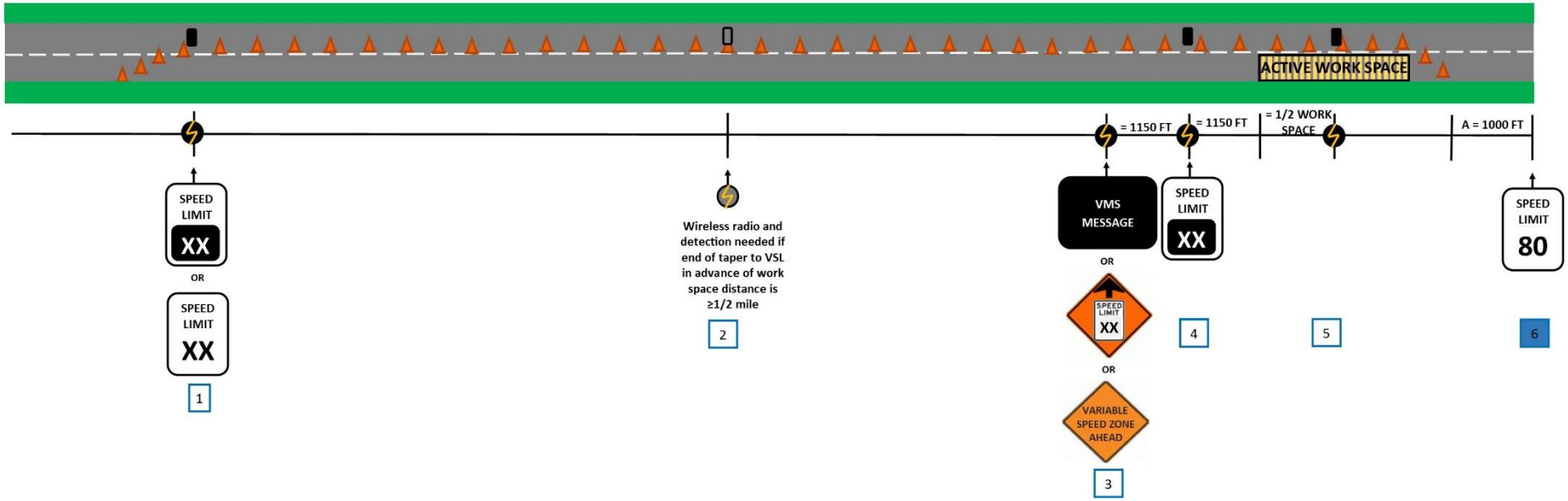
System Architecture Diagram



Typical VSL Signage



Typical VSL Downstream Set Up



For More Information:

Josh Van Jura
Utah DOT
jvanjura@utah.gov

Smarter Work Zones

Michigan DOT Late "Zipper" Lane Merge

Traditional Lane Merge

- Vehicles queue in a single file line
- Road users experience long queues and frustration/confusion when capacity is exceeded

Source: Michigan DOT

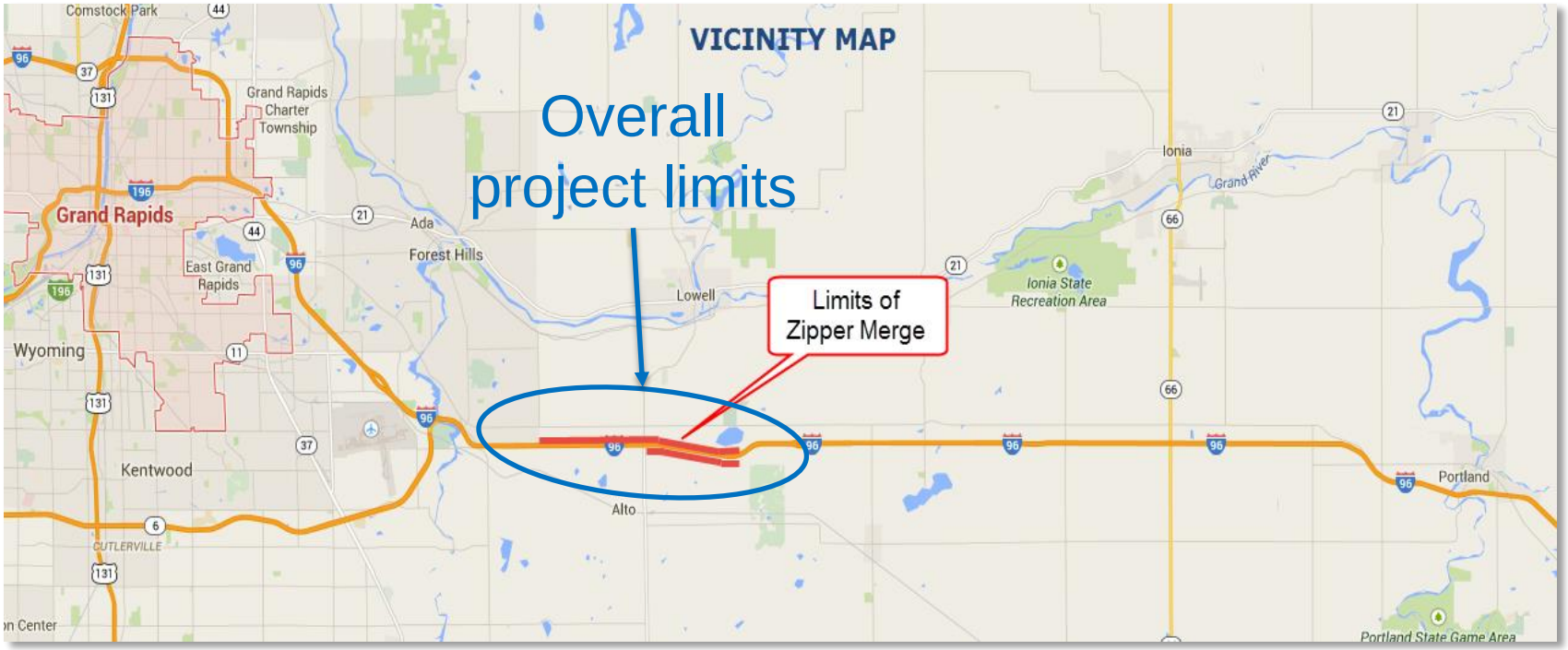
Source: Michigan DOT

Late “Zipper” Lane Merge Concerns

- Driver confusion and steep learning curve
- Frustration at the merge point
- Increased motorist delay

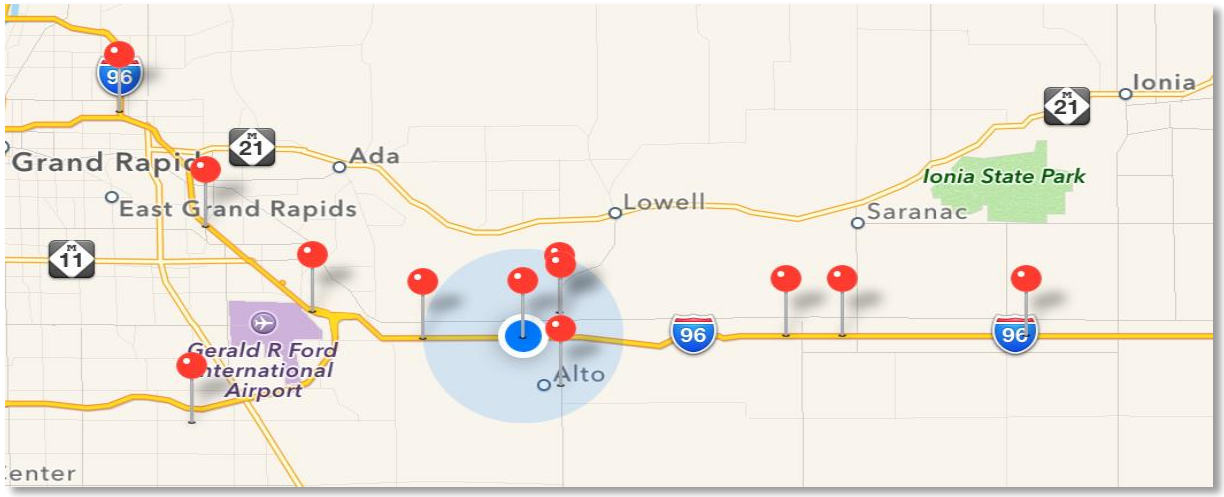
Recent Projects – I-96 Concrete Joint Repairs

