2024

QUEUE WARNING SYSTEM FEASIBILITY STUDY REPORT

Ohio Department of Transportation

GANNETT FLEMING

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1.0 EXECUTIVE SUMMARY

Effective traffic management is crucial for ensuring road safety, reducing congestion, and minimizing delays. A key component of this management is the use of Queue Warning Signs (QWS), which notify drivers of upcoming traffic queues. These signs are instrumental in preventing accidents, improving traffic flow, and enhancing overall road safety. As essential tools in modern traffic management, queue warning signs contribute to safer and more efficient roadways.

By understanding their impact and implementing best practices, transportation authorities can significantly enhance traffic safety and flow. This report offers valuable insights and recommendations to optimize the use of queue warning signs, ultimately improving the driving experience for all road users.

This report offers a comprehensive overview of the types of technology employed and the various Transportation Systems Management and Operations (TSMO) considerations necessary for the project's success. It also analyzes specific locations with past traffic queuing incidents. Each location in Districts 04, 05, 06, 08, and 12 is assessed based on factors such as queue buildup duration, safety, mobility, and geometric limitations.

Special emphasis is placed on ensuring that the goals and objectives of this project are in full alignment with the state's long term TSMO program. This alignment is critical to the project's success, as it ensures that all efforts are coordinated with state-level strategies and initiatives aimed at optimizing traffic flow, enhancing road safety, and improving overall transportation efficiency. By closely integrating the project with the TSMO program, we aim to leverage state-of-the-art technologies and best practices, thereby maximizing the positive impact on the transportation system.

2.0 PROJECT INTRODUCTION

According to a report published by AASHTO, end-of-queue highway crashes in Ohio have been increasing over the past three years to 8,811 crashes in 2023. [1] In order to create safer roads by reducing end-of-queue crashes, the Ohio Department of Transportation (ODOT) has identified 13 strategic sites within five Districts (4, 5, 6, 8, 12) across three regions (Northeast, Central, and Southwest) of the state to pilot and expand Queue Warning Systems (QWS) at high-congestion, high-crash, and limited sight distance areas.

The QWS aims to address safety, congestion, and operational issues by detecting slow or stopped traffic and triggering a message board to alert approaching drivers of upcoming queues that may not be expected or visible in addition to recurring queuing. Early information helps anticipate the upcoming slowdowns and reduce unexpected behavior at the end of queues. It is estimated that QWS deployed at the sites can potentially reduce end-of-queue crashes by at least 16%. With support from Governor DeWine, the Ohio State Highway Patrol, and ODOT, the 13 sites are expected to be operational within two years.

ODOT's selection process for the initial sites involved evaluating Traffic Operation Assessment Systems Tool (TOAST) data , INRIX data, and consulting with District staff to identify known queuing locations that could benefit from QWS deployments. Input from the Traffic Management Center (TMC) and the Maintenance Team also played an important role in site selection and device placement. The evaluation methodology included data collection, safety and congestion analysis, and field reviews to optimize site specific locations for this preliminary study.

This report serves to outline the safety benefits of using QWS in the specified locations. It will include an overview of the technology used for the systems, important Transportation Systems Management and Operations (TSMO) considerations, guidelines for future implementation of the devices, and vital next steps to ensure efficient use of QWS. To provide resources for further evaluation, additional references will be available in the appendix at the end of this report.

1: https://aashtojournal.transportation.org/ohio-dot-unveils-traffic-congestion-detection-system/

2.1 GOALS

The QWS aims to address safety concerns, traffic congestion, and frequent queuing throughout the state. Queues form due to various factors, including complex roadway configurations, challenging merge areas, events, weather conditions, traffic incidents, recurring congestion, capacity limitations, and erratic driver behavior. Implementation of a QWS seeks to enhance safety and mobility by achieving the following objectives:

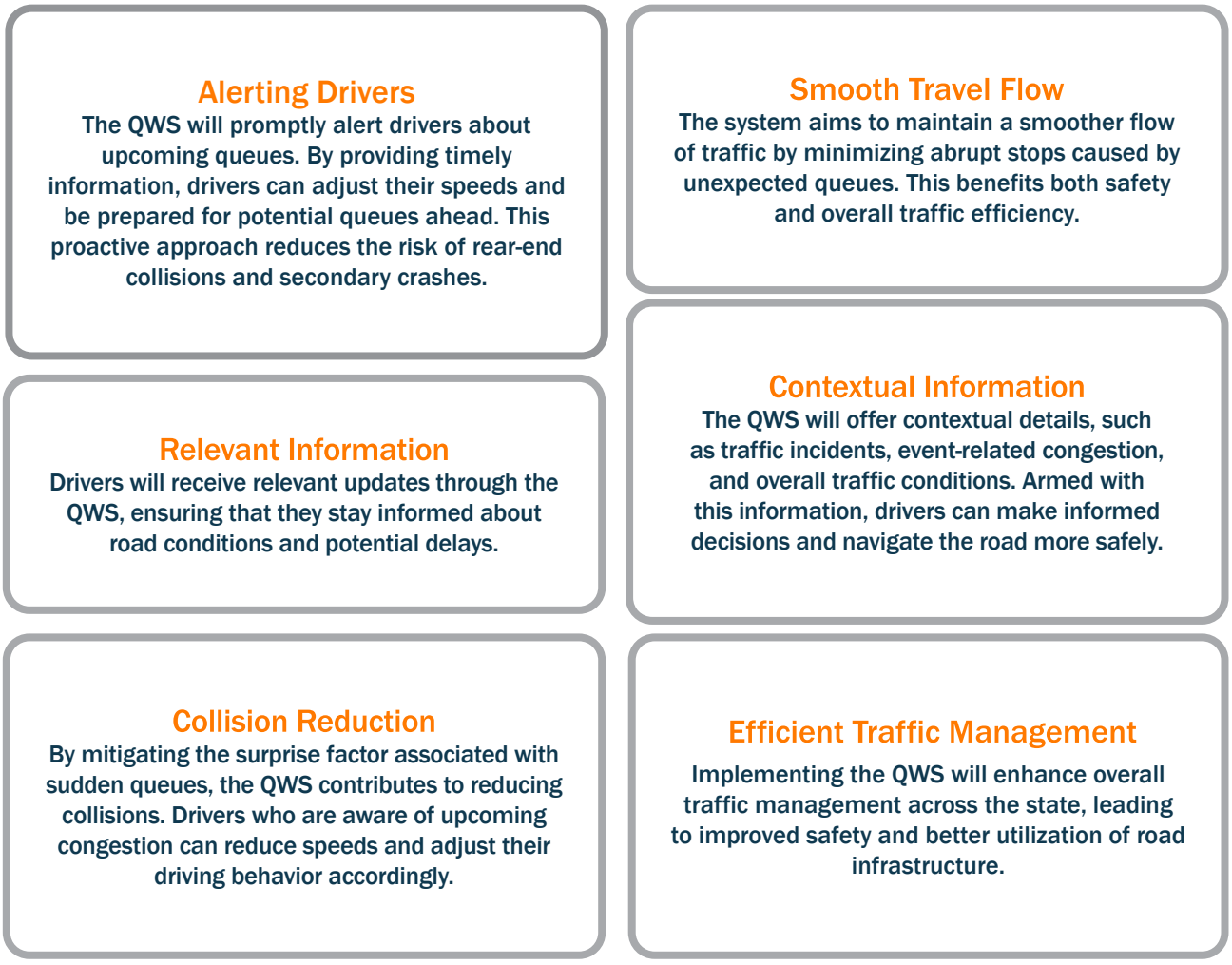


Figure 1: QWS Goals

3.0 TECHNOLOGY OVERVIEW

A QWS offers vehicle queue detection and communicates their locations in real-time. Depending on the sophistication of the deployed technology, the QWS can operate either independently or networked into the ODOT Intelligent Transportation System (ITS) network. Traffic detectors, dynamic message signs, and static signs with flashing beacons or limited information message signs (such as “fog warning”) are the typical devices found in a QWS.

ODOT conducted evaluations of multiple devices and configurations to identify the most effective devices and equipment for statewide use. This project utilized an iterative approach to determine the optimal number of cameras, as well as the number and types of Dynamic Message Signs (DMS) to use at each location. The selected devices by ODOT include a queue detection camera, dynamic message signs, and potentially, static signs with flashing beacons. Below are brief descriptions and specifications of the ITS equipment.

3.1 QUEUE DETECTION CAMERAS

The process of locating a QWS starts with queue detection cameras. These fixed-position cameras are specifically designed to monitor vehicle movement. They actively track vehicle movements and use trigger conditions such as line crossing, objects in area, and time in area to detect a queue accurately that has formed beyond a set threshold. Once detected, they generate an alert at that location. This alert is then transmitted to display a corresponding message on the associated Dynamic Message Signs (DMS). For these initial pilot sites, ODOT has selected the Bosch NBE-7703-ALX Bullet Camera. Following are the key highlights and specifications of the camera:

NBE-7703-ALX BULLET CAMERA

- 4MP HDR X 4.7-10mm IP66/67 IK10
- Utilizes Starlight X technology for increased low-light performance
- HDR X enables visible detail in bright and dark areas without HDR motion blur and artefacts
- Long range (850nm) intelligent IR illumination up to 80m (262ft)
- Built-in Intelligent Video Analytics Pro (IVA Pro) allows for deep-learning based detection of vehicles

Additional supporting structures and equipment the cameras may need include CCTV poles, existing trusses and structures to mount the camera, cabinets, power, and communications. The current Bosch camera and newer cameras are typically powered over ethernet cables requiring only one ethernet cable for power and communications.

Figure 2: NBE-7703-ALX Bullet Camera

3.2 DYNAMIC MESSAGE SIGNS

DMSs for QWS actively warn drivers based on the detected queue. With their ability to change messaging, they can adapt to any traffic situation and provide the best warning to protect drivers. This capability offers ODOT an opportunity to use the DMS for other TSMO strategies and systems. Different types of DMS are deployed for different scenarios to ensure optimal messaging.

Figure 3: Truss

Figure 4: Pedestal

Figure 5: Front Access

- Figure 3: A truss-mounted DMS extends over a highway
- Figure 4: Pedestal or cantilever DMS is elevated from the side of the roadway and remains visible to the drivers in the queue
- Figure 5: A front access/ground-mounted DMS can also be used, provided sight lines and visibility are not obstructed by other objects such as signs, bridges, trees, etc.

The choice of DMS type largely depends on the area of installation. Other important considerations when installing DMS include geometric considerations, cabinet location, maintenance access, power, and communications.

SIGN PLACEMENT CONSIDERATIONS

The proximity of the proposed DMS with existing static signs and other DMSs in the vicinity is a key planning and design consideration during the installation of DMSs. The quantity of signs within the proximity of the DMS was considered to ensure the effectiveness of the messages and to avoid potential safety hazards due to too many signs vying for driver attention aka "sign pollution". Engineering judgement determined whether nearby signs should be removed based on the ideal location of the DMS.

QWS-LITE: STATIC SIGNS WITH FLASHING BEACONS

Three of the locations discussed in this report benefited from the use of static signs with flashing lights (QWS-Lite) due to other anticipated near-term project that will improve safety, congestion, and/or operations.. It is assumed that the QWS-Lite locations in the near term with other project improvements will add additional QWS equipment such as a DMS at a later time. Additional considerations for QWS-Lite could include geometric limitations, temporary locations, and seasonal conditions.

The beacons/lights on the static signs are typically equipped with LED lights powered by solar panels, but many models can be powered using basic 120/240V power as well.

4.0 SITE SPECIFIC DESCRIPTIONS

Each site is unique to the causes of queuing and the solution that is needed. A QWS is flexible to address multiple purposes and objectives while following a reliable procedure in determining device location. The process that was used to determine the number and location of devices is listed below:

- The first step in the process was to evaluate crash data, INRIX and TOAST data, to develop length of queues and areas of impact.
- Maximize the use of existing ITS infrastructure to reduce implementation costs and minimize the proliferation of roadway signage, aligning with safety considerations.
- Locate proposed devices near existing fiber optic and power resources to facilitate straightforward installation and connectivity as feasible.
- Position proposed cameras to effectively monitor incoming traffic queues.
- Strategically locate proposed DMS QWS Lite installations to account for the end of traffic queues and adequate sight distance.

The following is the initial list developed by ODOT with the assistance of each district based on crash, INRIX, and TOAST data:

LIST OF LOCATIONS

4.1 DISTRICT 04

a) LITE-D4-OH-8_NB AT HOWE AVE

4.2 DISTRICT 05

a) QWS-D5-I-70_WB

4.3 DISTRICT 06

a) QWS-D6-I-70_EB at Kelton Ave

b) QWS-GRND-D6-I-71_SB AT MORSE RD

c) QWS-GRND-D6-I-270_SB AT SR 317

d) QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE

e) QWS-GRND-D6-OH-315_SB AT IR-670

4.4 DISTRICT 08

a) QWS-OVRHD-D8-I-71_SR 126

b) QWS-OVRHD-D8-OH-126_EB AT I-71 NB

c) QWS-OVRHD-D8-I-275_WB AT I-75 NB

d) QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE

4.5 DISTRICT 12

a) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

b) QWS-GRND-D12-OH-176_NB AT STEELYARD

Figure 6: List of Locations

4.1 DISTRICT 04

A) LITE-D4-OH-8_NB AT HOWE AVE *Location: OH-8 NB & Howe Ave*

- **Queue Identification:** This location is a concern for safety and queuing due to its TOAST scores from the northbound exit ramp that was backing up onto the mainline.
- **Build up Duration:** Daily repeated queues aren't significant at this location
- **End of Queue:** Start of Howe Ave exit ramp
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Given this congestion appears to be caused by queueing at the interchange ramp, consideration should be given to exploring improvements to the ramp traffic signal and overall operation in the short-term to address the root cause before installing a QWS as the primary countermeasure
- **Geometric Limitations:** Horizontal curve after Exit 3B and before the Howe Ave ramp
- **Location Map:** Proposed QWS Lite on existing truss structure, Proposed Detection camera on existing DMS

- **Cost:** Proposed QWS Lite on existing truss structure - $75,000. Proposed detection camera on existing DMS structure $20,000. Total : $95,000
- **Existing Conditions:**
  - **Power:** The power for the proposed QWS Lite sign will come from either Tallmadge or Easton at existing ITS power services. Power for the proposed detection camera to come from the existing DMS sign local to the camera.
  - **Fiber/Telecommunications:** Communications for both the QWS Lite sign and detection camera will come from the same communication service as the existing DMS.

Note: Given additional conversations with the local municipality and ODOT District 4, there may be some operational benefits by adjusting the signal timing and phasing that may fix the underlying queue issues that would reduce the need for a QWS. Efforts are underway to study and implement changes as applicable this summer (2024)

4.1 DISTRICT 04

A) LITE-D4-OH-8_NB AT HOWE AVE

Figure 7: Aerial Image: SLM 3.75 NB (Existing Truss) LITE-D4-OH-8_NB AT HOWE AVE Proposed QWS Lite sign on existing truss structure adjacent to the North SR 8/East SR 59 guide sign

Figure 8: Street View: LITE-D4-OH-8_NB AT HOWE AVE Street view of proposed QWS Lite sign on existing truss structure adjacent to the North SR 8/East SR 59 guide sign

4.1 DISTRICT 04

A) LITE-D4-OH-8_NB AT HOWE AVE

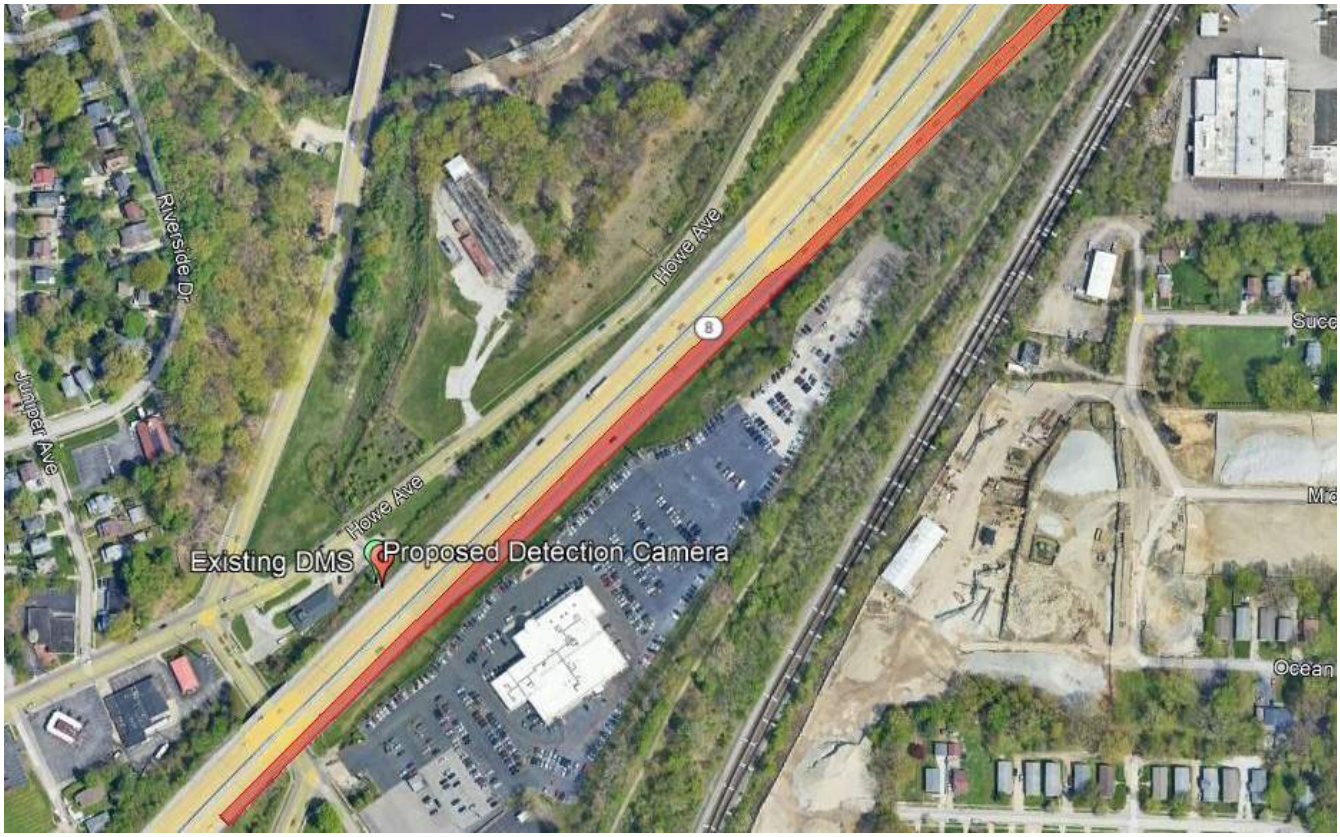


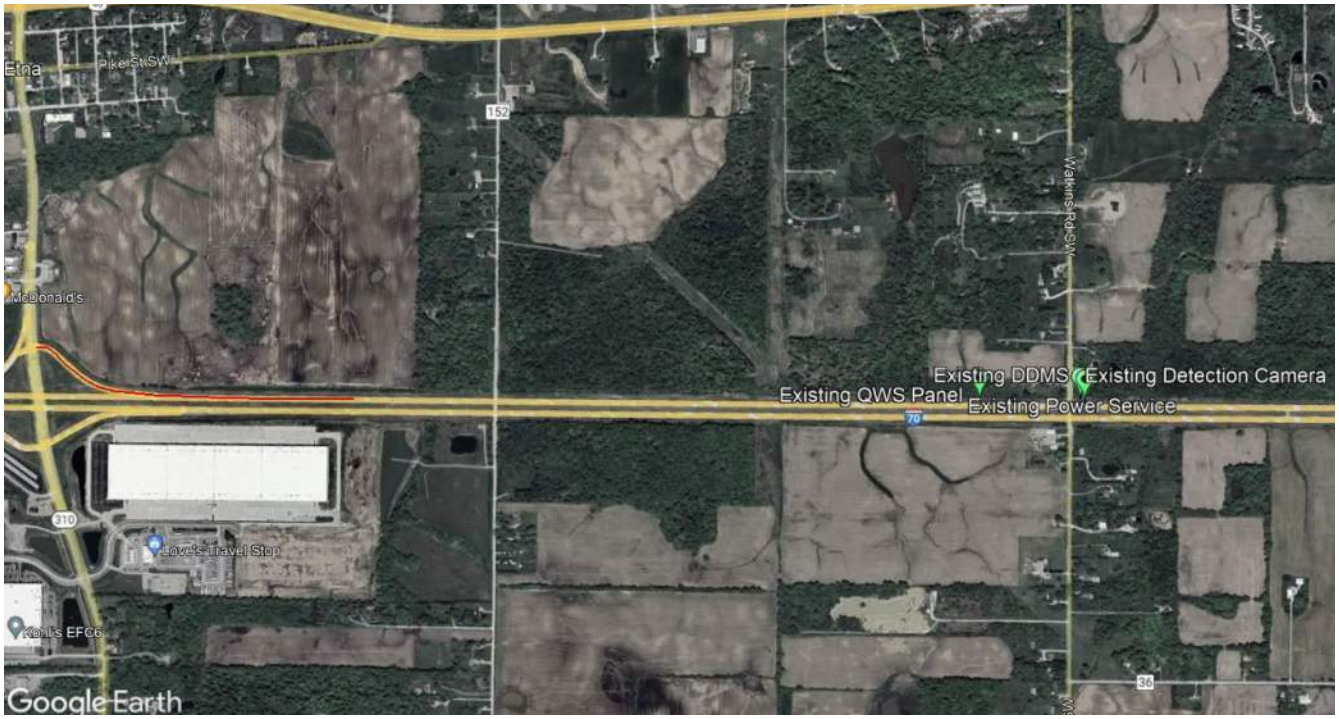
Figure 9: LITE-D4-OH-8_NB AT HOWE AVE Proposed detection camera on existing SB DMS Structure

Figure 10: LITE-D4-OH-8_NB AT HOWE AVE Street view of proposed detection camera on existing SB DMS structure

4.2 DISTRICT 05

A) QWS-D5-I-70_WB *Location: I-70 WB & SR-310*

- **Queue Identification:** The stretch from I-70 Westbound to SR-310 is recognized as the motor crash site associated with multiple fatalities. An existing QWS system is present at this location that was installed after the crash.
- **Build up Duration:** All Day, heavier for 2 hours in the AM and PM peak hours.
- **End of Queue:** Approximately Smoke Road Overpass
- **Safety and Mobility Considerations:**
  - Driver behavioral considerations: Existing site of fatal rear end crash
  - **Events/hours etc:** Morning peak hour between 6:30 to 8:45am and afternoon peak hour 4:30 to 6:30pm
- **Geometric Limitations:** Watkins Rd overpass between existing detection camera and QWS panel sign could cause obstructions between drivers and view of the QWS panel.
- **Location Map:**



- **Cost:** Detection camera and new pole $65,000. Total $65,000
- **Existing Conditions:**
  - **Power:** Existing power service from detection camera and QWS panel. Additional power by existing Tourist-Oriented Direction Sign 850' west of Watkin Road Overpass
  - **Fiber/Telecommunications:** Existing communications for detection camera and QWS panel. Additional Communication by existing Tourist-Oriented Direction Sign 850' west of Watkin Road Overpass

4.2 DISTRICT 05

A) QWS-D5-I-70_WB

Figure 11: QWS-D5-I-70_WB Existing QWS

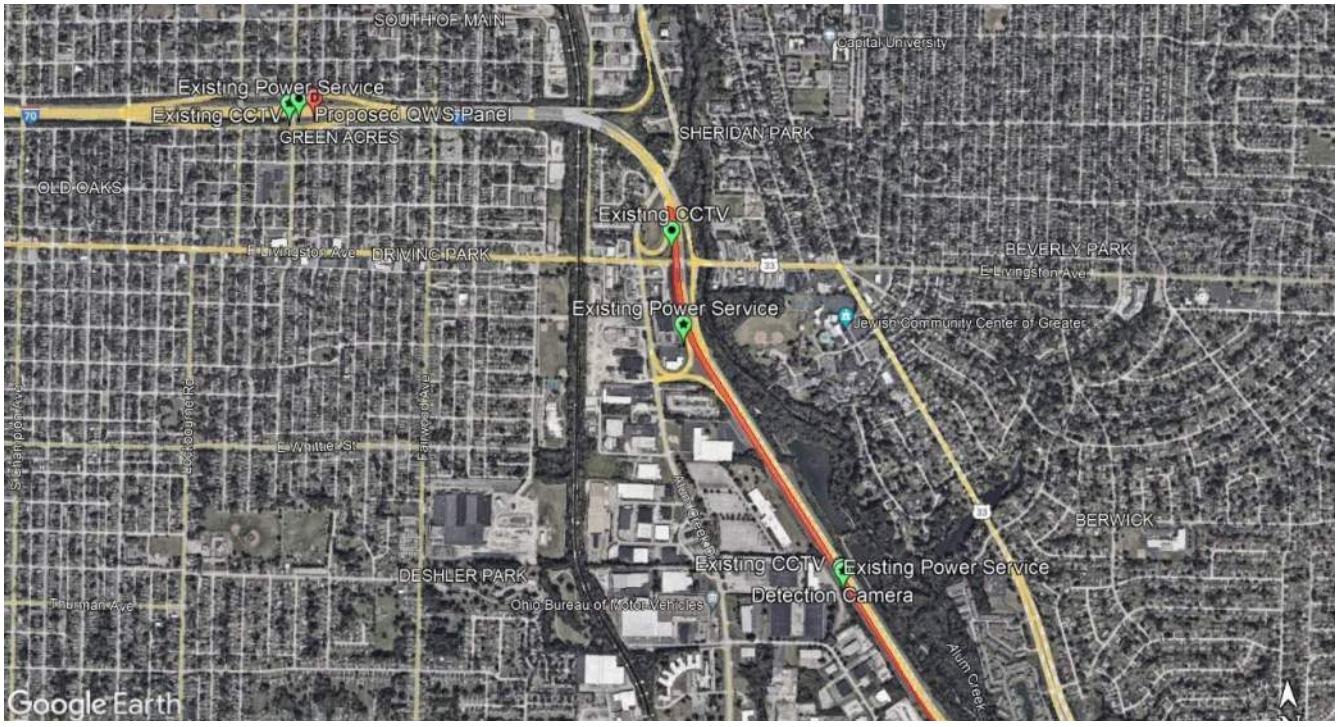
Figure 12:QWS-D5-I-70_WB Existing DDMS with existing detection camera attached to back of sign

Figure 13: QWS-D5-I-70_WB Existing detection camera on back of existing DDMS

4.3 DISTRICT 06

A) QWS-D6-I-70_EB AT KELTON AVE *Location: I-70 EB between US-33 and E Livingston Ave (US-33)*

- **Queue Identification:** Queuing frequently starts at the traffic signal of US-33 and Petzinger Rd, south of I-70, and extends back up I-70 ramp to Alum Creek Dr.
- **Build up Duration:** 2.5 hours during PM hours
- **End of Queue:** Exit 103B Alum Creek
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Afternoon peak hours between 3:00 PM and 5:30 PM
- **Geometric Limitations:** Horizontal curve between Rhoads Ave and E Livingston Ave. Kelton Ave overpass 200 ft in advance of ground mounted QWS sign. QWS sign placement will miss traffic getting onto I-70 EB from Mooberry St.
- **Location Map:**



- **Cost:** Ground mounted QWS panel $150,000. Detection camera $15,000. Total : $165,000
- **Existing Conditions:**
  - **Power:** Existing CCTV and power service at Kelton Ave and Franklin Rd
  - **Fiber/Telecommunications:** Existing fiber along I-70

4.3 DISTRICT 06

A) QWS-D6-I-70_EB AT KELTON AVE

Figure 14: QWS-D6-I-70_EB at Kelton Ave Proposed QWS Panel Location

Figure 15: QWS-D6-I-70_EB at Kelton Ave Street view of proposed QWS panel location

