Queue Protection



NATIONAL WORKZONE SAFETY INFORMATION CLEARINGHOUSE

ATSSA

Safer Roads Save Lives

Queue Protection

Eric Perry, PE, PMP



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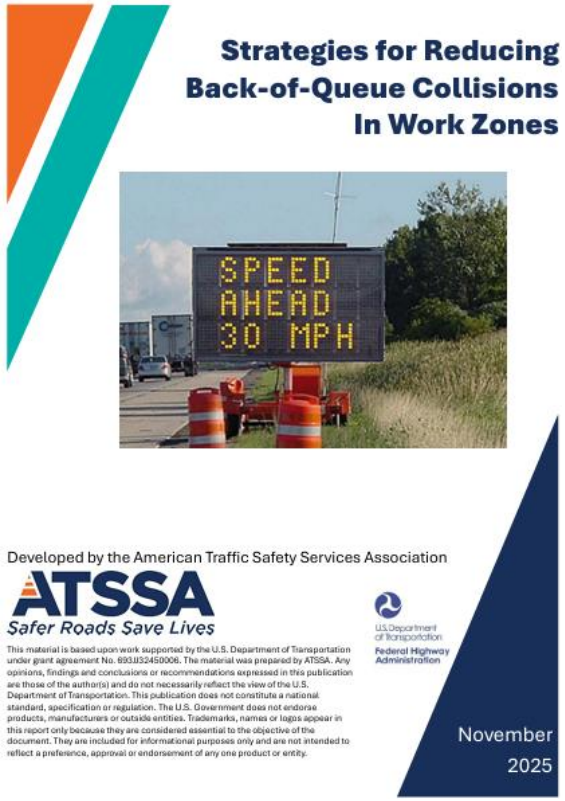
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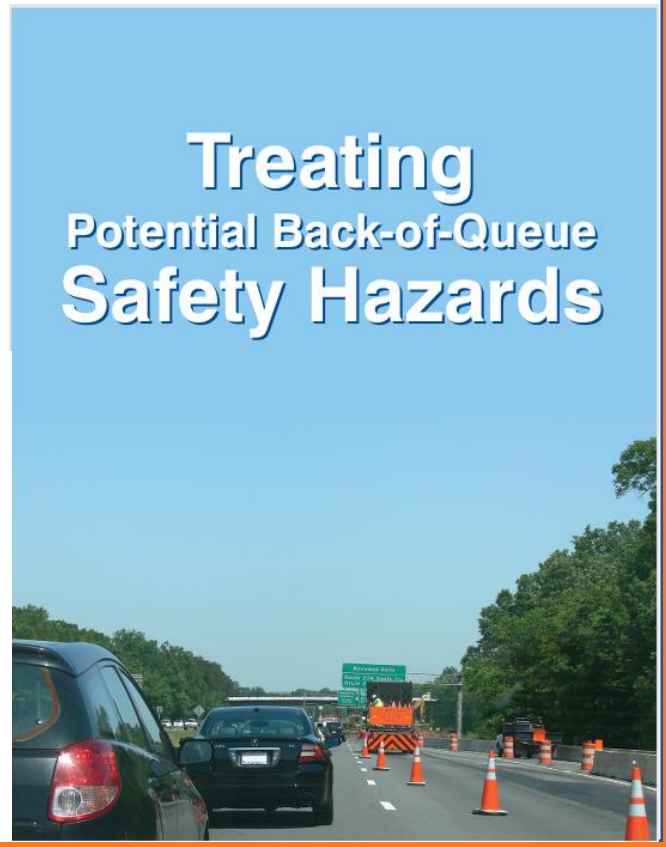
FHWA Work Zone Safety Grant Publications

NATIONAL WORKZONE SAFETY INFORMATION CLEARINGHOUSE

- Published in 2025



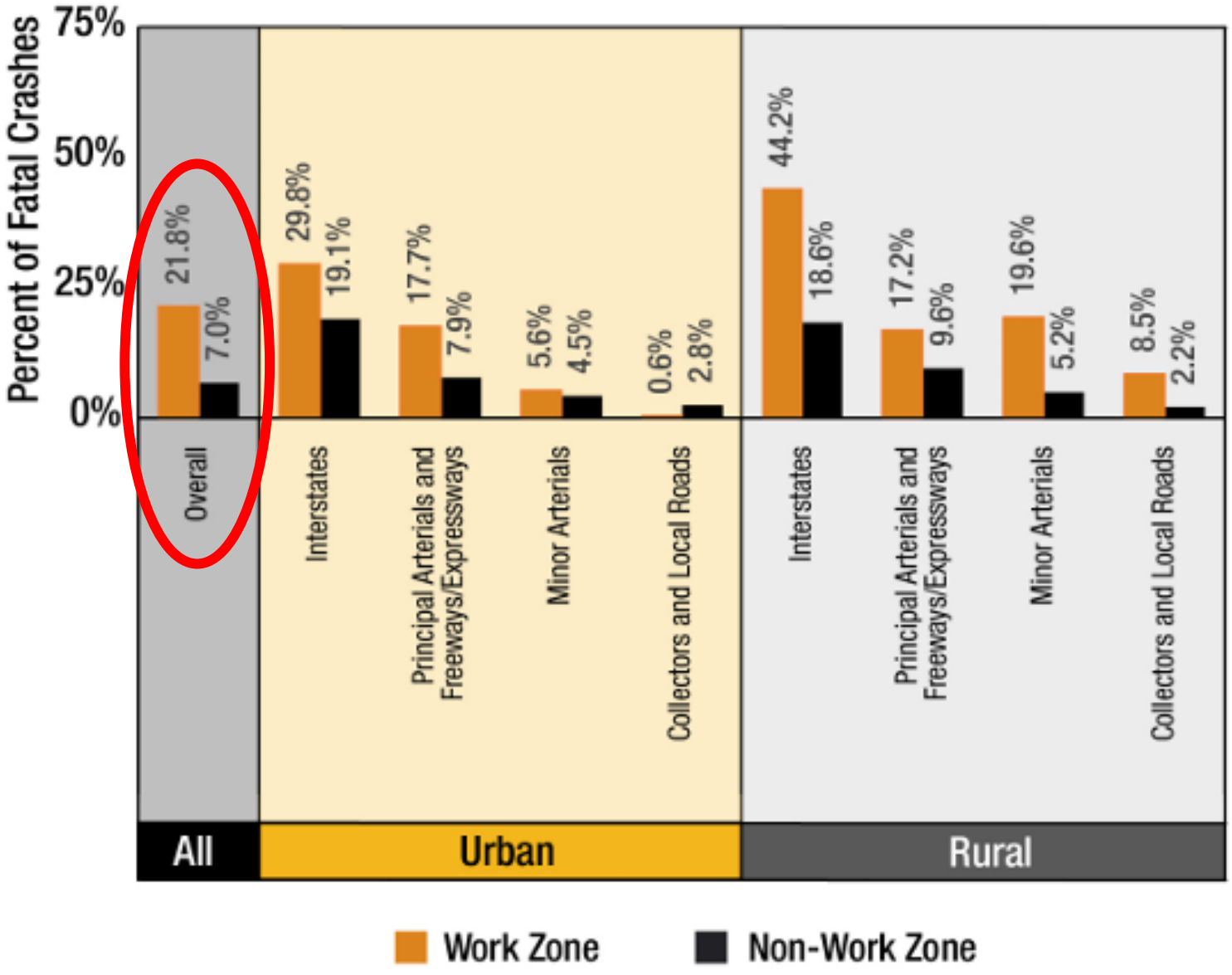
- Published in 2009



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Source: National Work Zone Safety Information Clearinghouse



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How does a queue start?

DEMAND > **CAPACITY**

Once demand exceeds available capacity, the queue begins growing upstream.

Note: Curvature, grades and limited sight distance shrink the time drivers have to respond.

30–40 mph

reported backward-moving queue growth



≈ 1 mile every 2 minutes



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How can we mitigate?