- Construction May to September 2014



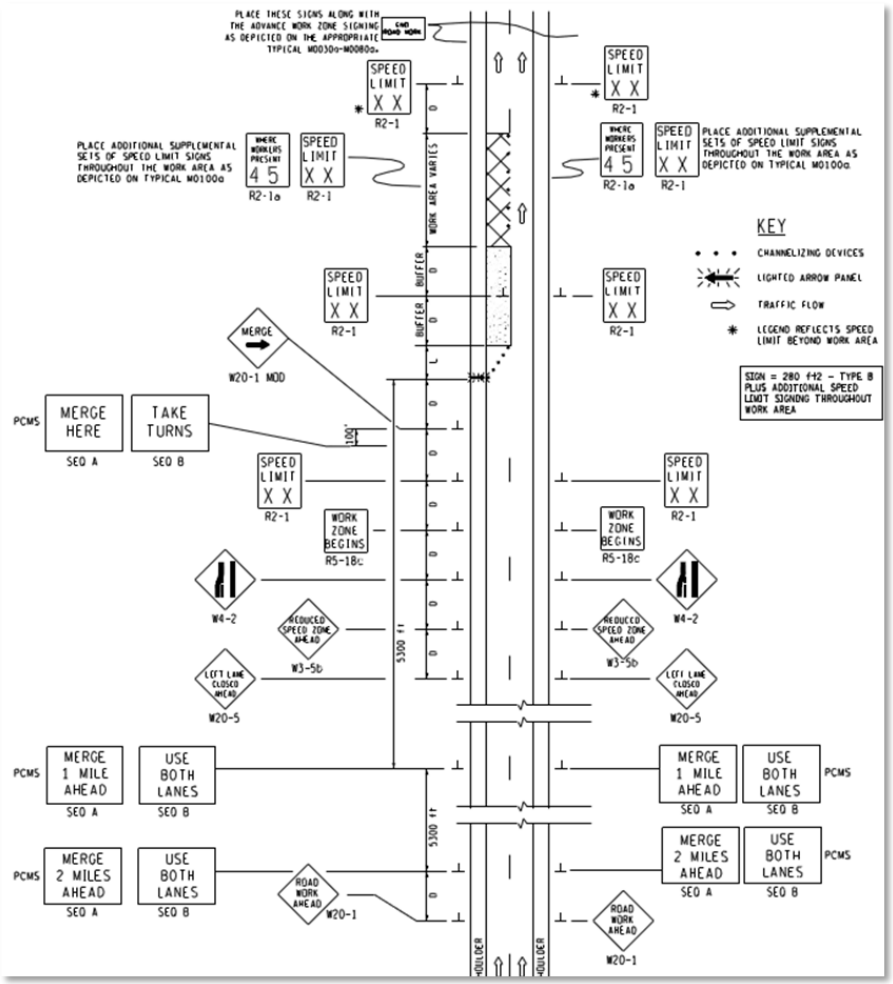
I-96 Concrete Joint Repairs

- Tried various mitigation measures during construction
  - Weekend lane closures
  - Additional alternate route messaging
  - Active work at night; curing during the day
  - Late “Zipper” Lane Merge



Late “Zipper” Lane Merge Signing

- Utilized 3 Portable Changeable Message Signs (PCMS) in each direction and a special fabrication sign



Source: Michigan DOT

Media Outreach for Zipper Lane Merge

- Grand Rapids area media covered use zipper merge on I-96
- Lansing area media decided not to cover the story

Source: Michigan DOT

Source: Michigan DOT

Source: Michigan DOT

Late “Zipper” Lane Merge Capacity Performance

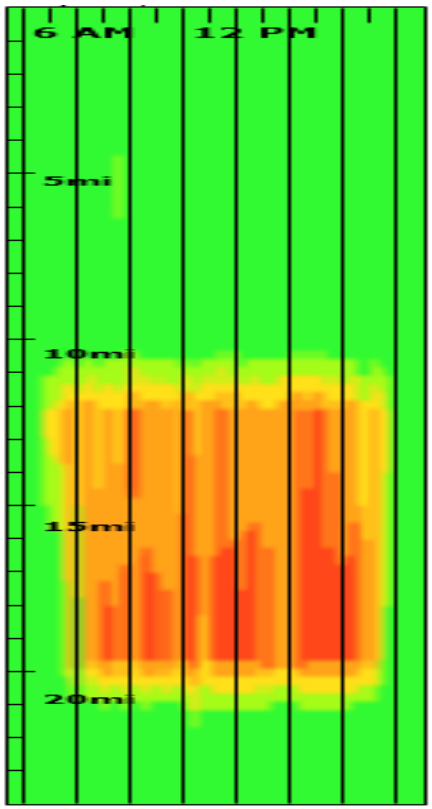
- Capacity was increased when using a zipper lane merge
  - Traffic utilized both lanes

Source: Minnesota DOT

Late “Zipper” Lane Merge Queue Reduction (1 of 2)

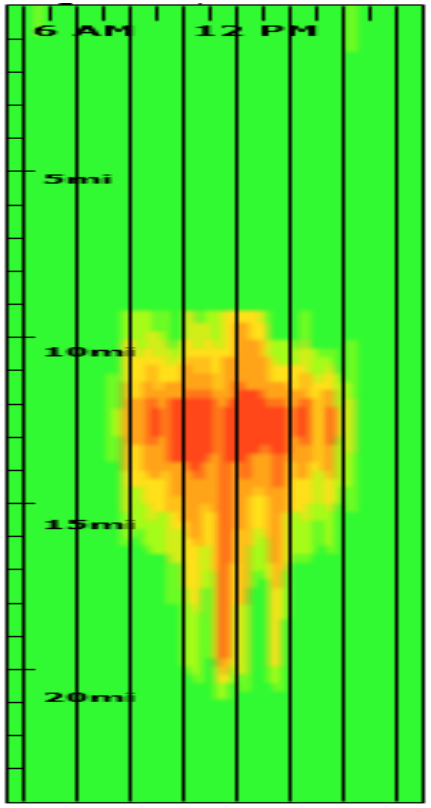
- Eastbound queues were reduced

Traditional Lane Merge – Weekend Closure



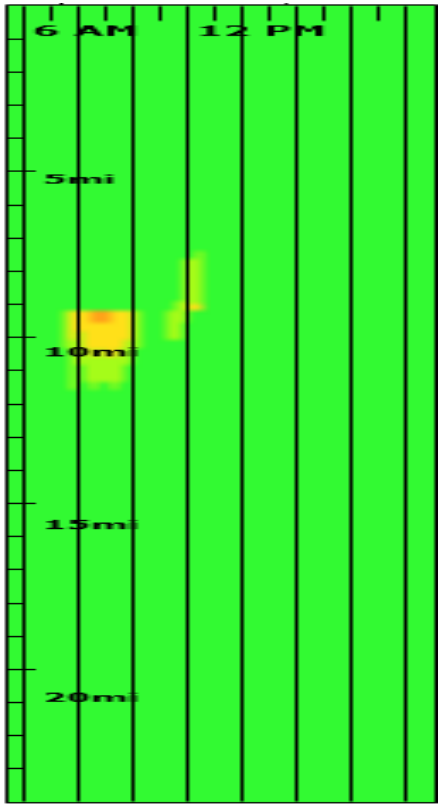
Queue Length :~ 10 miles

Traditional Lane Merge – Weekday Closure



Queue Length :~ 5 miles

Zipper Lane Merge



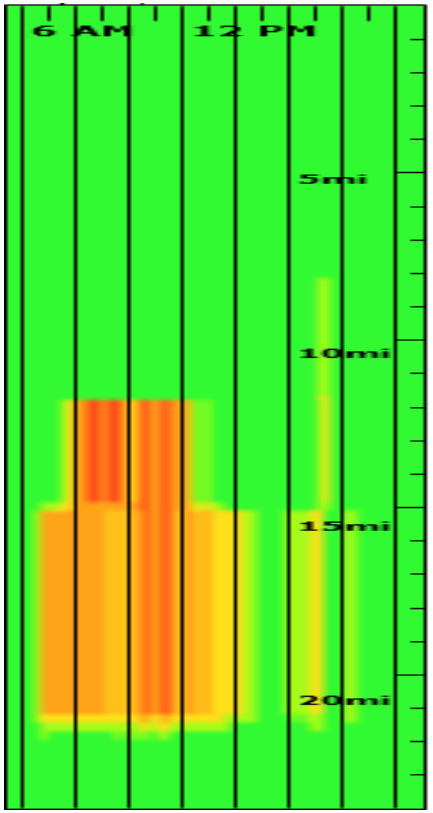
Queue Length: < 2 miles

The raw measured speed.

Late “Zipper” Lane Merge Queue Reduction (2 of 2)