4.3 DISTRICT 06

A) QWS-D6-I-70_EB AT KELTON AVE

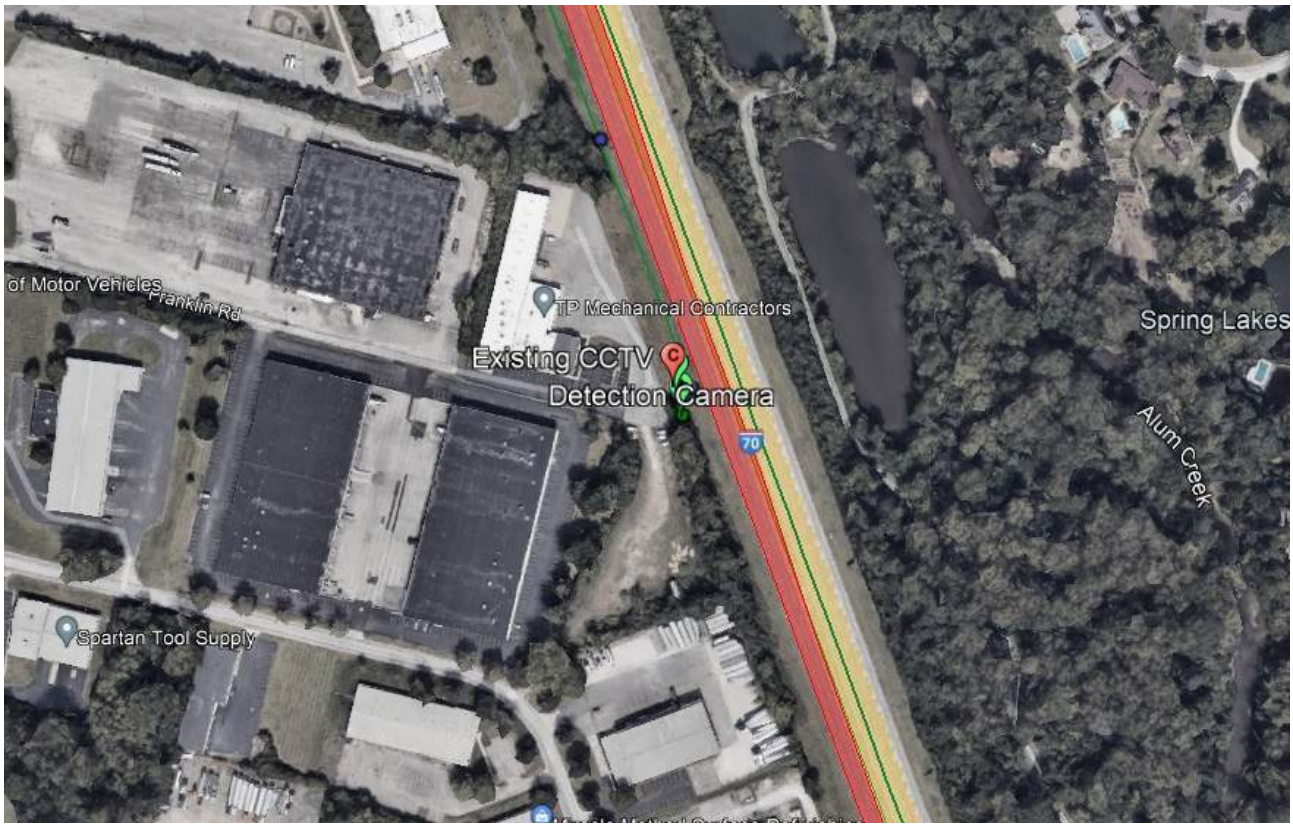


Figure 16: QWS-D6-I-70_EB at Kelton Ave proposed detection camera location

Figure 17: QWS-D6-I-70_EB at Kelton Ave Street view of proposed detection camera location in EB direction

4.3 DISTRICT 06

B) QWS-GRND-D6-I-71_SB AT MORSE RD *Location: I-71 SB between E 17th Ave and Morse Rd*

- **Queue Identification:** Queueing begins at the sharp curve near the former Crew stadium and extends during peak hours to Cooke road. Ramp meters are installed in this area to help manage the flow of traffic. A SmartLane is under design to improve this section of roadway.
- **Build up Duration:** 1.75 Hours in the AM
- **End of Queue:** Overbrook Dr
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Morning Peak hours between 6:45 AM and 8:30 AM
- **Geometric Limitations:** Horizontal curve by Crew stadium near the beginning of the queue.
- **Location Map:**

- **Cost:** Ground mounted QWS Panel: $150,000 Detection camera: $15,000 Detection camera and new pole: $50,000. Total : $215,000
- **Existing Conditions:**
  - **Power:** Existing power services at existing CCTVs and ramp meters at Morse Rd.,Weber Rd.,and Hudson St.
  - **Fiber/Telecommunications:** Existing fiber trunk along I-71

4.3 DISTRICT 06

B) QWS-GRND-D6-I-71_SB AT MORSE RD

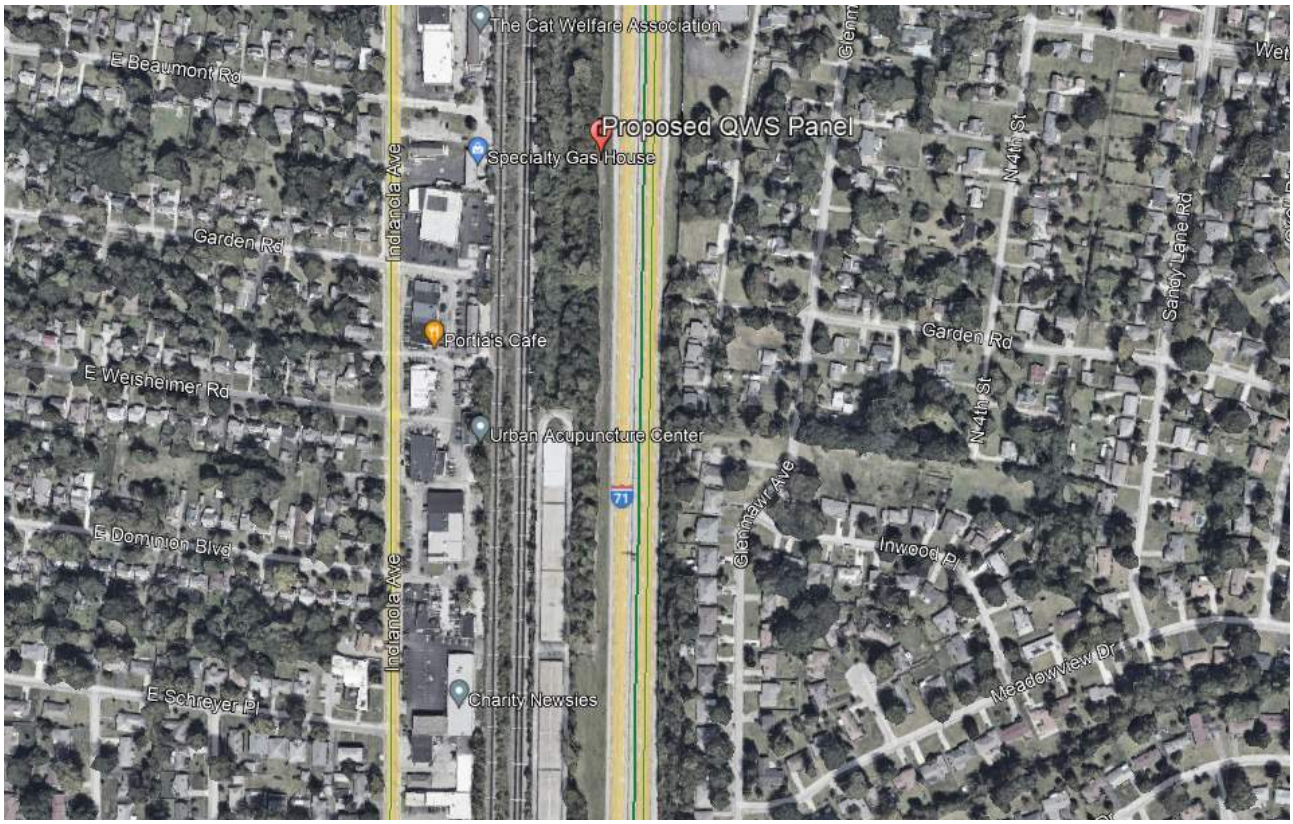


Figure 18: QWS-GRND-D6-I-71_SB AT MORSE RD proposed ground QWS panel location

Figure 19: QWS-GRND-D6-I-71_SB AT MORSE RD view of proposed ground mounted QWS panel located at SLM 24.12 SB at Morse Rd on the right-hand side of the road

4.3 DISTRICT 06

B) QWS-GRND-D6-I-71_SB AT MORSE RD

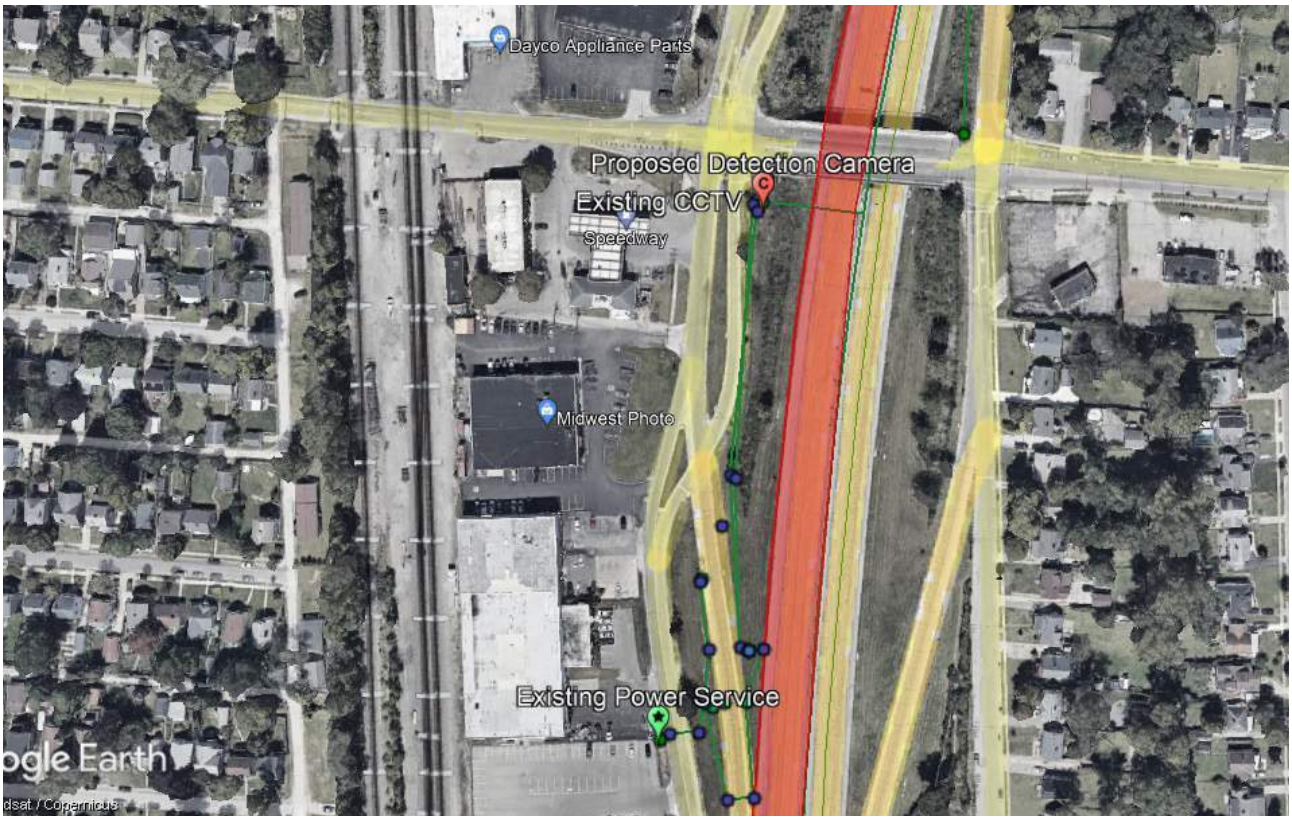


Figure 20: QWS-GRND-D6-I-71_SB AT MORSE RD proposed detection camera on existing CCTV pole location

Figure 21: QWS-GRND-D6-I-71_SB AT MORSE RD street view of proposed detection camera on existing CCTV pole location

4.3 DISTRICT 06

B) QWS-GRND-D6-I-71_SB AT MORSE RD

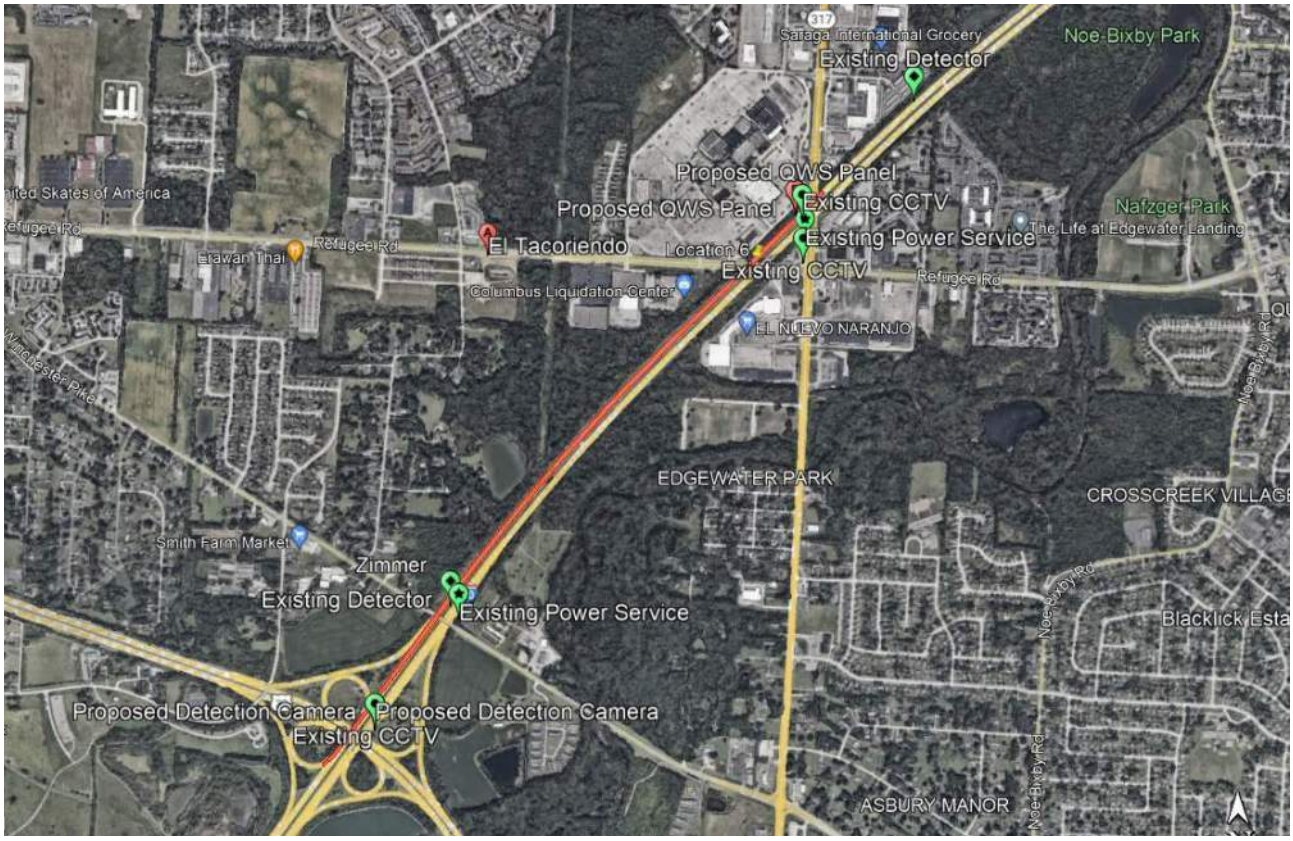
Figure 22: QWS-GRND-D6-I-71_SB AT MORSE RD proposed detection camera and new pole location

Figure 23: QWS-GRND-D6-I-71_SB AT MORSE RD street view of proposed detection camera and pole location at Hudson Street and IR-71 SLM 21.09

4.3 DISTRICT 06

C) QWS-GRND-D6-I-270_SB AT SR 317 *Location: I-270 SB/WB and US-33 SB*

- **Queue Identification:** The cloverleaf interchange at US-33 is contributing to congestion at this location, especially during the evening rush hour.
- **Build up Duration:** 2 Hours during PM hours
- **End of Queue:** SR 317 overpass
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Considerable congestion times are during the afternoon peak hours between 5:00 PM and 7:00 PM. Backup onto I-270 SB/WB from entrance ramp onto US-33 SB
- **Geometric Limitations:** None. Detection camera location on existing CCTV pole needs to clear over existing static sign truss structure.
- **Location Map:**



- **Cost:** Ground mounted QWS panel $150,000. Detection camera $15,000. Total: $160,000
- **Existing Conditions:**
  - **Power:** Power from QWS panel from existing power service on SR-317; currently for existing CCTV on I-270. Power for detection camera from existing CCTV camera
  - **Fiber/Telecommunications:** Existing fiber trunk along I-270 for existing CCTV cameras on I-270

4.3 DISTRICT 06

C) QWS-GRND-D6-I-270_SB AT SR 317

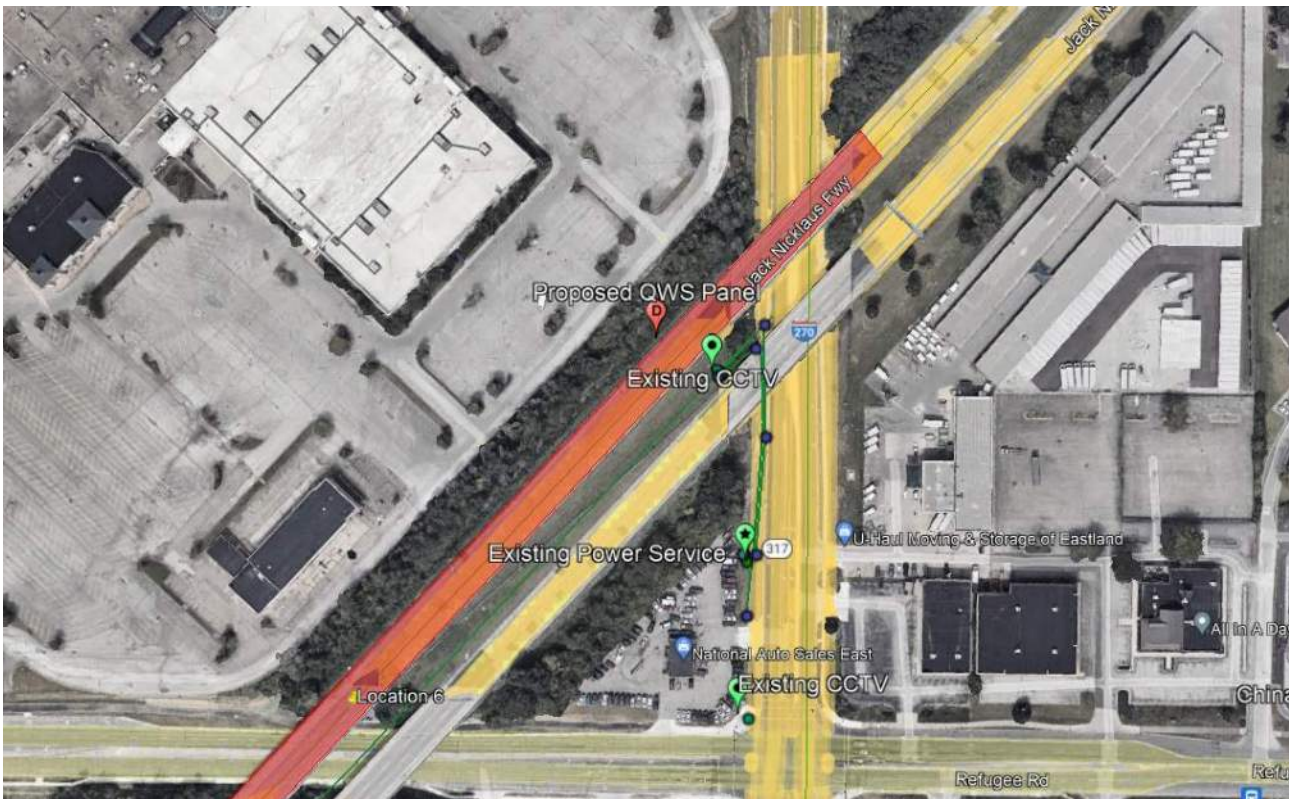


Figure 24: QWS-GRND-D6-I-270_SB AT SR 317 QWS Panel. Location to be placed to avoid being impacted by future bridge project.

Figure 25: QWS-GRND-D6-I-270_SB AT SR 317 QWS Panel street view

4.3 DISTRICT 06

C) QWS-GRND-D6-I-270_SB AT SR 317

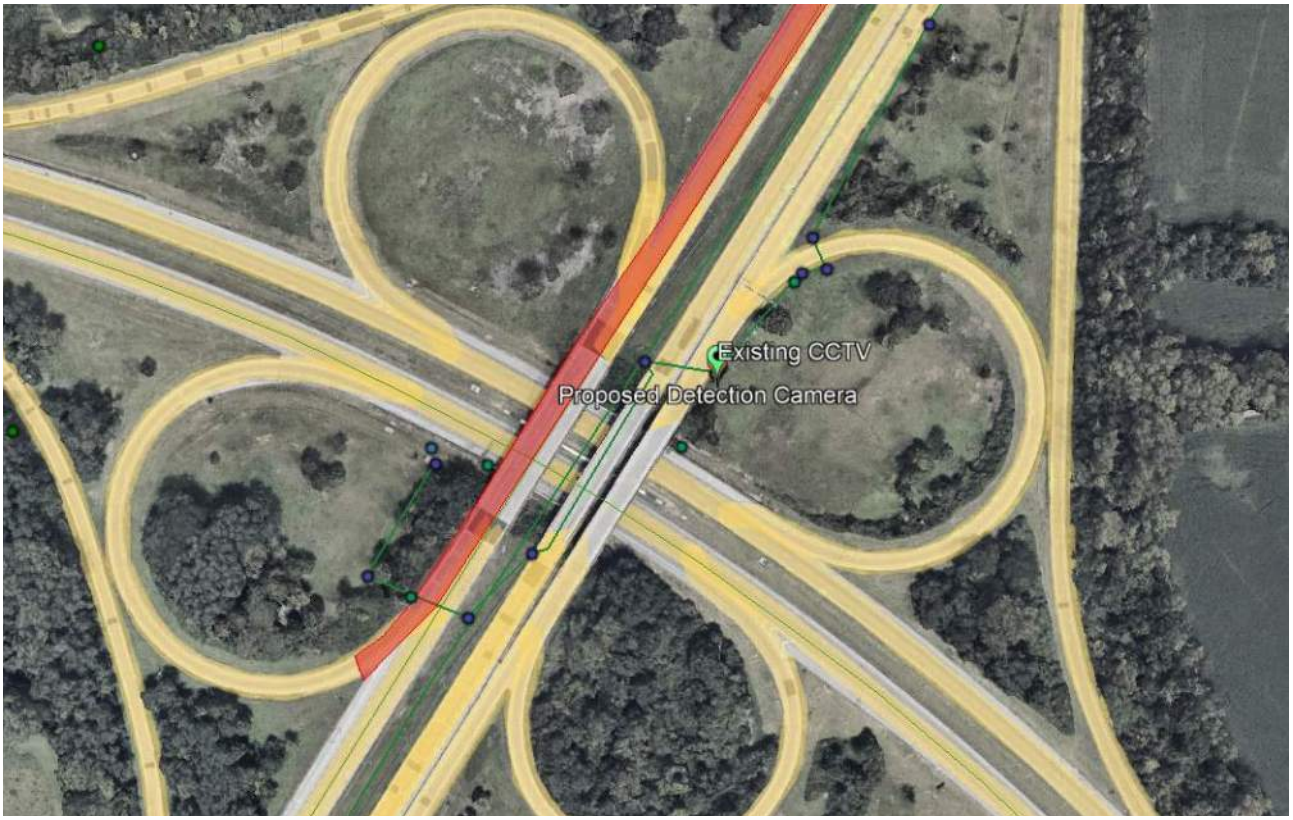


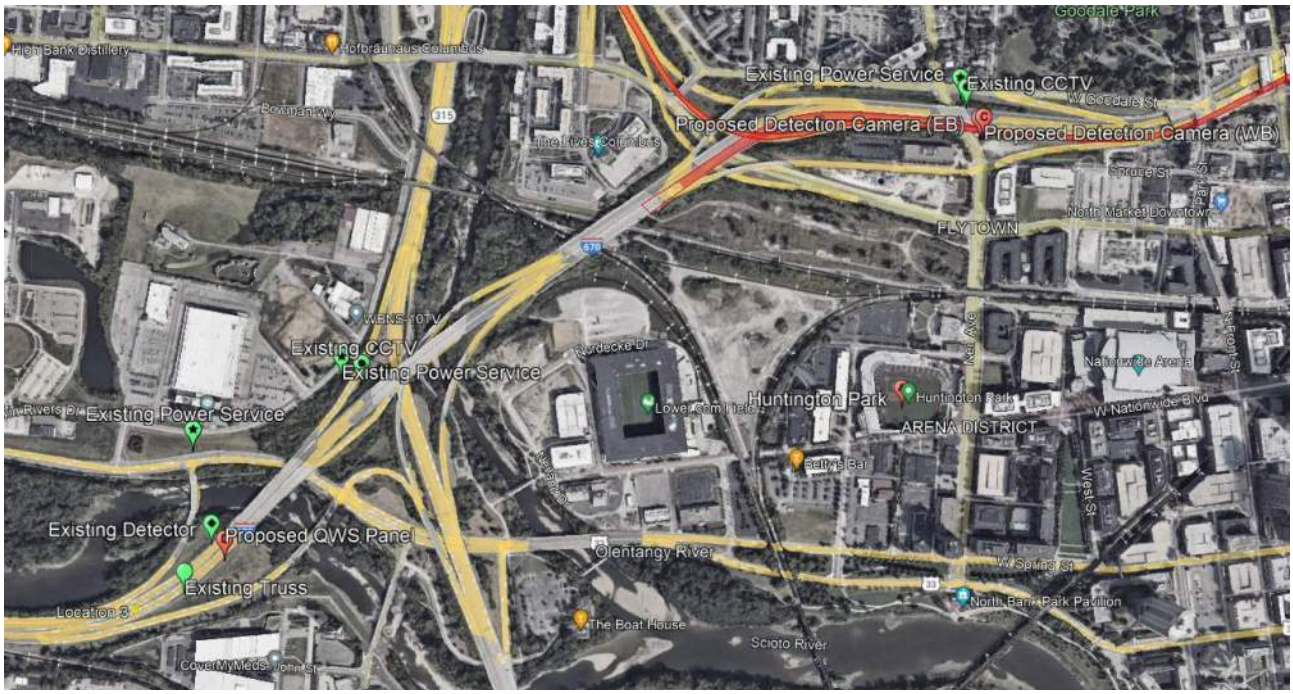
Figure 26: QWS-GRND-D6-I-270_SB AT SR 317 proposed detection camera location at US 33 off-ramp SLM 46.09 NB

Figure 27: QWS-GRND-D6-I-270_SB AT SR 317 street view of proposed detection camera location

4.3 DISTRICT 06

D) QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE *Location: I-670 EB & OH-315 SB/EB*

- **Queue Identification:** Queuing begins at approximately the 3rd and 4th street exit ramps, impacted by the influx of traffic on I-670 Eastbound and OH-315 Southbound. Queuing occurs throughout the week and during large events at the convention center.
- **Build up Duration:** AM 1 hour. PM 2.75 hours
- **End of Queue:** I-670 EB at Exit 2B OH-315 North
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Morning peak hours between 6:45 AM and 7:45 AM. Afternoon peak hours between 2:15 PM and 5:00 PM
- **Geometric Limitations:** Horizontal curve on I-670 EB fly over ramp before I670 EB/OH-315 merge.
- **Location Map:**



- **Cost:** Ground mounted QWS panel $150,000. New camera pole with two detection cameras $115,000. Total: $265,000
- **Existing Conditions:**
  - **Power:** New power service needed for QWS panel. Closest existing power service is located at Dublin Rd and I670 WB on-ramp. Power for detection cameras will come from an existing power service on the north side of I-670 currently for and existing CCTV camera.
  - **Fiber/Telecommunications:** Existing fiber trunk on I-670 WB.

