Smart Work Zone Systems

NORTH CAROLINA
Department of Transportation

Dynamic Zipper Merge Systems

Zachary Clark, PE

ARTBA National Work Zone Management Conference
October 28, 2026

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina

Disclaimer

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Smart Work Zone Tools Used by the NCDOT

- Connected Lane Closure Devices
- End-Of-Queue Warning System
- Dynamic Zipper Merge Systems
- Variable Speed Limits in WZs
- Travel Time Systems
- Truck Entering Systems

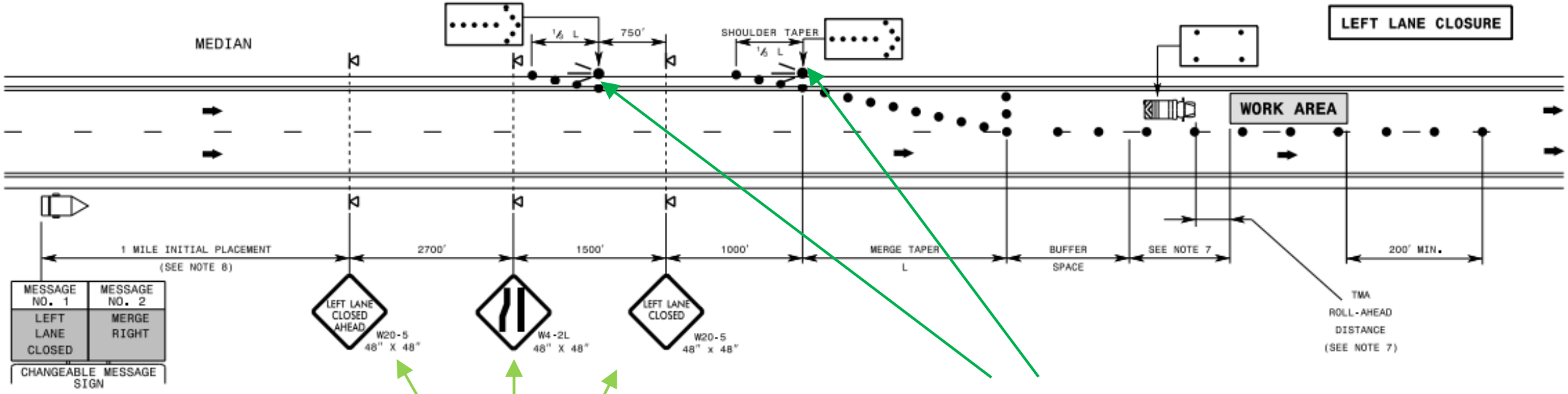
Early Lane Merge

- Conventional Method of closing lanes on a freeway facility
  - CMS several miles upstream of merge
  - Static signs ~1 mile upstream of merge
- Encourage Drivers to Change Lanes Early through advanced warning signs and message boards
- Effective when volumes are less than roadway capacity (e.g. free flowing condition)
- Early Lane Merge setups during queuing (i.e. demand exceeds capacity) may cause:
  - Longer queues
  - Queue jumping
  - Abrupt lane merging
  - Aggressive driving
  - Increase in crashes



https://www.360wichita.com/BusinessServices/Signs/Traffic-Control-Services-Inc.html

Early Lane Merge (or Conventional Merge)



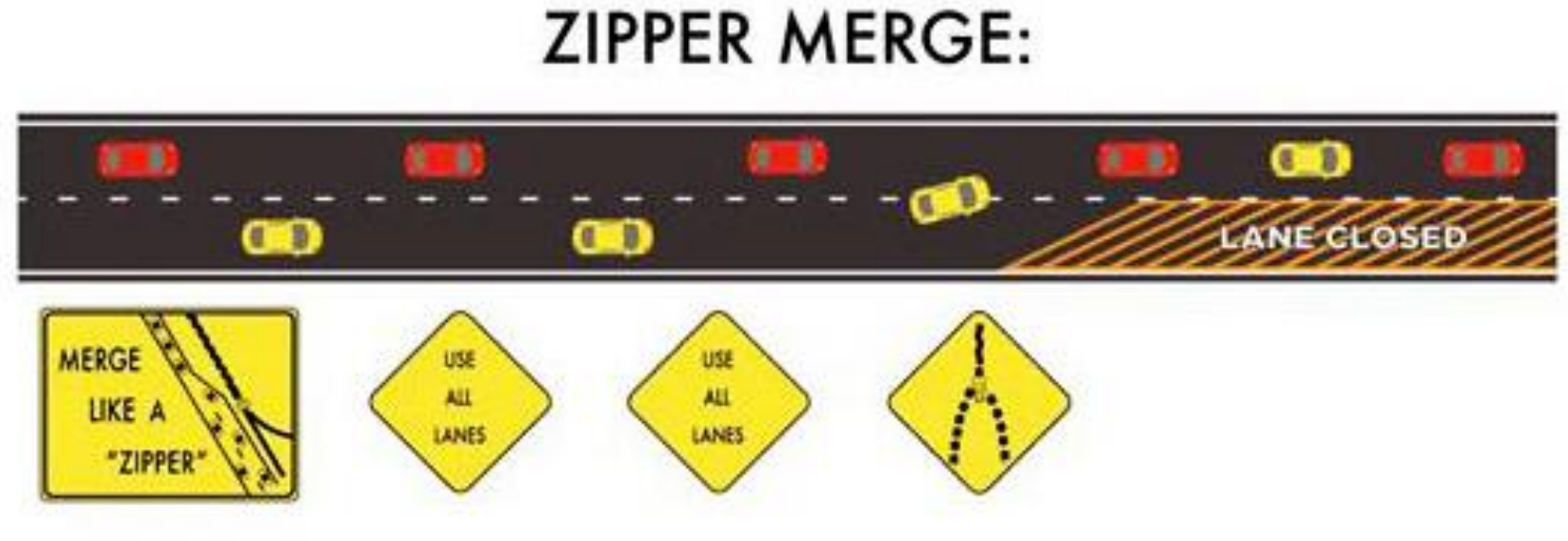
Changeable Message Sign*

Advanced Warning Signs

Flashing Arrow Boards

Late Lane Merge (aka Zipper Merge)

- Encourage Drivers to use all lanes to merge point
- Don’t tell drivers which lane is closed
- Encourage drivers to take turns at merge point



Source: ITRE

Dynamic Zipper Merge System allows you to do both Early and Late Lane Merge depending on conditions

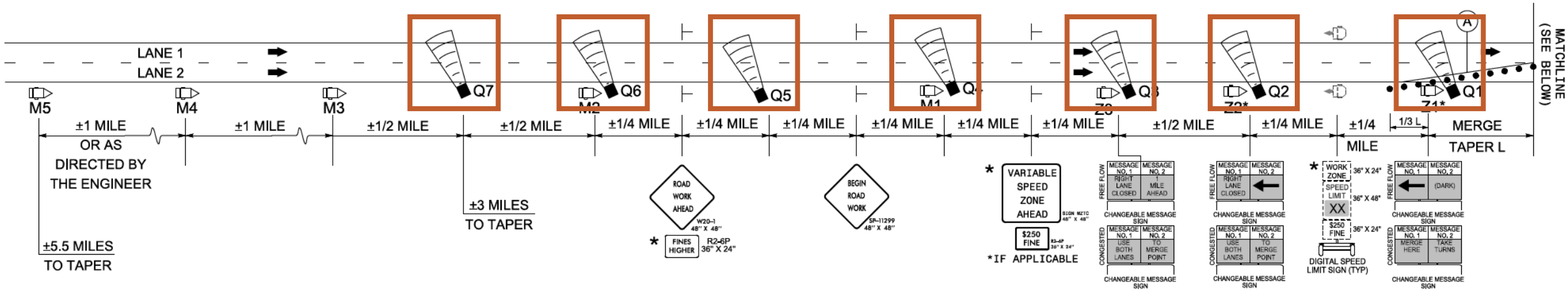
Speed Sensors

- Zipper Merge System Layout is included in the Transportation Management Plan (TMP)