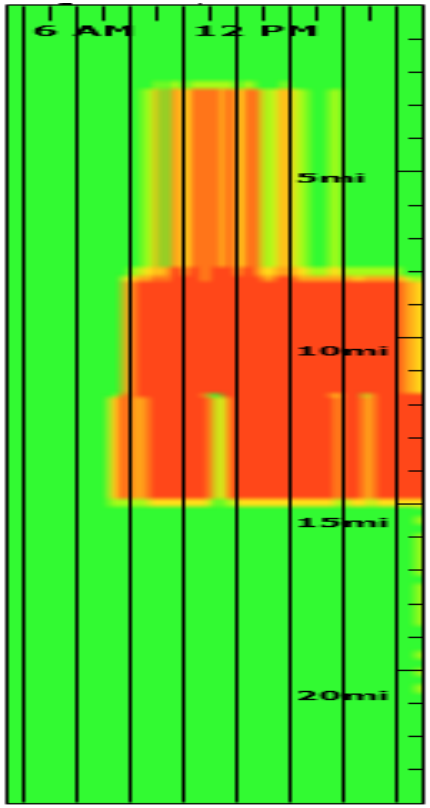
- Westbound queues were reduced

Traditional Lane Merge – Weekend Closure



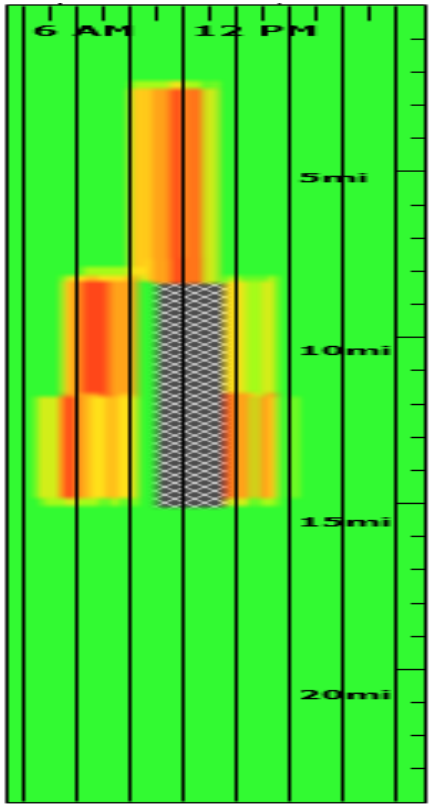
Queue Length :~ 10 miles

Traditional Lane Merge – Weekday Closure



Queue Length :~ 7 miles

Zipper Lane Merge

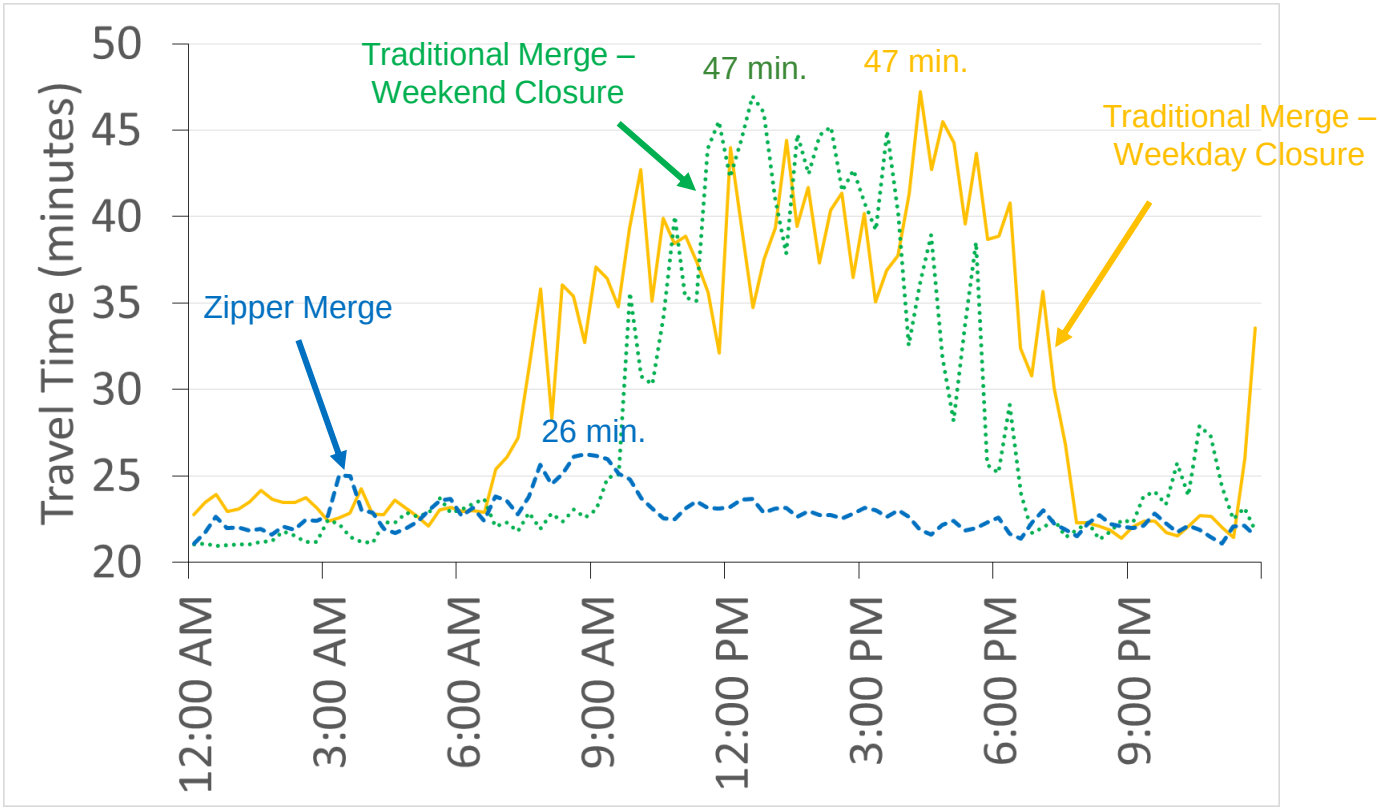


Queue Length: 0 miles in PM

The raw measured speed.

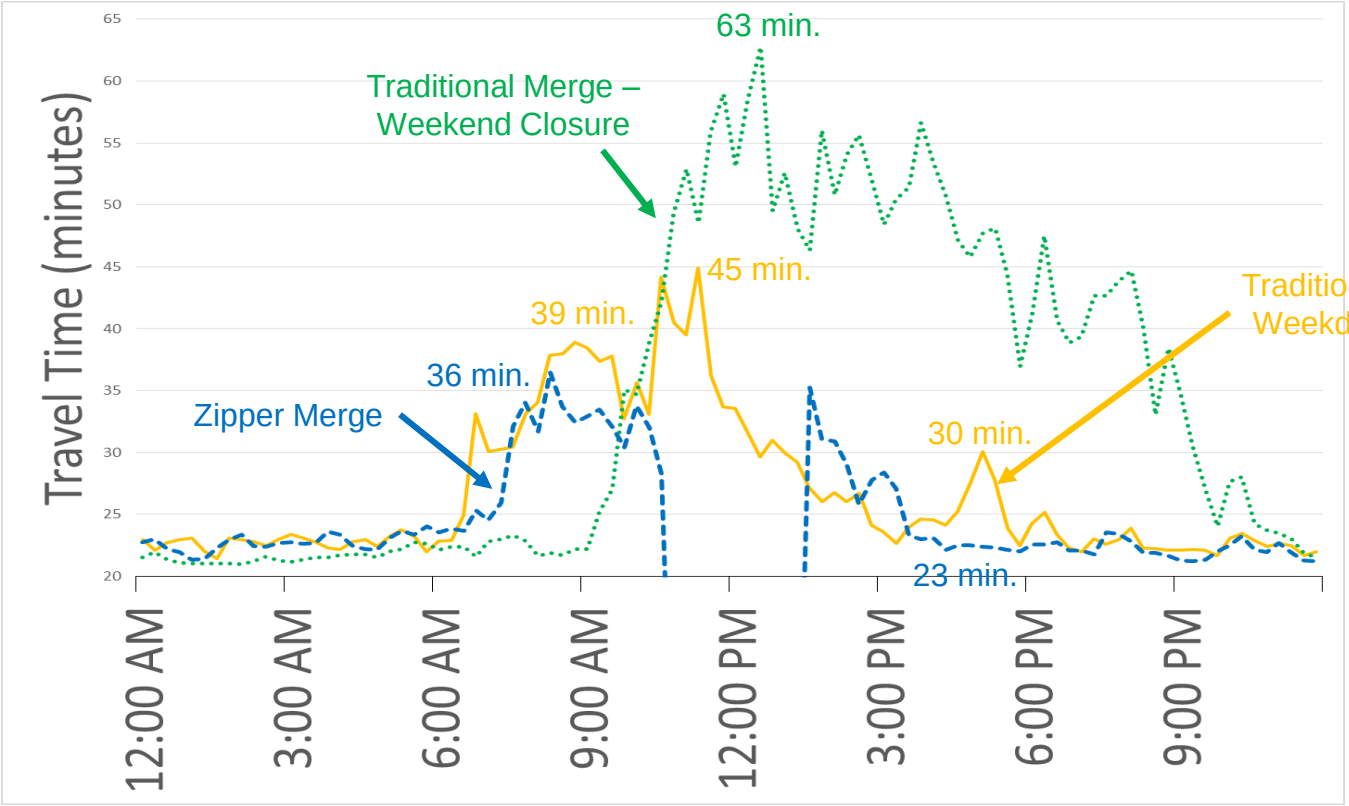
Late “Zipper” Lane Merge Delays – Eastbound

- Eastbound delays were reduced from 24 minutes to 3 minutes



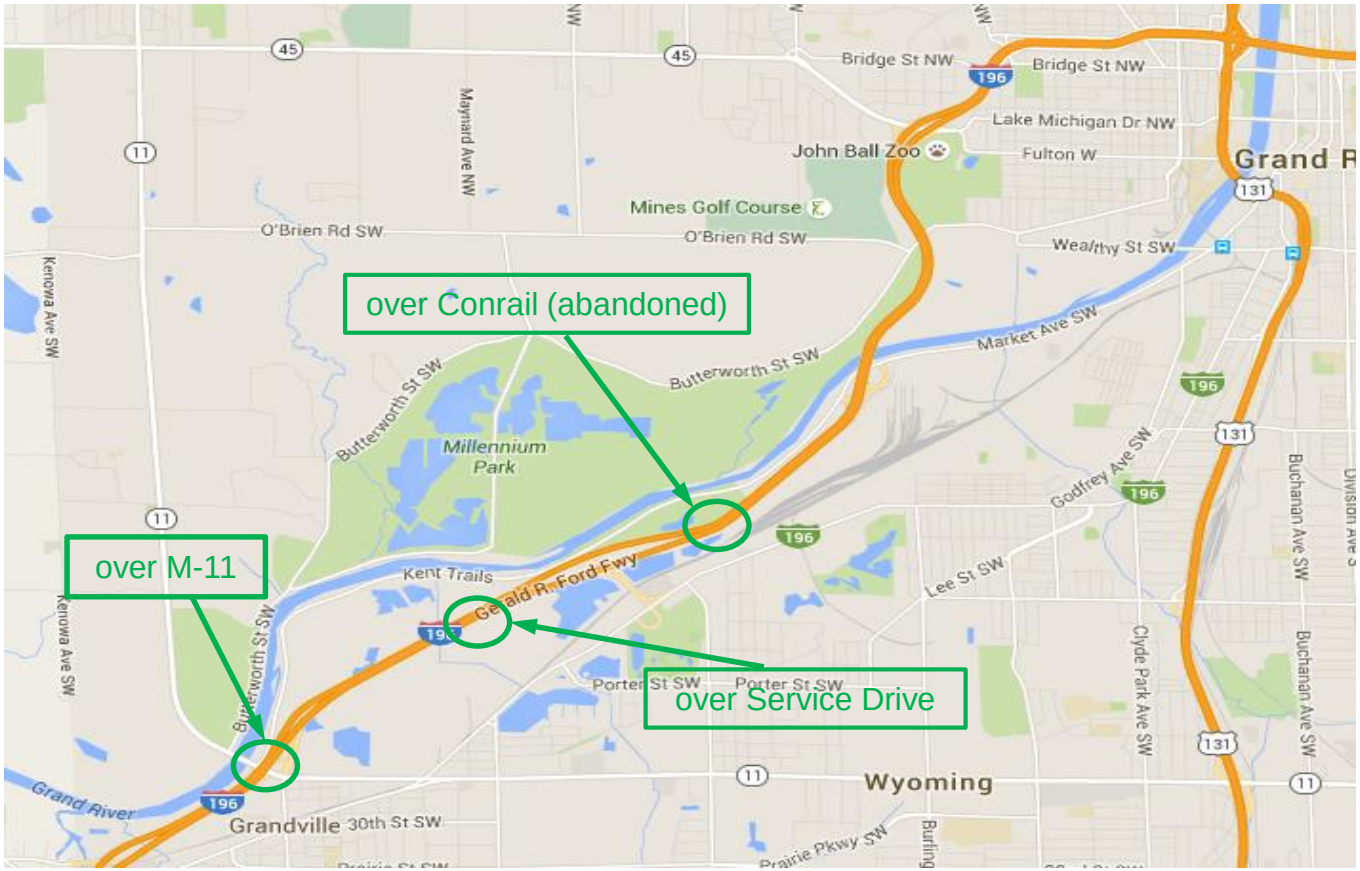
Late “Zipper” Lane Merge Delays – Westbound