4.3 DISTRICT 06

D) QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE

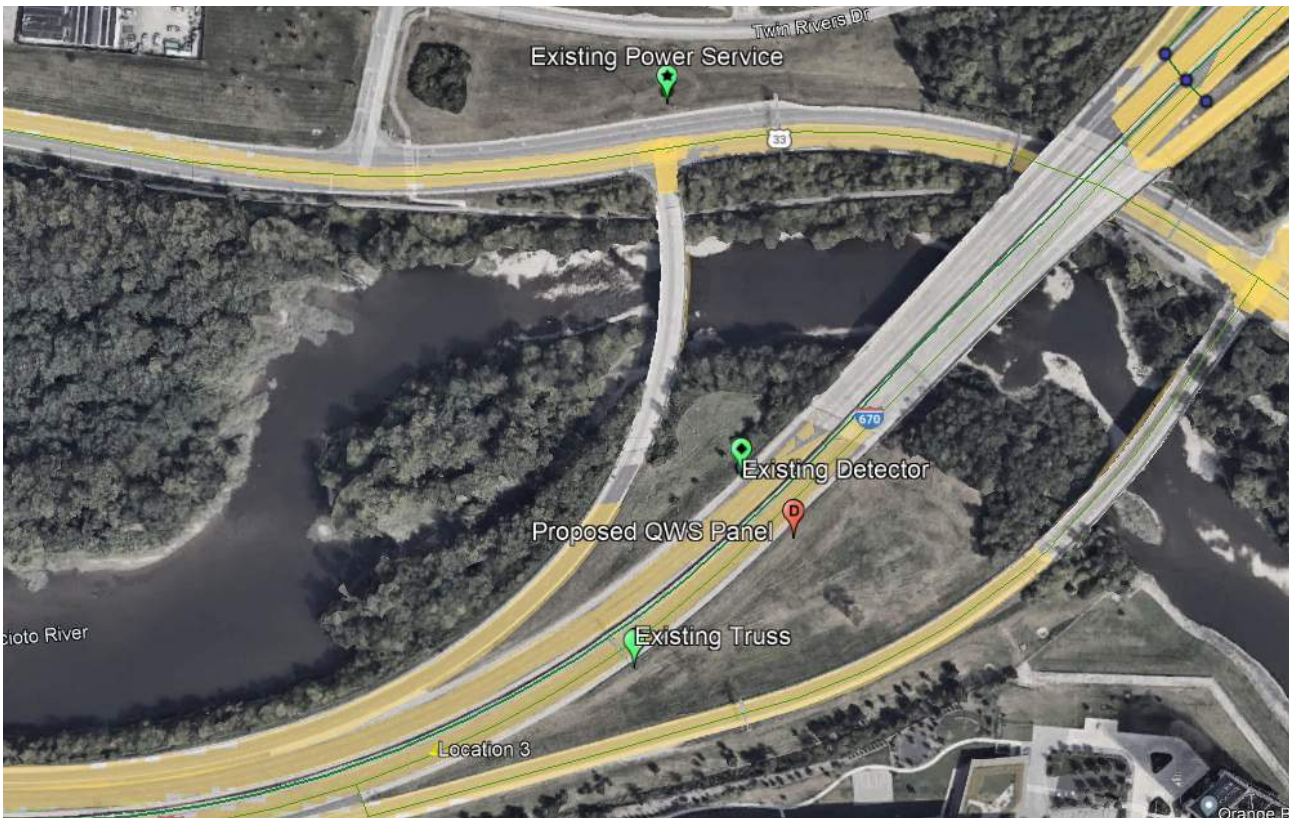


Figure 28: QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE proposed detection camera location and QWS panel

Figure 29: QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE street view of QWS panel at Scioto River Bridge at SLM 2.12 EB

4.3 DISTRICT 06

D) QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE

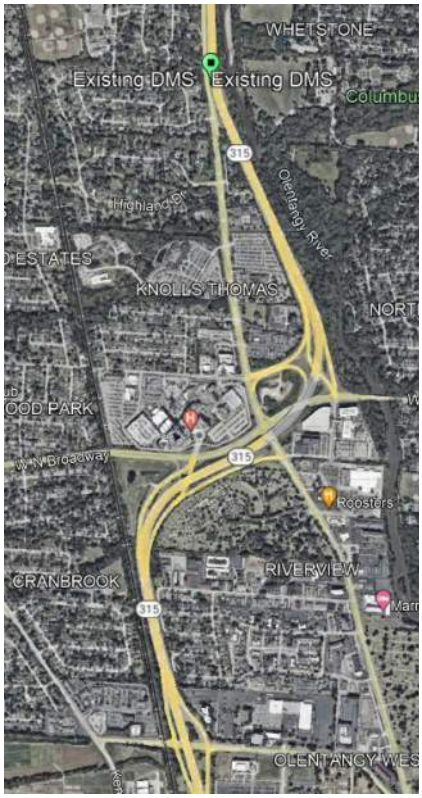
Figure 30: QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE proposed detection camera location

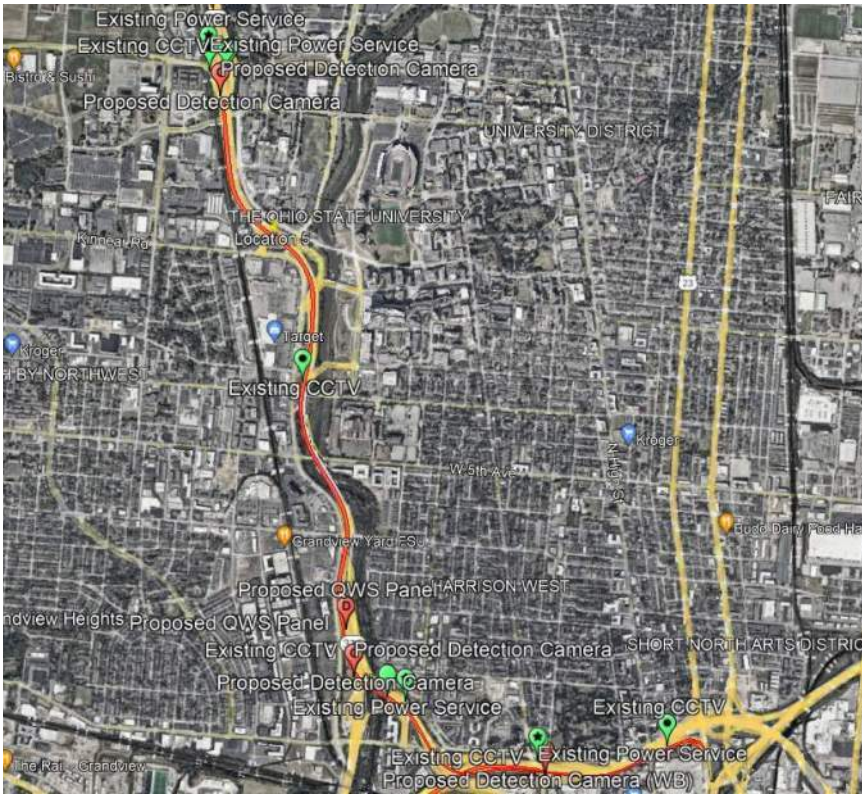
Figure 31: QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE street view of proposed detection cameras location, to be installed on Neil Ave, looking on I-670 EB/WB.

4.3 DISTRICT 06

E) QWS-GRND-D6-OH-315_SB AT IR-670 *Location: OH-315 SB merge to I-670 EB*

- **Queue Identification:** This location has been identified by the TMC as an area of concern, particularly due to queuing on SR-315 Southbound in the morning
- **Build up Duration:** 0.5 hours during AM and 2.75 hours during PM
- **End of Queue:** Exit 4/Lane Ave
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Morning peak hours between 6:45 Am and 7:15 AM congestion is minimal. The afternoon peak hours between 2:15 PM and 5:00 PM
- **Geometric Limitations:** The fly over ramp from OH-315 SB to I-670 EB going over the Olentangy River has blind curves
- **Location Map:**





- **Cost:** Existing full color DMS $0. Proposed ground mounted QWS panel $150,000. Proposed detection camera and pole at Lane Ave $50,000. Proposed detection camera on existing CCTV camera pole $15,000. Total: $215,000
- **Existing Conditions:**
  - **Power:** New power for proposed ground mounted QWS panel or if possible use the same power service for the existing CCTV camera at the fly over ramp on OH-315 SB. Power for the detection camera at Lane Ave to come from the existing power service at Lane Ave. Power for the detection camera is located at the existing CCTV camera at the fly over ramp.
  - **Fiber/Telecommunications:** Existing fiber trunk along OH-315 SB

4.3 DISTRICT 06

E) QWS-GRND-D6-OH-315_SB AT IR-670

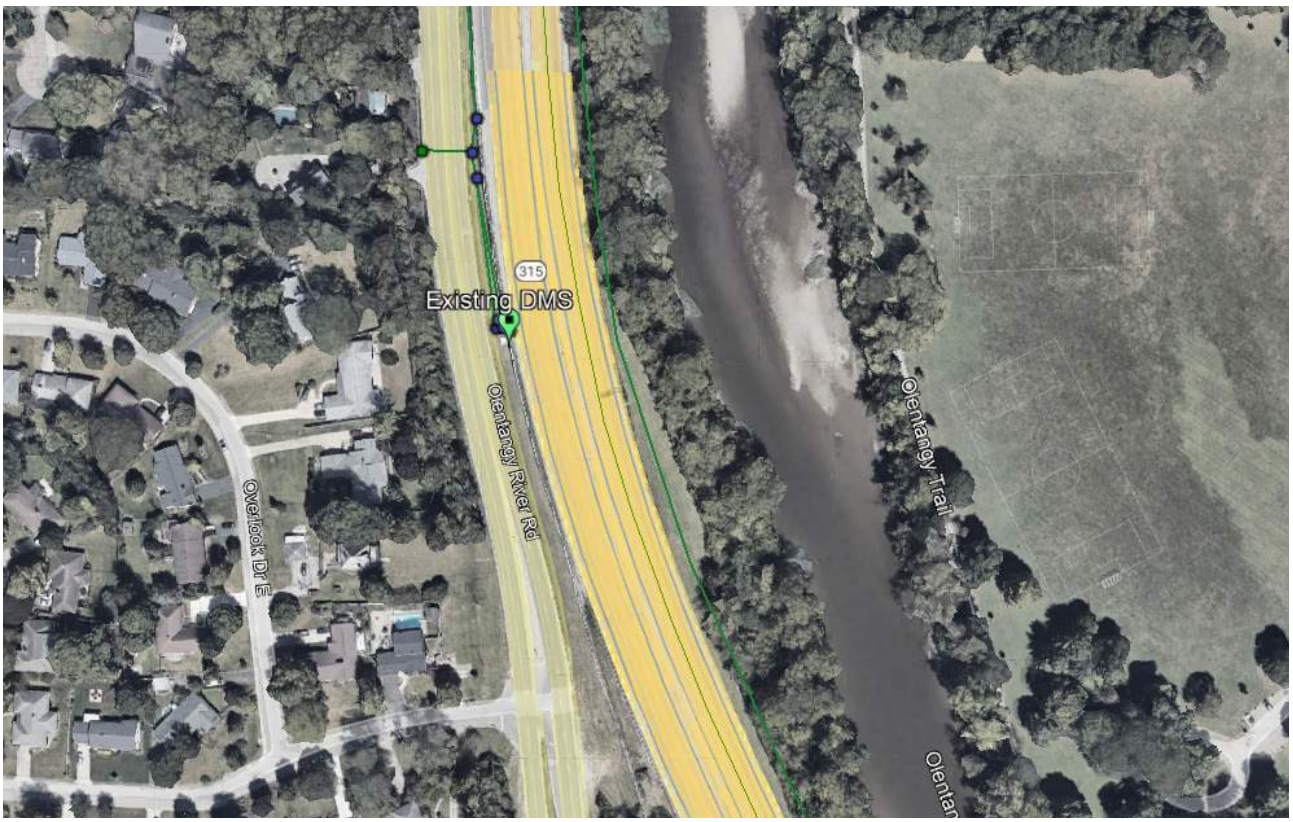


Figure 32: QWS-GRND-D6-OH-315_SB AT IR-670 existing DMS Location

Figure 33: QWS-GRND-D6-OH-315_SB AT IR-670 street view of existing DMS Location

4.3 DISTRICT 06

E) QWS-GRND-D6-OH-315_SB AT IR-670

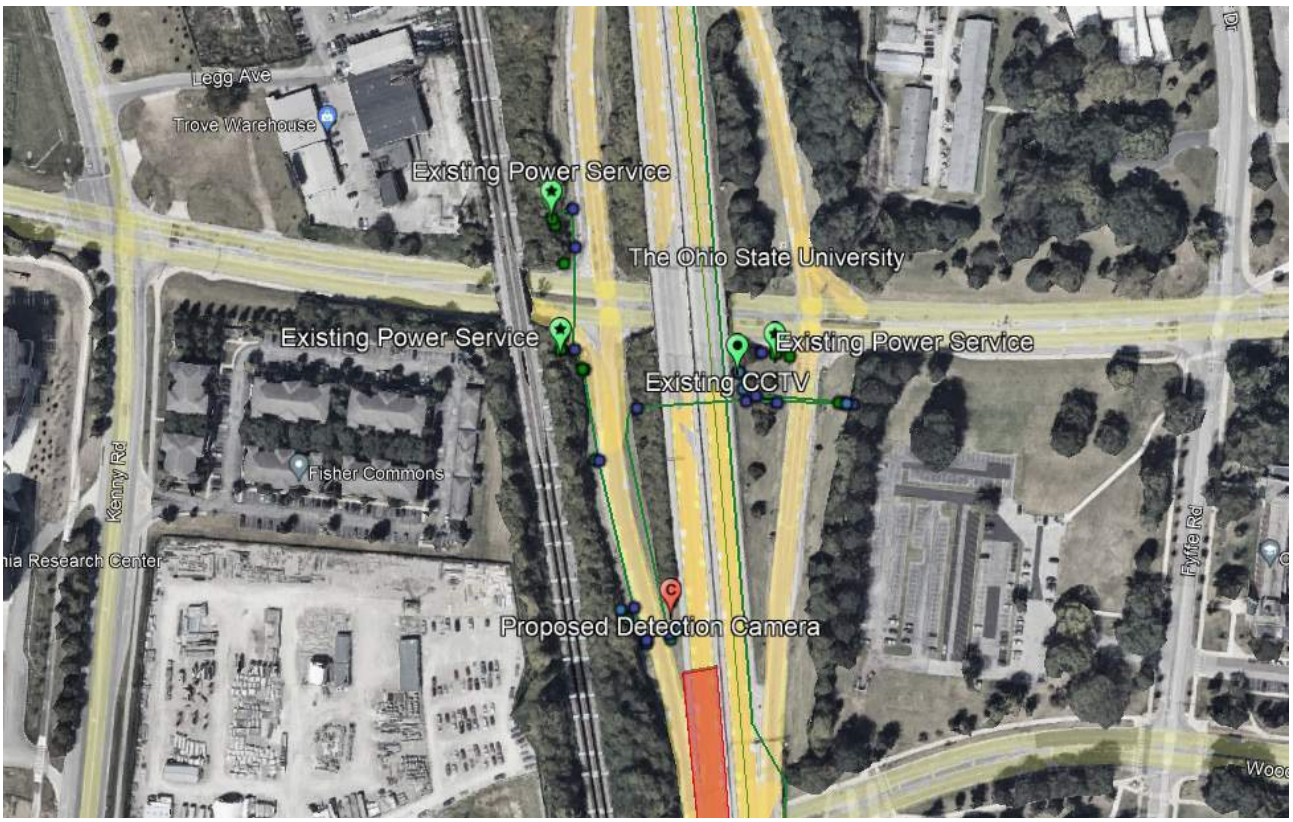


Figure 34: QWS-GRND-D6-OH-315_SB AT IR-670 aerial of proposed detection camera.

Figure 35: QWS-GRND-D6-OH-315_SB AT IR-670 street view of proposed detection camera.

4.3 DISTRICT 06

E) QWS-GRND-D6-OH-315_SB AT IR-670

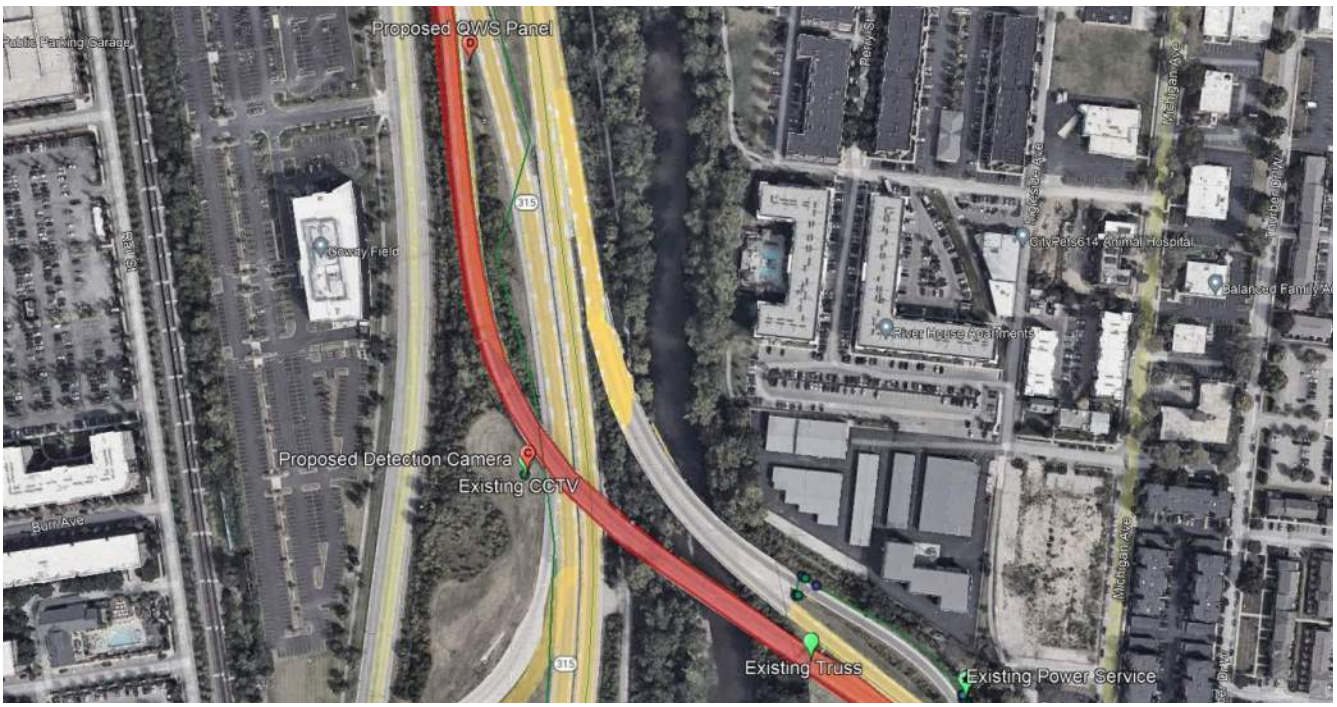


Figure 36: QWS-GRND-D6-OH-315_SB AT IR-670 proposed detection camera and QWS Panel

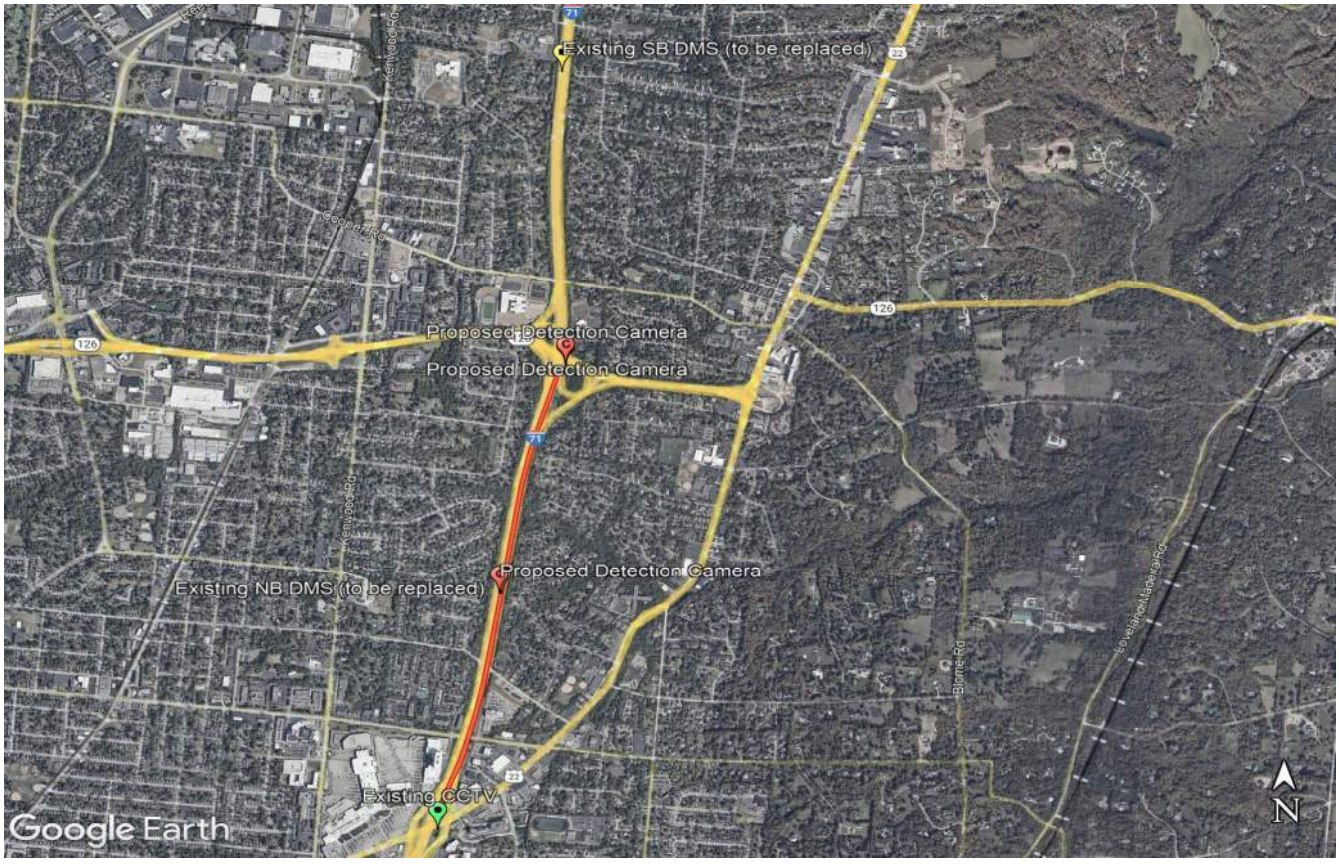
Figure 37: QWS-GRND-D6-OH-315_SB AT IR-670 street view proposed QWS Panel

Figure 38: QWS-GRND-D6-OH-315_SB AT IR-670 street view proposed detection camera

4.4 DISTRICT 08

A) QWS-OVRHD-D8-I-71_SR 126 *Location: I-71 NB & OH-126 EB*

- **Queue Identification:** During the evening peak, queuing becomes a major issue in this location due to merging challenges. Specifically, on I-71 Northbound, there are often queues that back up due to vehicles merging from OH-126 Eastbound.
- **Build up Duration:** 0.75 hours during AM. 3.25 hours during PM.
- **End of Queue:** I-71 NB & US-22
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Morning peak hours between 6:45 AM and 7:30 AM. Afternoon peak hours between 3:00 PM and 6:15 P
- **Geometric Limitations:** N/A
- **Location Map:**



- **Cost:** Replacement of two existing DMS sign and structures $620,000. Three structure mounted detection cameras $45,000. Total: $ 665,000
- **Existing Conditions:**
  - **Power:** Power for all locations will come from existing DMS or CCTV devices at the same location.
  - **Fiber/Telecommunications:** Existing fiber backbone along I-71 and existing fiber drops are local to the proposed device locations.