1 ELIMINATE OR REDUCE THE QUEUE — Schedule, stage, maintain lanes, divert demand

2 SHAPE TRAFFIC BEFORE THE BOTTLENECK — Tapers, merge strategy, sign spacing

3 WARN BEFORE THE QUEUE — Static, mobile or active warning

4 MONITOR + RESPOND — Detect, move, update

Queue protection works as a system

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Example: Queue Detectors

- In combination with Portable Changeable Message Signs
- Display advisory information
  - Current speeds
  - Stopped or slowed traffic
  - Delays
  - Alternate routes



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Examples: Advance Warning System

- Portable queue warning system
- Device is located on shoulder
- Use of static sign in combination with flashing lights
- Warn motorists

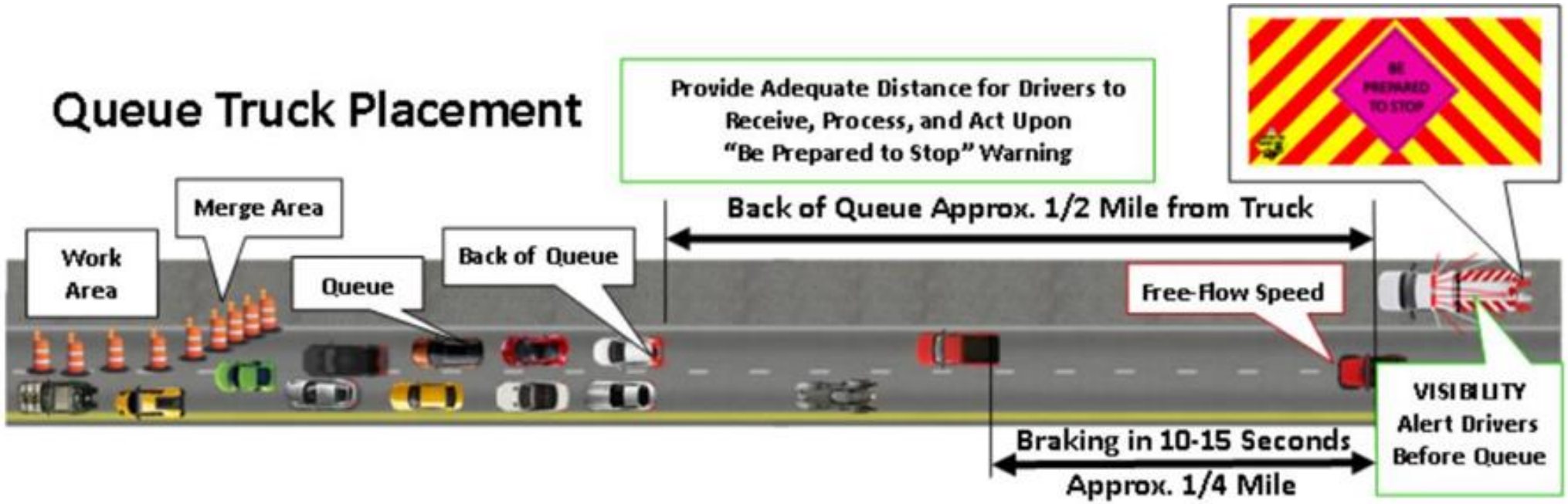


Queue Warning Using a Mast Arm Device
Source: MDOT

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Example: Dynamic Queue Trucks



Indiana Queue Warning Design (Source: Indiana DOT)



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Closing

- Queue protection is a system:
  - Anticipate
  - Reduce
  - Warn
  - Adapt
- Ask yourself three questions
  - Where will the queue form?
  - How will drivers be warned before they reach it?
  - How will the response adapt as the queue moves?



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Practices and Innovations for Queue Protection Truck Deployment in Work Zones

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CUTR Center for Urban Transportation Research

UNIVERSITY of SOUTH FLORIDA

October 29, 2026

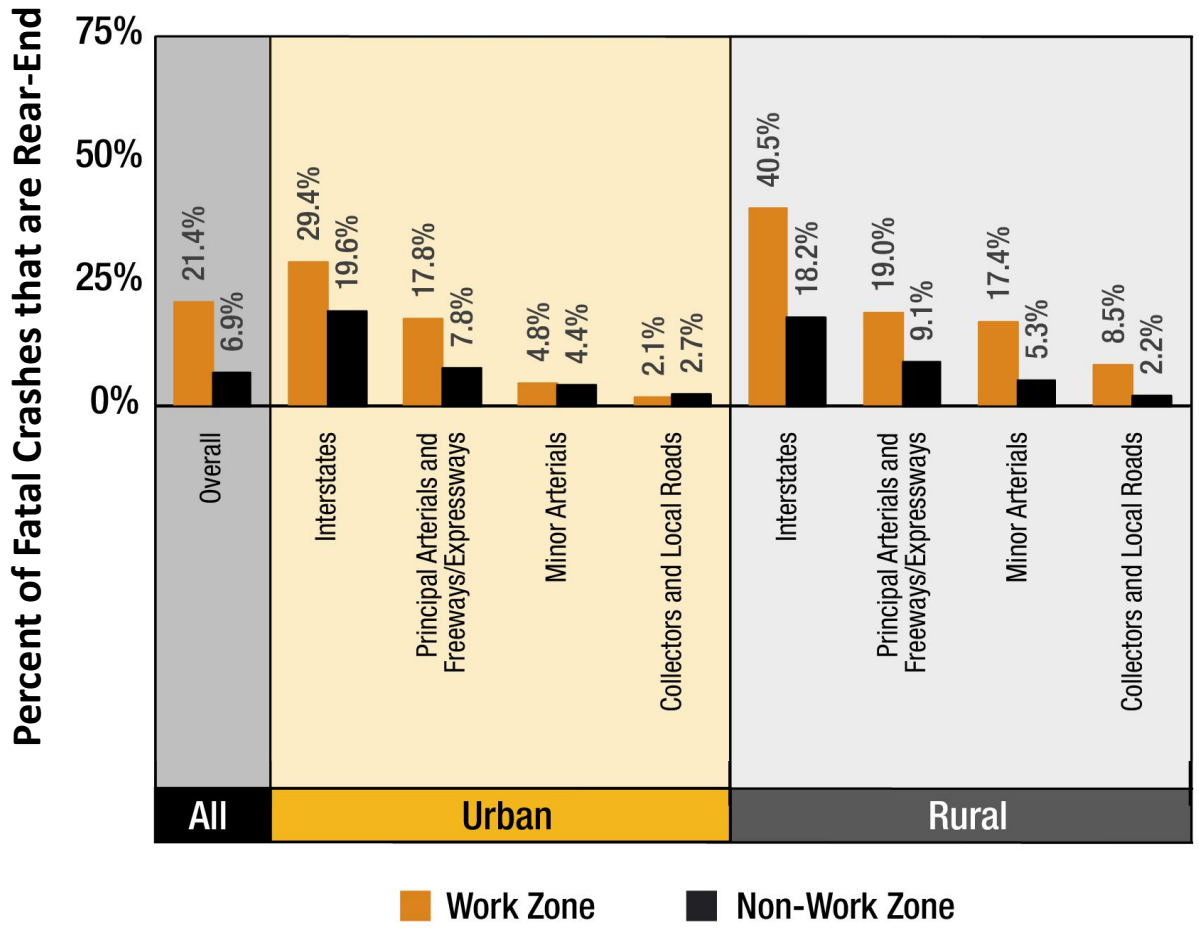


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Source: National Work Zone Safety Information Clearinghouse

Rear-End Collision Involvement in Fatal Work Zone and Non-Work Zone Crashes, 2022-2024 Average



Do Queue Protection Trucks Help?

TDOT's Protect the Queue Campaign showed a 25% to 48% reduction in secondary crashes (queueing occurred as the result of a primary incident)

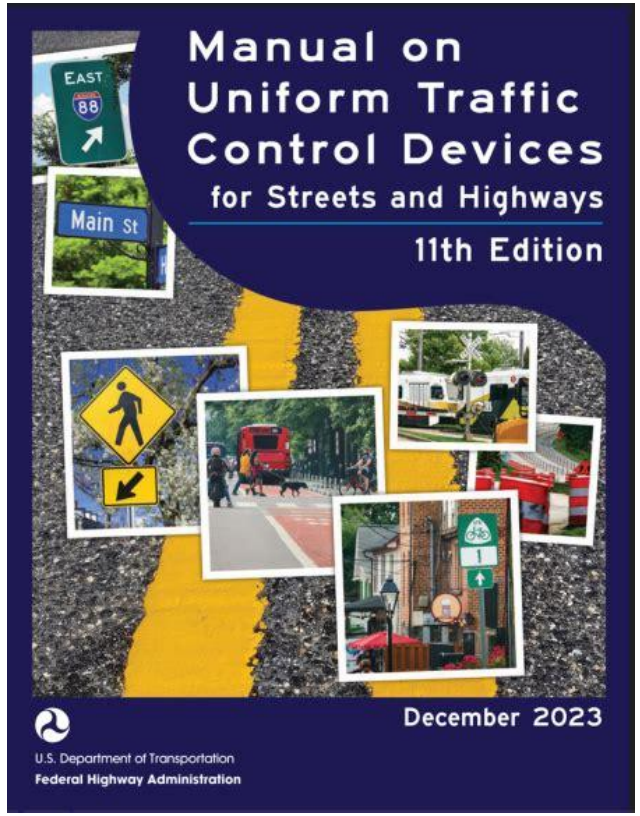
INDOT's Protect the Queue Program showed an 87% reduction in hard braking events

https://www.safehighways.org/wp-content/uploads/2018/07/SSPIdeaSharingSessionX_KDuaneManning_6.28.2018.pdf

https://www.itskrs.its.dot.gov/2022-I01100

MUTCD and FHWA Basics

"An assessment of the expected queue length, which should be a part of the TTC plan design process, might result in adjustments to the sign spacing and number of signs, as well as the use of more conspicuous devices to increase the distance and conspicuity of the advance warning area."