Every ½ Mile

LEGEND

- SPEED SENSOR Q#(1-7)
- PORTABLE CHANGEABLE MESSAGE SIGNS (PCMS)
  - M#(1-5) = MAINLINE
  - Z#(1-3) = ZIPPER MERGE
  - *Z1 & Z2 SHALL BE FULL MATRIX
- CONNECTED LANE CLOSURE DEVICE
- DRUM
- TRUCK MOUNTED ATTENUATOR (TMA)
- STATIONARY SIGN

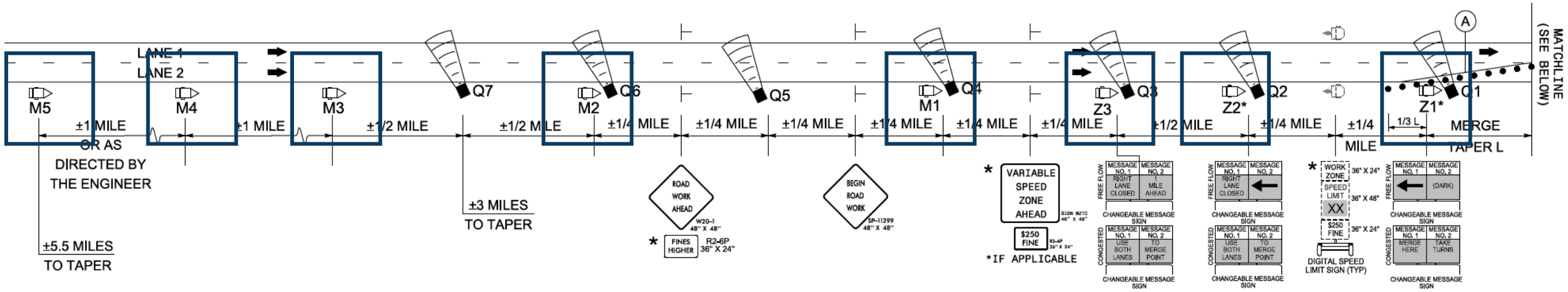


Portable Changeable Message Signs

Every 1 Mile

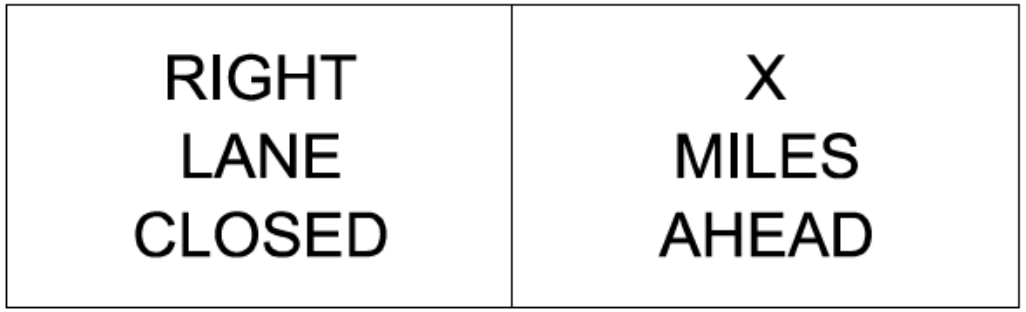
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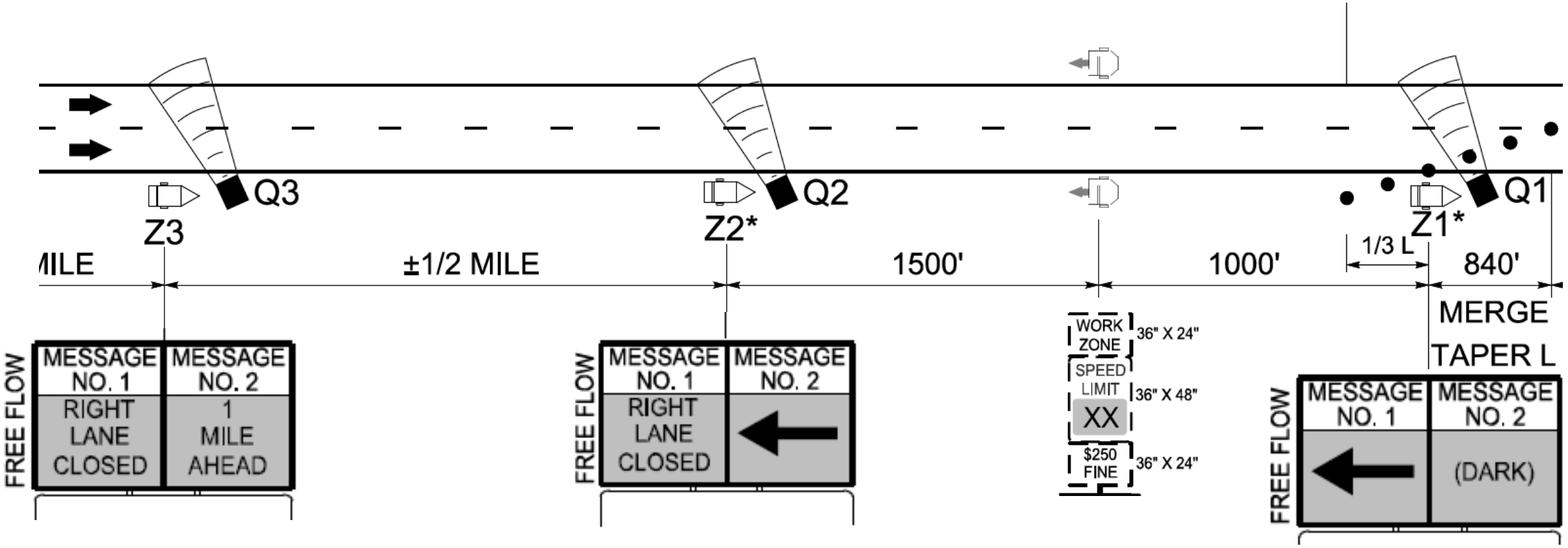
How it Works

- Several Miles in advance of lane reduction:
  - Speed sensors approximately every ½ mile
  - Changeable Message Signs (CMS) approximately every mile
  - Data from the speed sensors determines the messages on the CMS
- When traffic is free-flowing, the messages will follow an Early Lane Merge setup
  - CMS furthest upstream alert motorist of the closure.
  - CMS closer to merge post action information (e.g. arrow).



How it Works

- When traffic is free-flowing, the messages will follow an Early Lane Merge setup
- CMS further upstream post “RIGHT LANE CLOSED / X MILES AHEAD”.



How it Works

As speeds fall (e.g. <45 mph), signs begin to warn drivers of slow traffic ahead.



Signs approaching merge point encourage use of both lanes.



At the taper, signs encourage to merge like a zip.