4.4 DISTRICT 08

A) QWS-0VRHD-D8-I-71_SR 126

Figure 39: QWS-0VRHD-D8-I-71_SR 126 proposed detection cameras location

Figure 40: QWS-0VRHD-D8-I-71_SR 126 street view of proposed detection cameras

4.4 DISTRICT 08

A) QWS-OVRHD-D8-I-71_SR 126

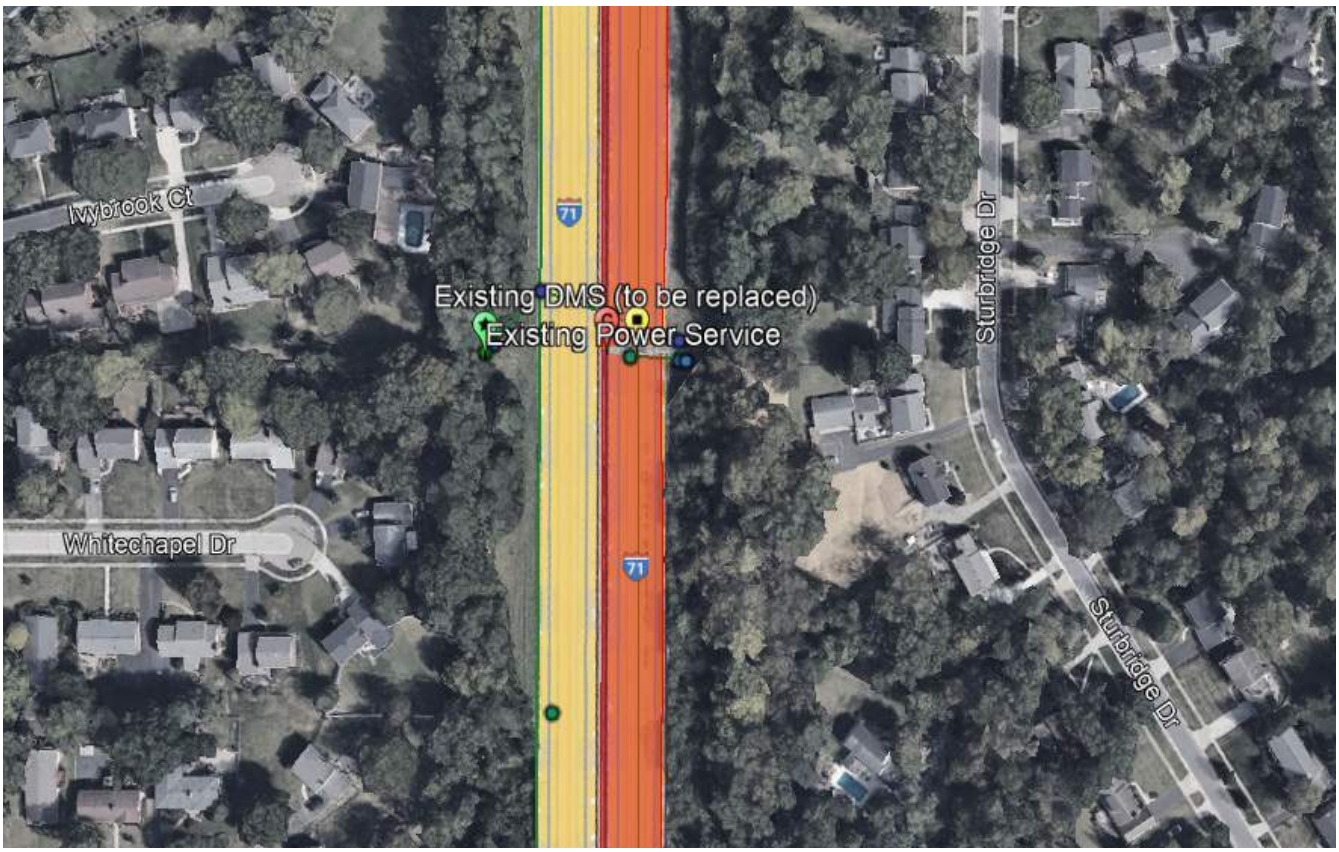


Figure 41: QWS-OVRHD-D8-I-71_SR 126 proposed detection camera location

Figure 42: QWS-OVRHD-D8-I-71_SR 126 street view of proposed detection camera (with DMS to be replaced)

4.4 DISTRICT 08

A) QWS-0VRHD-D8-I-71_SR 126

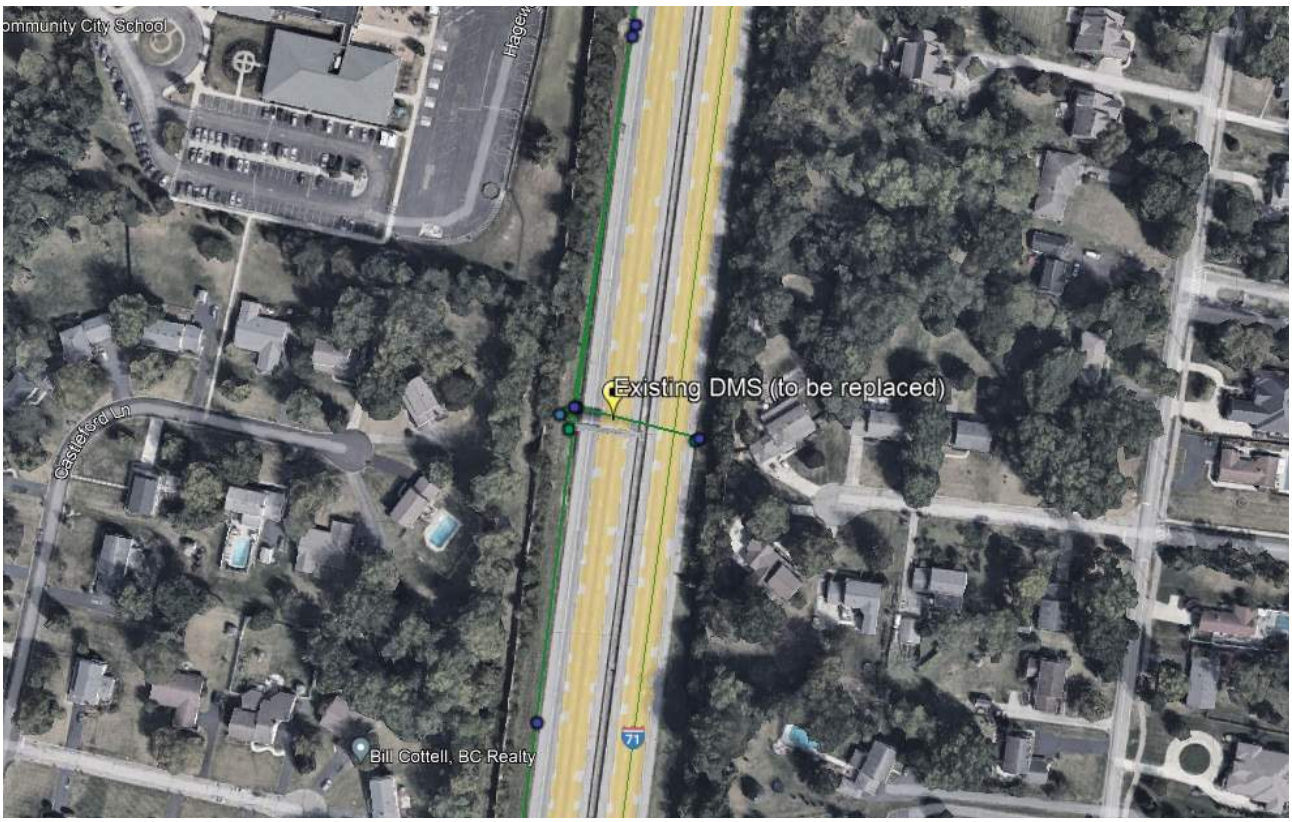


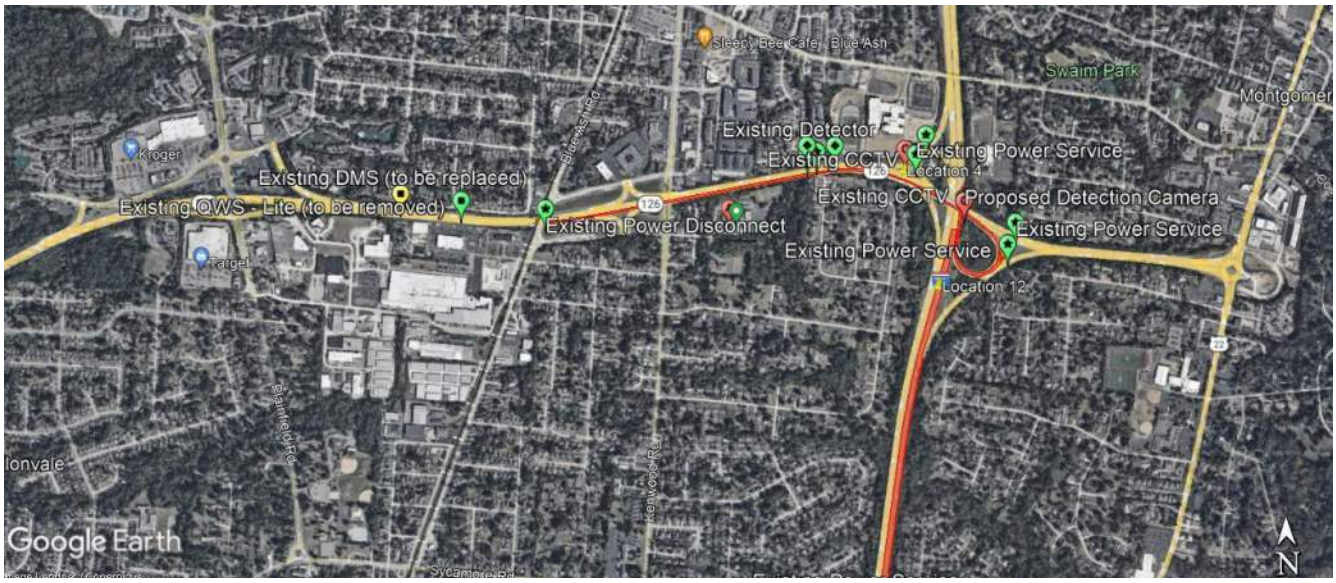
Figure 43: QWS-0VRHD-D8-I-71_SR 126 existing DMS (to be replaced)

Figure 44: QWS-0VRHD-D8-I-71_SR 126 street view of existing DMS (to be replaced)

4.4 DISTRICT 08

B) QWS-OVRHD-D8-OH-126_EB AT I-71 *Location: OH-126 Eb & I-71 NB*

- **Queue Identification:** During the evening peak, queuing becomes a major issue in this location due to merging challenges. Specifically, on I-71 Northbound, there are often queues that back up due to vehicles merging from OH-126 Eastbound.
- **Build up Duration:** 2.5 hours during AM peak. 4 hours during PM peak.
- **End of Queue:** OH-126 Eb & Blue Ash Rd/Kenwood Rd.
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Morning peak is from 6:30 AM to 9:00 AM. Afternoon peak is from 2:00 PM to 6:00 PM
- **Geometric Limitations:** There is a crest vertical curve followed by a sag vertical curve on OH-126 EB from the existing DMS at SLM 18.49 and continuing to the Blue Ash Rd/Kenwood Rd exits. At the detection camera site on the existing strain pole there is an existing truss with static signage to consider when mounting the camera.
- **Location Map:**



- **Cost:** Replacement of existing overhead DMS and sign structure with a new full-color DMS sign and truss structure - $310,000. New detection camera on existing traffic signal strain pole - $15,000. Total: $325,000
- **Existing Conditions:**
  - **Power:** There is existing power service at the existing DMS to be replaced. The proposed detection camera location at the traffic signal strain pole has an existing power service next to the location.
  - **Fiber/Telecommunications:** The existing DMS and structure to be replaced with new currently is suing a cellular modem for communications. The new DMS sign will need to also use a cellular modem for communication unless fiber optic cable is to be ran from the I-71 trunk line. For the detection camera there is an existing fiber trunk that runs along I-71.

4.4 DISTRICT 08

B) QWS-OVRHD-D8-OH-126_EB AT I-71

Figure 45: QWS-OVRHD-D8-OH-126_EB AT I-71 existing DMS to be replaced

Figure 46: QWS-OVRHD-D8-OH-126_EB AT I-71 existing DMS to be replaced

4.4 DISTRICT 08

B) QWS-OVRHD-D8-OH-126_EB AT I-71

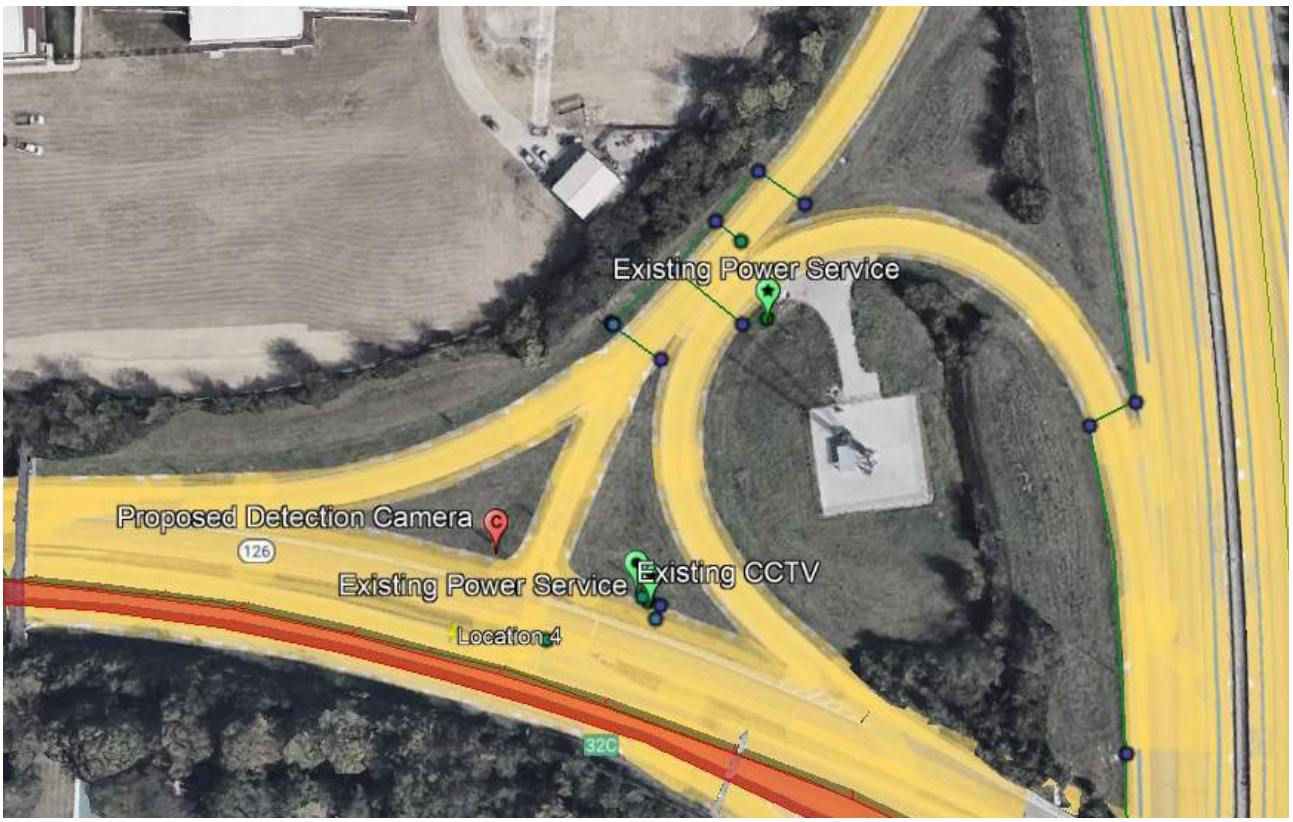


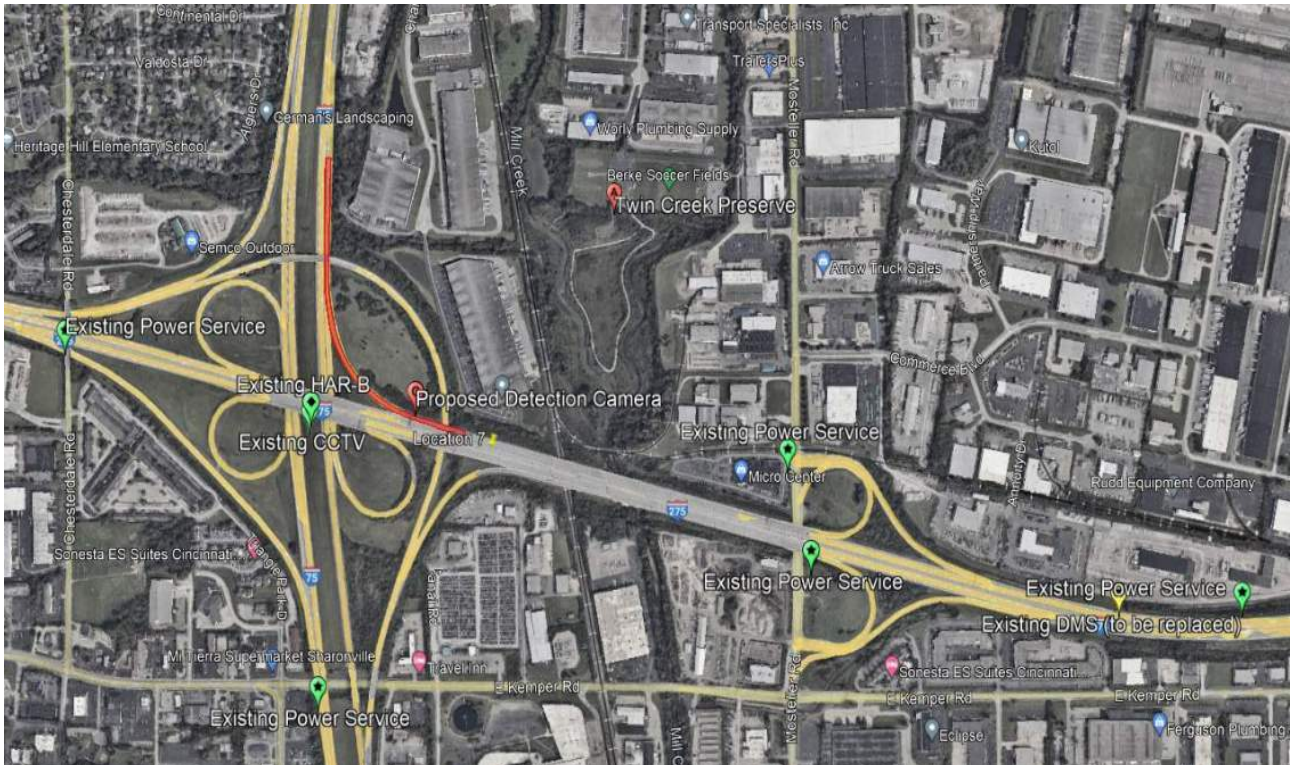
Figure 47: QWS-OVRHD-D8-OH-126_EB AT I-71 detection camera proposed location

Figure 48: QWS-OVRHD-D8-OH-126_EB AT I-71 street view detection camera proposed location on existing traffic signal at the I-71 off-ramp

4.4 DISTRICT 08

C) QWS-OVRHD-D8-I-275_WB AT I-75 NB Location: I275 WB at I-75 NB Interchange

- **Queue Identification:** I-275 Westbound and I-75 Southbound frequently experience extended queues in the evening, primarily due to slow weave points at the system interchange.
- **Build up Duration:** 2 hours during PM.
- **End of Queue:** Along ramp from I-275 WB to I-75 NB, spilling over into the exit lane on I-275 WB
- **Safety and Mobility Considerations:** There was a fatal accident at this location earlier this year.
  - **Events/hours etc:** Congestion only present during the afternoon peak hours from 3:00 PM to 5:00 PM. Stoppages can occur from drivers trying to merge into the exit lane from the travel lane from a stop or low speeds.
- **Geometric Limitations:** Limited shoulder in this section.
- **Location Map:**



- **Cost:** Replacement of existing DMS Sign and structure with a new full-color DMS sign and truss structure - $310,000. New detection camera on an existing static sign truss structure - $70,000. Total: $380,000
- **Existing Conditions:**
  - **Power:** Power service for replacement DMS is local to the existing DMS location. Detection camera on the existing static sign truss structure will require a new power service.
  - **Fiber/Telecommunications:** Existing fiber communications at the exiting DMS location. The detection camera will need a new fiber drop at this location but there is an existing fiber trunk along I-275

4.4 DISTRICT 08

C) QWS-0VRHD-D8-I-275_WB AT I-75 NB

Figure 49: QWS-0VRHD-D8-I-275_WB AT I-75 NB existing DMS to be replaced

Figure 50: QWS-0VRHD-D8-I-275_WB AT I-75 NB existing DMS to be replaced

4.4 DISTRICT 08

C) QWS-OVRHD-D8-I-275_WB AT I-75 NB

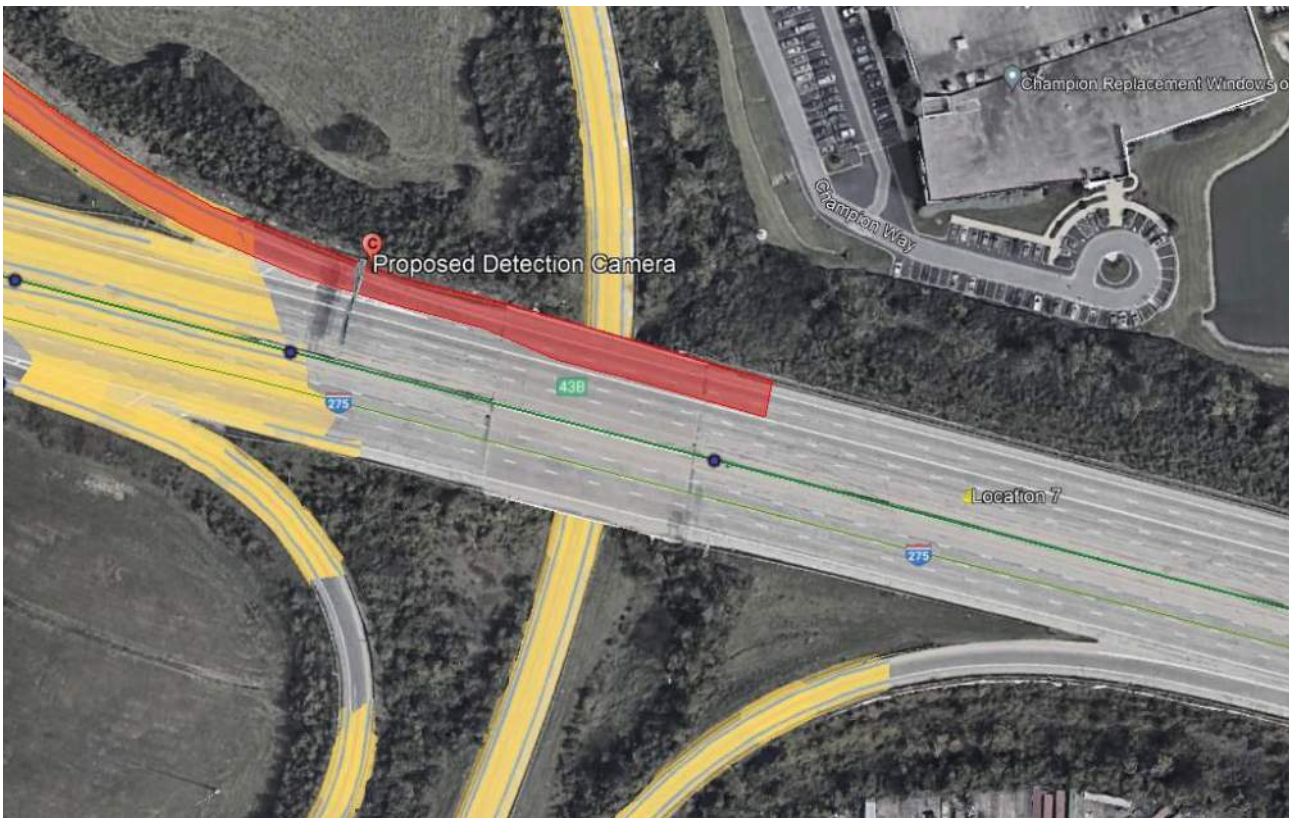


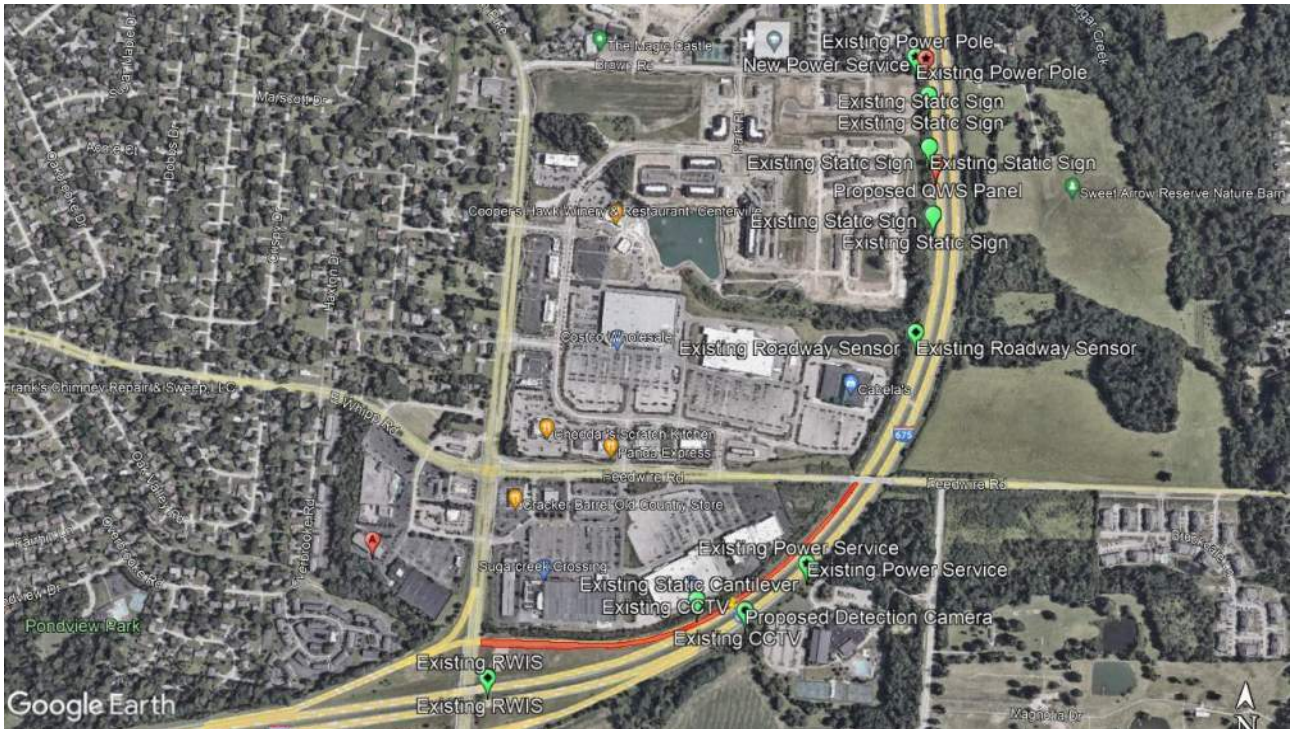
Figure 51: QWS-OVRHD-D8-I-275_WB AT I-75 NB proposed detection camera

Figure 52: QWS-OVRHD-D8-I-275_WB AT I-75 NB street view proposed detection camera

4.4 DISTRICT 08

D) QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE Location: I-675 SB & Wilmington Pike junction

- **Queue Identification:** Queuing on I-675 Southbound during PM peak hours is a significant concern, especially as people turn left onto Wilmington Pike. Additionally, in the evenings, there are queues backing up past the Feedwire Rd exit for I-675 Southbound.
- **Build up Duration:** 2 hours during PM.
- **End of Queue:** N/A
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Congestion only present during the afternoon peak hours from 3:00 PM to 5:00 PM. Area is subjected to higher rear end crashes
- **Geometric Limitations:** Horizontal curve near Feedwire Rd overpass can block drivers view of stopped traffic at the exit for Wilmington Pike.
- **Location Map:**



- **Cost:** Proposed ground mounted QWS panel - $150,000. Proposed detection camera on existing CCTV pole - $15,000. Total: $165,000
- **Existing Conditions:**
  - **Power:** Power service for replacement DMS is local to the existing DMS location. Detection camera on the existing static sign truss structure will require a new power service.
  - **Fiber/Telecommunications:** New communications service will be needed for the QWS Panel. The proposed detection camera will use the same communication service the existing CCTV camera is using.