Source: MUTCD

How do you decide when to use Queue Protection Trucks?

Queue Protection Truck Guidance for KYTC Work Zones

When to consider Queue Protection Truck(s)

- Interstates, parkways, and other high-speed/high-volume routes
- Adequate shoulder widths to allow the placement of Queue Protection Truck(s)
- Anticipated queue lengths more than ½ mile

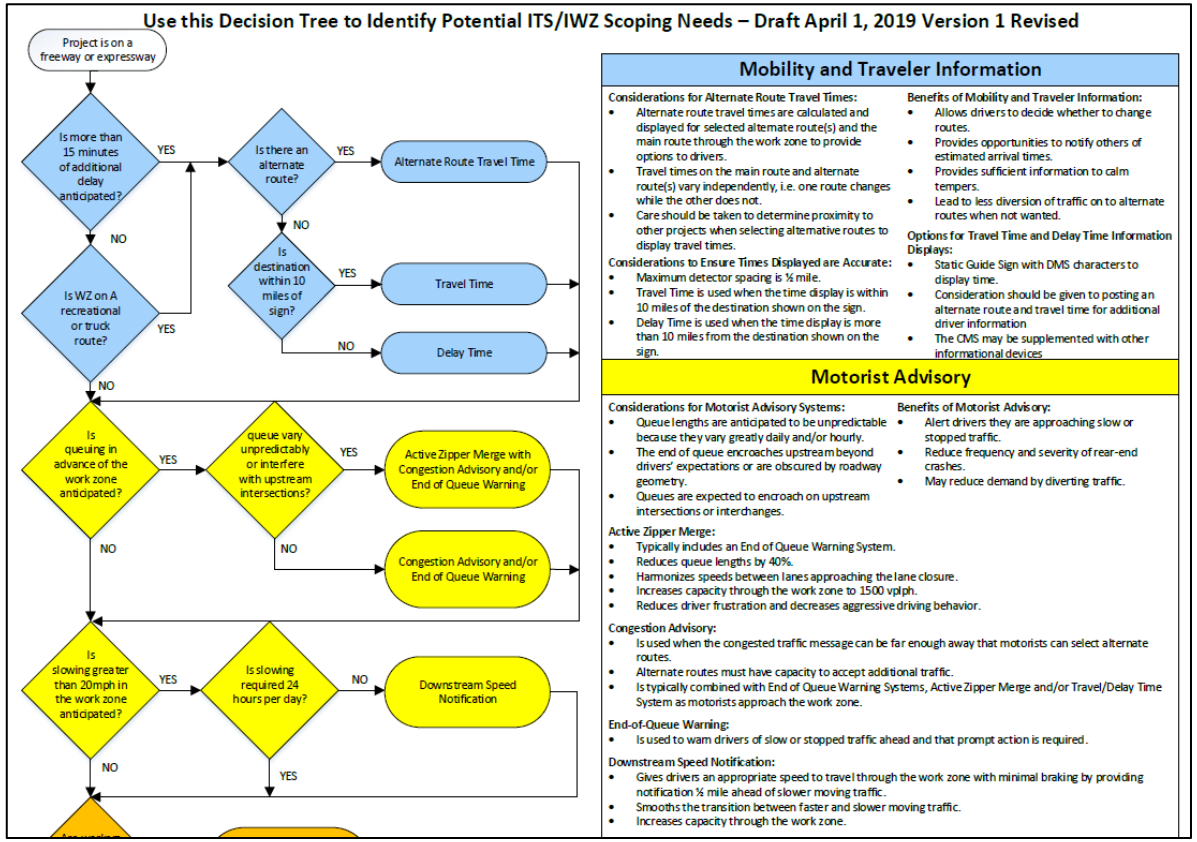


Source: KYTC

How do you decide when to use Queue Protection Trucks?

Queue Protection Checklist Form for MNDOT Work Zones

https://www.dot.state.mn.us/its/docs/scopingdecisiontree.pdf



Use this Decision Tree to Identify Potential ITS/IWZ Scoping Needs – Draft April 1, 2019 Version 1 Revised

Project is on a freeway or expressway

Is more than 15 minutes of additional delay anticipated? YES → Is there an alternate route? YES → Alternate Route Travel Time; NO → Is destination within 10 miles of sign? YES → Travel Time; NO → Delay Time

Is more than 15 minutes of additional delay anticipated? NO → Is WZ on A recreational or truck route? YES → Is there an alternate route? YES → Alternate Route Travel Time; NO → Is destination within 10 miles of sign? YES → Travel Time; NO → Delay Time

Is WZ on A recreational or truck route? NO

Is queuing in advance of the work zone anticipated? YES → queue vary unpredictably or interfere with upstream intersections? YES → Active Zipper Merge with Congestion Advisory and/or End of Queue Warning; NO → Congestion Advisory and/or End of Queue Warning

Is queuing in advance of the work zone anticipated? NO

Is slowing greater than 20mph in the work zone anticipated? YES → Is slowing required 24 hours per day? NO → Downstream Speed Notification; YES

Is slowing greater than 20mph in the work zone anticipated? NO

Mobility and Traveler Information

Considerations for Alternate Route Travel Times:
- Alternate route travel times are calculated and displayed for selected alternate route(s) and the main route through the work zone to provide options to drivers.
- Travel times on the main route and alternate route(s) vary independently, i.e. one route changes while the other does not.
- Care should be taken to determine proximity to other projects when selecting alternative routes to display travel times.

Considerations to Ensure Times Displayed are Accurate:
- Maximum detector spacing is ½ mile.
- Travel Time is used when the time display is within 10 miles of the destination shown on the sign.
- Delay Time is used when the time display is more than 10 miles from the destination shown on the sign.

Benefits of Mobility and Traveler Information:
- Allows drivers to decide whether to change routes.
- Provides opportunities to notify others of estimated arrival times.
- Provides sufficient information to calm tempers.
- Lead to less diversion of traffic on to alternate routes when not wanted.

Options for Travel Time and Delay Time Information Displays:
- Static Guide Sign with DMS characters to display time.
- Consideration should be given to posting an alternate route and travel time for additional driver information
- The CMS may be supplemented with other informational devices

Motorist Advisory

Considerations for Motorist Advisory Systems:
- Queue lengths are anticipated to be unpredictable because they vary greatly daily and/or hourly.
- The end of queue encroaches upstream beyond drivers' expectations or are obscured by roadway geometry.
- Queues are expected to encroach on upstream intersections or interchanges.

Benefits of Motorist Advisory:
- Alert drivers they are approaching slow or stopped traffic.
- Reduce frequency and severity of rear-end crashes.
- May reduce demand by diverting traffic.

Active Zipper Merge:
- Typically includes an End of Queue Warning System.
- Reduces queue lengths by 40%.
- Harmonizes speeds between lanes approaching the lane closure.
- Increases capacity through the work zone to 1500 vplph.
- Reduces driver frustration and decreases aggressive driving behavior.

Congestion Advisory:
- Is used when the congested traffic message can be far enough away that motorists can select alternate routes.
- Alternate routes must have capacity to accept additional traffic.
- Is typically combined with End of Queue Warning Systems, Active Zipper Merge and/or Travel/Delay Time System as motorists approach the work zone.

End-of-Queue Warning:
- Is used to warn drivers of slow or stopped traffic ahead and that prompt action is required.

Downstream Speed Notification:
- Gives drivers an appropriate speed to travel through the work zone with minimal braking by providing notification ½ mile ahead of slower moving traffic.
- Smooths the transition between faster and slower moving traffic.
- Increases capacity through the work zone.

DEPARTMENT OF TRANSPORTATION

Source: MNDOT

Noteworthy Practices: TMA and Sign Packages

Queue Protection Truck Guidance for INDOT Work Zones

- Retractable TMA
- Distinct lighting
- Hass transmitter system
- Custom warning sign

BE PREPARED TO STOP sign

- Fluorescent pink background
- Retroreflective yellow/red hatching



Source: INDOT



Noteworthy Practices: Deployment Triggers and Placement

Queue Protection Truck Guidance for KYTC Work Zones

1. QPT positioned no further than ½ mile upstream
2. QPT positioned on shoulder
3. Reposition as needed to maintain ½ mile upstream
4. 2nd QPT held in reserve to support the 1st if needed
5. Queue length estimates and traffic conditions shall be reported to the KYTC project engineer or designee at the same periods as TDOT note



Source: KYTC

Research and Innovation Case Study: JTRP and INDOT

Queue Warning Truck Results



- 45,000 hours of alerting/26 months
- The impact of queue warning trucks
- 370 hours w/trucks vs. 52 hours without trucks
- Decrease of 80% in hard braking events
- Traffic speeds reduced 1500 to 2000 feet in advance of Q Truck



Key Takeaways

Purpose & Importance – Queue Protection Trucks are a proven countermeasure to reduce rear-end crashes by providing an early, visible warning of slowing or stopped traffic.