How it Works

As speeds fall further (e.g. <25 mph), signs begin to warn drivers of stopped traffic ahead.

STOPPED TRAFFIC AHEAD (or X MILE)	PREPARE TO STOP

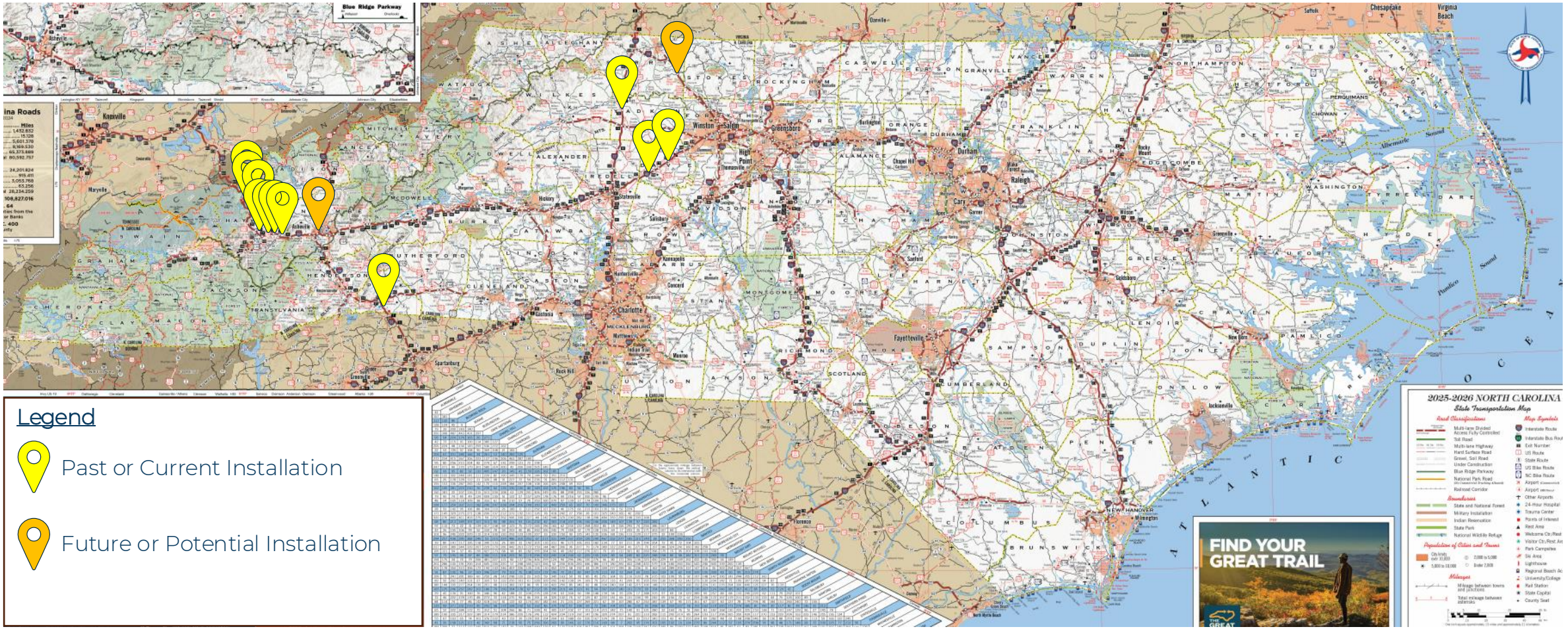
Signs approaching merge point encourage use of both lanes.



At the taper, signs encourage to merge like a zip.



Installations



NCDOT Research Project Number: 2024-05

Conducted through the NCDOT's Research and Development Office

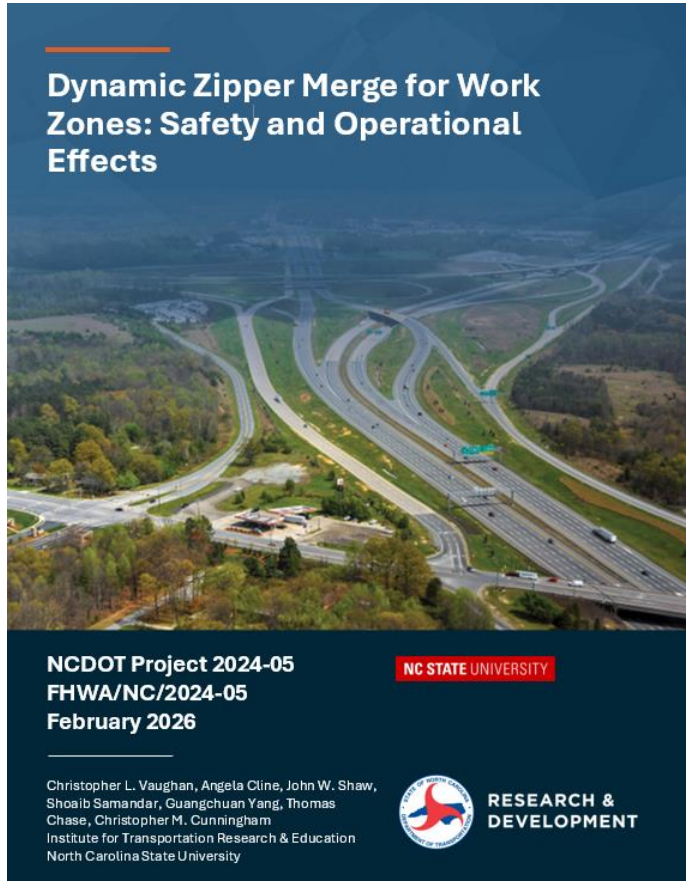
NCDOT Research Project *Effectiveness of NCDOT's Dynamic Zipper Merge System*

- ITRE / NCSU performed the work
- Completed March 2026

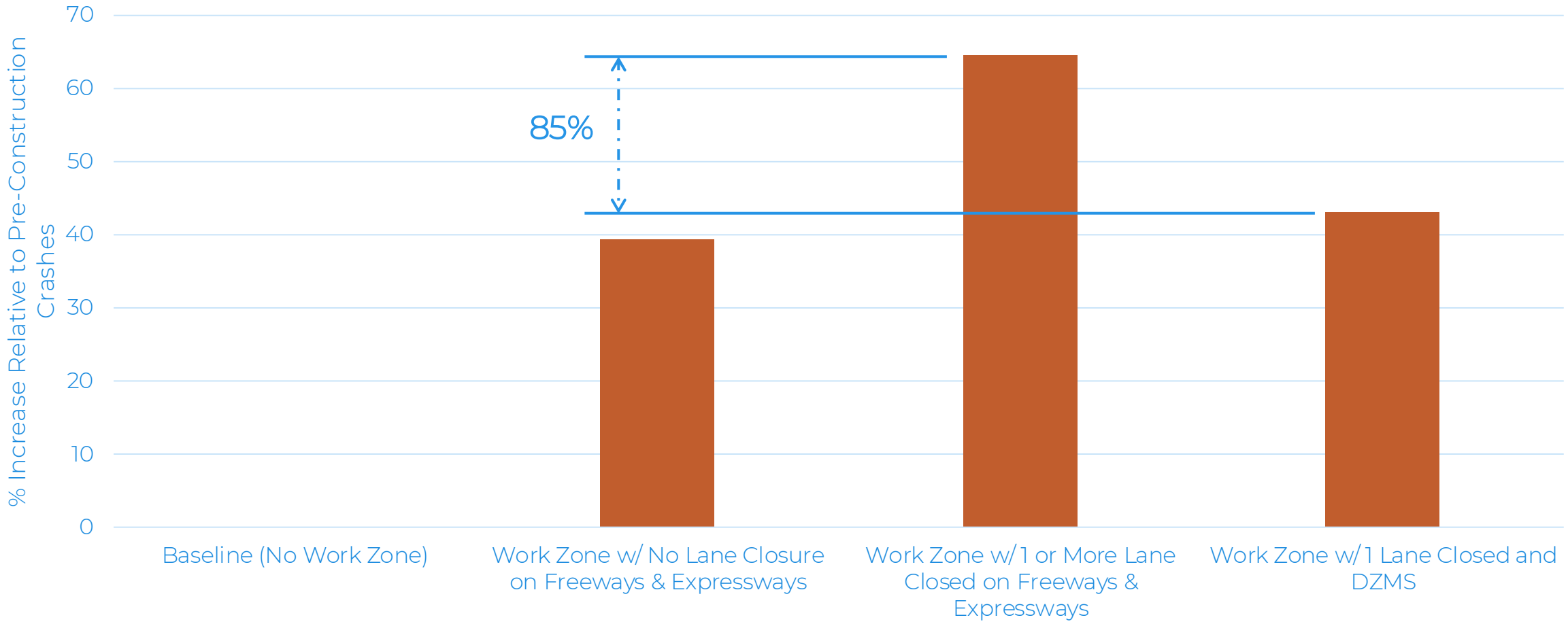
Available at: https://connect.ncdot.gov/projects/research/