4.4 DISTRICT 08

D) QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE

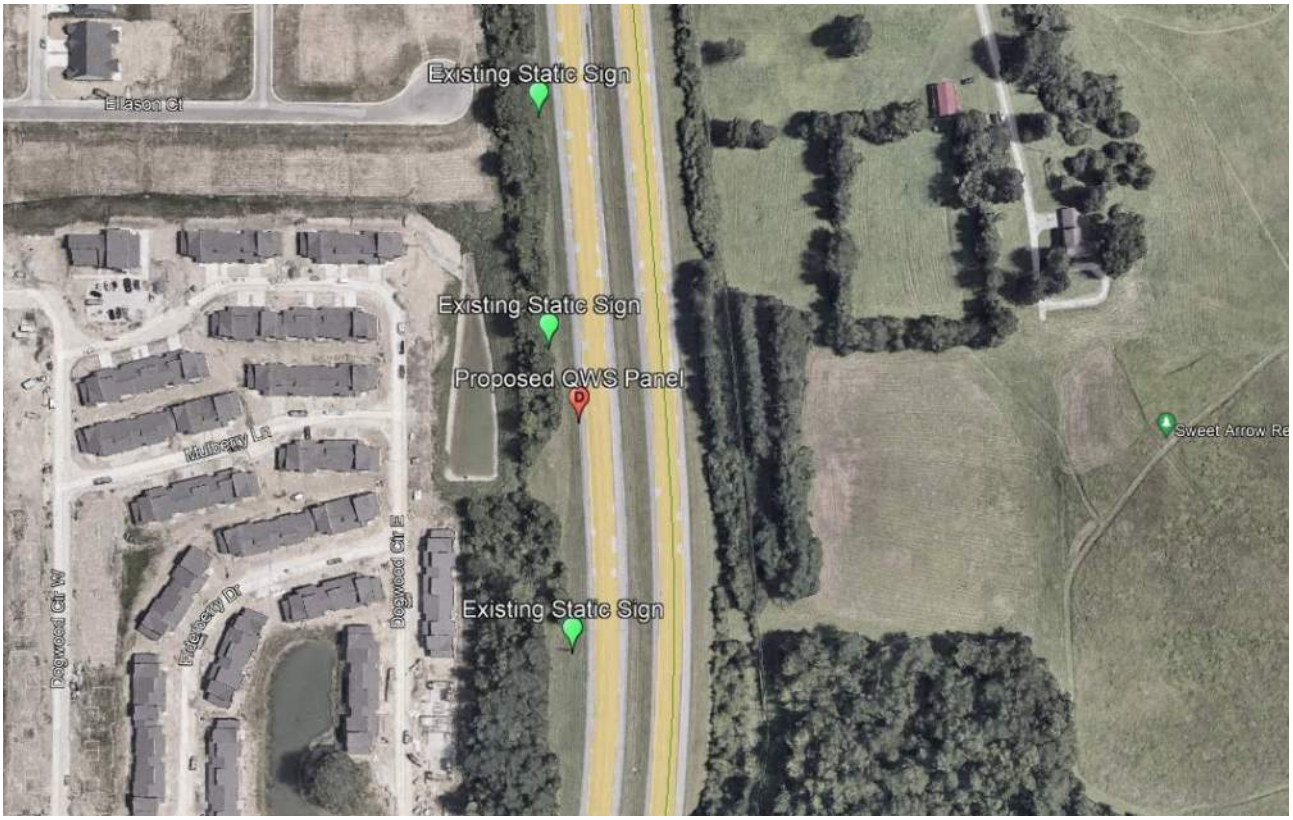


Figure 53: QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE proposed QWS Panel location

Figure 54: QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKEproposed street view of QWS Panel location

4.4 DISTRICT 08

D) QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE

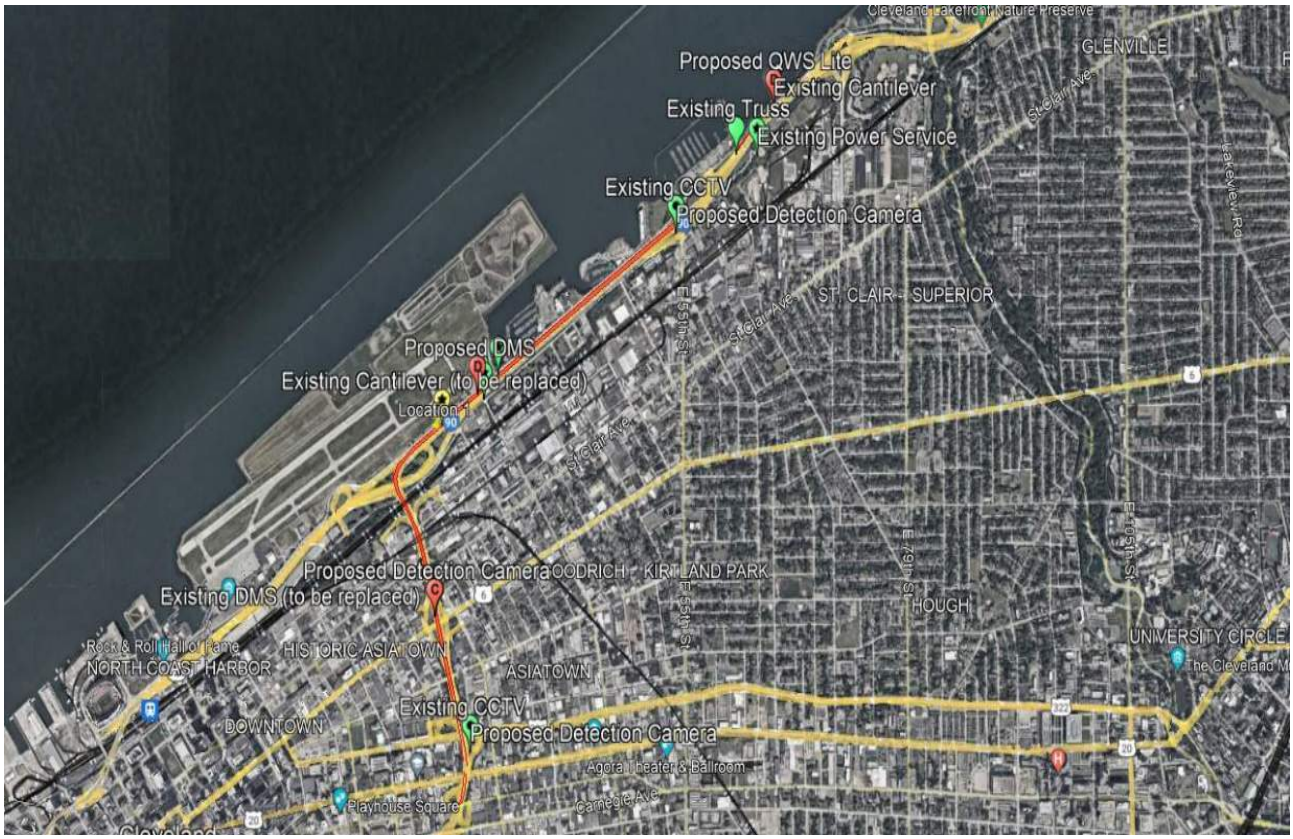
Figure 55: QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE detection camera proposed location

Figure 56: QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE street view detection camera proposed location

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Location:I-90 WB; Innerbelt Curve

- **Queue Identification:** The Innerbelt curve poses a significant safety concern at this location and queues are a common occurrence during peak rush hours.
- **Build up Duration:** 4.5 hours during PM
- **End of Queue:** East 55th Street Overpass
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** Reoccurring congestion. Area is subjected to higher rear end crashes
- **Geometric Limitations:** Innerbelt curve on I-90 has frequent accidents due to substandard curve.
- **Location Map:**



- **Cost:** For three (3) replacements of existing DMS signs and structures with new full-color DMS signs and truss structures - $880,000. The QWS Lite on existing cantilever vertical support - $50,000. The new overhead sign support box truss - $180,000. Three (3) new detection cameras on existing structures - $45,000. One new detection camera with pole - $75,000. Total: $1,230,000
- **Existing Conditions:**
  - **Power:** The proposed QWS Lite sign will require new power service. All other locations have existing power service local to the proposed device location.
  - **Fiber/Telecommunications:** The proposed QWS Lite sign will require new communication service. All other locations have existing communication services local to their proposed locations.

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

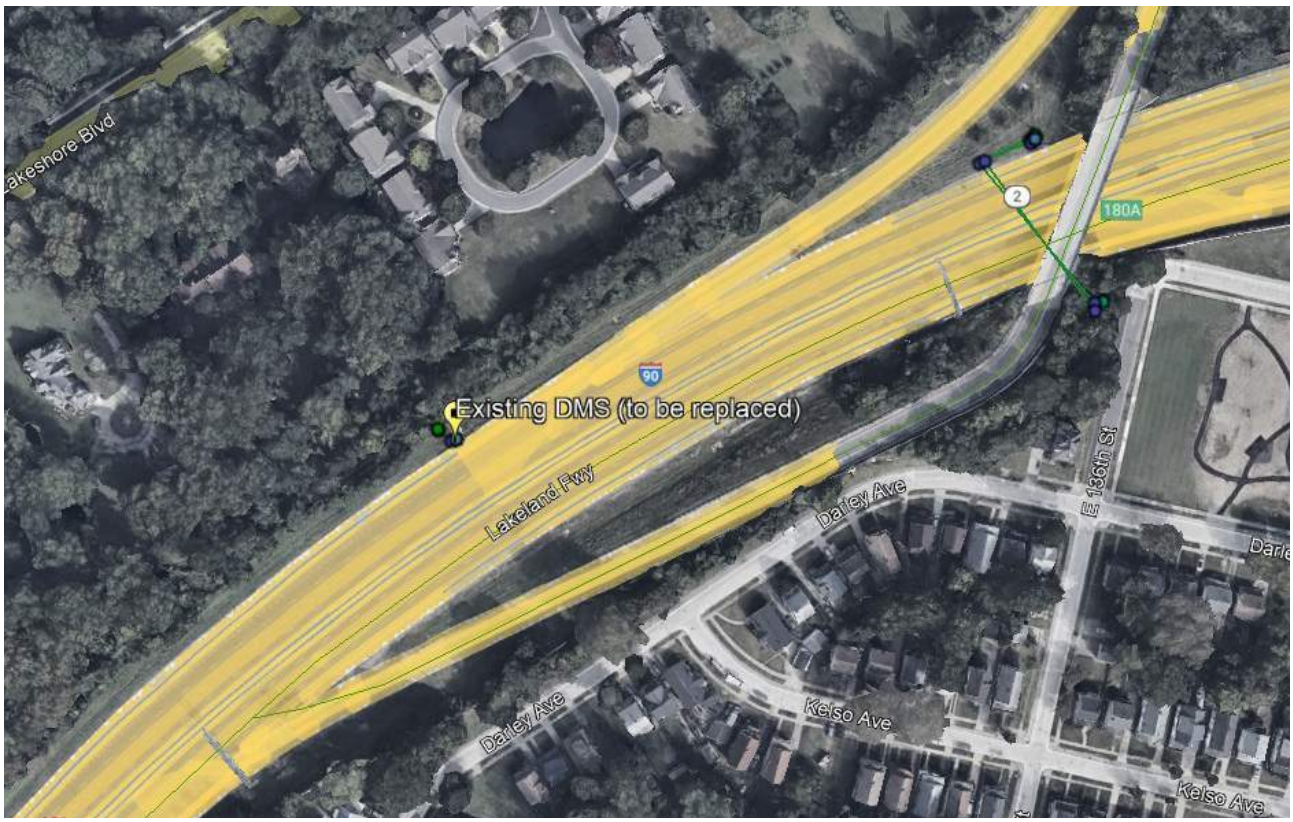


Figure 57: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN proposed detection cameraand pole location

Figure 58: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of existing DMS to be replaced

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

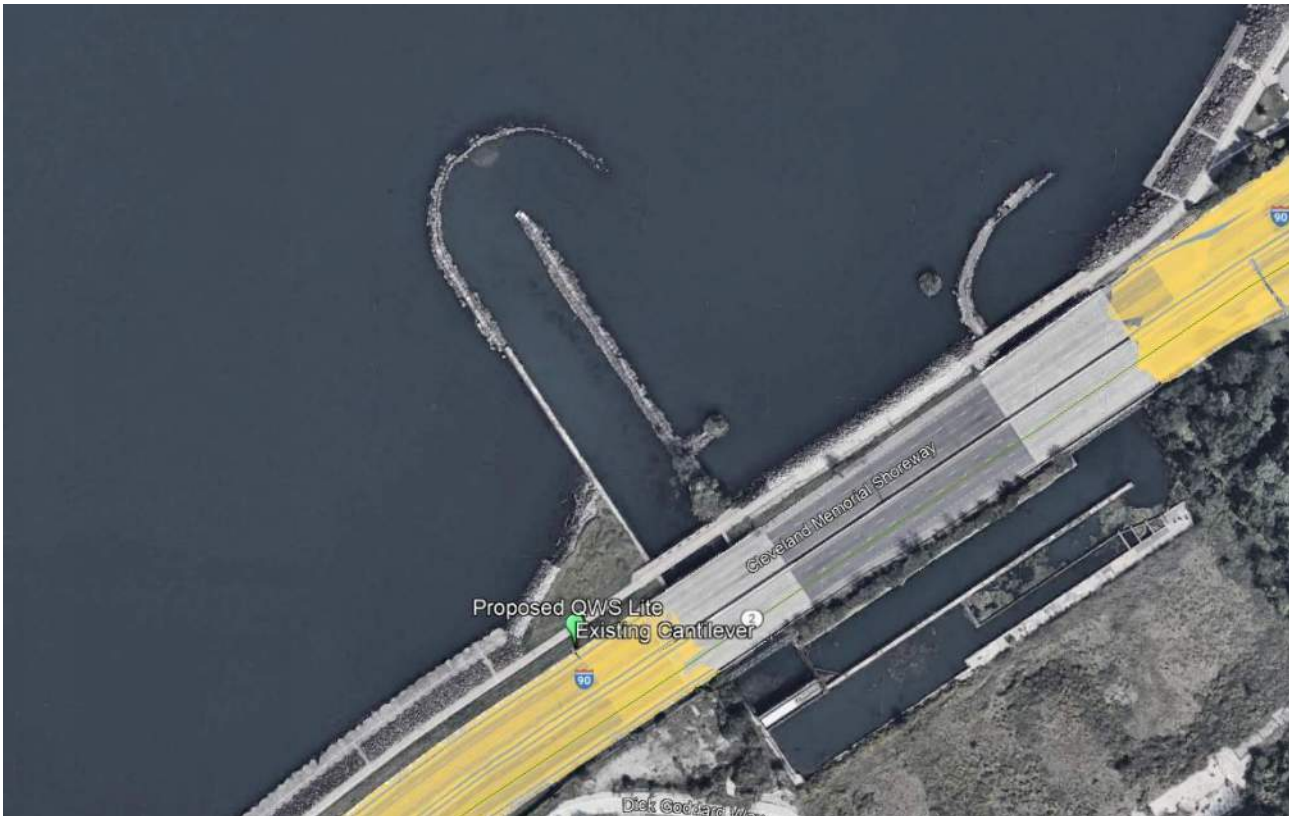


Figure 59: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Proposed QWS Lite on existing cantilever sign

Figure 60: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of Proposed QWS Lite on existing cantilever sign

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

Figure 61: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN replacement of existing sign structure with new DMS and structure along with a proposed detection camera on existing CCTV pole

Figure 62: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of replacement sign, new DMS, and new detection camera on existing CCTV pole

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

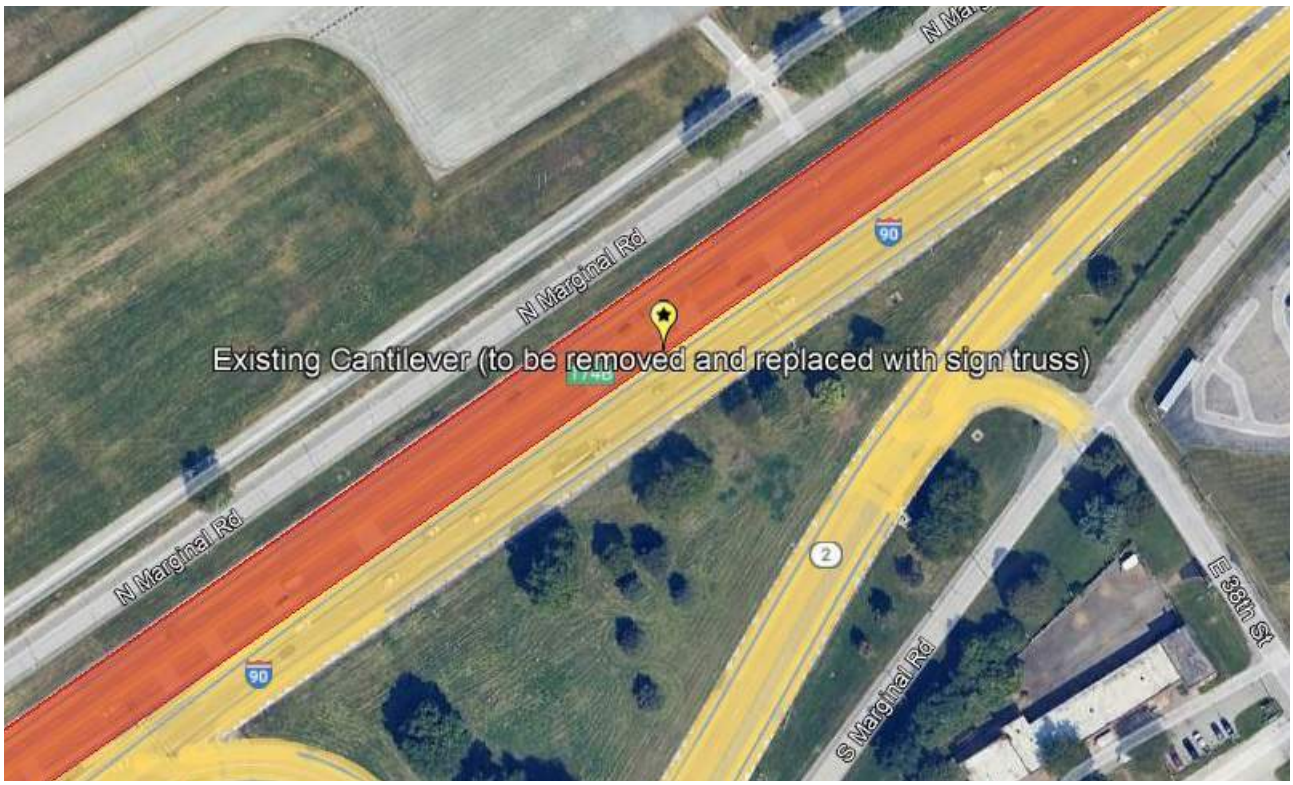


Figure 63: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN replacement of existing sign structure with new DMS and structure along with a proposed detection camera on existing CCTV pole

Figure 64: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of replacement structure, new DMS, and new detection camera on existing CCTV pole

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

Figure 65: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Existing cantilever structure to be replaced with static sign truss structure

Figure 66: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street View existing cantilever structure to be replaced with static sign truss structure and location of proposed detection camera pole.

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

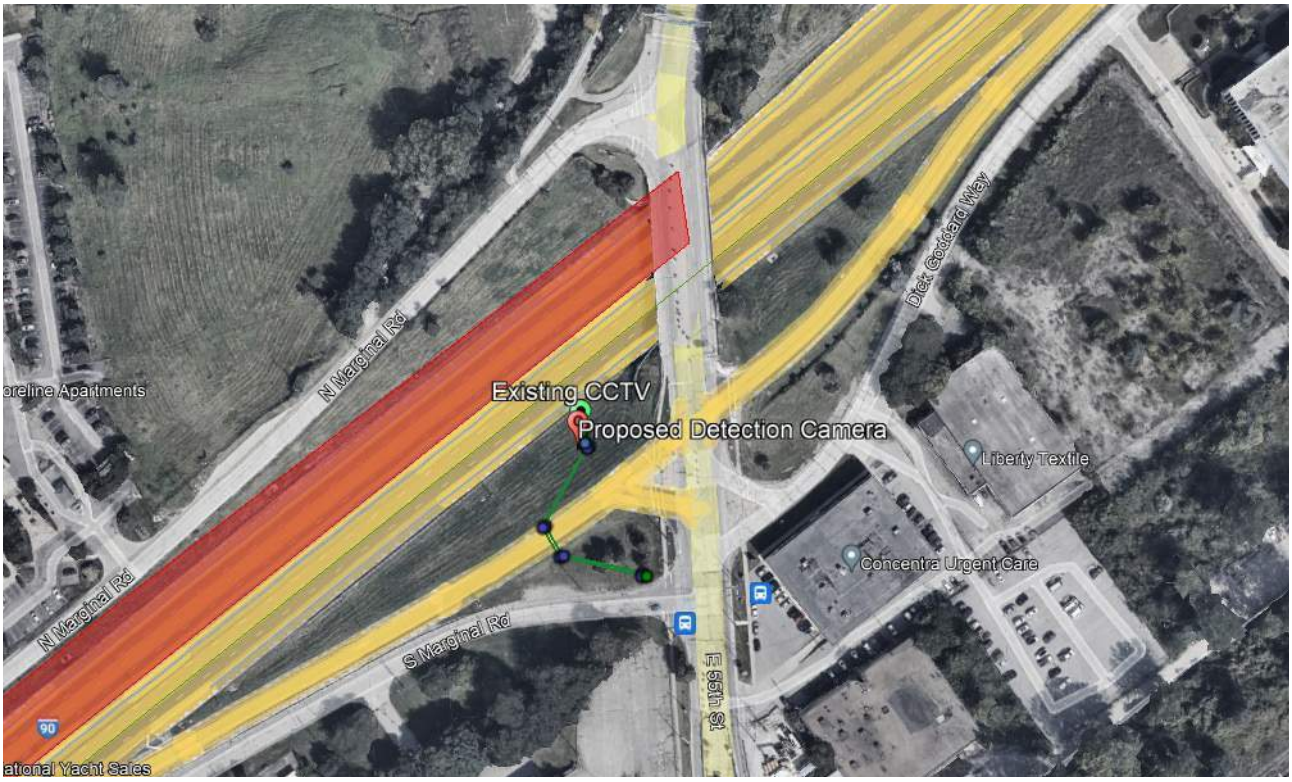


Figure 67: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Existing DMS and structure to be replaced with new full-color DMS and new truss structure. Proposed detection camera to be attached to new DMS truss structure

Figure 68: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of DMS sign and structure to be replaced with new detection camera

4.5 DISTRICT 12

A) QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

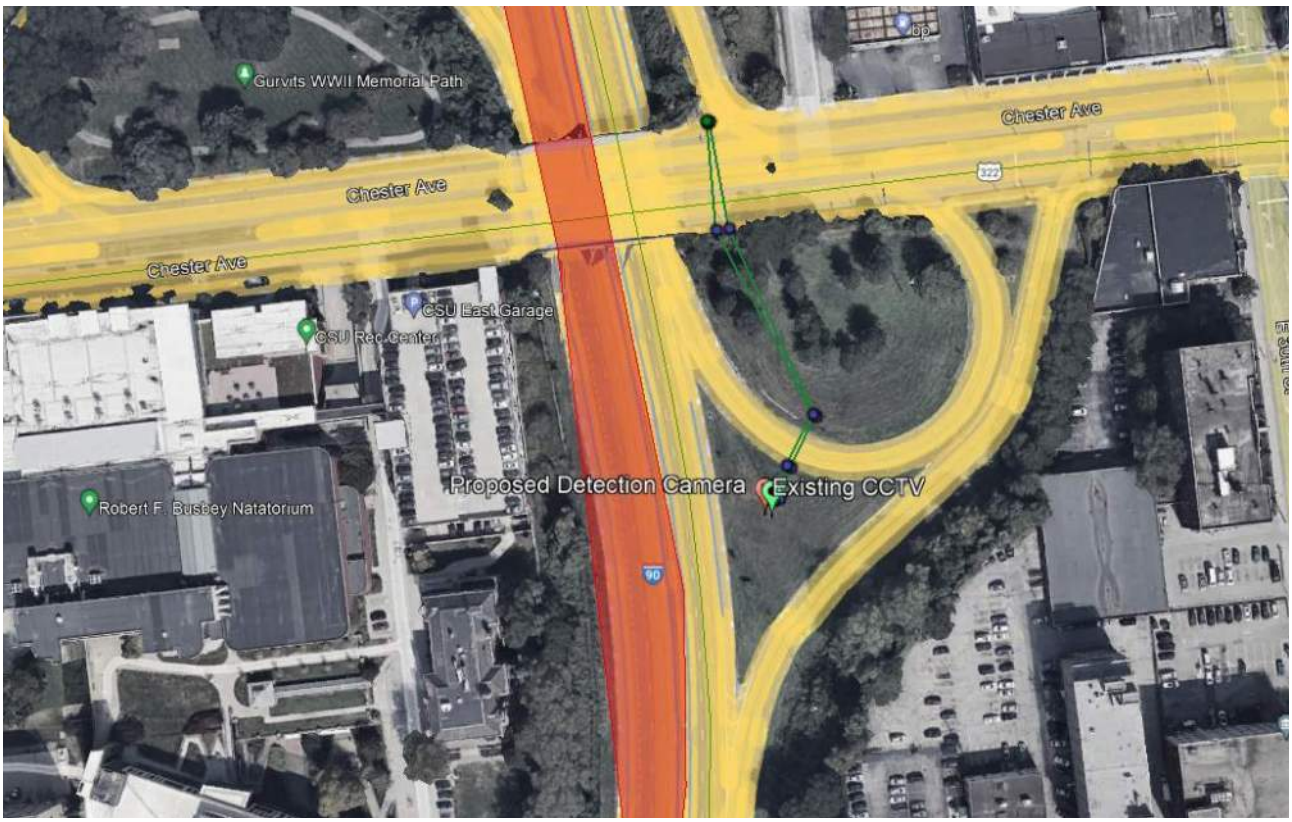


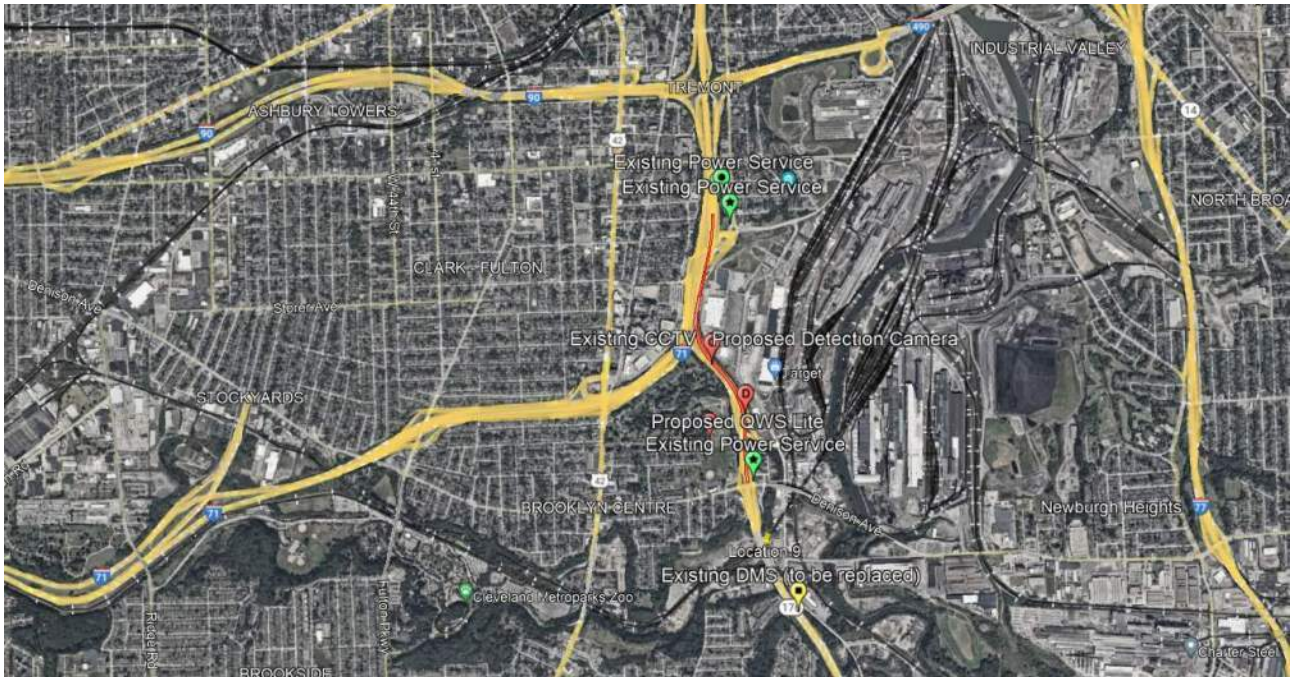
Figure 69: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Proposed detection camera on existing CCTV pole

Figure 70: QWS-OVRHD-D12-I-90_WB AT DOWNTOWN Street view of proposed detection camera on existing CCTV pole

4.5 DISTRICT 12

b) QWS-GRND-D12-OH-176_NB AT STEELYARD Location: OH-176 NB/I-71 NB merge

- **Queue Identification:** During peak hours and special events, extended queues are present heading downtown, particularly on I-71 Northbound past Denison. There is a noted blind spot underneath the double-decker bridge where OH-176 and I-71 intersect that makes it challenging for drivers to know of any queues forming.
- **Build up Duration:** 1.75 hours during AM and 4.0 hours during PM
- **End of Queue:** OH-176 NB at Denison Ave
- **Safety and Mobility Considerations:**
  - **Events/hours etc:** 6:30 AM and 8:15 AM and 1:45 PM and 5:45 PM
- **Geometric Limitations:** Blind horizontal curve on OH0176 before going under I-71 NB
- **Location Map:**



- **Cost:** Replacement of existing DMS and structure with a new full-color DMS sign and truss structure - $310,000. Proposed QWS Lite sign - $30,000. Proposed detection camera on existing CCTV pole - $15,000. Total: $355,000
- **Existing Conditions:**
  - **Power:** The proposed QWS Lite sign will require new power service. All other locations have existing power service local to the proposed device location.
  - **Fiber/Telecommunications:** The proposed QWS Lite sign will require new communication service. All other locations have existing communication services local to their proposed locations.