Guidelines – Deployment should follow established DOT specifications, MUTCD principles, and site-specific traffic control plans for maximum safety and compliance.

Noteworthy Practices – Strategic placement, real-time repositioning, and integration with ITS tools maximize effectiveness while minimizing disruption.

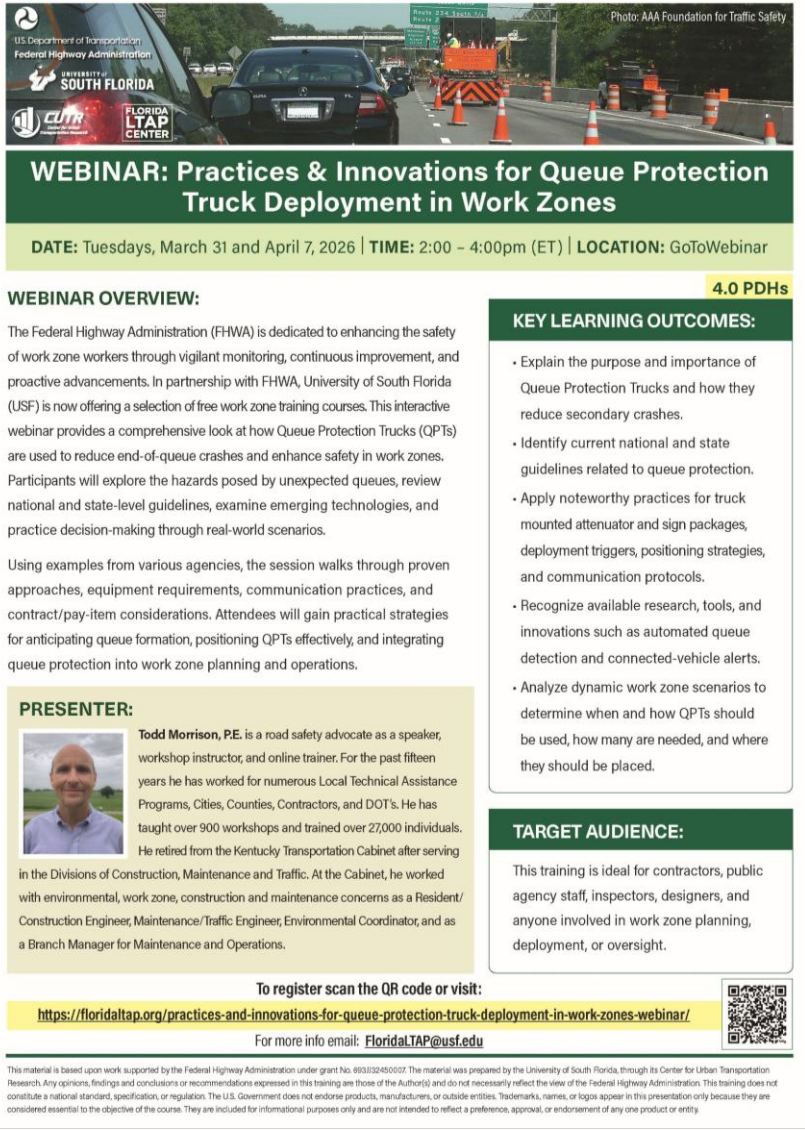


Resources

Recorded Webinar on Florida LTAP Website:
https://floridaltap.org/recorded-webinar-practices-innovations-for-queue-protection-truck-deployment-in-work-zones/

- 2-part webinar series (4-hour training).
- Certificates or PDHs available upon completion and request.

National Work Zone Safety Information Clearinghouse Link:
https://workzonesafety.org/training/practices-innovations-for-queue-protection-truck-deployment-in-work-zones/





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Thank You!

Questions?

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Senior Research Associate

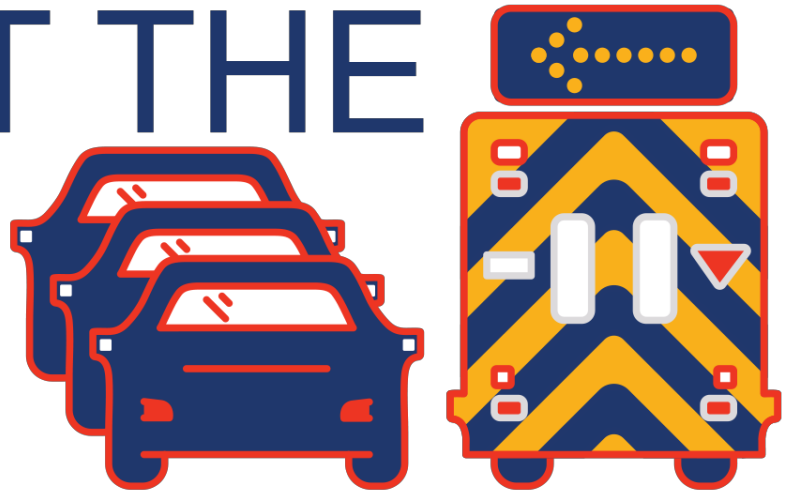
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PROTECT THE QUEUE!

TN TDOT Department of Transportation



TDOT’s Journey in Queue Protection Practice

2026 National Work Zone Management Conference, October 27-29,2026

Why are queues a concern?



- Studies prove the likelihood of a secondary crash increases by 2.8 percent for each minute the primary incident continues to be a hazard.
- Interstates and freeways make up only 15% of all annual fatalities but make up 50% of WZ fatalities.
- #1 cause of WZ fatality is rear end crashes.

What sparked TDOT's Protect the Queue movement?

- Crash On I-24
- Bonnaroo

- June 13, 2013

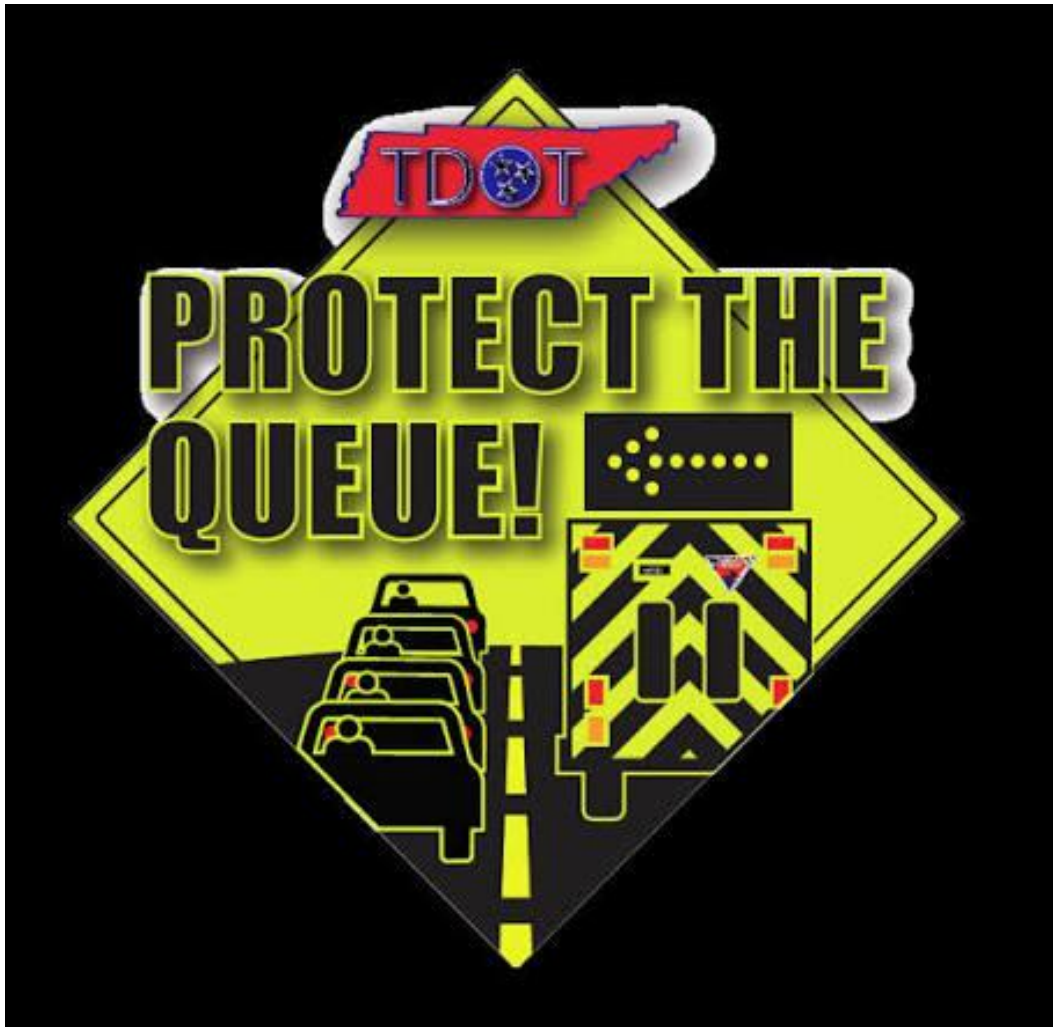
- 2 fatalities
- 6 injuries

- Involved 9 cars
- 1 tractor-trailer



Brandon Wilson and Deja Morris

Protect the Queue Campaign was born



- The “Protect the Queue” Campaign was born in June of 2013.
  - TDOT formed a partnership with local governments and first responders to work on getting roadway closures from crashes opened back up in 90 minutes or less. (Critical injury, fatalities, or hazmat incidents allow for a longer closure, when needed.)
  - TDOT provided training to TDOT employees, partnering agencies, tow companies, and contractors that work on our highways.