The study examines impacts to:

- Safety
- Travel Time Index
- Capacity
- Queuing



Safety Benefits



Summary of Results (Compared to Conventional Merge)

- Mitigates crashes caused by lane closure by ~85%.
- Reduced queue length due to more even lane distribution of 60/40.
- Increases post-breakdown capacity by ~65 pcph
- Reduced deterioration of travel time.

When to Consider

- Long-duration work zones to achieve beneficial B/C (varies by site).
  - Breakeven is 2-3 weeks
  - 1-year deployment provides B/C ~11.
- Construction Considerations
  - Scheduling impacts
    - Work requires more time than what can be accomplished under lane closure & holiday restrictions
    - Long-term lane closure provides significant schedule reduction
  - Prohibitive cost of adequate on- or off-site detour
    - Construction Cost
    - User Cost (e.g. long off-site detour or inadequate capacity)
- Identify while developing the staging concept and management strategies of TMP

Resources

- Project Special Provision available on Workzone Application for Special Provisions (WASP)
  - Use with caution
  - Applicable for up to ~5 miles of expected queueing on a single facility
  - Consider use of Digital Speed Limit Signs and Connected Lane Closure Systems in conjunction
  - Before including any Dynamic Zipper Merge System in a contract, contact the WZTC section
- DRAFT Standard Detail and Conditional Logic Matrix available upon request



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Thank you!

2026 NATIONAL WORK ZONE MANAGEMENT CONFERENCE
OCTOBER 27-29
Reston, Va.
JOIN US, SAVE LIVES!

NATIONAL WORKZONE SAFETY INFORMATION CLEARINGHOUSE

Automated Actionable Road Anomalies (AARA) Lessons Learned





Kelly Wells, PE – NCDOT



Automated Actionable Road Anomalies (AARA)

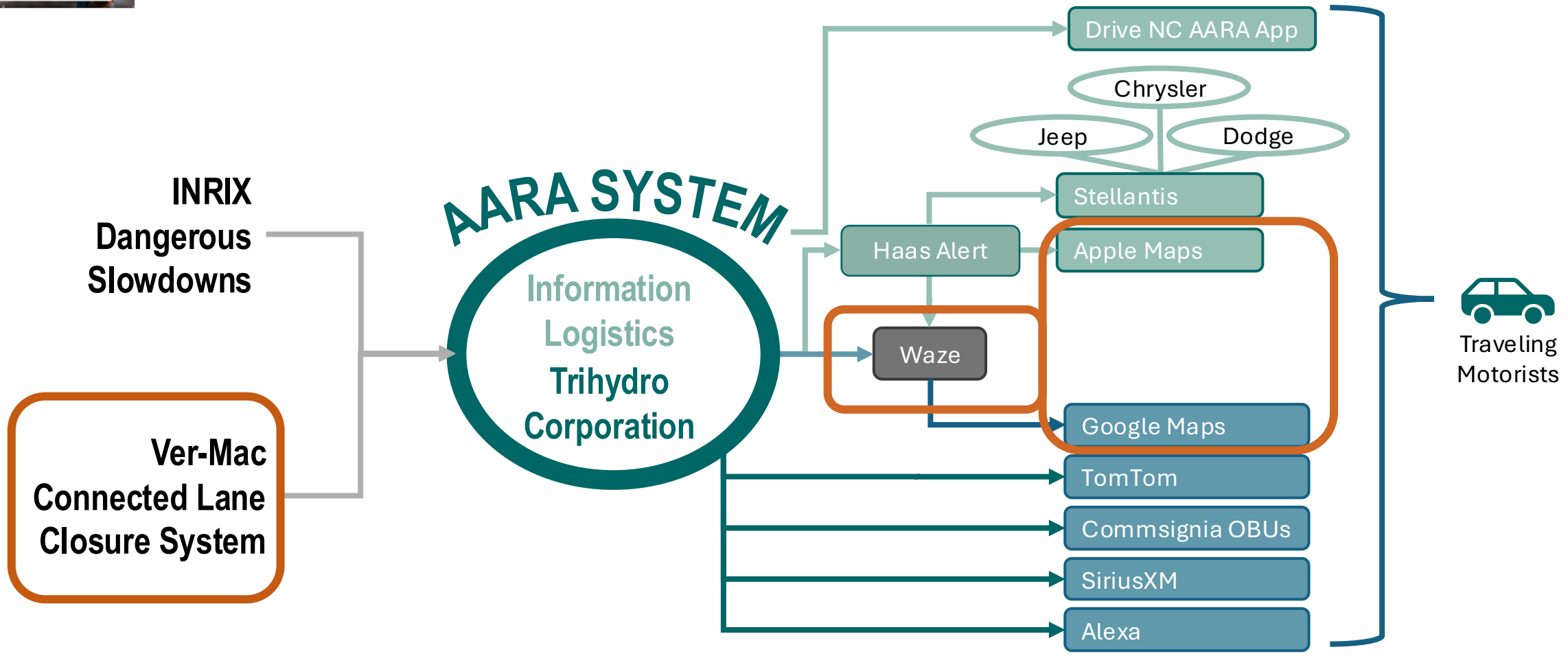
- Real time alerts of things that require **ACTION** on freeways
  - You must change lanes
  - You must slow down
- Info is **AUTOMATED** (no human action needed)
- Into people's **EXISTING APPS** (Waze, Google Maps, and Apple Maps)
- Alerts are **HANDS FREE** and **EYES FREE**

Strengthening Mobility and Revolutionizing Transportation (SMART)