4.5 DISTRICT 12

B) QWS-GRND-D12-OH-176_NB AT STEELYARD

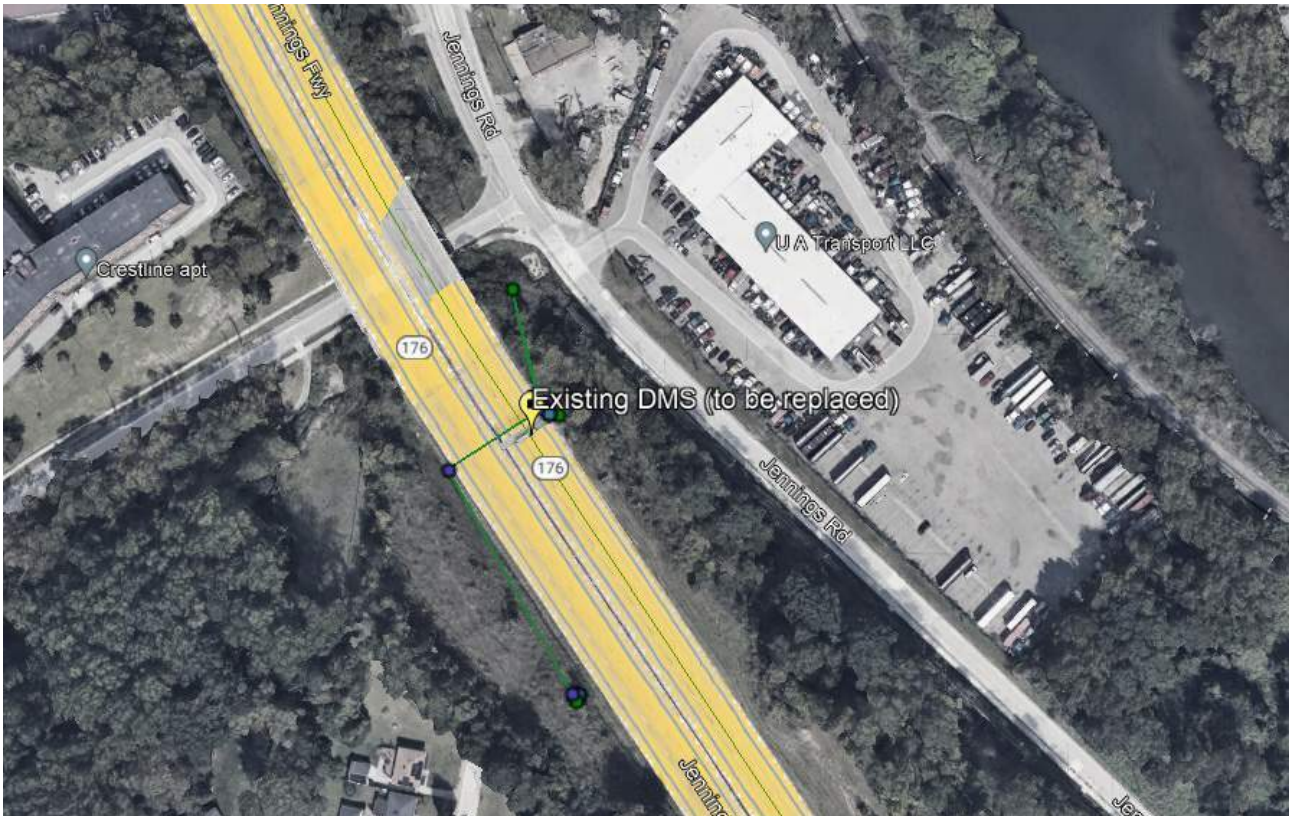


Figure 71: QWS-GRND-D12-OH-176_NB AT STEELYARD Existing DMS sign and structure to be replaced with new full-color DMS and truss structure

Figure 72: QWS-GRND-D12-OH-176_NB AT STEELYARD Street view of existing DMS sign and structure to be replaced with new

4.5 DISTRICT 12

B) QWS-GRND-D12-OH-176_NB AT STEELYARD

Figure 73: QWS-GRND-D12-OH-176_NB AT STEELYARD Proposed QWS Lite location

Figure 74: QWS-GRND-D12-OH-176_NB AT STEELYARD Street view of proposed QWS Lite location

4.5 DISTRICT 12

B) QWS-GRND-D12-OH-176_NB AT STEELYARD

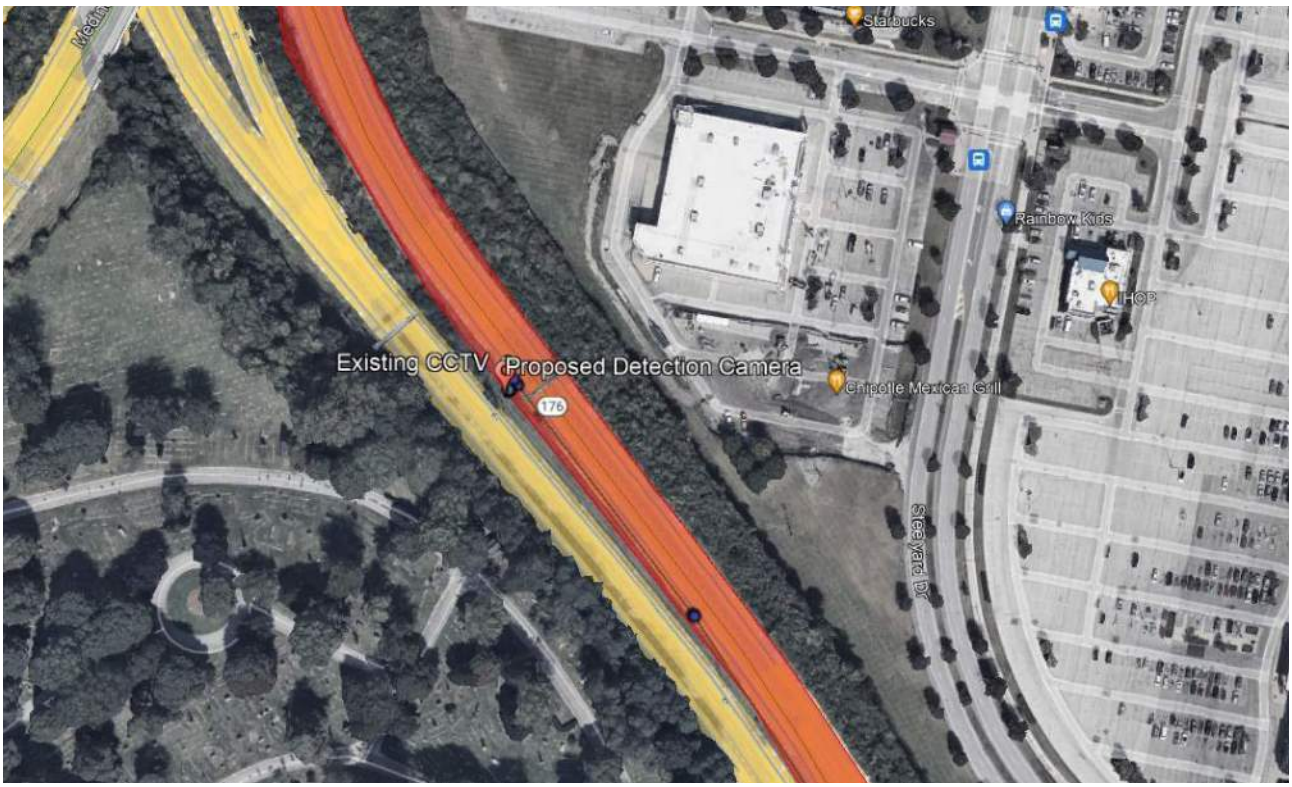


Figure 75: QWS-GRND-D12-OH-176_NB AT STEELYARD Proposed detection camera on existing CCTV pole

Figure 76: QWS-GRND-D12-OH-176_NB AT STEELYARD Street view of proposed detection camera on existing CCTV pole

5.0 TSMO CONSIDERATIONS

5.1 QWS IDENTIFICATION PROCESS

The QWS adds additional system capabilities and functionality in addressing the effects of congestion and queuing on roadways. The location determination and commitment to install the QWS at the pilot locations have provided vital information in a recommended process for identifying future QWS locations. Considerations should also include operations, maintenance (including end-of-life considerations), and proposed QWS performance measures that will contribute to ODOT's mission of providing a transportation system that is safe, accessible, well maintained, and positioned for the future[2] .

PROCESS FOR IDENTIFYING QWS LOCATIONS

The process of determining the preliminary locations for the QWS in this pilot project offered valuable perspectives and insights into available materials and methods. These insights will assist the Ohio Department of Transportation (ODOT) in developing a defined process for determining future QWS locations. The outcome of this pilot program facilitates a multi-pronged process to identify and define the requirements for future QWS locations.

The key factors in identifying QWS locations are:

PART 1 - IDENTIFYING LOCATIONS

1. Step 1: Investigate TOAST within the Southwest, Central and Northeast Ohio regions to develop a hot spot map

Investigate the three regions using TOAST to identify possible bottlenecks, secondary crashes and high truck volume percentages based on data collected between 2021 and 2023

2. Step 2: Provide hot spot maps to local ODOT Districts for field observations and verifications to develop specific location list

Data verification of TOAST identified congestion with field observations and experience from ODOT Districts more knowledgeable of their roadways

Consider reported congestion, geometric constraints, and sight distance issues in selecting locations

3. Step 3: Investigate Statewide Crash Data and INRIX data for areas around the identified locations.

   Investigate crash data, specifically secondary and rear-end crashes, to determine more detailed crash history

   Investigate INRIX data to determine build-up duration, end-of-queue, and thresholds for queuing that are useful in determining the necessity and positioning of multiple detection camera locations and queue warning sign placement

2: Ohio DOT Strategic Plan - https://www.transportation.ohio.gov/about-us/odot-strategic-plan

PART 2- GROUND-TRUTH KNOWLEDGE

1. District knowledge

- Working with District staff, ascertain whether the location is known to have queues that develop and potential conditions, time of day, and causes at the identified locations.

2. TMC operations

- Consult with TMC staff through videos and regular monitoring to get initial queue confirmations and spot check the provided data. This will also be useful as the Crash and TOAST data may be older as traffic conditions change.
- If CCTV cameras for verification are not available, consider working with the drone department to obtain recorded footage at select times for the locations.

3. Granular Analysis of locations (if applicable)

- Certain locations may require obtaining recent congestion data to determine the appropriate queuing situation, location, duration, and frequency. Utilizing recent and historical congestion probe data, raw incident reports, or TMC event data, may provide a more thorough picture of why queuing is occurring.
- Note: given the extensive analysis needed for this, it is recommended that this additional step only be utilized for highly sensitive or complex locations.

PART 3- LOCATION DETERMINATION CONSIDERATIONS

1. The initial location for QWS devices should be planned for each location based on the available congestion and queue data. Existing ITS device location proximities can also be considered utilizing available GIS information.
2. A field visit should take place to ascertain any visible obstruction, irregularities, and roadway considerations that may require a different location for each device. Existing equipment should also be considered for mounting surfaces and existing signs/devices be considered for driver attention factors.

- Considerations for geometric and driver behavioral limitations, power distribution, and ITS communications.
- Review crash, toast, INRIX, and volume information along with Streetview to determine if other site-specific factors may need to be investigated

3. Consulting the Maintenance district and ITS Team for device placement and maintenance access is very important at this step to ensure safe access can be accommodated and proposed as needed.
4. Refine locations based on comments from various ODOT stakeholders.

5.2 TMC OPERATIONS CONSIDERATIONS

Operationally, a new Standard Operating Procedure (SOP) for the QWS will need to be created, tested, and implemented for a successful QWS. SOPs for the QWS will be incorporated into the Traffic Management Center (TMC) guidebook. These SOPs aim to provide accessible operational procedures for both TMC and District staff. The primary role of the TMC operators is verifying the messages on the DMSs when the QWS activates and utilizing other tools for a multi-step verification of queues as resources and time permit.

While TMC Operators do not directly control the QWS, they verify DMS alerts triggered by QWS activations through nearby CCTV cameras. The SOPs will outline the verification process for CCTVs near QWS DMS locations, ensuring the visibility of the DMS when activated. Having preset camera views for each QWS will aid the operator in accurately and efficiently verifying the DMS activation and the correctness of the message.

In cases where CCTVs are not available, TMC operators can use alternative verification methods, such as Safety Service Patrol or Law Enforcement verification, followed by a callback to the TMC as resources are available. Another step in the process involves TMC operators cross-referencing the message on the DMS with what is displayed on ODOT's OHGO app. It is important to ensure that all messages display properly, which will need initial verification at implementation and regular checks afterwards.

Anticipated QWS disruptions such as pole knockdowns, camera detection interruptions, software bugs, system malfunctions, and communications interruptions would benefit from having pre-defined approaches to addressing the issues if they arise. Incorporating this information in the SOPs and training is recommended for TMC operators and maintenance staff to be prepared for multiple scenarios.

In addition, TMC operators should assess Waz or other 3rd party platforms and congestion data to have a second source for detecting traffic congestion and proper QWS system activation. This multi-step verification process provides confidence to ODOT that the QWS is functioning properly.

5.3 MAINTENANCE AND LIFE-CYCLE CONSIDERATIONS

Maintenance for a QWS is similar to that of normal CCTV and DMS devices. The key difference being that the queue detection camera will require periodic optimizations and calibrations to ensure proper accuracy is maintained. The impact to ODOT and District operations will be the number of devices that are added to the list of existing devices that will need to be maintained. The table below provides the proposed number of devices in this pilot deployment by District.

Table 1: Maintenance and Life Cycle Considerations

Proposed QWS Location	District	Anticipated Construction Cost	# of queue detection cameras	# of truss-mounted QWS Lite	# of DMS structure replacements	# of ground-mounted QWS panels	# of overhead trusses
LITE-D4-OH-8_NB at Howe Ave	4	$0.095M	1	1	0	0	0
QWS-D5-I-70_WB	5	$0.065M	1	0	0	0	0
QWS-D6-I-70_EB at Kelton Ave	6	$0.165M	1	0	0	1	0
QWS-GRND-D6-I-71_SB at Morse Rd	6	$0.215M	2	0	0	1	0
QWS-GRND-D6-I-270_SB at SR 317	6	$0.165M	1	0	0	1	0
QWS-GRND-D6-I-670_EB at Scioto River Bridge	6	$0.265M	2	0	0	1	0
QWS-GRDN-D6-OH-315_SB at IR-670	6	$0.215M	2	0	0	1	0
QWS-OVRHD-D8-I-71_SR 126	8	$0.665M	3	0	2	0	0
QWS-OVRHD-D8-OH-126_EB at I-71 NB	8	$0.325M	1	0	1	0	0
QWS-OVRHD-D8-I-275_WB at I-75 NB	8	$0.380M	1	0	1	0	0
QWS-GRND-D8-I-675_SB before Wilmington Pike	8	$0.165M	1	0	0	1	0
QWS-OVRHD-D12-I-90_WB at Downtown	12	$1.170M	4	1	3	0	1
QWS-GRND-D12-OH-176_NB at Steelyard	12	$0.355M	1	1	1	0	0

The following maintenance practices are provided to be considered for the long-term operations and smooth functioning of the system as described below:

1. *Scheduled Inspections:* Regular maintenance and inspection checks for system components such as sensors, display, mounting hardware and electrical wiring to function smoothly.
2. *Optimizations:* Periodic calibrations of sensors and other detection systems to ensure the accuracy of que lengths and traffic flow. Consider software updates that need to be remotely pushed into the devices to ensure compatibility.

   Additional optimization may be needed if major shifts in traffic flow are observed due to roadway and mobility improvements, changes in travel patterns, and changes in land-use may impact the detection zones.
3. *Remote Monitoring:* Implement the ability to monitor assets remotely and allow for real-time fixes and changes to be made for emergency/critical situations.
4. *Emergency/Incident Management:* develop a protocol for incidents and emergency events that affect the specific devices of the QWS. Include aspects such as pole knockdowns, camera detection interruptions, software bugs, system malfunctions, and communications interruptions.
5. *Workforce Training:* Train staff with knowledge related to operations and maintenance of the devices.

END-OF-LIFE CONSIDERATIONS

The queue detection cameras have unique end-of-life considerations given their specific purpose and use. Unlike regular CCTV cameras that have multiple uses to monitor and view traffic, queue detection cameras are useful as long as queues are forming at that specific location of the roadway. Anticipated roadway and mobility improvements, changes in travel patterns, and changes in land-use may all contribute to the significant reduction of queues that would eliminate the need for a QWS at that location. While a particular location may not need the QWS after a relatively short period, the equipment may still be useful in other locations. DMSs are not expected to be removed even if a queue detection camera is no longer needed as they can be utilized for traveler information purposes.

Recommendation: Tracking the number of activations can provide leading indicators of the usefulness of the particular queue detection zone and end-of-life.

Recommendation: Evaluation of queue data for all QWS locations on a regular basis can help determine if the QWS is still needed.

Another consideration is to monitor and assess new technologies that may become prolific on the vehicles to reduce the need for queue detection cameras because of higher fidelity of data and accuracy.

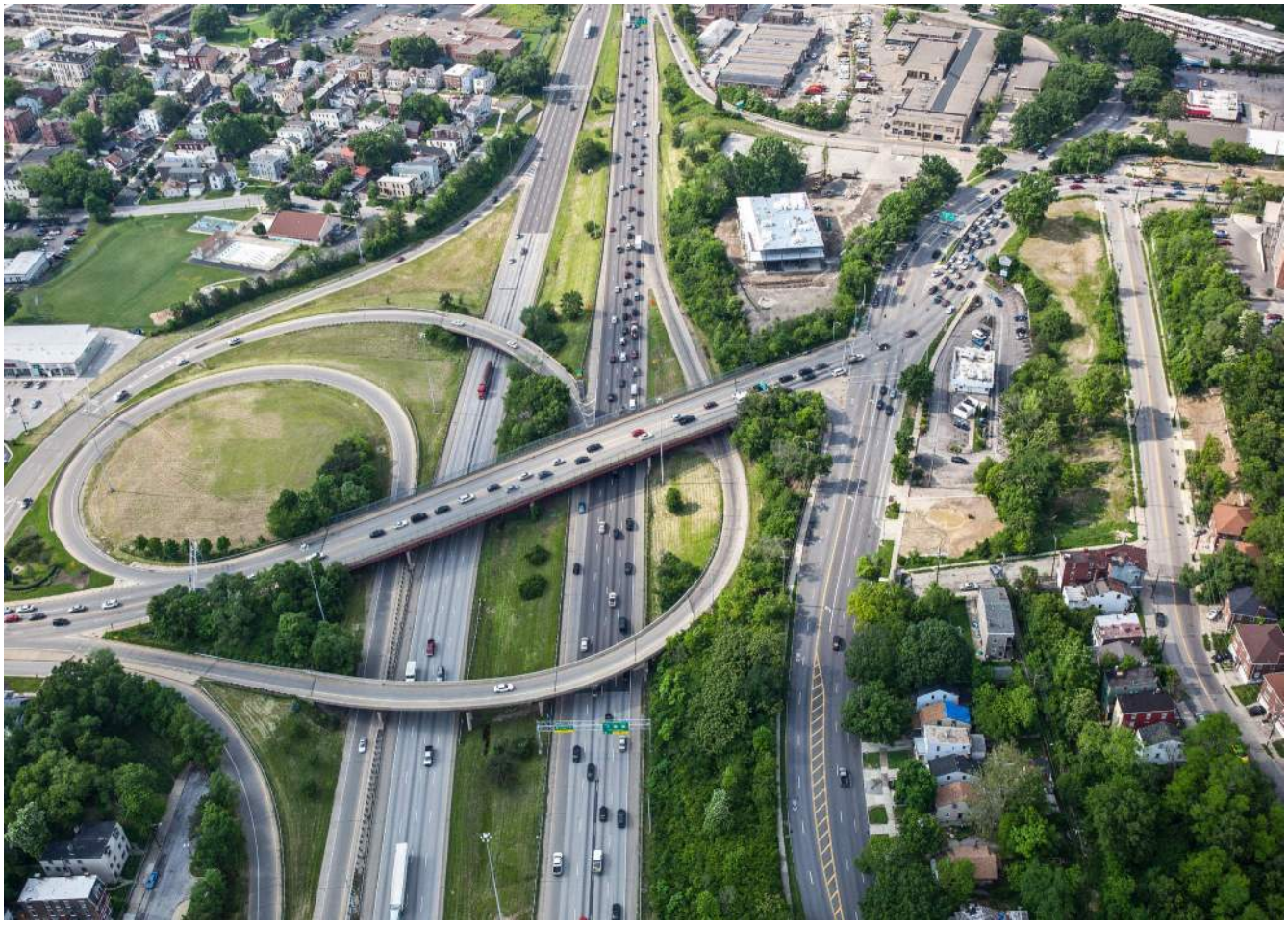
5.4 PERFORMANCE MEASURES AND MEASURES OF EFFECTIVENESS

Performance measures for QWS should ideally reflect their primary objectives - reducing crashes and easing congestion. Key performance indicators are:

- Number of Crashes - with a focus on observing a downward trend over time. This would directly indicate the system's effectiveness in enhancing road safety.
- Secondary Incidents – with an understanding that congestion queues are not the sole reason for secondary incidents, observing a downward trend would indicate the contribution of the QWS to improve road safety.
- Congestion delays - can help assess the system's impact on traffic flow and efficiency.
- Hard-Braking events – provide insights into the effectiveness of the messages and whether drivers are adjusting their driving patterns based on the warning messages via programs such as TOAST, INRIX, etc.

MEASURES OF EFFECTIVENESS

Operational data such as the number of QWS activations can provide insights into how frequently the system is triggered, indicating the prevalence of queue formation. The frequency of maintenance required can serve as a measure of the system's reliability and durability. Lastly, the accuracy of messages displayed by the QWS is crucial in evaluating the system's ability to provide timely and correct information to drivers.



3: "Impacts to Traffic Behaviour From Queue Warning Truck: Current Pilot Project", Joint Transportation Research Program, 2022. https://rosap.ntl.bts.gov/view/dot/66435.

REDUCTION IN CONGESTION

Another advantage of QWS is their capacity to alleviate congestion. To reduce congestion and crashes along the I-25, the Colorado Department of Transportation (CDOT) deployed various smart work zone systems, including queue warning systems. In 2020, CDOT released an evaluation of these devices, demonstrating a significant increase in travel speeds (compared to stop-and-go traffic due to construction) and a decrease in abrupt speed reductions[4].

To measure this, CDOT used sensors to detect the average speed of vehicles during queue warning activation periods and compared the frequencies of abrupt speed drops within one-minute periods during these activations. CDOT then compared a one-month period when the queue warning systems were visible with a one-month period when they were not visible to the public, enabling them to observe the systems' impact on traffic flow.

After accounting for reliability issues encountered during testing, researchers observed an overall increase in average speed of about 5-10mph, depending on the distance of the sensor from the queue. They also measured abrupt speed reductions by counting the number of speed reductions of 10+ and 15+ mph during periods when the queue warning systems were visible and not visible. On average, the results showed a decrease in abrupt speed reductions of about 30% when the queue warning systems were made visible to the public.

Multiple states have studied the efficiency of QWS over the years after implementing them. Since their implementation, they have contributed to reducing crashes and hard-braking incidents, decreasing congestion, and enhancing overall road safety and traffic flow. This section summarizes the results of various studies conducted by other State Departments of Transportation.

REDUCTION IN CRASHES

Upon identifying a hazardous segment of I-94, the Minnesota Department of Transportation (MNDOT) implemented queue warning systems to mitigate crashes. More specifically, they installed cameras and sensors and devised an algorithm to enhance crash prediction along the highway. After undergoing testing from 2016 to 2018, researchers noted a 56% reduction in crashes and a 69% decrease in near-crashes, underscoring the significance of employing warning systems. In 2011, the California Department of Transportation (Caltrans) deployed a Queue Warning System (QWS) with five portable Dynamic Message Signs (DMS) and corresponding traffic sensors within a work zone. This led to a 66% decrease in incidents and no fatalities during the peak holiday traffic within the project limits.

REDUCTION IN HARD-BRAKING

The implementation of queue warning systems can significantly reduce the amount of hard braking when drivers approach queues, potentially leading to a decrease in crashes. From 2020 to 2022, the Indiana Department of Transportation (INDOT) used connected vehicles to track driver data and study the impact of queue warning trucks. They utilized digital alerts from the trucks to monitor the number of vehicles that experienced hard-braking both before and after the deployment of the queue warning trucks. Since their implementation in 2020, they observed an approximately 80% reduction in hard-braking incidents when using the trucks, along with lower traffic speeds near work zones and unexpected queues[3]. By comparing 370 hours of queuing near queue trucks with 58 hours of queuing without the trucks, they noticed a clear difference. Before the trucks were used, 14.8% of the 4,195 motorists approaching the queue experienced hard-braking. After the implementation of the queue warning trucks, only 2.6% of the 6,240 observed motorists experienced hard-braking.

4: I-25 South Gap Queue Warning System Evaluation", Applied Research & Innovation Branch, 2020. https://www.codot.gov/programs/research/reports/2020-research-reports/cdot-i-25-south-gap-queue-warning.pdf.

6.0 LONG TERM PROGRAM RECOMMENDATIONS

Assuming that congestion and queues will persist on the roadway system for the foreseeable future, it's important to acknowledge long-term programmatic considerations at the beginning of this deployment. Besides the programmatic factors described in the report so far, workforce needs and future applications of connected vehicles are additional areas that require an intentional plan and periodic monitoring.

6.1 WORKFORCE NEEDS

Training for the workforce that will be interacting with, operating, and managing the QWS is important to keep current and integrate systematically. As device software, capabilities and functionality changes, training materials and opportunities will need to be refreshed to have the content be relevant for the intended personnel. The identified personnel that will need training on the QWS are:

- Maintenance Technicians – Receiving a brief overview of the queue detection camera capabilities and functions along with a hands-on demonstration of the features would be beneficial as more devices get added.

  Note: software updates that changes the user interface, zone placement, and features may necessitate an updated training.
- TMC Operators – operators will need an initial and refresher SOP training for QWS as software updates are implemented and the impact of updates in other systems connected with the QWS should be tested.
- District and Central Office Training – Provide a short course on the purpose, deployment, implementation, process for identifying locations, performance measures, and measures of effectiveness of the QWS as part of TSMO training offered from ODOT. As additional sites are deployed, ODOT specific data can be used to supplement the training materials.

6.2 FUTURE CONNECTED VEHICLE APPLICATIONS

Connected Vehicle (CV) applications have the potential to aid in detecting queues, identifying behaviors such as incidents and hard-braking, and facilitating in-vehicle communications. By aggregating and analyzing real-time CV data from vehicles communicating with the infrastructure, we can identify and detect queues and queue-forming behavior. This real-time data aggregation and analysis will likely benefit from Machine Learning and Artificial Intelligence. Once the data is processed, the infrastructure can communicate appropriate messages to the vehicles, which then display these messages to the drivers. This method significantly improves the actual delivery of messages to individual drivers compared to the assumed delivery as is currently with DMSs.