- Westbound delays were reduced slightly



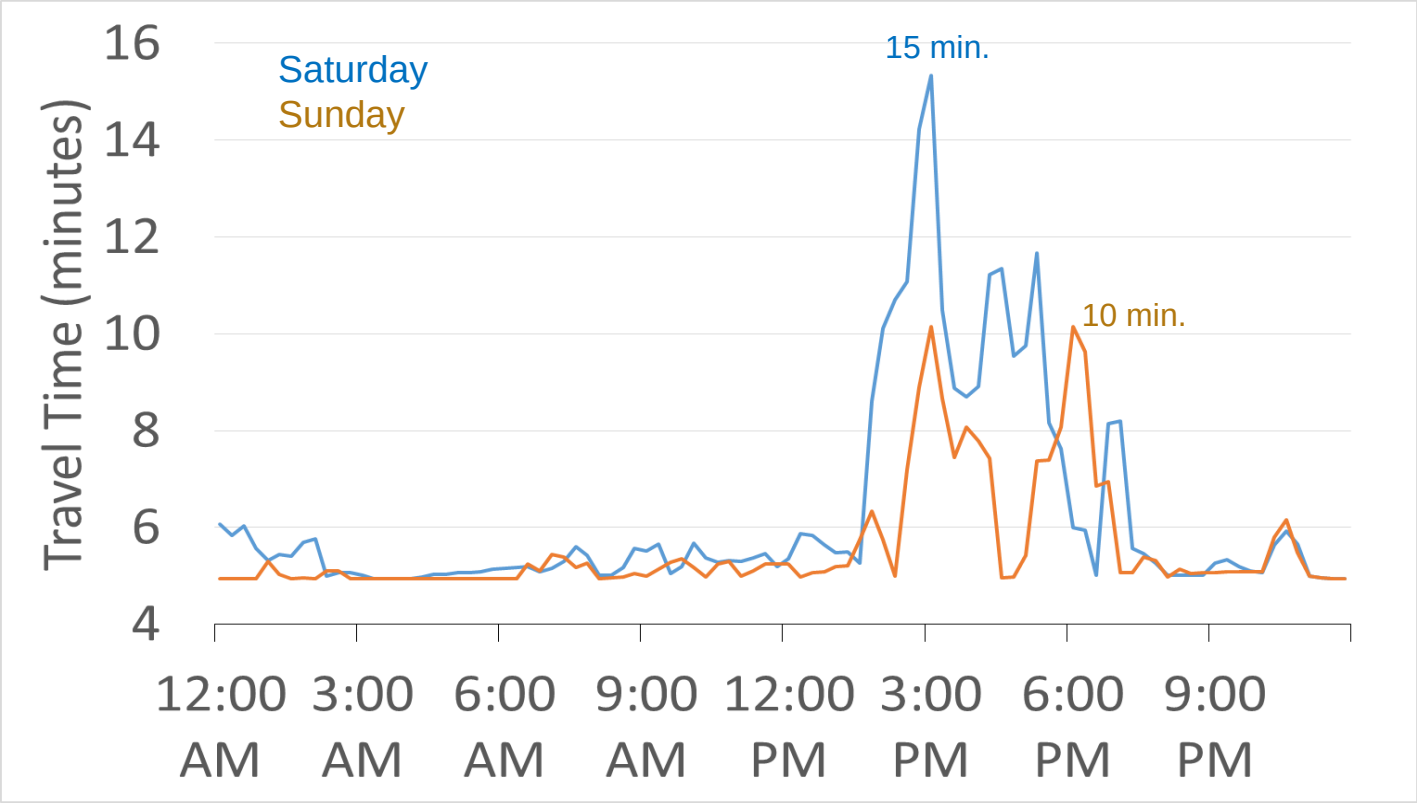
Recent Projects: I-196 Bridge Work

- Lane closures were limited to nights and weekends



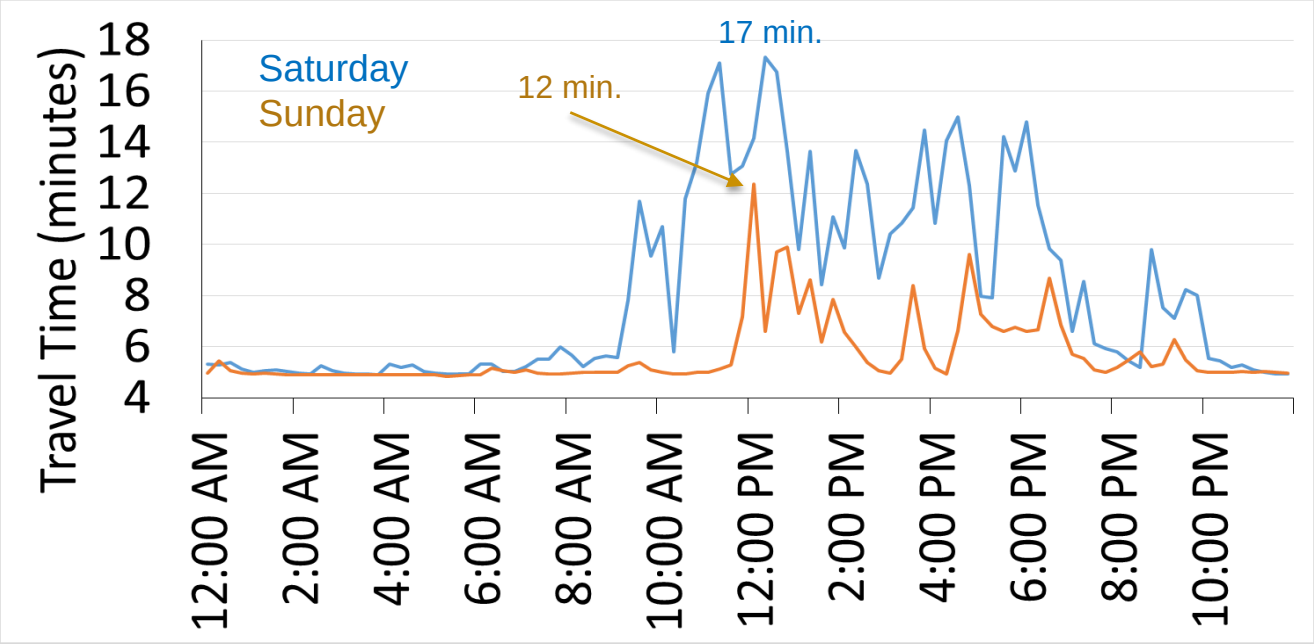
Eastbound I-196 Traditional Weekend Lane Closures

- Experienced peak delays of 5-10 minutes



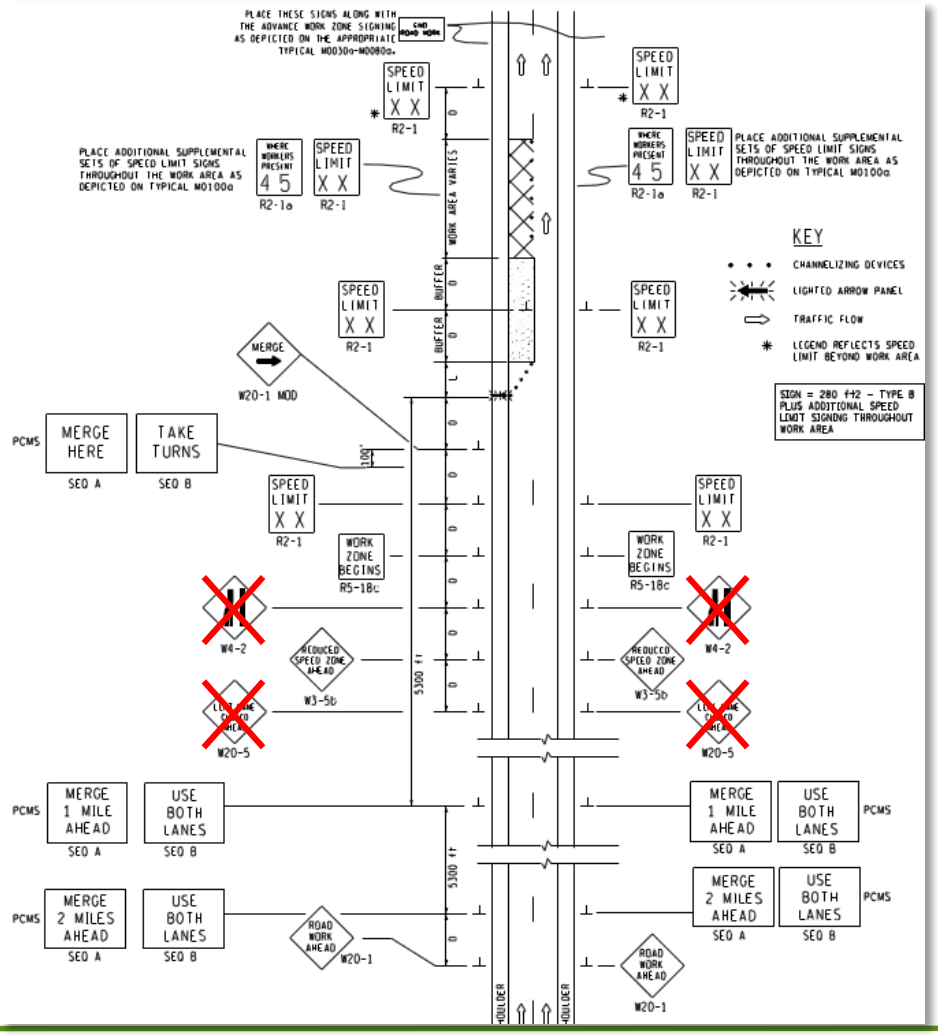
Eastbound I-196 Weekend Zipper Lane Merge