We add Queue Trucks for our in-house crews

- Maintenance Crews
  - Add message boards to pickup trucks
  - Built trucks that include message boards and attenuators

- When Used?
  - When a queue is expected
    - Maintenance lane closures
    - Emergency lane closures





Construction Projects

- In 2015, we added Traffic Queue to construction projects. (SP712PTQ)
  - Trucks with mounted attenuators
  - 4 round yellow strobe lights
  - 1 cab-mounted light bar
  - Truck-mounted message boards

- In 2024, we added that 2 trucks are required to be deployed when a queue is predicted or observed to be over a mile long.

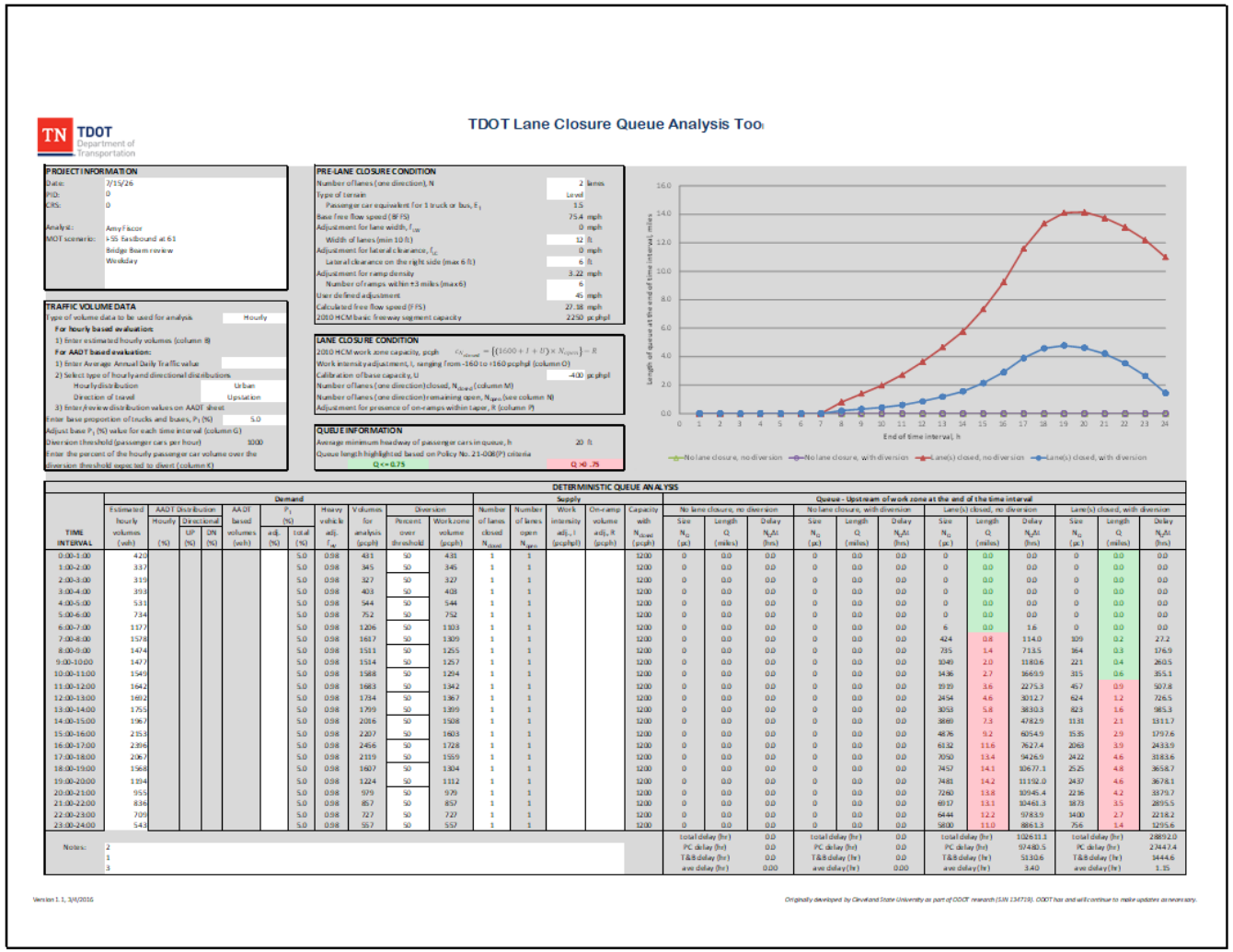


Why do we use them?



They save lives!

How do we predict if we expect queues?



TDOT Lane Closure Queue Analysis Too

PROJECT INFORMATION

Date:	7/15/26
PID:	0
CRS:	0
Analyst:	Amy Facor
MOT scenario:	I-55 Eastbound at 61 Bridge Beam review Weekday

TRAFFIC VOLUME DATA

Type of volume data to be used for analysis	Hourly
For hourly based evaluation:	
1) Enter estimated hourly volumes (column B)	
For AADT based evaluation:	
1) Enter Average Annual Daily Traffic value	
2) Select type of hourly and directional distributions	
Hourly distribution	Urban
Direction of travel	Upstation
3) Enter/review distribution values on AADT sheet	
Enter base proportion of trucks and buses, P_T (%)	5.0
Adjust base P_T (%) value for each time interval (column G)	
Diversion threshold (passenger cars per hour)	1000
Enter the percent of the hourly passenger car volume over the diversion threshold expected to divert (column K)	

PRE-LANE CLOSURE CONDITION

Number of lanes (one direction), N	2 lanes
Type of terrain	Level
Passenger car equivalent for 1 truck or bus, E_T	1.5
Base free flow speed (BFS)	75.4 mph
Adjustment for lane width, f_{LW}	0 mph
Width of lanes (min 10 ft)	12 ft
Adjustment for lateral clearance, f_{LC}	0 mph
Lateral clearance on the right side (max 6 ft)	6 ft
Adjustment for ramp density	3.22 mph
Number of ramps within ±3 miles (max 6)	6
User defined adjustment	45 mph
Calculated free flow speed (FFS)	27.18 mph
2010 HCM basic freeway segment capacity	2250 pc/hpl

LANE CLOSURE CONDITION

2010 HCM work zone capacity, pcph	$c_{N_{closed}} = \{(1600 + I + U) \times N_{open}\} - R$
Work intensity adjustment, I, ranging from -160 to +160 pc/hpl (column O)	
Calibration of base capacity, U	-400 pc/hpl
Number of lanes (one direction) closed, N_{closed} (column M)	
Number of lanes (one direction) remaining open, N_{open} (see column N)	
Adjustment for presence of on-ramps within taper, R (column P)	

QUEUE INFORMATION

Average minimum headway of passenger cars in queue, h	20 ft
Queue length highlighted based on Policy No. 21-00(P) criteria	
	Q <= 0.75 Q >0 .75