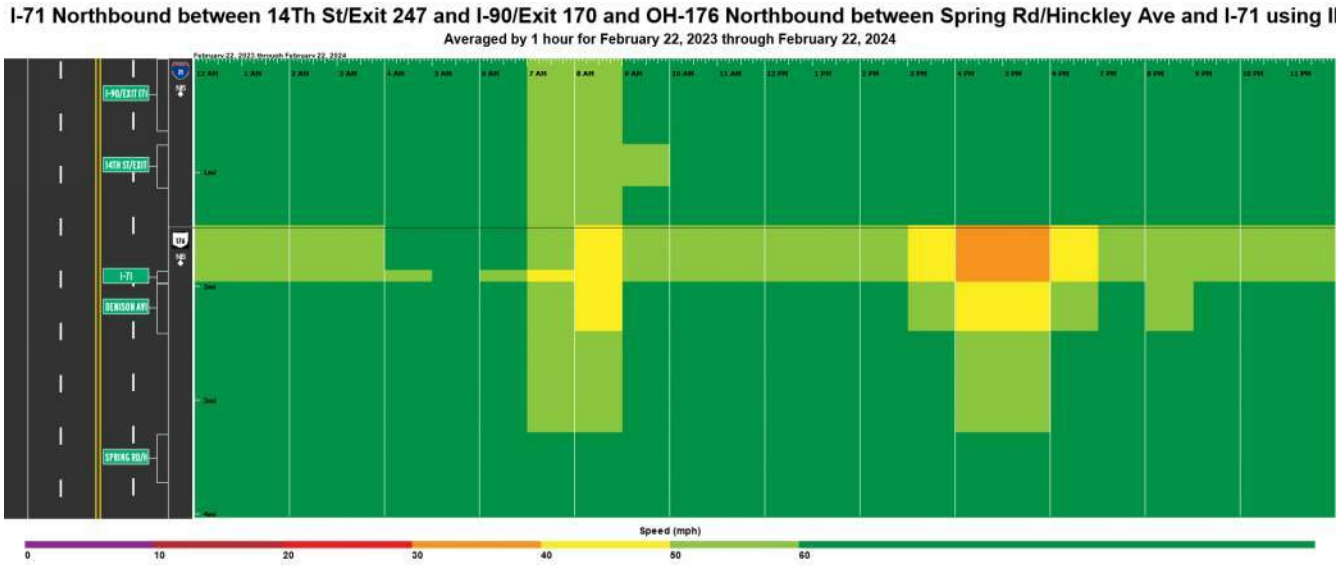
While we may not realize the future CV application as described above all at once, elements of each step of the CV environment may emerge sooner rather than later. Therefore, it's crucial for ODOT to stay updated with CV developments for future consideration and implementation.

7.0 APPENDIX A - REFERENCED DOCUMENTS

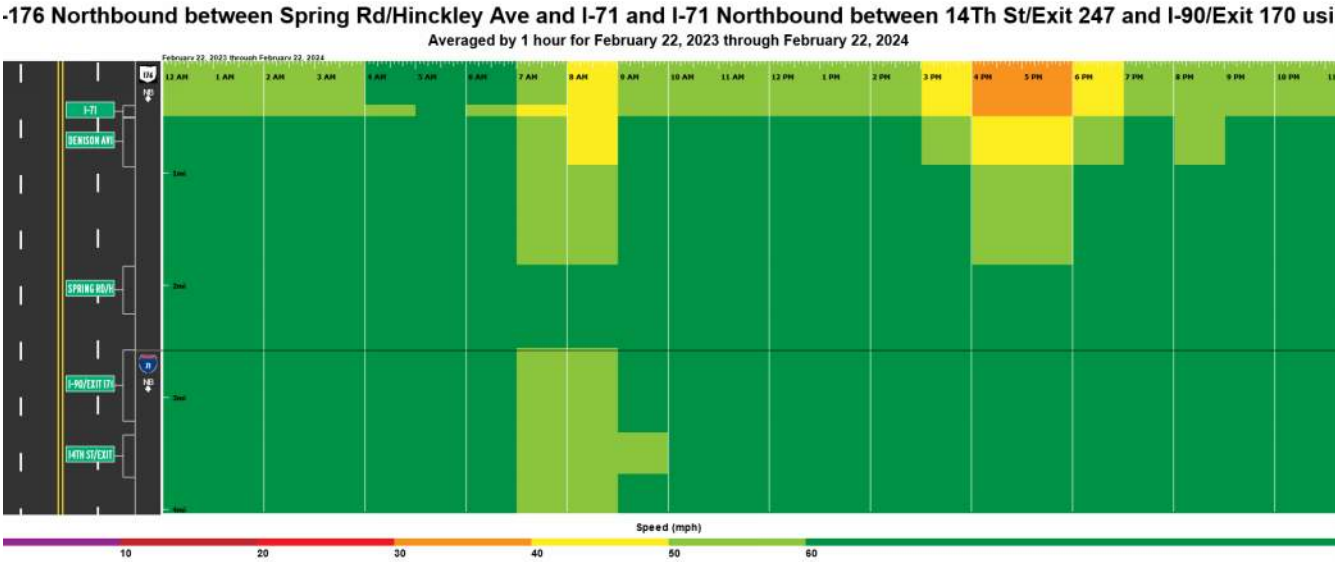
INRIX DATA

This section contains inrix data for all locations.

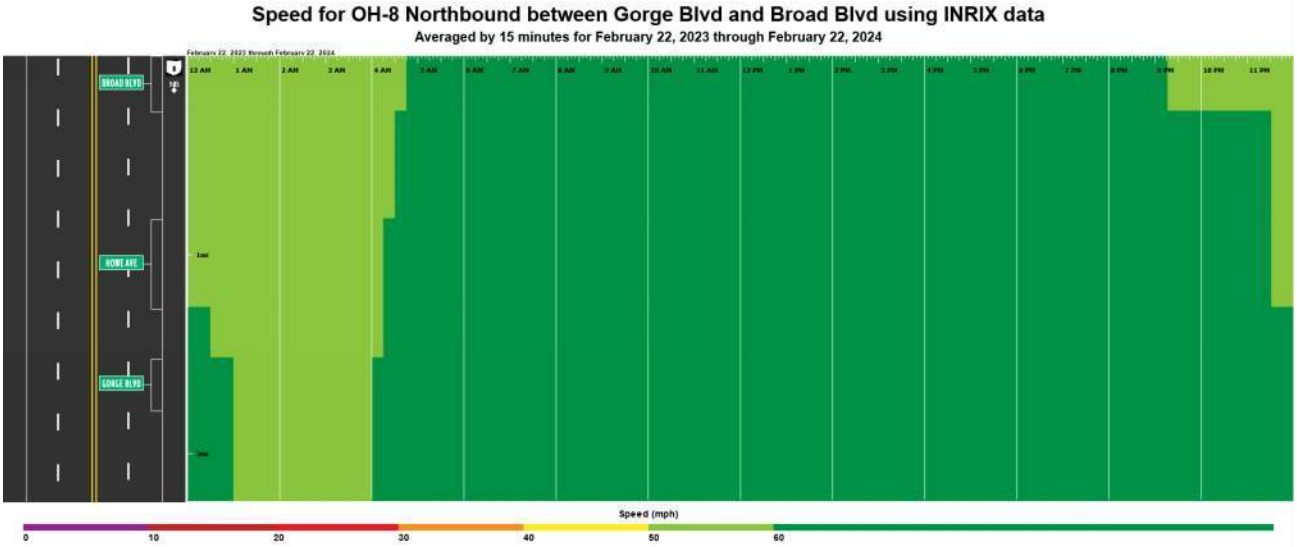
Congestion Scan for I-71 Northbound between 14Th StExit 247 and I- for February 22, 2023 through February 22, 2024



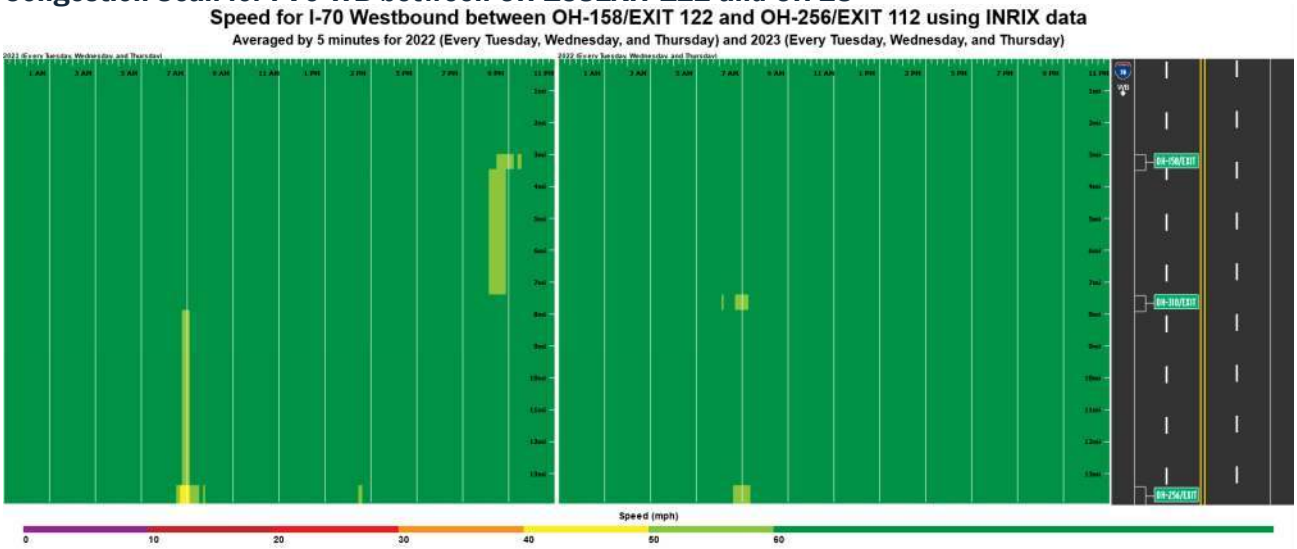
Congestion Scan for OH-176 Northbound between Spring RdHinckley Av for February 22, 2023 through February 22, 2024February 22, 2024



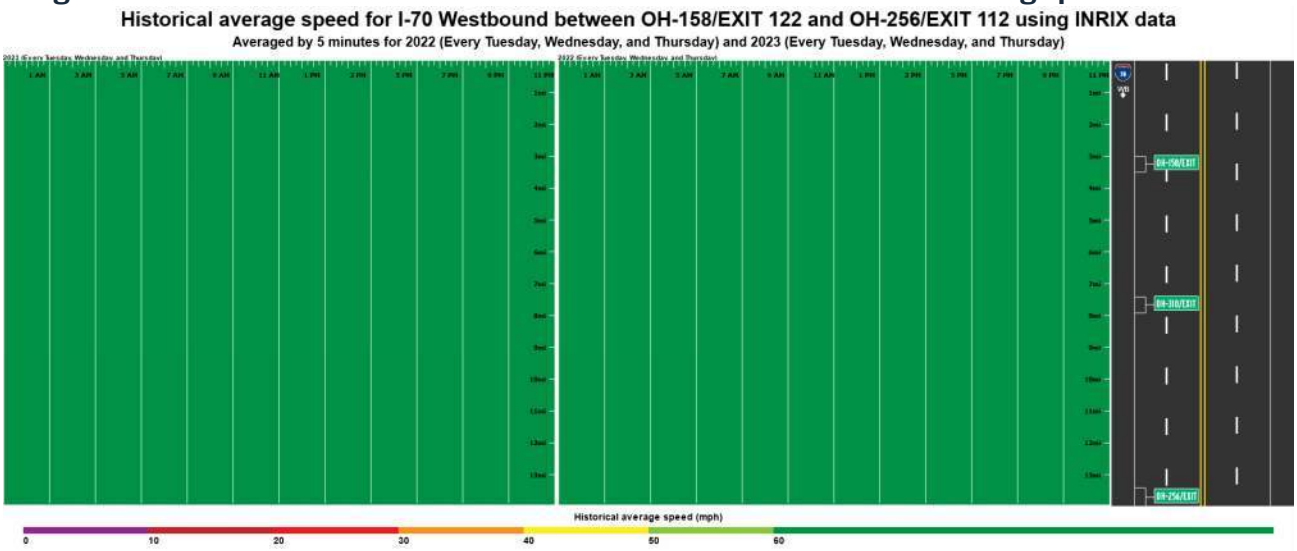
Congestion Scan for OH-8 Northbound between Gorge Blvd and Broad Blvd for February 22, 2023 through February 22, 2024



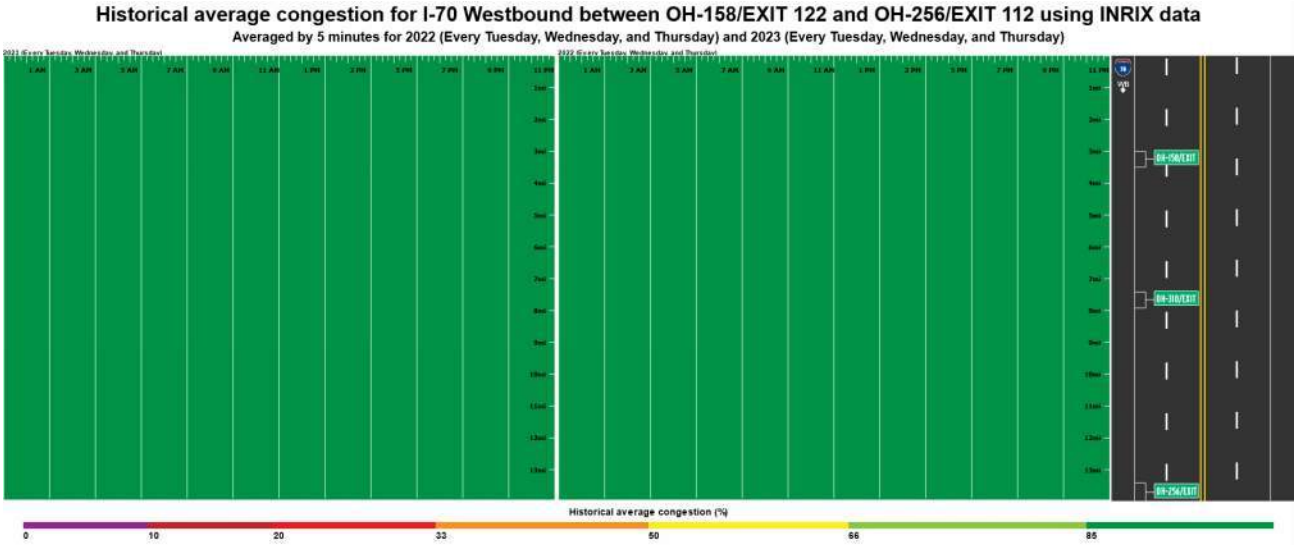
Congestion Scan for I-70 WB between OH-158EXIT 122 and OH-2S



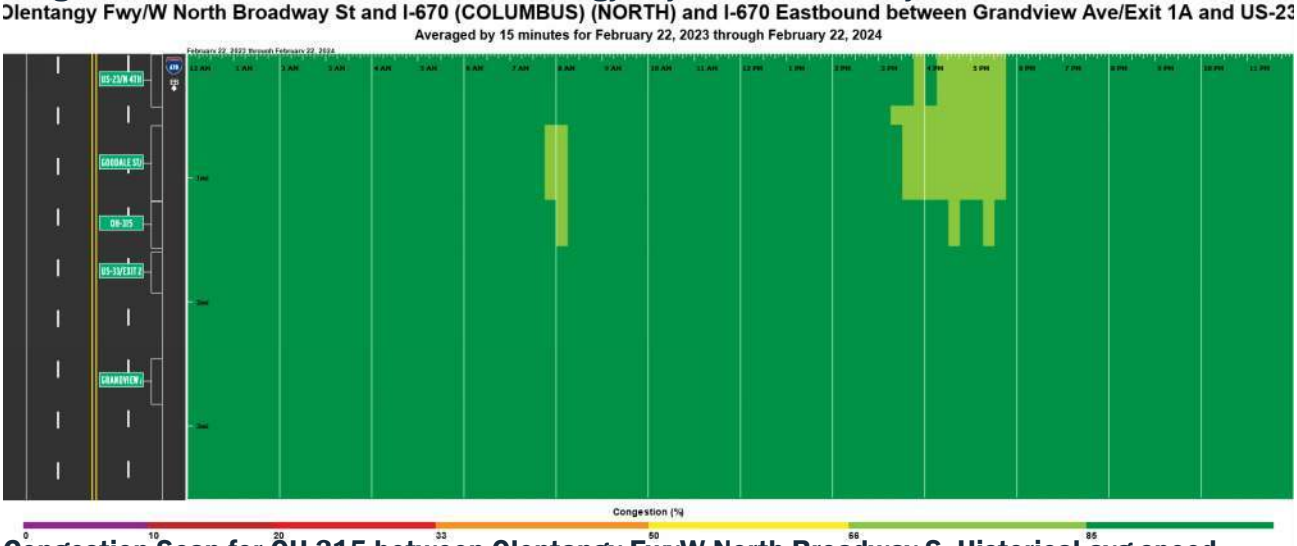
Congestion Scan for I-70 WB between OH-158EXIT 122 and OH-2S Historical avg speed



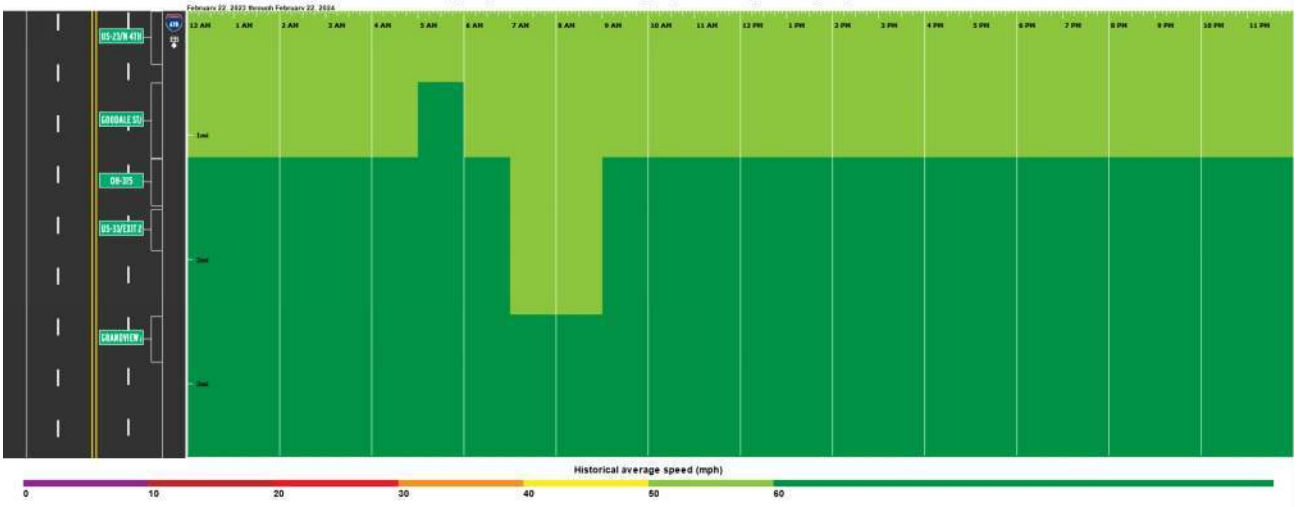
Congestion Scan forI-70 WB between OH-158EXIT 122 and OH-2S



Congestion Scan for OH-315 between Olentangy FwyW North Broadway S



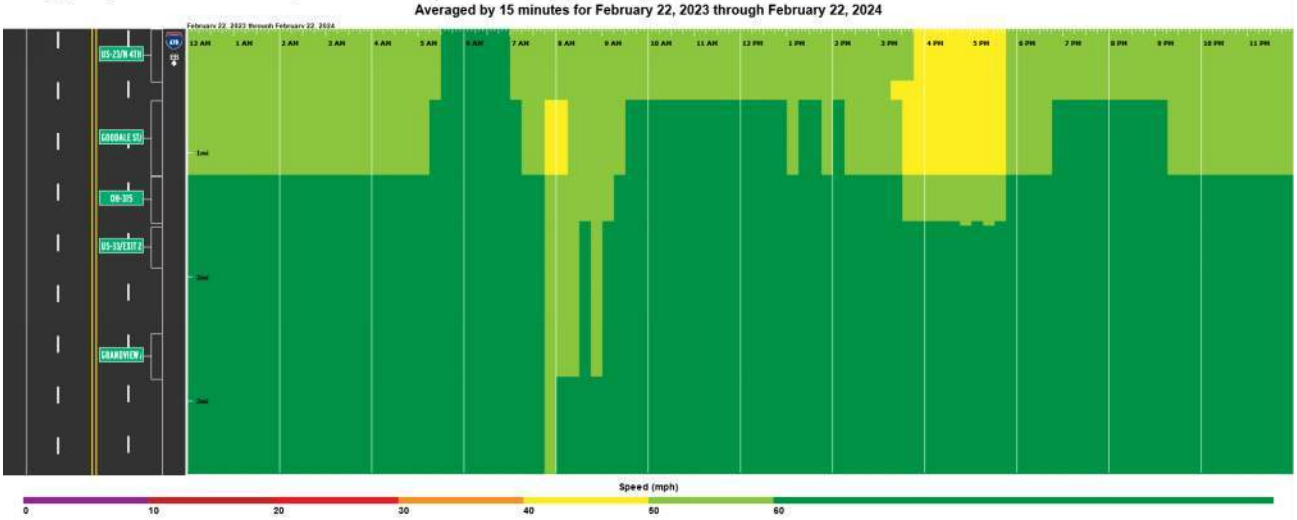
Congestion Scan for OH-315 between Olentangy FwyW North Broadway S. Historical avg speed



Congestion Scan for OH-315 between Olentangy FwyW North Broadway S

ntangy Fwy/W North Broadway St and I-670 (COLUMBUS) (NORTH) and I-670 Eastbound between Grandview Ave/Exit 1A and US-23/N

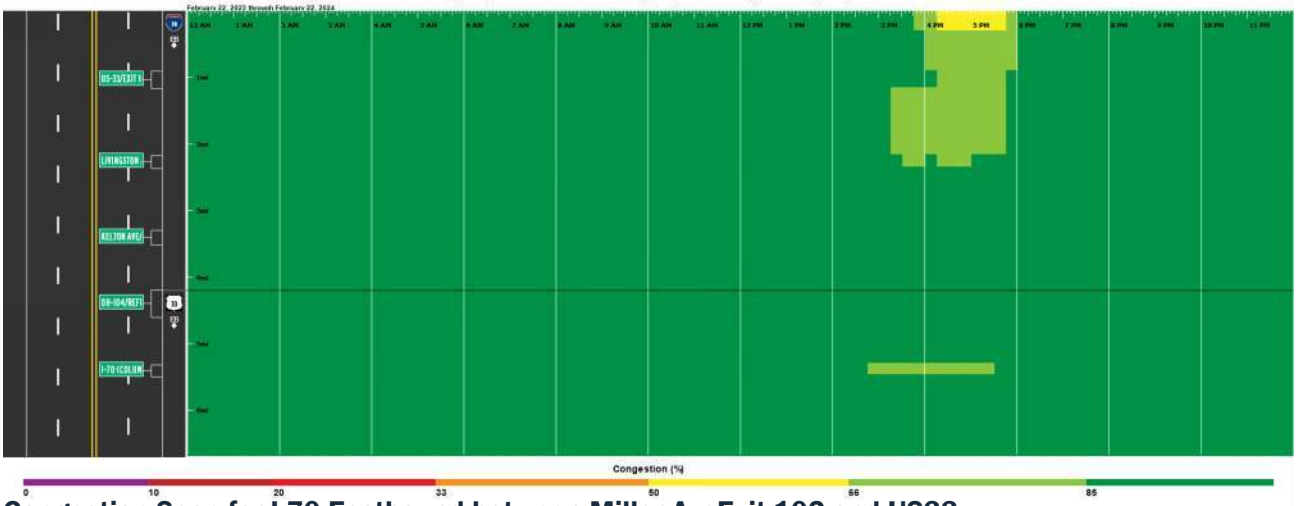
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



Congestion Scan for I-70 Eastbound between Miller AveExit 102 and US33

tbound between Miller Ave/Exit 102 and James Rd/Exit 105 and US-33 Eastbound between I-70 (COLUMBUS) (EAST) and OH-104/Refug

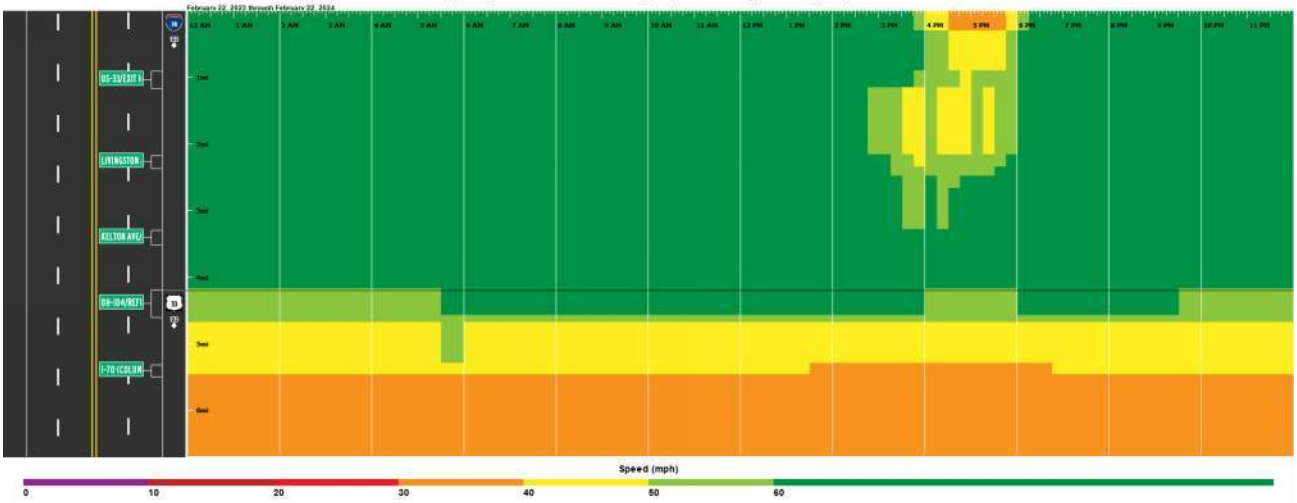
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



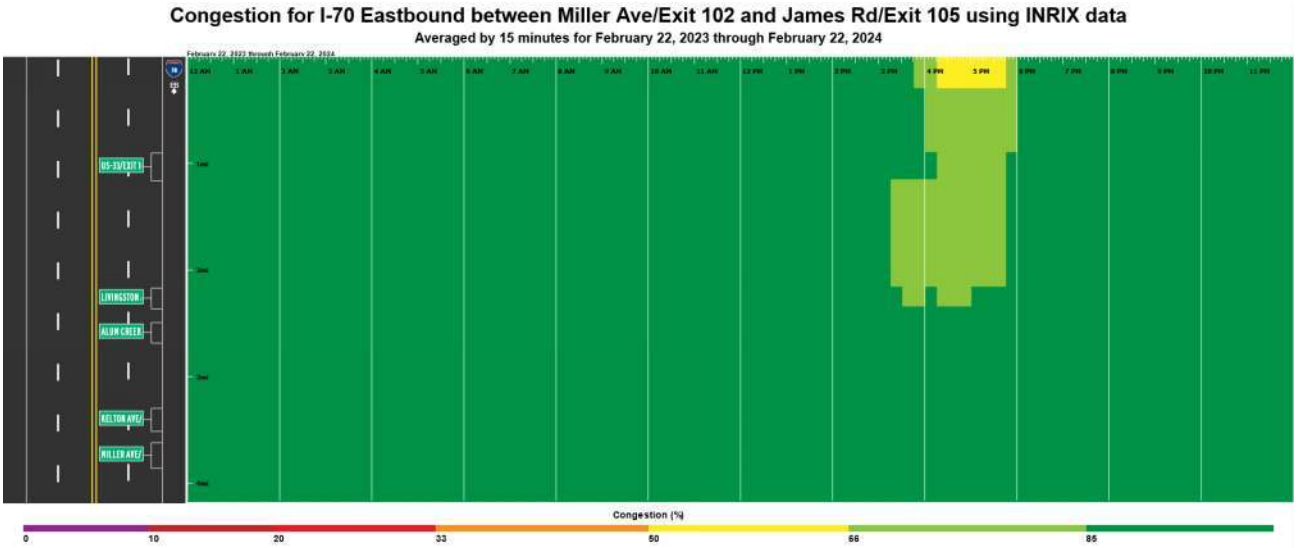
Congestion Scan for I-70 Eastbound between Miller AveExit 102 and US33

und between Miller Ave/Exit 102 and James Rd/Exit 105 and US-33 Eastbound between I-70 (COLUMBUS) (EAST) and OH-104/Refugee