- Delays increased by 2 minutes



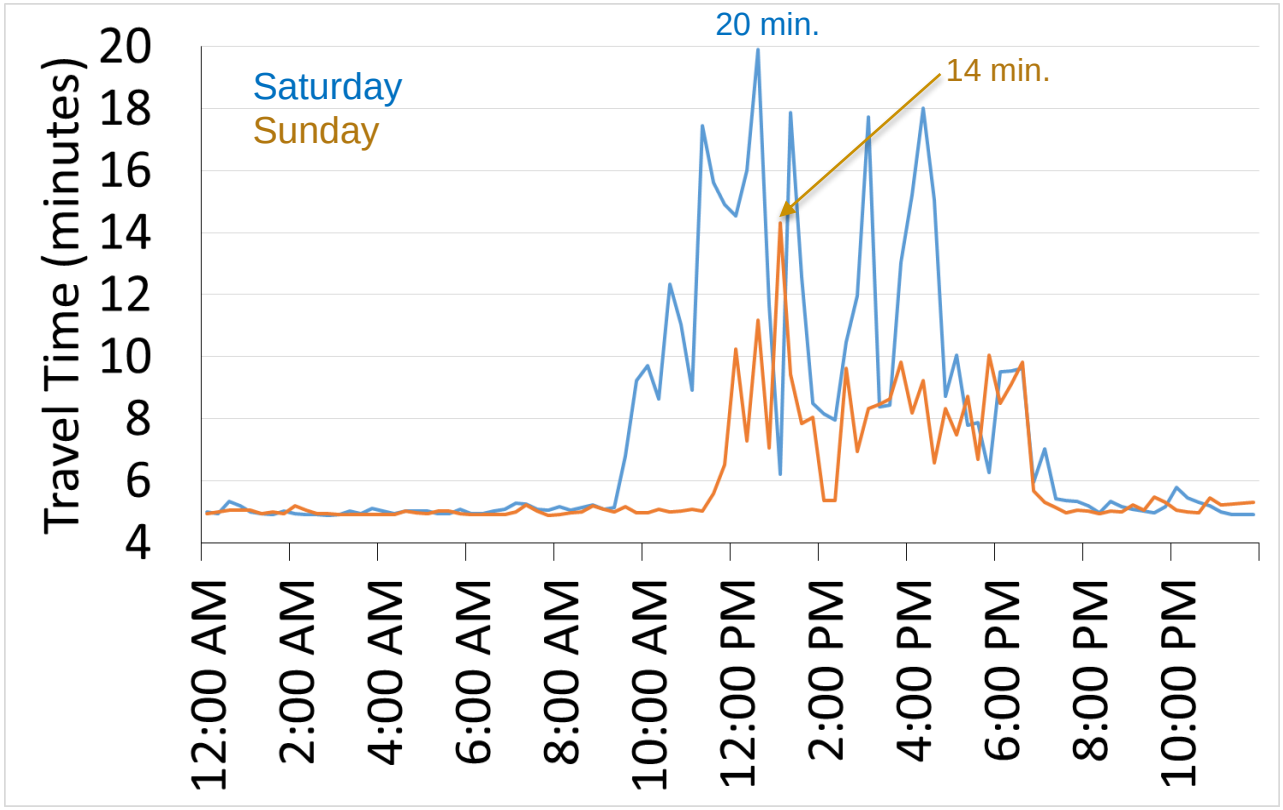
Modifications for Weekend #2 of Work

- Reduced signing from one location on each side of road



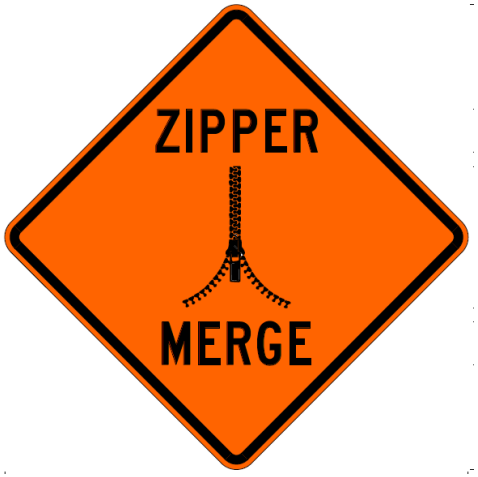
Eastbound I-196 2nd Weekend Zipper Lane Merge

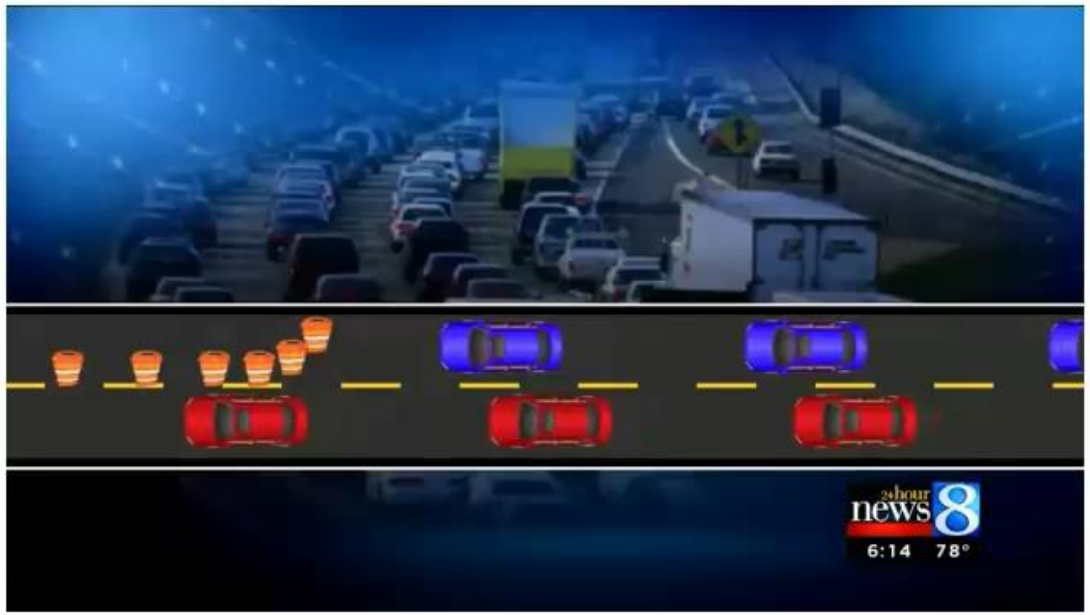
- Delays increased by another 2-3 minutes



Modifications for Weekend #3 of Work

- Created a new special fabrication sign
- Media picked up the story and ran a feature story including “how-to” graphics