SMART

SMART Grants Program | US Department of Transportation

AARA Solution

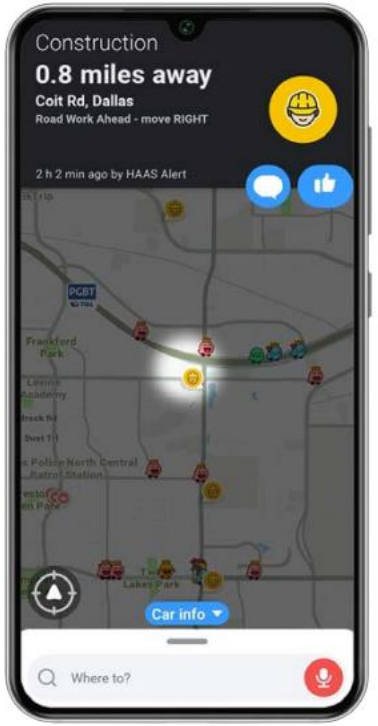


Connected Arrow Board




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WZDX Feed

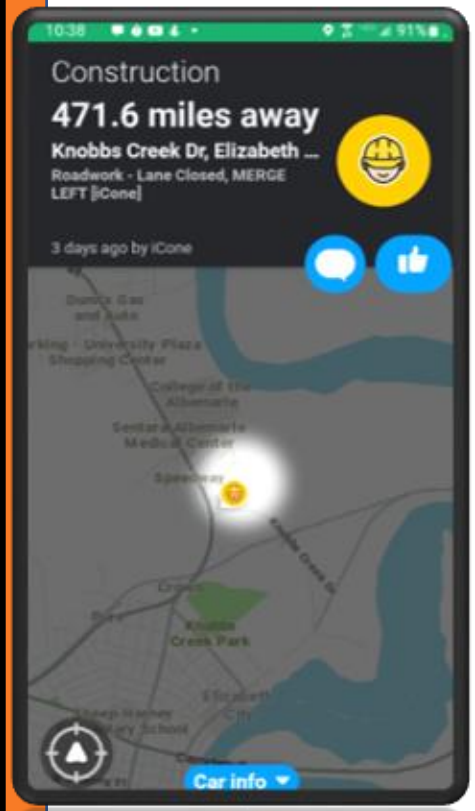




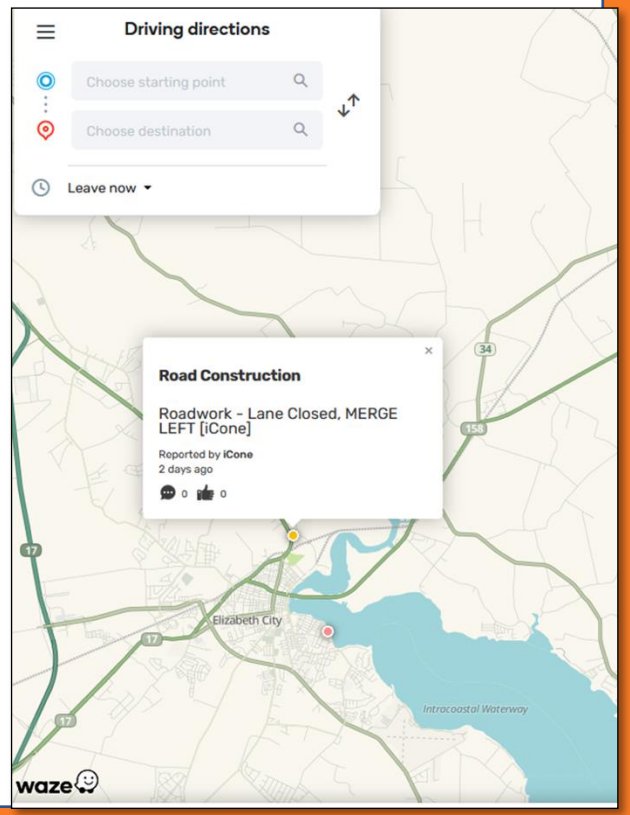
Evaluation Outcomes

- **Waze:** Broadcasted Vermac connected lane closures ☺
  - Waze already doing this before we came along 😐
  - We muddied the water a bit (alert overload) ☹
- **Google and Apple:** Did not consistently see alerts
- **Stellantis:** Verified alert
- **Others:** Not able to verify
- **Outcome:** Lots of process improvements to be made
  - Navigation partners
  - NCDOT

Lesson Learned: Navigation Partners
(i.e., Waze, Google Maps, Stellantis, HAAS Alerts, etc.)



- Operate independently, may not:
  - Broadcast alerts
  - Use preferred wording
- Alerts look different
  - Desktop or Phone
  - Car Play or Android Auto
  - Navigating or Not Navigating
- Waze won't repeat alerts; VERY hard to test



Lessons Learned: Equipment Best Practice

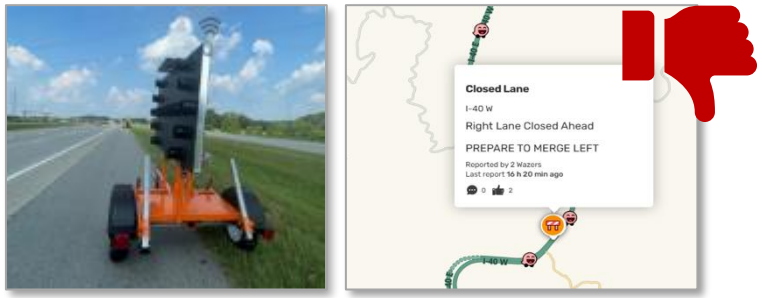
TURN IT OFF — NOT DOWN OR AROUND

(because Waze thinks you're still out there)



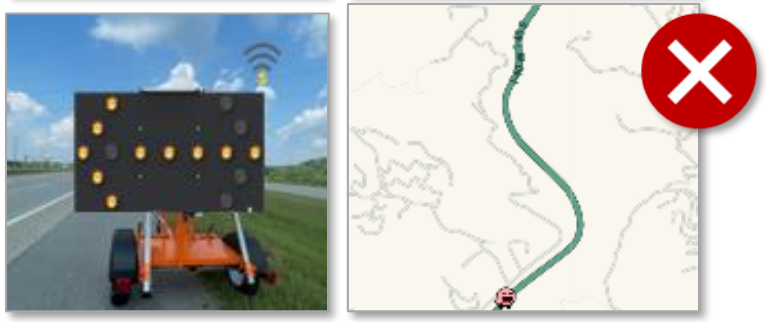
Lane closed:

- Arrow board in place – Waze alerting



Lane opens:

- Arrow board turned sideways – still transmitting to Waze
- Driver gives thumbs down – Waze NOT alerting



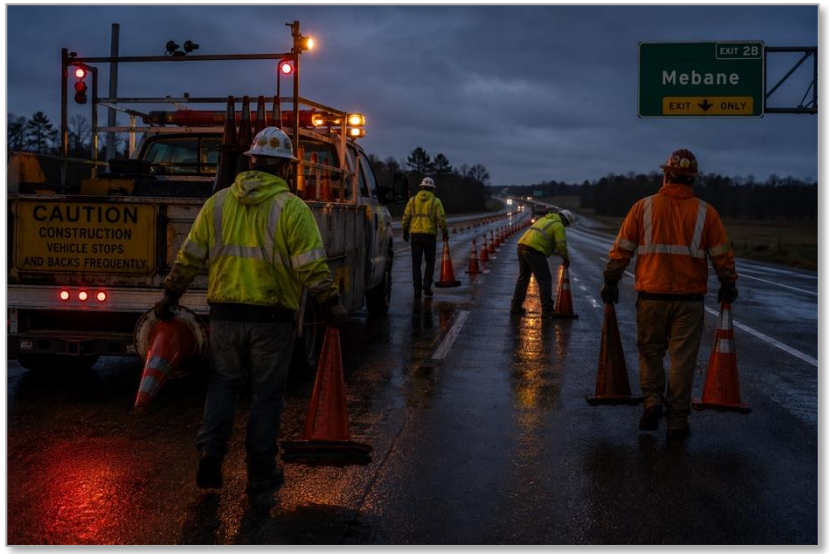
Lane closed:

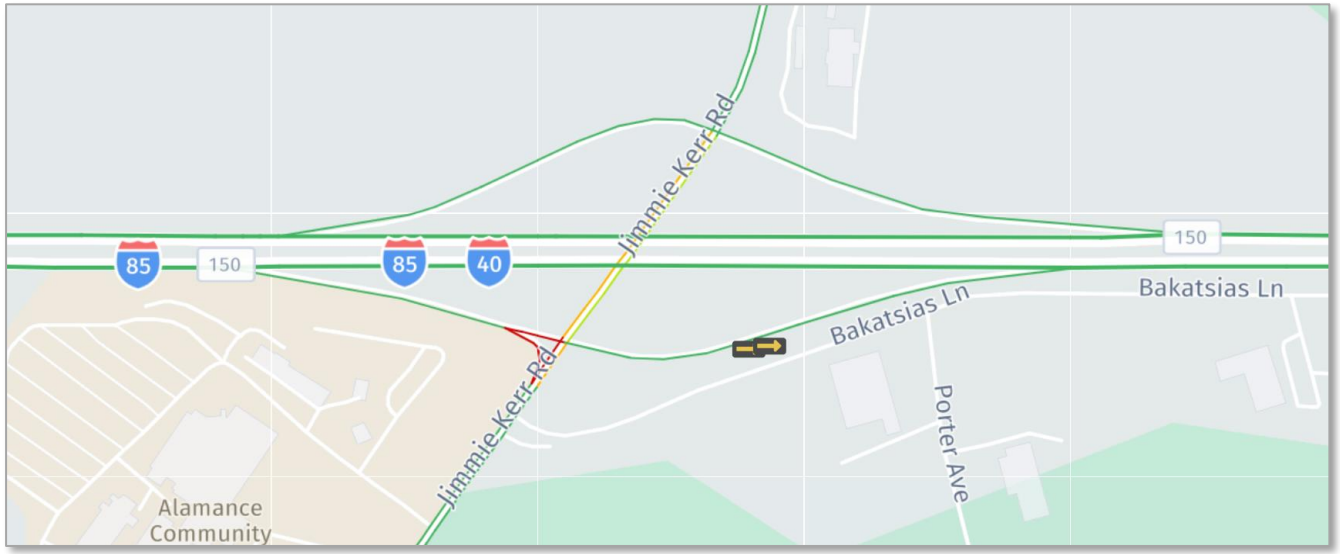
- Arrow board turned back to face traffic – Waze still NOT alerting

Scenario # 2 – Arrow Board On and Moved

3 am: Overnight road work ends

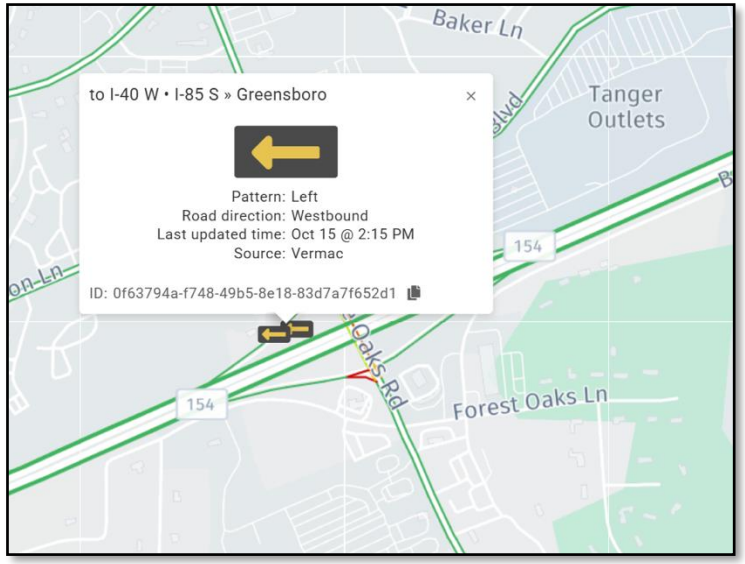
- Lane closure picked up
- Arrow board re-located to gore or ramp
- Not turned off





later that day….





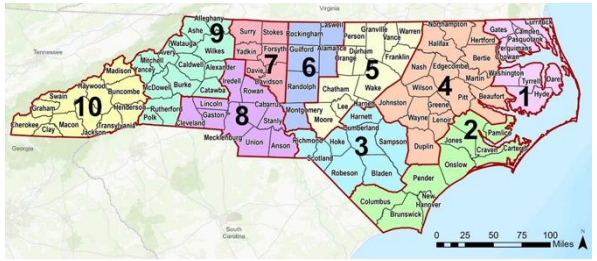




NATIONAL WORKZONE SAFETY INFORMATION CLEARINGHOUSE

- Need your help.
- Alerts intended to improve safety.
- Hurting credibility of alerts.
- What can we do?

Not as easy as it looks…



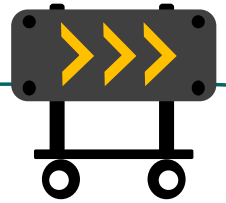


Source: Ver-Mac

NCDOT Connected Lane Closure System (CLCS) Spec

QPL/APL

DOT Engineer
Prime Contractor
MOT Subcontractor



Ver-Mac
Wanco
iCone
Haas

Work Zone Data Exchange (WZDx) Feed

ATMS

Ram
Chrysler
Jeep
Dodge
Stellantis

HAAS ALERT
HAAS Alert
Apple Maps
Waze
GoogleMaps
TomTom
HERE

Traveling Motorists

CONNECTED LANE CLOSURE DEVICES:
(10/29/2018)

Description

Furnish, install, operate, maintain, relocate, and remove connected lane closure devices for use on Interstate and Freeway lane closures. The connected lane closure devices shall transmit the location of the lane closure to navigational companies such as WAZE, Google Maps, Inrix, Here, TrafficCast, TomTom, Apple Maps, Panasonic, the Statewide Transportation Operations Center, (STOC), and any other navigational companies that requests it. A connected lane closure device shall be installed on the flashing arrow board identifying the beginning of a lane closure, and another connected lane closure device shall be installed on a crashworthy traffic control device (such as a drum) at the end of the same lane closure.