DETERMINISTIC QUEUE ANALYSIS

TIME INTERVAL	Demand: Estimated hourly volumes (veh)	AADT Distribution: Hourly (%)	AADT Distribution: Directional UP (%)	AADT Distribution: Directional DN (%)	AADT based volumes (veh)	P_T adj. (%)	P_T total (%)	Heavy vehicle adj. f_{HV}	Volumes for analysis (pcph)	Diversion: Percent over threshold	Diversion: Work zone volume (pcph)	Supply: Number of lanes closed N_{closed}	Supply: Number of lanes open N_{open}	Supply: Work intensity adj., I (pc/hpl)	Supply: On-ramp volume adj., R (pcph)	Supply: Capacity with N_{closed} (pcph)	Queue - Upstream of work zone at the end of the time interval: No lane closure, no diversion: Size N_Q (pc)	No lane closure, no diversion: Length Q (miles)	No lane closure, no diversion: Delay $N_Q\Delta t$ (hrs)	No lane closure, with diversion: Size N_Q (pc)	No lane closure, with diversion: Length Q (miles)	No lane closure, with diversion: Delay $N_Q\Delta t$ (hrs)	Lane(s) closed, no diversion: Size N_Q (pc)	Lane(s) closed, no diversion: Length Q (miles)	Lane(s) closed, no diversion: Delay $N_Q\Delta t$ (hrs)	Lane(s) closed, with diversion: Size N_Q (pc)	Lane(s) closed, with diversion: Length Q (miles)	Lane(s) closed, with diversion: Delay $N_Q\Delta t$ (hrs)
0:00-1:00	420						5.0	0.98	431	50	431	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
1:00-2:00	337						5.0	0.98	345	50	345	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
2:00-3:00	319						5.0	0.98	327	50	327	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
3:00-4:00	393						5.0	0.98	403	50	403	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
4:00-5:00	531						5.0	0.98	544	50	544	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
5:00-6:00	734						5.0	0.98	752	50	752	1	1			1200	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
6:00-7:00	1127						5.0	0.98	1206	50	1103	1	1			1200	0	0.0	0.0	0	0.0	0.0	6	0.0	1.6	0	0.0	0.0
7:00-8:00	1578						5.0	0.98	1617	50	1309	1	1			1200	0	0.0	0.0	0	0.0	0.0	424	0.8	114.0	109	0.2	27.2
8:00-9:00	1474						5.0	0.98	1511	50	1255	1	1			1200	0	0.0	0.0	0	0.0	0.0	735	1.4	713.5	364	0.3	176.9
9:00-10:00	1477						5.0	0.98	1514	50	1257	1	1			1200	0	0.0	0.0	0	0.0	0.0	1049	2.0	1180.6	221	0.4	260.5
10:00-11:00	1549						5.0	0.98	1588	50	1294	1	1			1200	0	0.0	0.0	0	0.0	0.0	1436	2.7	1669.9	315	0.6	355.1
11:00-12:00	1642						5.0	0.98	1683	50	1342	1	1			1200	0	0.0	0.0	0	0.0	0.0	1939	3.6	2275.3	457	0.9	507.8
12:00-13:00	1682						5.0	0.98	1734	50	1367	1	1			1200	0	0.0	0.0	0	0.0	0.0	2454	4.6	3012.7	624	1.2	726.5
13:00-14:00	1755						5.0	0.98	1799	50	1399	1	1			1200	0	0.0	0.0	0	0.0	0.0	3053	5.8	3830.3	823	1.6	985.3
14:00-15:00	1967						5.0	0.98	2016	50	1508	1	1			1200	0	0.0	0.0	0	0.0	0.0	3869	7.3	4782.9	1131	2.1	1311.7
15:00-16:00	2153						5.0	0.98	2207	50	1603	1	1			1200	0	0.0	0.0	0	0.0	0.0	4876	9.2	6054.9	1535	2.9	1797.6
16:00-17:00	2396						5.0	0.98	2456	50	1728	1	1			1200	0	0.0	0.0	0	0.0	0.0	6132	11.6	7627.4	2068	3.9	2433.9
17:00-18:00	2067						5.0	0.98	2119	50	1559	1	1			1200	0	0.0	0.0	0	0.0	0.0	7050	13.4	9426.9	2422	4.6	3183.6
18:00-19:00	1568						5.0	0.98	1607	50	1304	1	1			1200	0	0.0	0.0	0	0.0	0.0	7457	14.1	10677.1	2525	4.8	3658.7
19:00-20:00	1194						5.0	0.98	1224	50	1112	1	1			1200	0	0.0	0.0	0	0.0	0.0	7481	14.2	11192.0	2437	4.6	3678.1
20:00-21:00	955						5.0	0.98	979	50	979	1	1			1200	0	0.0	0.0	0	0.0	0.0	7260	13.8	10945.4	2236	4.2	3375.7
21:00-22:00	836						5.0	0.98	857	50	857	1	1			1200	0	0.0	0.0	0	0.0	0.0	6917	13.1	10483.3	1873	3.5	2895.5
22:00-23:00	709						5.0	0.98	727	50	727	1	1			1200	0	0.0	0.0	0	0.0	0.0	6444	12.2	9783.9	1400	2.7	2218.2
23:00-24:00	543						5.0	0.98	557	50	557	1	1			1200	0	0.0	0.0	0	0.0	0.0	5800	11.0	8861.3	756	1.4	1295.6
																	total delay (hr)		0.0			0.0			10261.1			2889.2.0
																	PC delay (hr)		0.0			0.0			97480.5			27447.4
																	T&S delay (hr)		0.0			0.0			5130.6			1444.6
																	ave delay (hr)		0.00			0.00			3.40			1.35

Notes: 2, 1, 3

Version 1.1, 3/4/2016

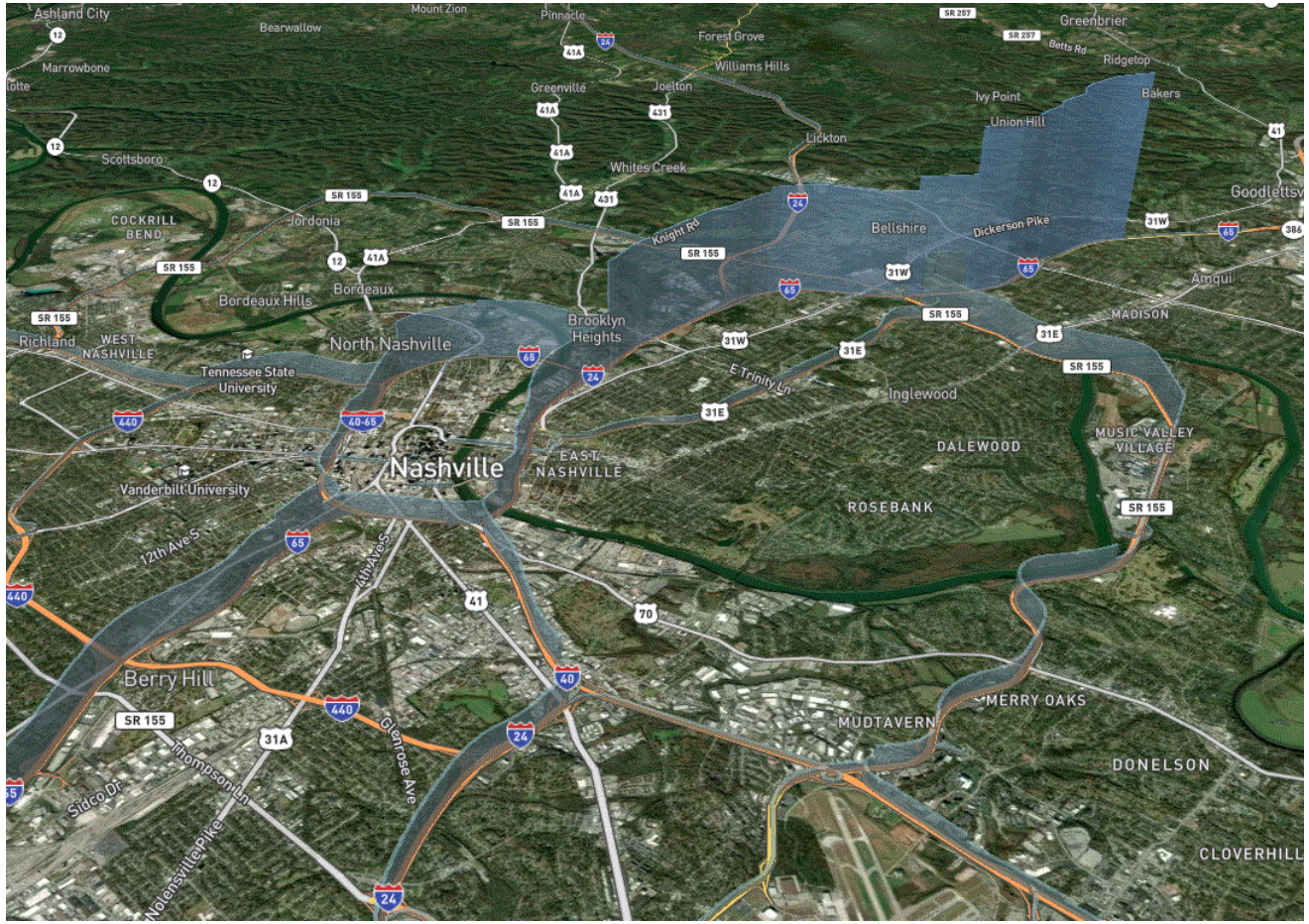
Originally developed by Cleveland State University as part of ODOT research (SJN 134719). ODOT has and will continue to make updates as necessary.

TDOT has a Lane Closure Queue Analysis Template Tool

- The Queue Tool helps us with planning in the Smart Work Zone layout footprint.