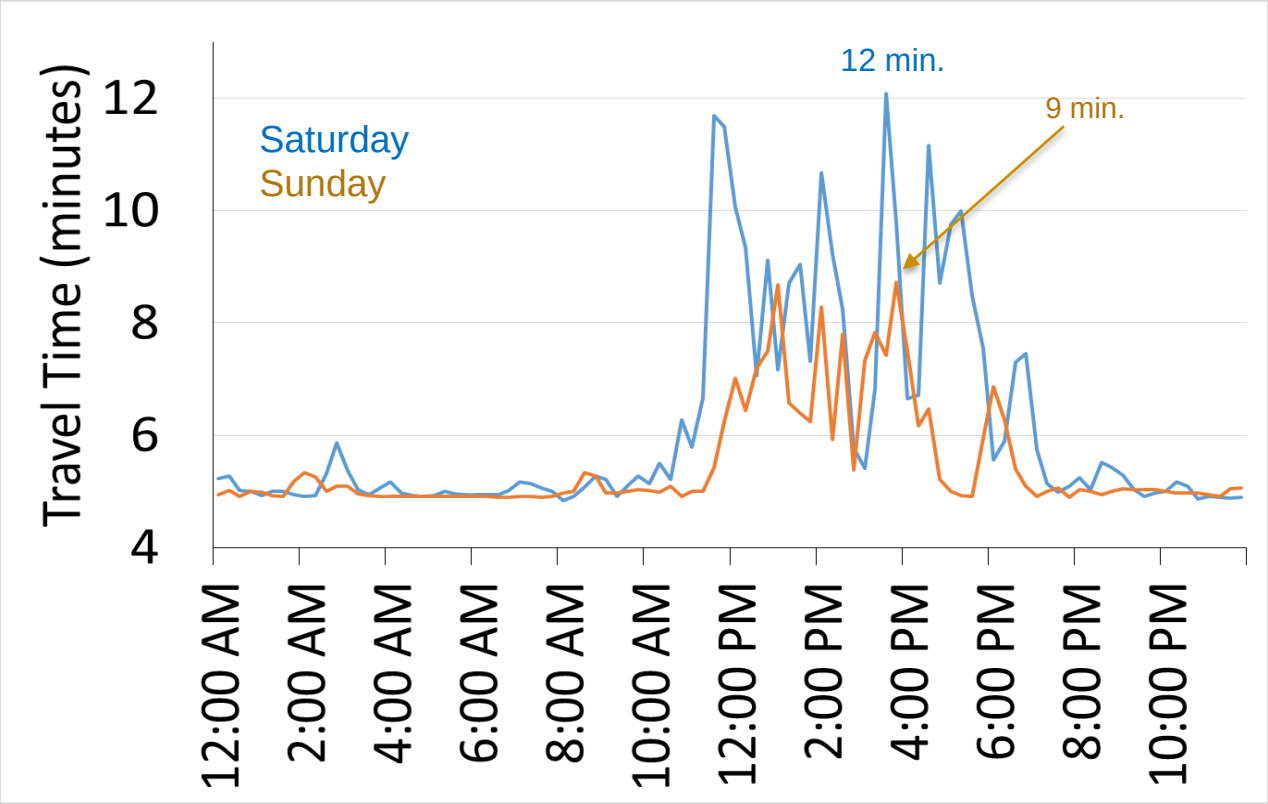




Source: Michigan DOT

Eastbound I-196 3rd Weekend Zipper Lane Merge

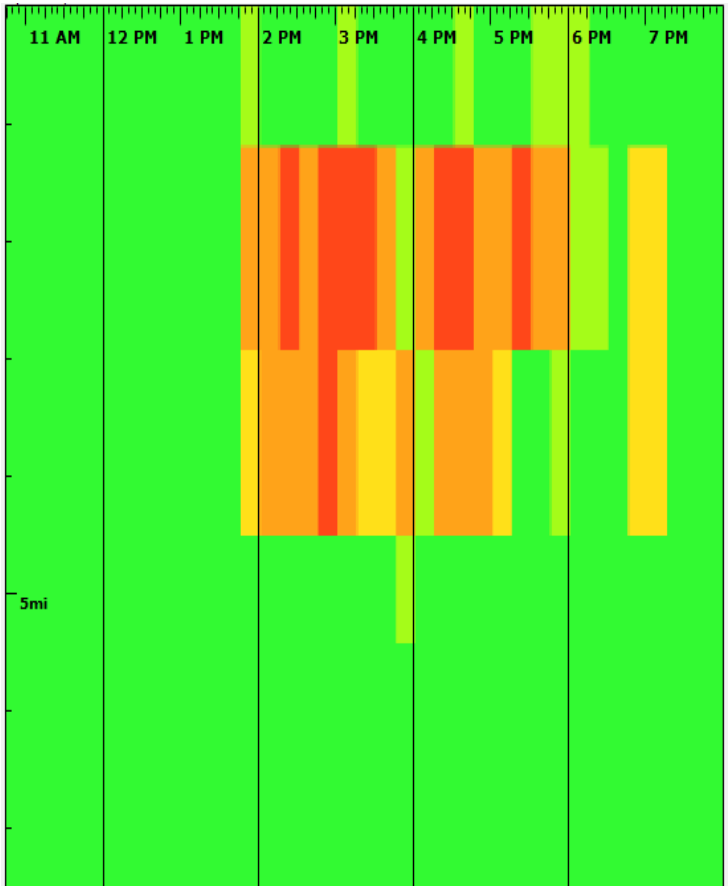
- Delays were 1-3 minutes lower than traditional lane merge



Westbound I-196 Queues

- Reduced by ½ mile to 1 mile

Traditional Lane Merge



Zipper Lane Merge

The raw measured speed.

Late “Zipper” Merge Benefits

- Reduced speed differential between the two open lanes in advance of the lane closure
- Reduced frustration by creating a sense of fairness
- Reduction in queue lengths
- Reduction in work zone delays

For More Information:

Chris Brookes

Michigan DOT

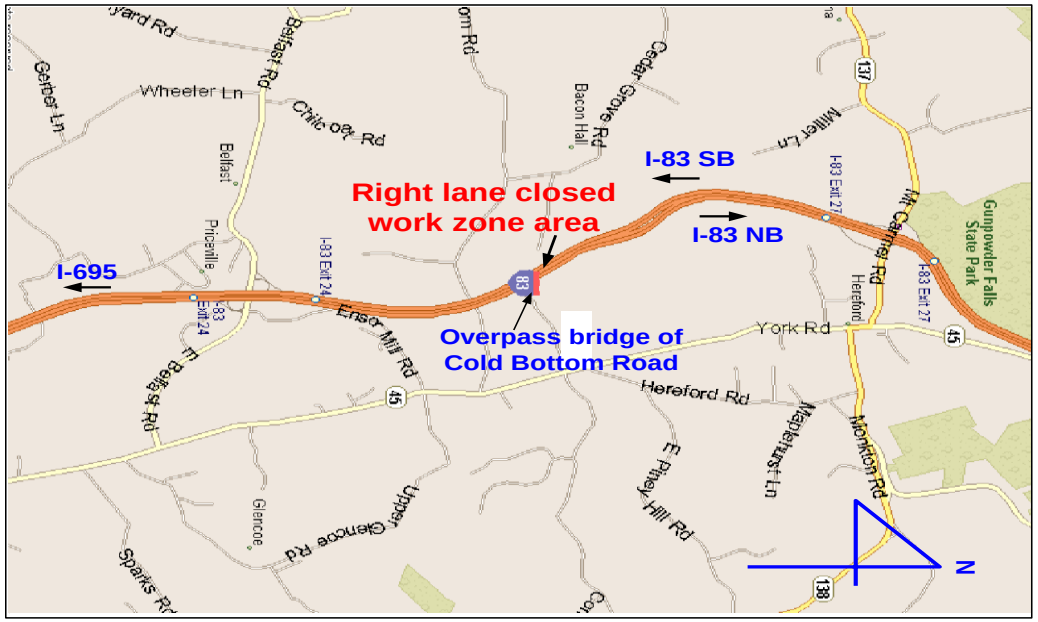
brookesc@michigan.gov

Smarter Work Zones

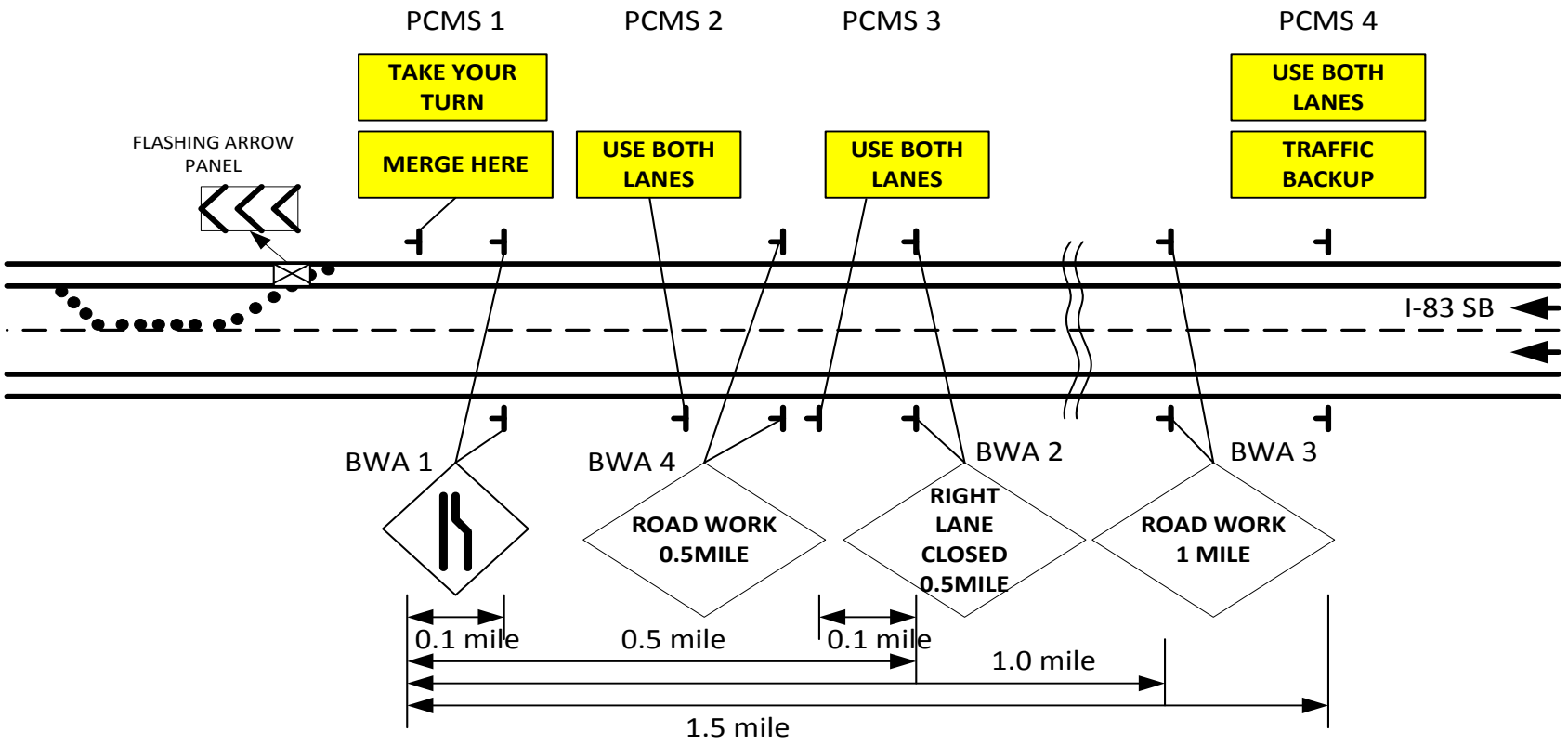
Maryland Dynamic Lane Merge

Maryland DLM Test Deployment

- Maryland SHA / University of Maryland partnership
- Test bed I-83 north of Baltimore
  - Four-lane divided freeway
  - 61,140 ADT (2014)
  - Southbound only work zone
  - Right lane closure