Source: Shutterstock

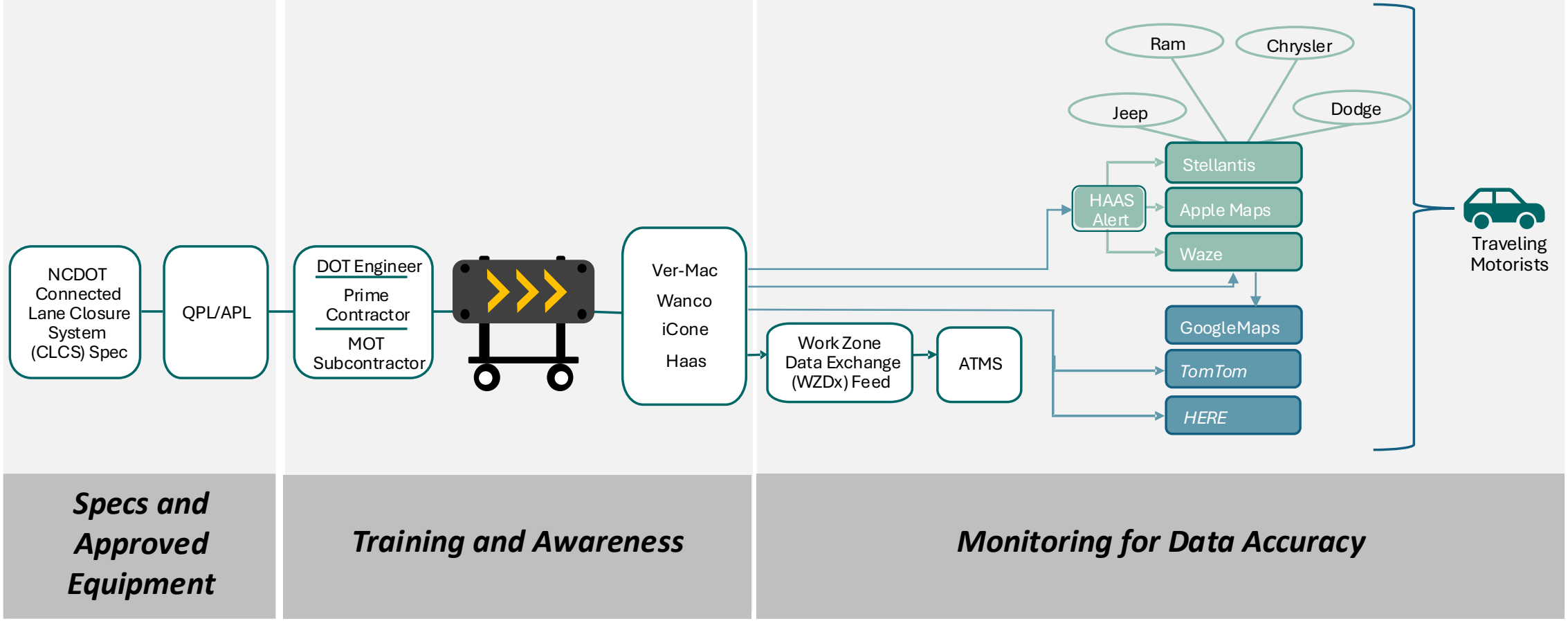
VER-MAC
WANCO
iCone
IoR - Internet of RoadWork
HAAS ALERT

Sources: Ver-Mac, Wanco, Icone, HAAS

WZDx
WORK ZONE DATA EXCHANGE

Source: Federal Highway Administration

Not as easy as it looks…*where to focus*



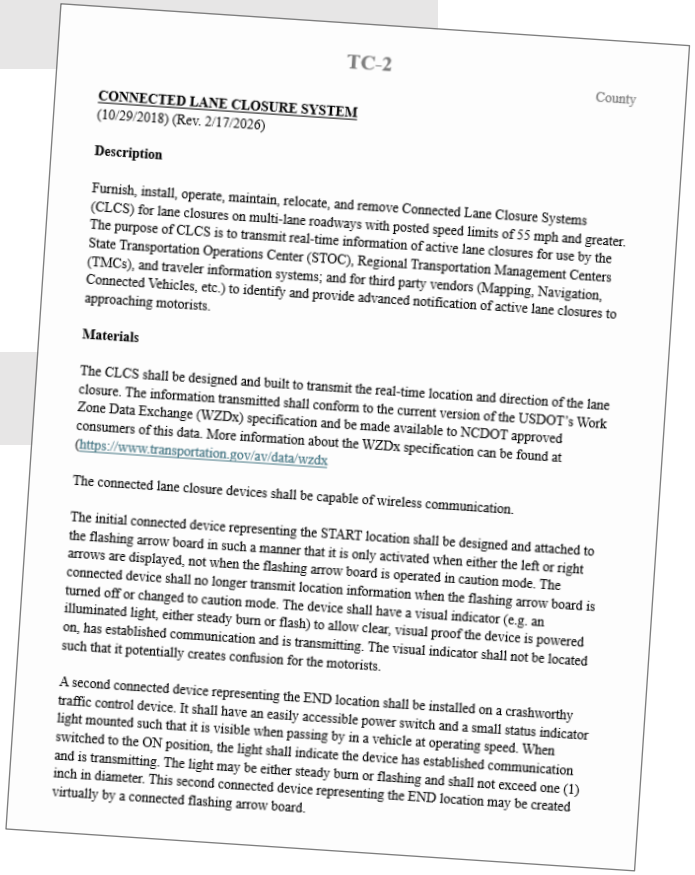
Focus Area: Connected Lane Closure System (CLCS) Specifications

Feed Update Frequency (15 minutes)

- Manufacturers comm costs increase
- DOTs want timely information

End Marker

- Spec requires but low usage in field
- Used to show length of lane closure?



TC-2

CONNECTED LANE CLOSURE SYSTEM County
(10/29/2018) (Rev. 2/17/2026)

Description

Furnish, install, operate, maintain, relocate, and remove Connected Lane Closure Systems (CLCS) for lane closures on multi-lane roadways with posted speed limits of 55 mph and greater. The purpose of CLCS is to transmit real-time information of active lane closures for use by the State Transportation Operations Center (STOC), Regional Transportation Management Centers (TMCs), and traveler information systems; and for third party vendors (Mapping, Navigation, Connected Vehicles, etc.) to identify and provide advanced notification of active lane closures to approaching motorists.

Materials

The CLCS shall be designed and built to transmit the real-time location and direction of the lane closure. The information transmitted shall conform to the current version of the USDOT's Work Zone Data Exchange (WZDx) specification and be made available to NCDOT approved consumers of this data. More information about the WZDx specification can be found at (https://www.transportation.gov/av/data/wzdx

The connected lane closure devices shall be capable of wireless communication.

The initial connected device representing the START location shall be designed and attached to the flashing arrow board in such a manner that it is only activated when either the left or right arrows are displayed, not when the flashing arrow board is operated in caution mode. The connected device shall no longer transmit location information when the flashing arrow board is turned off or changed to caution mode. The device shall have a visual indicator (e.g. an illuminated light, either steady burn or flash) to allow clear, visual proof the device is powered on, has established communication and is transmitting. The visual indicator shall not be located such that it potentially creates confusion for the motorists.

A second connected device representing the END location shall be installed on a crashworthy traffic control device. It shall have an easily accessible power switch and a small status indicator light mounted such that it is visible when passing by in a vehicle at operating speed. When switched to the ON position, the light shall indicate the device has established communication and is transmitting. The light may be either steady burn or flashing and shall not exceed one (1) inch in diameter. This second connected device representing the END location may be created virtually by a connected flashing arrow board.