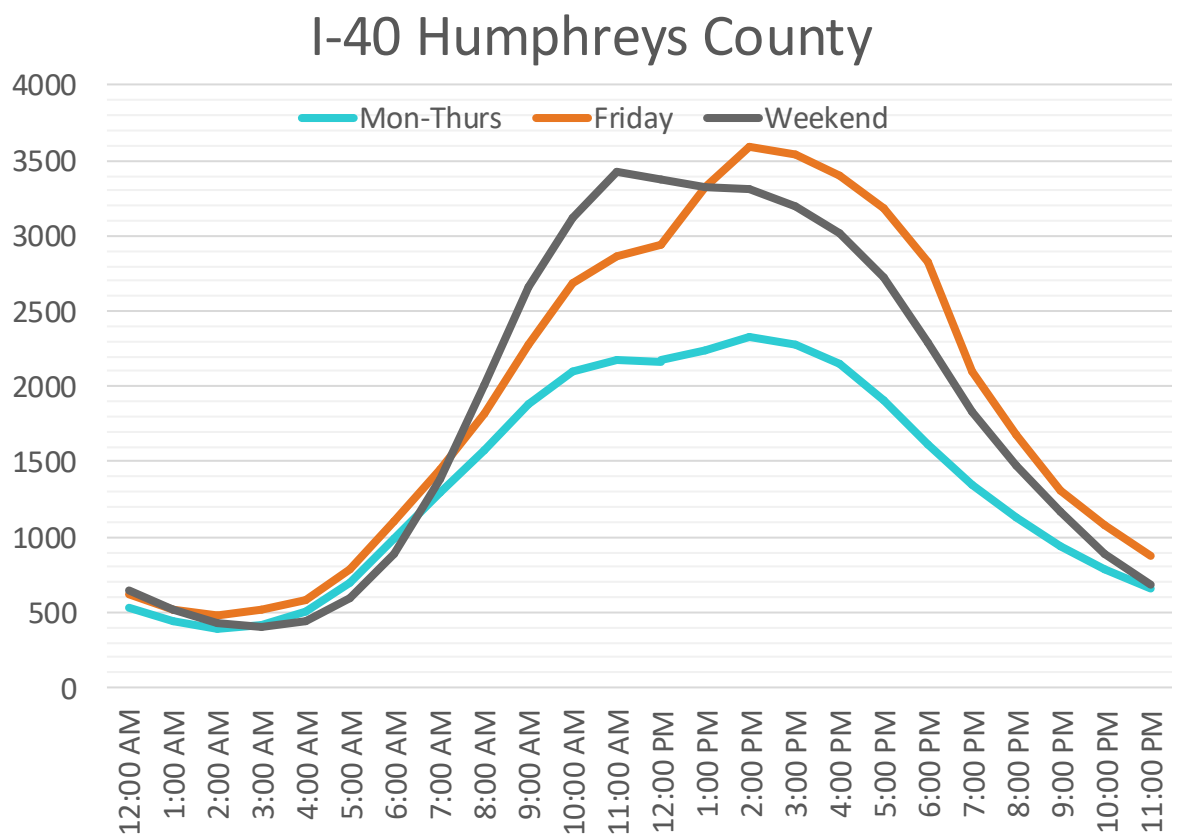
TN TDOT Department of Transportation

New Data Source for Work Zone Planning



- TDOT now has access to Streetlight, a probe data analytics platform.
- Provides accurate volume, including hourly data for individual years, months, and even specific days.
- Provides accurate visualizations and data for origin and destination, which show what routes drivers are taking to and from a certain location.

Streetlight Hourly Data – Determining Off Peak

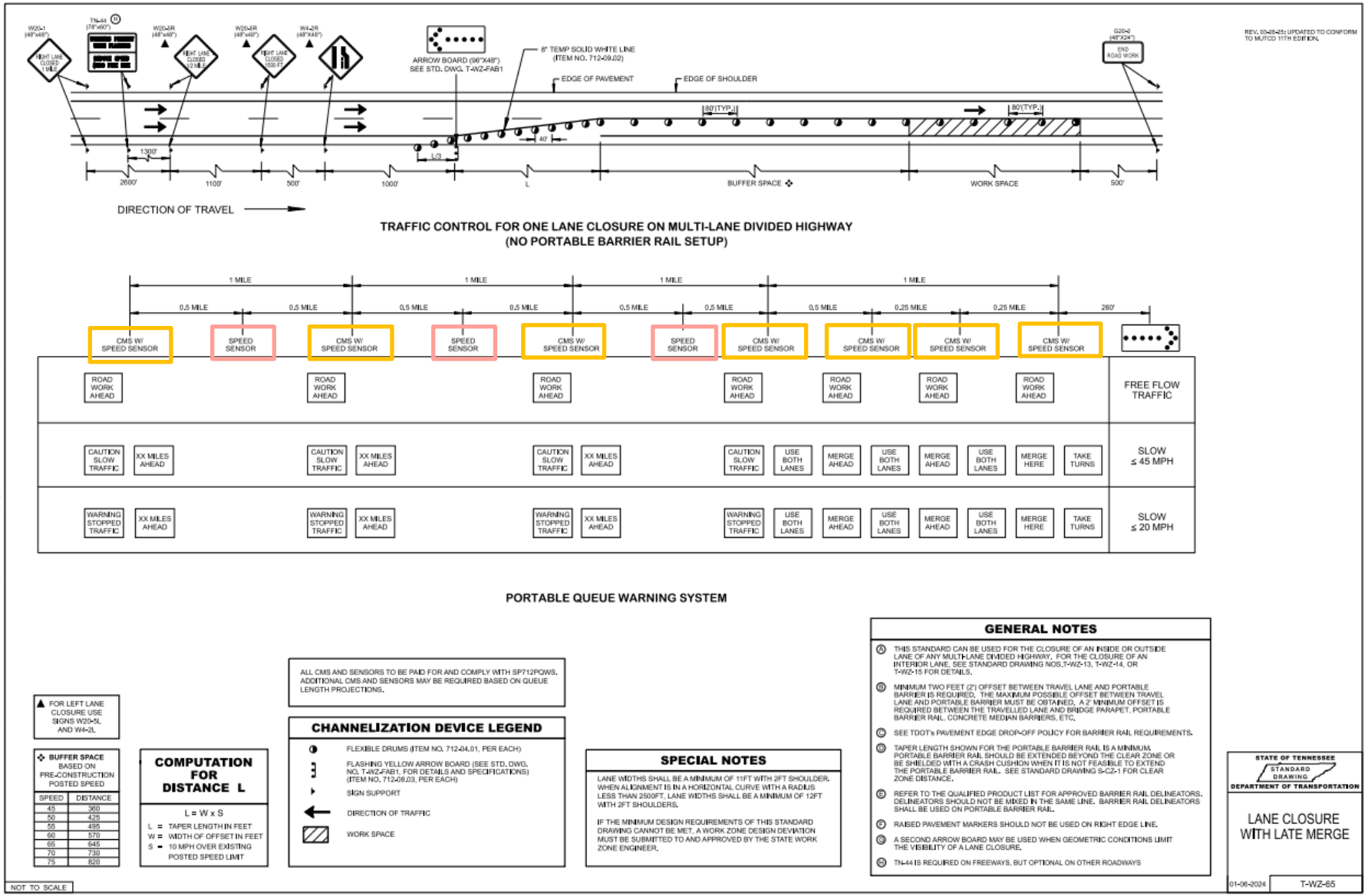


- We are now able to look at detailed hourly traffic data, including individual days of the week, months, etc.

- This can help us better plan our projects and decide our workdays, hour restrictions, and even have different restrictions for different directions.

- This will also help us to better predict what our queue lengths will be and be data-driven in our approach to working off-peak.

Smart Work Zones



Speed Sensor

Changeable Message Board & Speed Sensor

Used in long-term Work Zone where queues are predicted on

Work Zones

- Message boards in advance of the work zone



- Sensors in advance and in the work zone



Cost Savings Example

- Anderson / Campbell Co I-75
  - Bridge repair project requiring weeks of lane closures
  - Estimated queues and PQWS Systems exceed in each direction
  - Bid price of PTQ truck for this project was $1,850/day/shift (day= 2 shifts)
  - Bid price of PQWS was $6,600 day (day = calendar day)
  - Price of queue protection using only PTQ trucks on this project would have been approx. $133,200
  - PQWS was a total of $92,400, for a savings of 40%