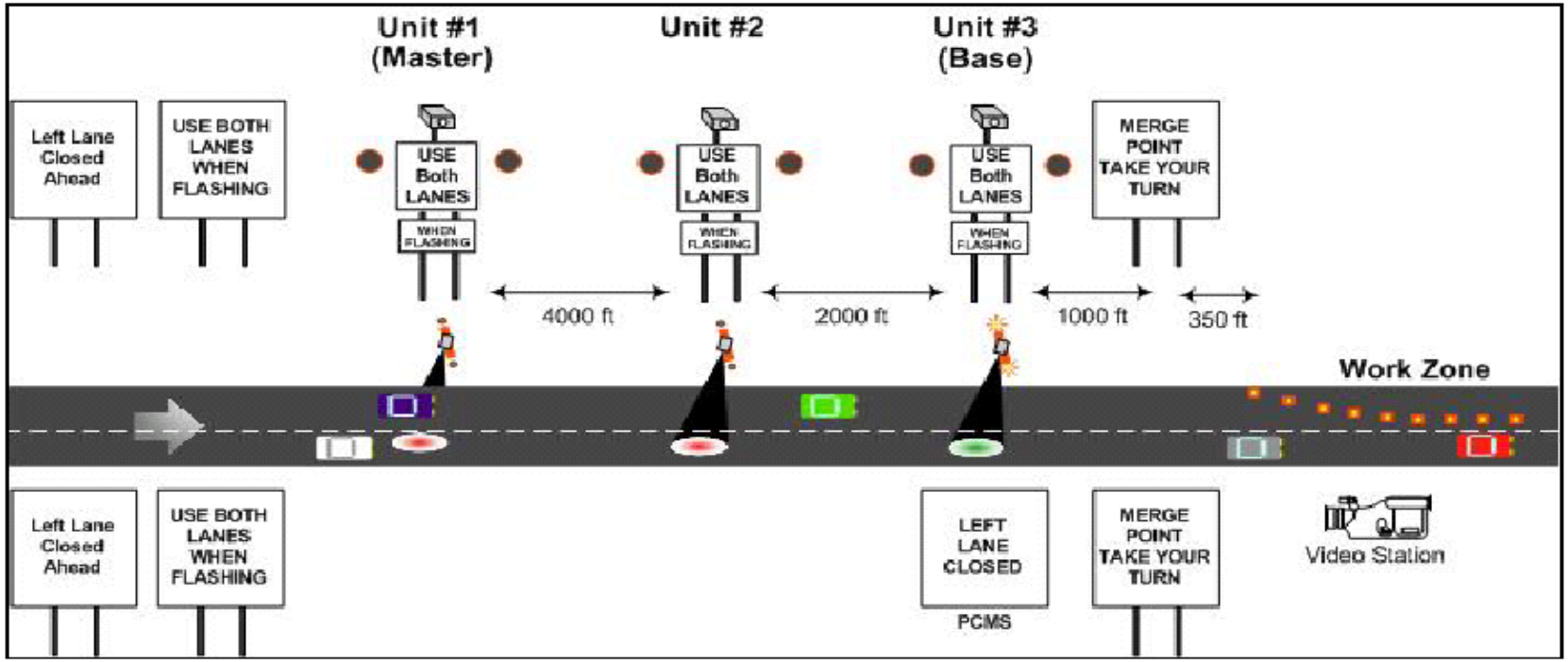


System Configuration



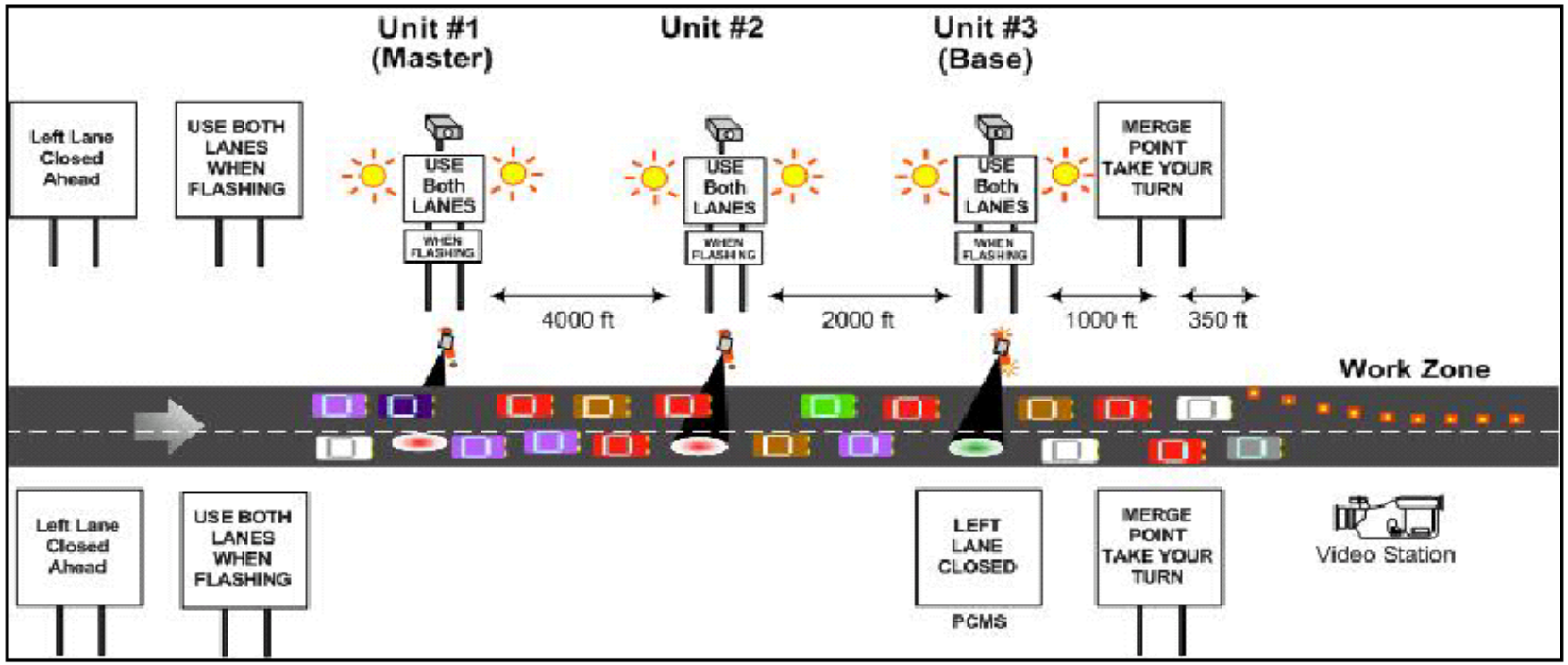
Operation – Low Volume

- "All On – All Off" algorithm.
- If all occupancies are below 5%, all PCMS are deactivated.



Operation – High Volume

- If any occupancy among the sensors is over 15%, all PCMSs are activated.



Evaluation - Methodology

- Manual data collection
  - Work zone throughputs, lane volume distributions, and queues
  - Obtained for no-control baseline and during DLM operation
- Simulation calibrated to no-control baseline conditions
- Simulated no-control throughput & queues based on upstream volumes measures during DLM operation

Evaluation - Results

- Throughput

Day	Simulation throughput (No control)	Manual counted throughput (DLM)	Percent Increased
1	1375	1814	14%
2	1476	1928	14%
3	1450	1883	9%
4	1390	1987	34%

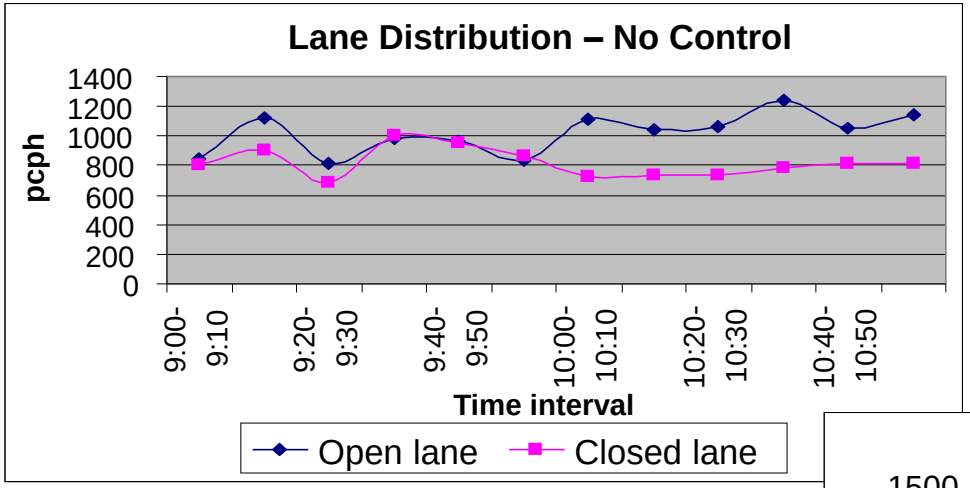
Evaluation - Results

- Maximum Queue Lengths

Day	Simulated Queue (No control)	Actual Queue (DLM)	Percent Reduced
1	1.3 miles	1.2 miles	8.3%
2	1.4 miles	1.2 miles	16.7%
3	2.0 miles	1.8 miles	11.1%
4	1.2 miles	0.9 miles	33.3%