Focus Area: Connected Lane Closure System (CLCS) Specifications (contd)

Gyroscope / Compass

- Could help with orientation of sign to traffic – not foolproof
- Helps verify message is transmitting on correct side of road

WZDx Device Feed Required Attributes

- Now Connected Work Zone standard
- NCDOT may require
  - Road Name
  - Direction
  - Transport Position

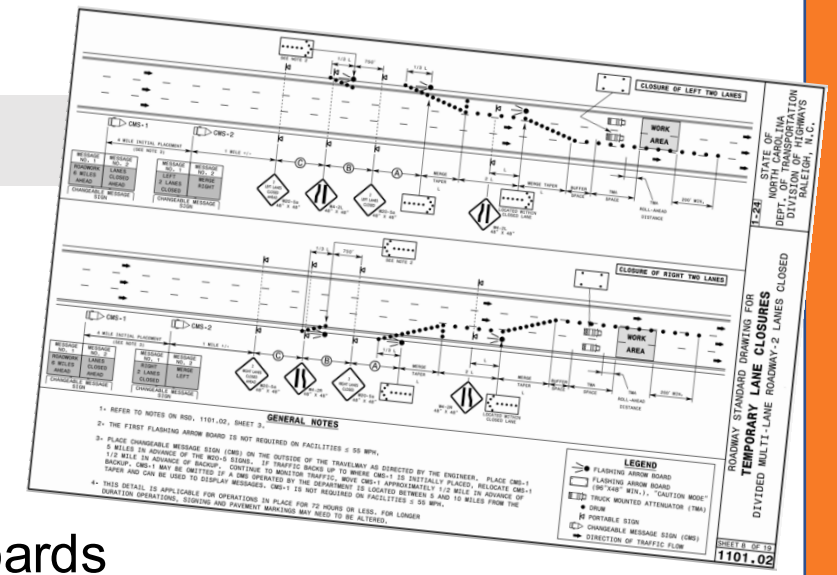
Focus Area: Spec Usage and Standards

Spec Usage

- How to get CLCS spec in all contracts?
- How to get Maintenance to use connected lane closures?

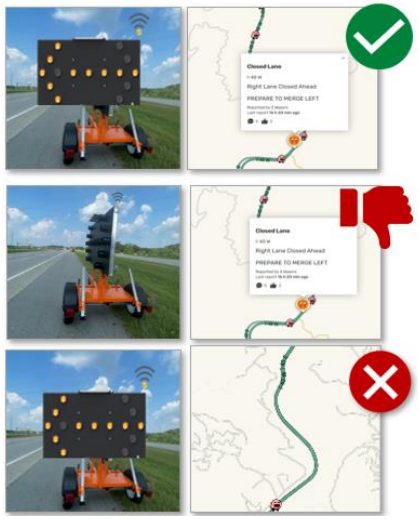
Standards

- Next update published in 2030
- Multi-lane closures
  - Triple lane closures = do we want 3 alerts?
  - If yes, they may come quickly
  - If no, will have connected and non-connected arrow boards on same project



Focus Area: Training and Awareness

TURN IT OFF — NOT DOWN OR AROUND



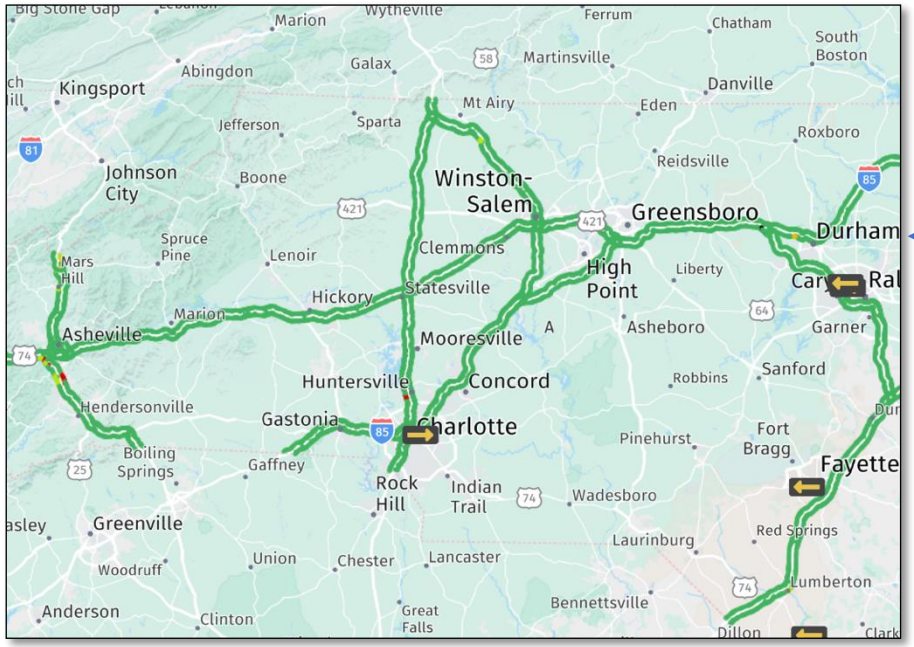
- Training Topics
  - Verify lane closure is activated and is transmitting
  - Verify lane closure is deactivated and is no longer transmitting
- Training Audience
  - Construction Inspector, Residents, Assistant Residents
  - Prime Contractors, Work Zone Traffic Control Sub-Contractors

Looking for a way to make the training STICK.

Got good ideas for videos, promotional trinkets, slogans, etc. – I have candy! ☺

Focus Area: Data Accuracy Mapping Tool

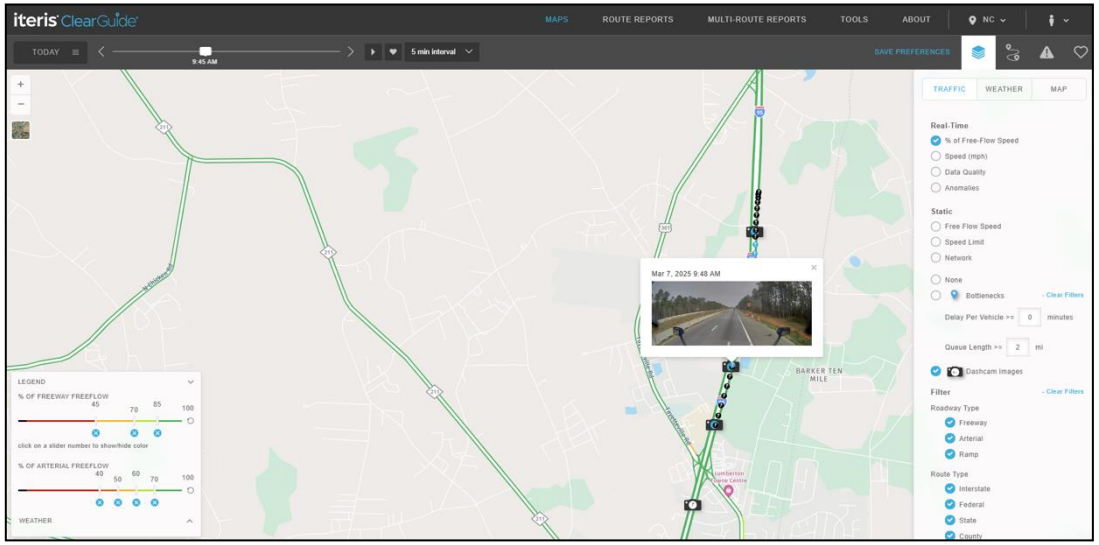
- Connected arrow boards integrated into Iteris Clearguide
- Connected arrow boards as work zone detection source for TMC's
- Plan to integrate into ATMS




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WZDX Feed

Focus Area: Data Accuracy Detection Tool





Source: Iteris/Vizzion Dashcam

- Vizzion Dashcams integrated into Iteris Clearguide
- Verification tool for lane closures
  - For work zones
  - For crashes, etc.
- Low frequency of images



Questions

Kelly E. Wells, PE

Traveler Information Engineer – Traffic Systems Operations

Transportation Mobility and Safety Division

kwells@ncdot.gov

Remember to share your ideas – I have candy!