Portable Queue Advance Warning System

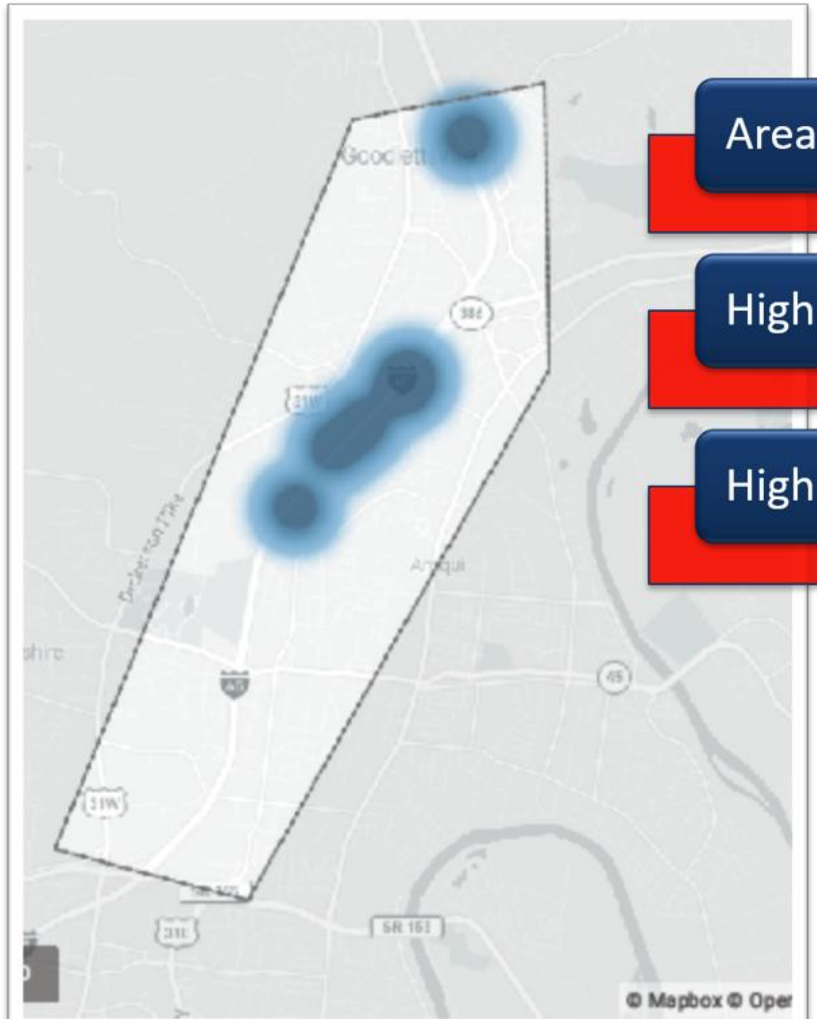


TDOT Pilot Project on I-65 north of Nashville, TN

Working with Horizon Signal

Portable Queue Advance Warning System

TDOT is piloting a portable advance warning system on our I-65 widening project.



- Area just North of Nasvhille
- High AADT near 100k veh/day
- High Crash Rate History

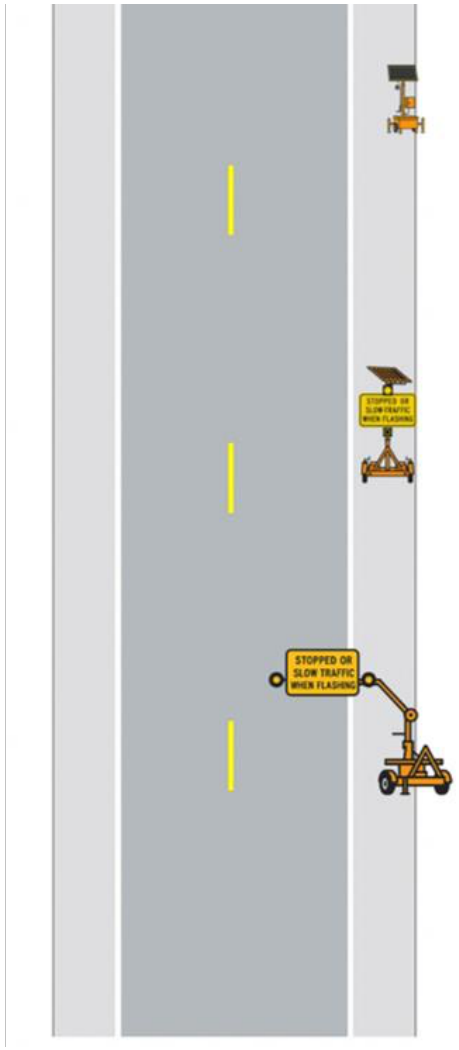
Portable Queue Advance Warning System





Portable Queue Advance Warning System

- Any combination of overhead and auxiliary trailers can be used
- An unlimited number of sensors can be used
- Programming thresholds vary and can be programmed and changed as needed
- Programming changes can be done remotely



Portable Queue Advance Warning System



- Portable design allows for fast, flexible deployment
- Lifting ring for easy signal placement
- Easy-up hydraulic lift
- Withstands sustained winds of 100 mph, gusts up to 110 mph

Portable Queue Advance Warning System



Additional Options Available

- **Video Monitoring —** PTZ camera gives a live look at traffic with resolutions up to full 1080 HD, and up to 60 frames per second.
- **15-Foot Extension Arm —** Longer extension arm for greater horizontal reach on SQ3TS trailer. Ideal for 2-lane applications.
- **Advanced Remote Monitoring —** Receive text and/or email alert notifications of system operation and battery voltage levels.

HAAS Alert


HIGHWAY INCIDENT RESPONSE UNIT





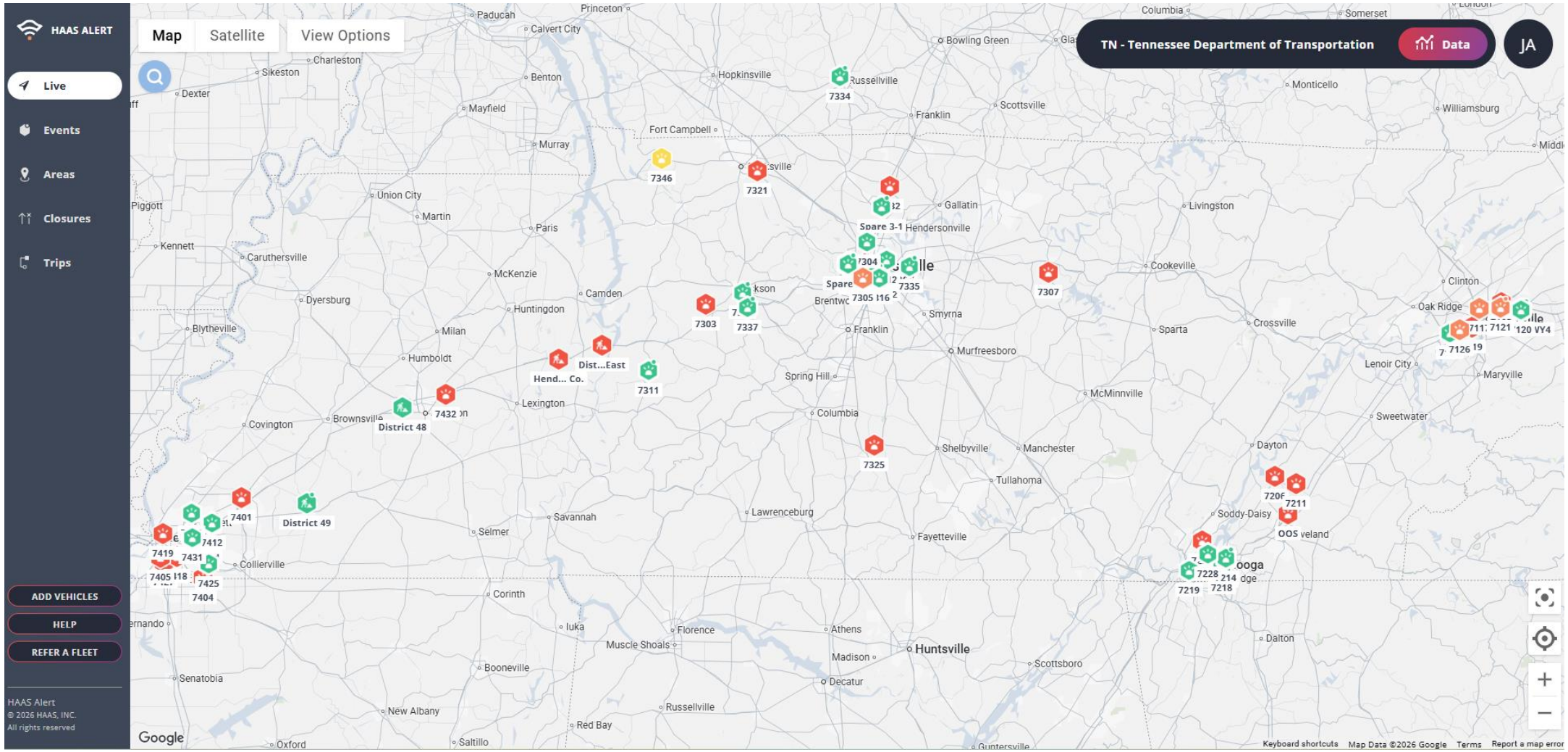

CAUTION
Emergency Vehicle Approaching
OK
SAFETY CLOUD

HAAS Alert

How it works

- When a TDOT vehicle or HELP (Highway Emergency Patrol) Truck activates its flashing warning lights or emergency equipment, a HAAS Alert Safety Cloud event is automatically triggered.
- The event instantly sends digital alerts to nearby motorists up to 30 seconds in advance.
- These alerts display on compatible in-dash digital systems and on mobile navigation apps such as Waze.
- The system does not require TDOT operators to manually enter information or use extra apps; it runs entirely in the background.

HAAS Dashboard



TN TDOT Department of Transportation

Questions?



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