Evaluation - Results

- Lane Volume Distribution

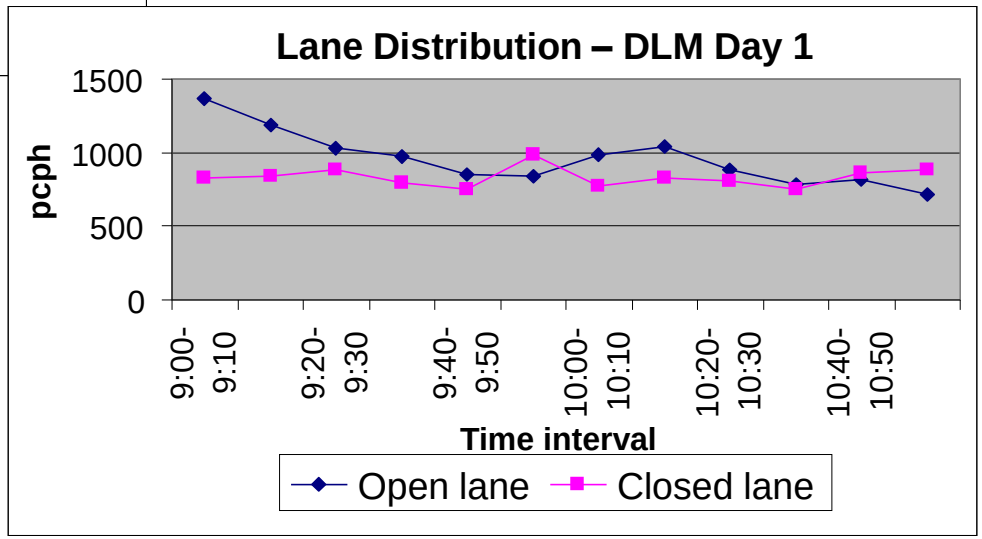


← No control

not uniform lane distribution

DLM control →

more uniform lane distribution

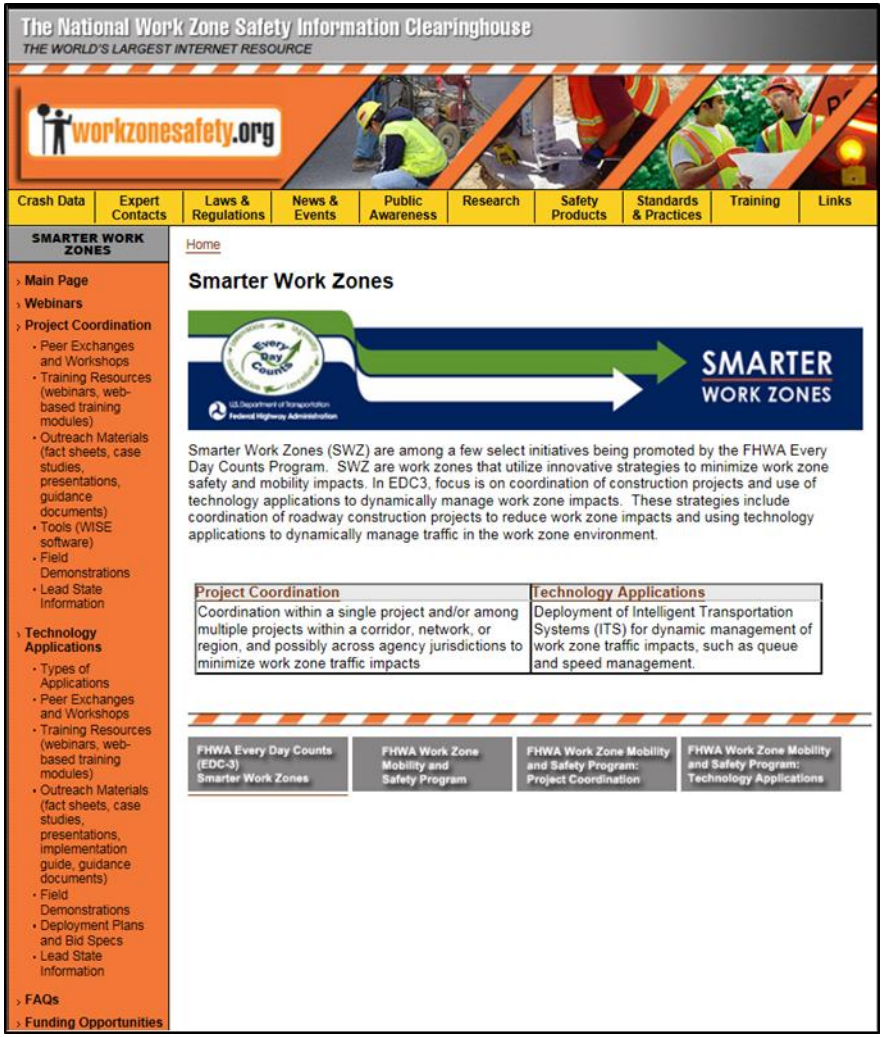


Smarter Work Zones

FHWA Resources

SWZ Interactive Toolkit Available!

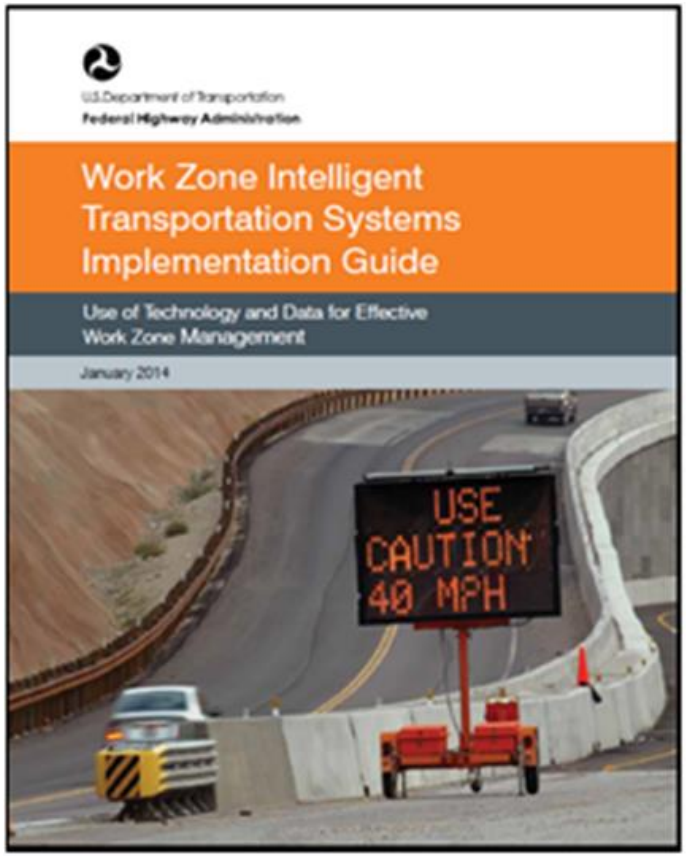
https://www.workzonesafety.org/swz/main



FHWA Work Zone ITS Implementation Guide

http://www.ops.fhwa.dot.gov/publications/fhwahop14008/fhwahop14008.pdf

- Step 1 – Assessment of Needs
- Step 2 – Concept of Operations
- Step 3 – Detailed System Planning
- Step 4 – Procurement
- Step 5 – System Deployment
- Step 6 – System Operation, Maintenance, and Evaluation



Other Resources

- Work Zone ITS Case Studies
  http://www.ops.fhwa.dot.gov/publications/fhwahop14007/

- FHWA Work Zone Mobility and Safety program website
  http://www.ops.fhwa.dot.gov/Wz/its/index.htm

- Work Zone ITS Overview Webinar
  http://www.ops.fhwa.dot.gov/wz/webinars/itsoverview013014/ullman/index.htm

- Variable Speed Limits in Work Zones – Summary of Uses and Benefits
  http://www.enterprise.prog.org/Projects/2010_Present/iwz/VSL_Summary_FINAL_June2014.pdf

- Dynamic Merge Systems in Work Zones – Summary of Uses and Benefits
  http://www.enterprise.prog.org/Projects/2010_Present/iwz/DynamicMerge_Summary_FINAL_June2014.pdf

- ATSSA Guidance for the Use of Dynamic Lane Merge Strategies
  https://www.workzonesafety.org/fhwa_wz_grant/atssa/atssa_dynamic_lane_merging

Thanks for joining us!

- **Upcoming Events**
  - Webinar #7: Smarter Work Zones – Program-Based Project Coordination
    - Wednesday, December 2, 2015, 2:00-3:30pm EST
    - Registration: https://connectdot.connectsolutions.com/e5u8oboez7z/event/event_info.html
  - Webinar #8: Project Coordination/Technology Application Showcase
    - Tuesday, December 15, 2015, 1:00-2:30pm EST
  - Regional Peer Exchanges

FHWA DFS Region	Location	Dates
Mid-America	Des Moines, Iowa	October 22-23
North	Springfield, Massachusetts	October 28-29
South	Raleigh, North Carolina	November 5-6
West	**Denver, Colorado**	**November 17-18**

  - Check The National Work Zone Safety Information Clearinghouse website for updates https://www.workzonesafety.org/SWZ/main
  - **Questions or Comments?**
    - Jawad Paracha (FHWA Operations, Program Manager WZ Team) Jawad.Paracha@dot.gov

For more information from our presenters:

- Todd Peterson, FHWA Office of Operations
  todd.peterson@dot.gov
- Josh Van Jura, Utah DOT
  jvanjura@utah.gov
- Chris Brookes, Michigan DOT
  brookesc@michigan.gov