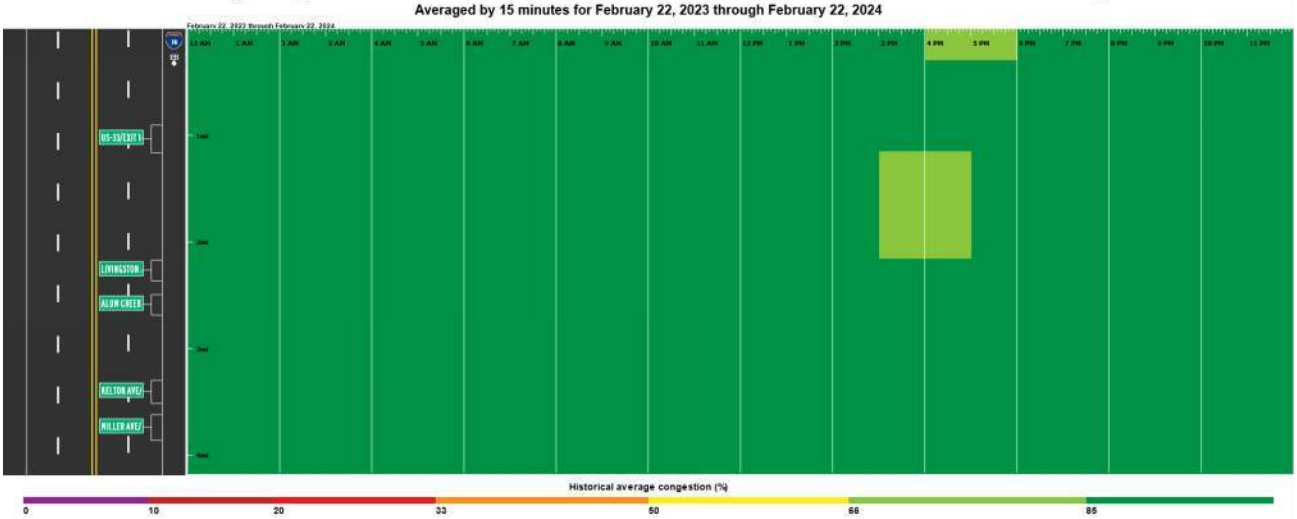
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



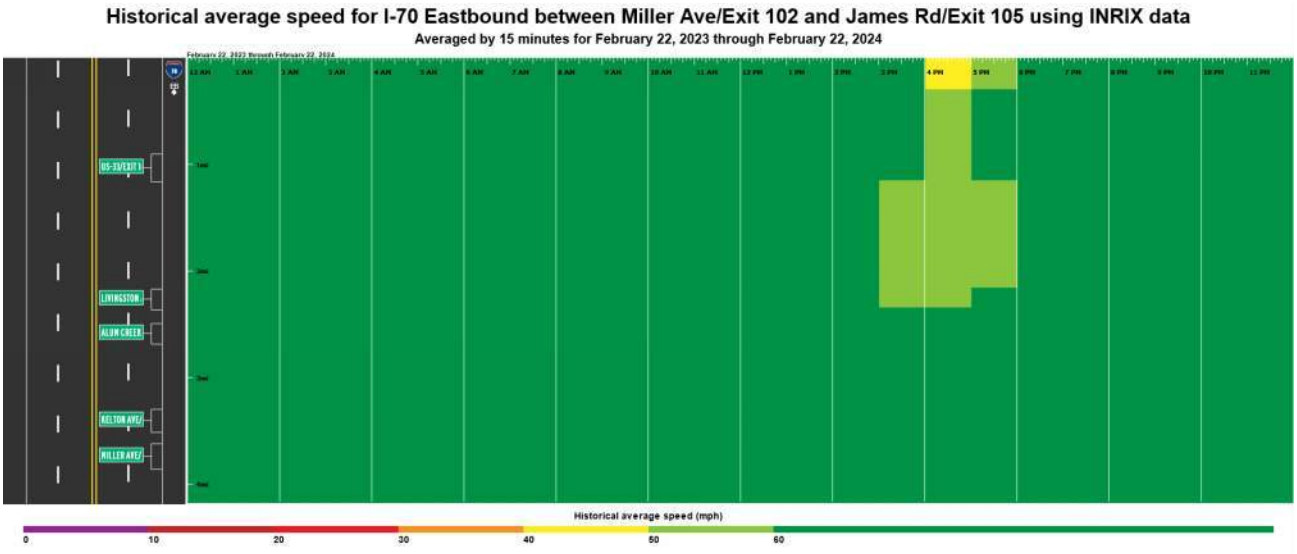
Congestion Scan for I-70 Eastbound between Miller AveExit 102



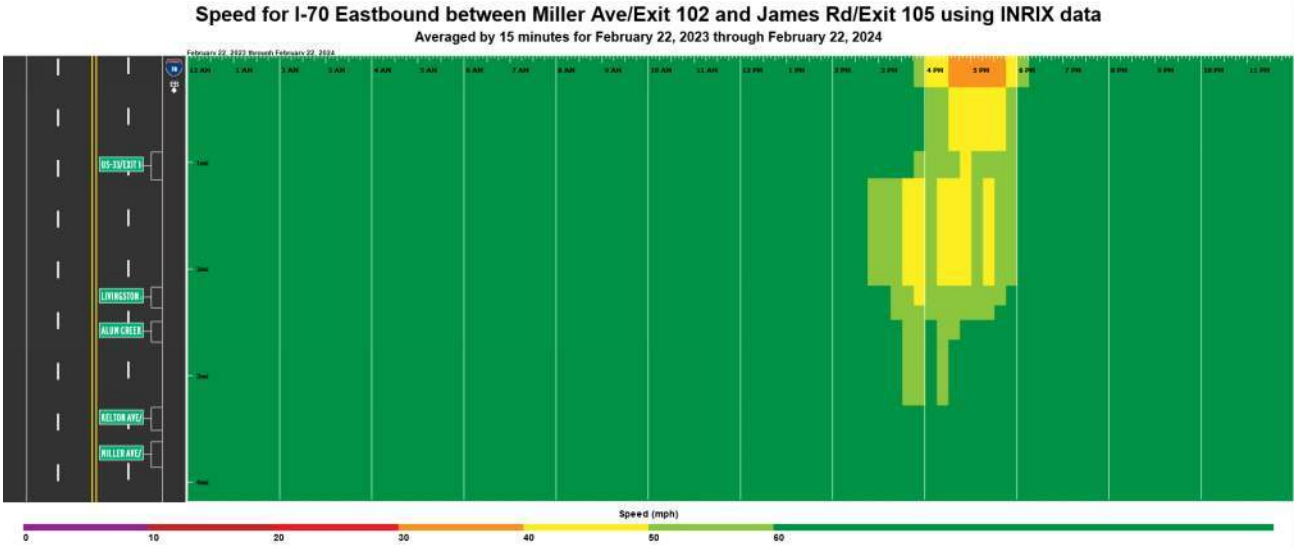
Congestion Scan for I-70 Eastbound between Miller AveExit 102



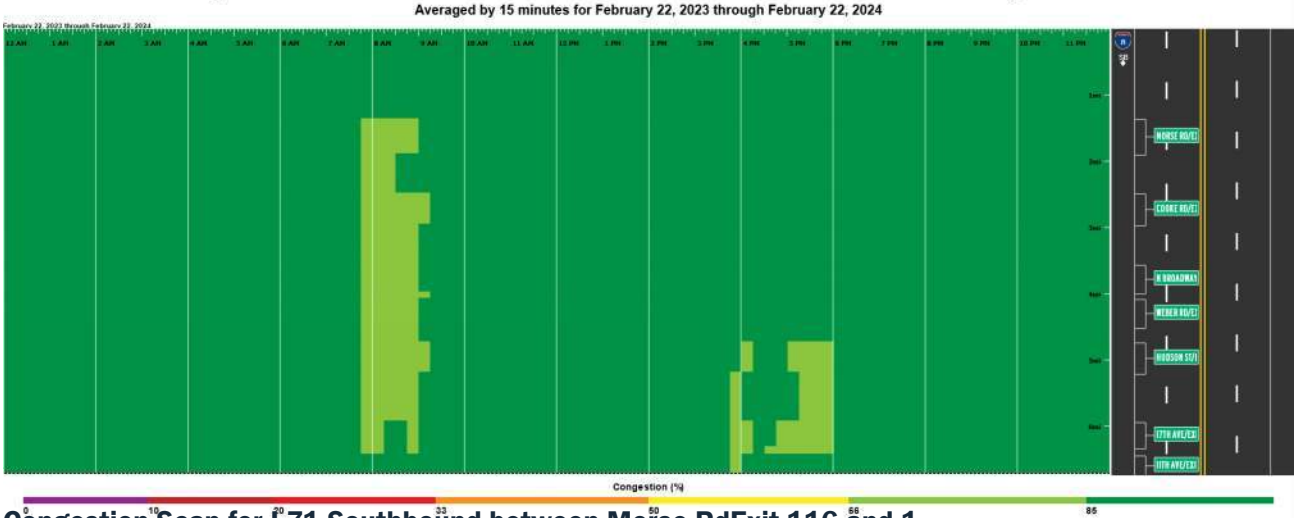
Congestion Scan for I-70 Eastbound between Miller AveExit 102_Historical avg speed



Congestion Scan for I-70 Eastbound between Miller AveExit 102



Congestion Scan for I-71 Southbound between Morse RdExit 116 and 1



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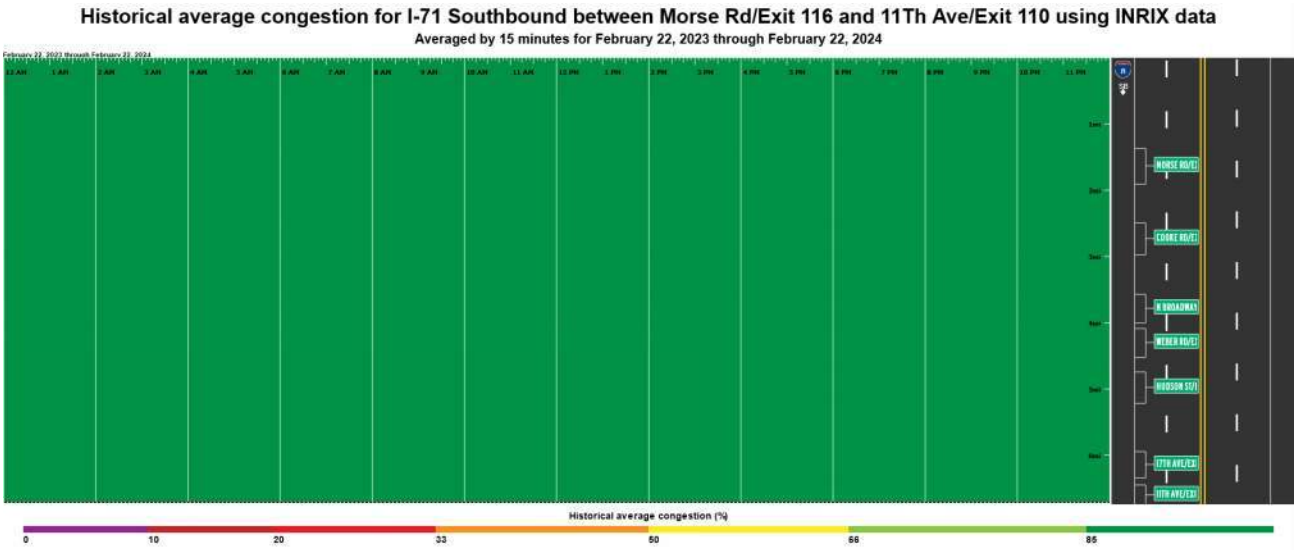

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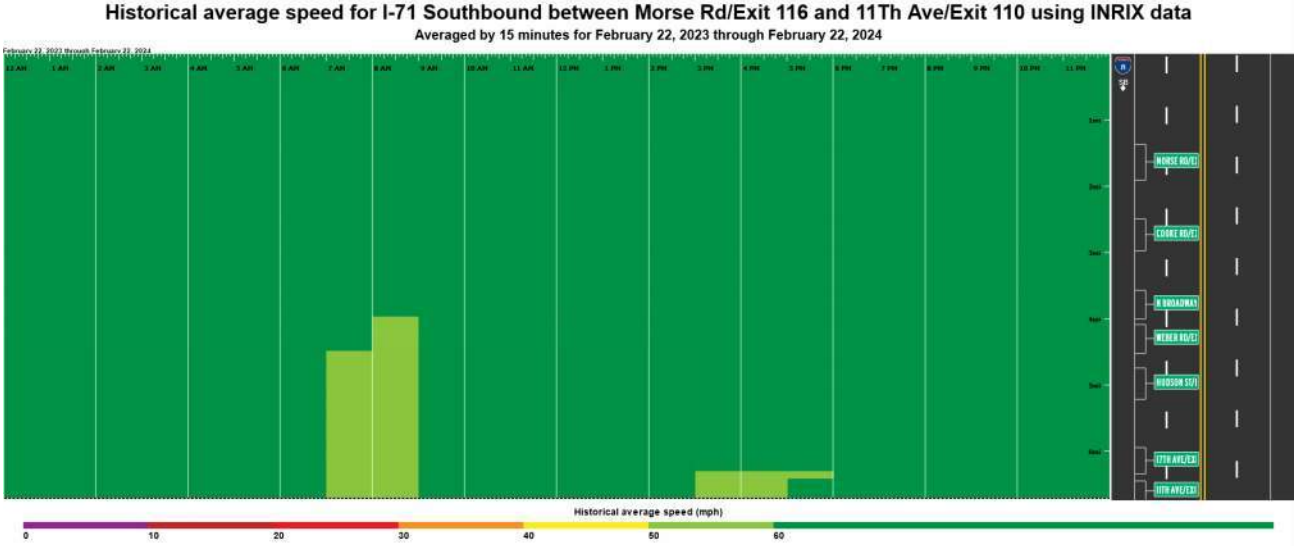

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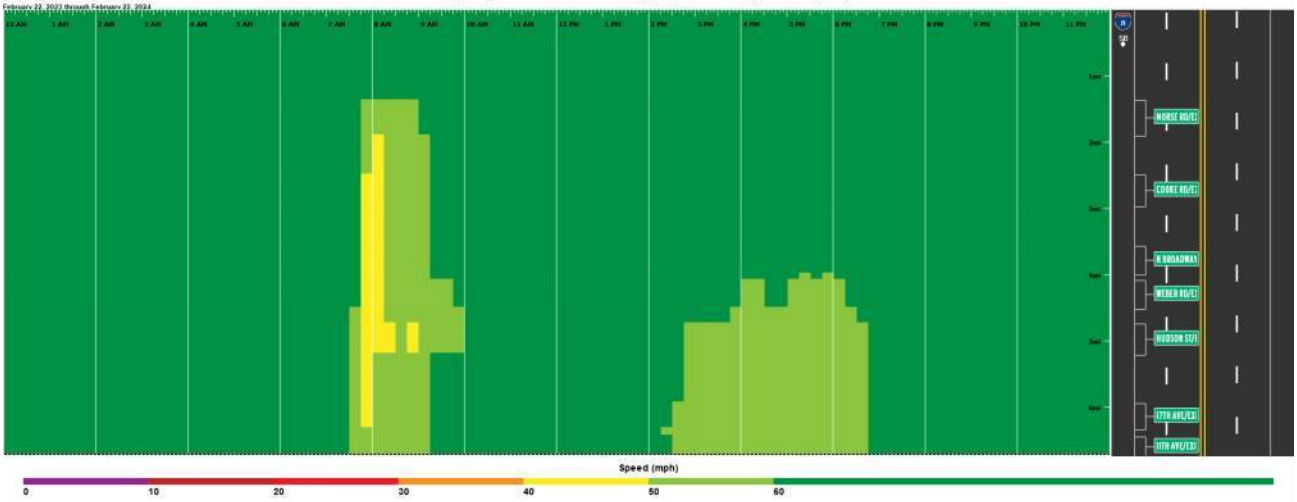
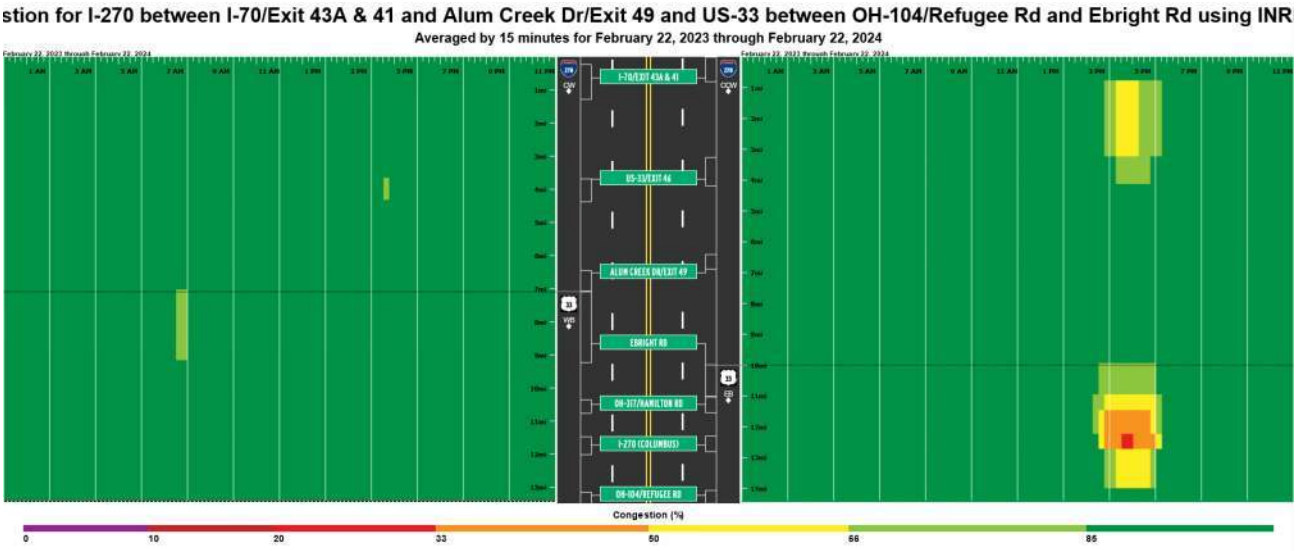


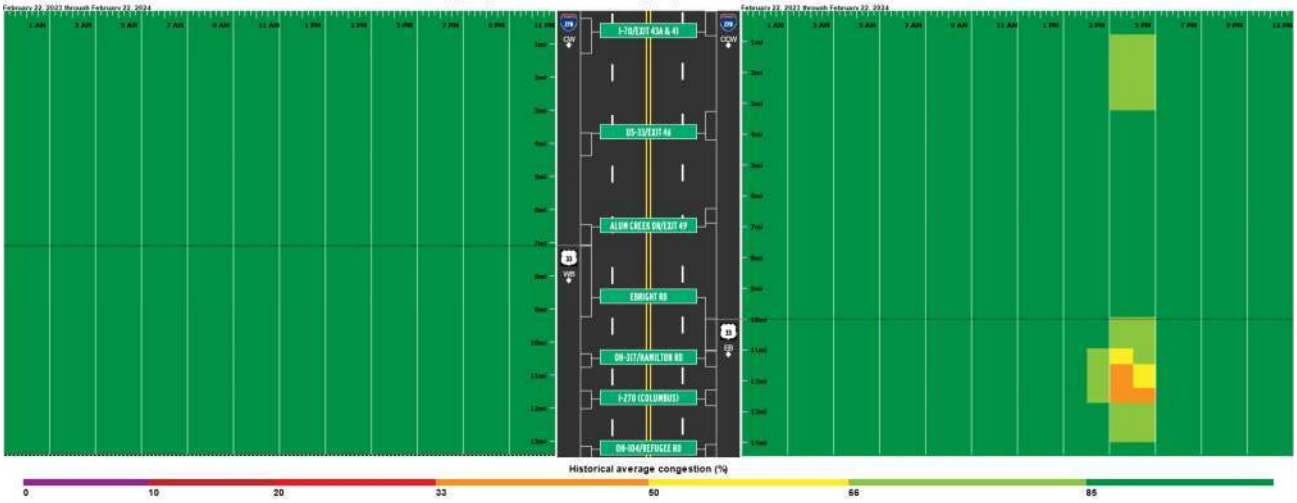
Congestion Scan for I-270 between I-70Exit 43A 41 and Alum Creek



Congestion Scan for I-270 between I-70Exit 43A 41 and Alum Creek

ge congestion for I-270 between I-70/Exit 43A & 41 and Alum Creek Dr/Exit 49 and US-33 between OH-104/Refugee Rd and Ebright Rd u

Averaged by 15 minutes for February 22, 2023 through February 22, 2024



Congestion Scan for I-270 between I-70Exit 43A 41 and Alum Creek

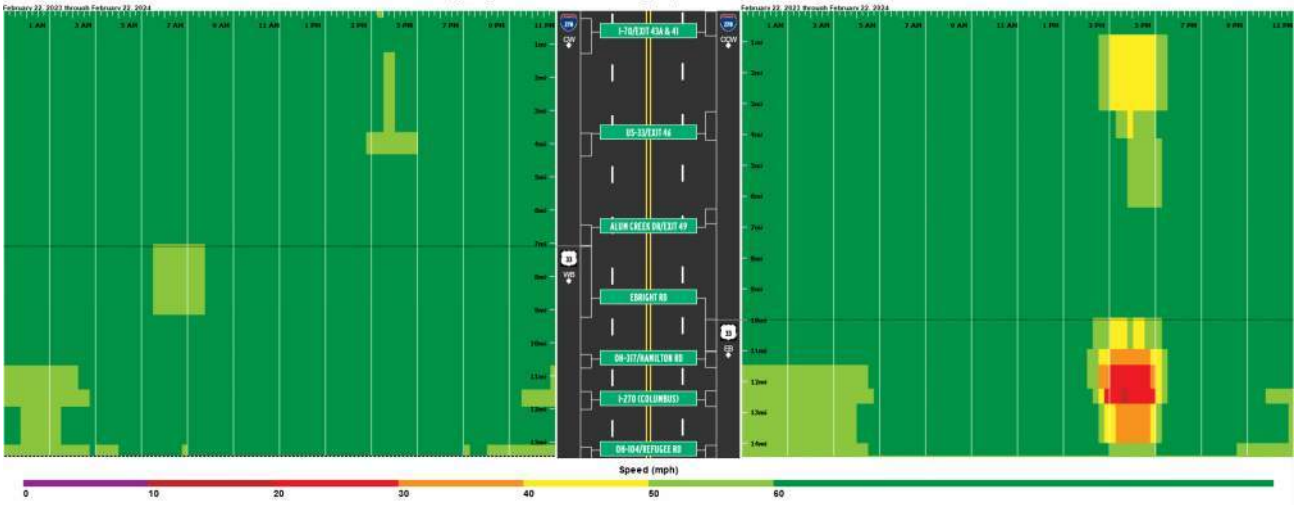
erage speed for I-270 between I-70/Exit 43A & 41 and Alum Creek Dr/Exit 49 and US-33 between OH-104/Refugee Rd and Ebright Rd usi

Averaged by 15 minutes for February 22, 2023 through February 22, 2024

Congestion Scan for I-270 between I-70Exit 43A 41 and Alum Creek

ed for I-270 between I-70/Exit 43A & 41 and Alum Creek Dr/Exit 49 and US-33 between OH-104/Refugee Rd and Ebright Rd using INRIX

Averaged by 15 minutes for February 22, 2023 through February 22, 2024



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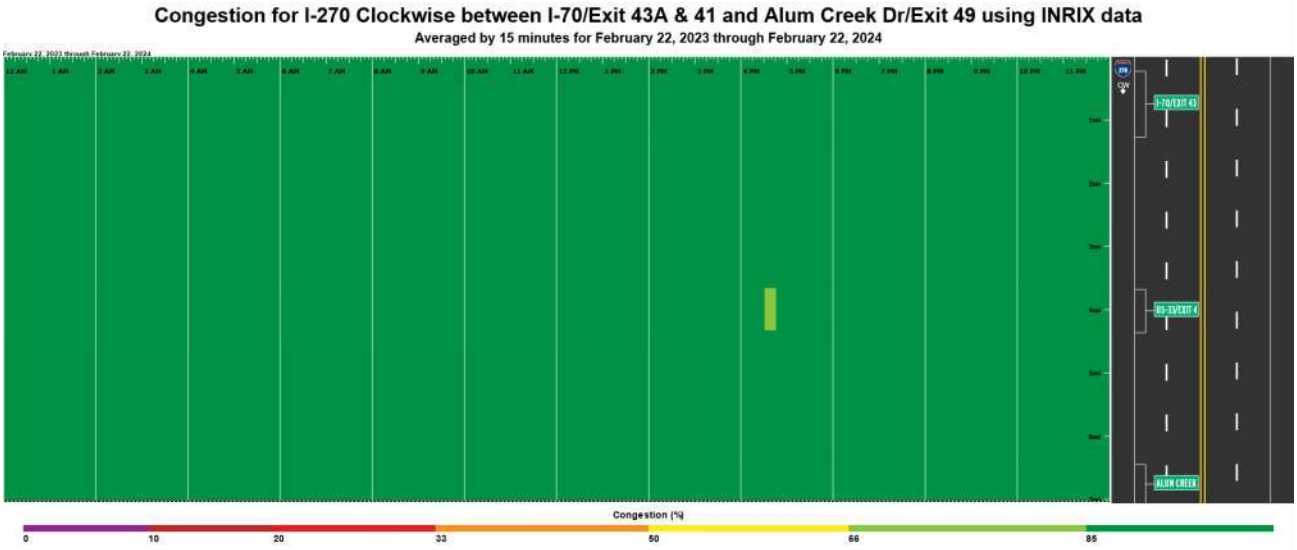

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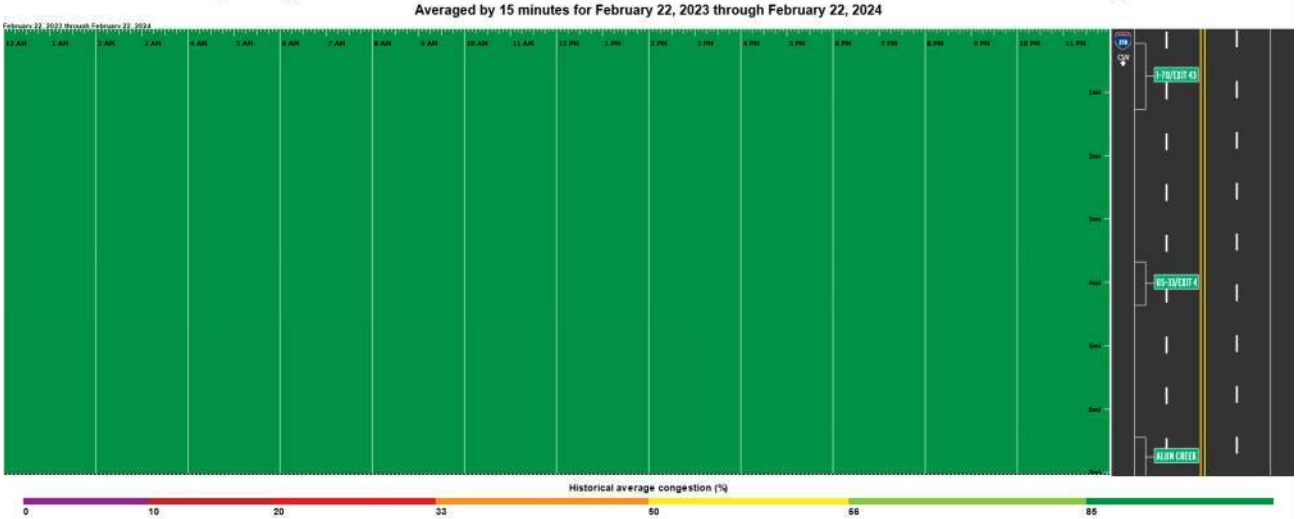
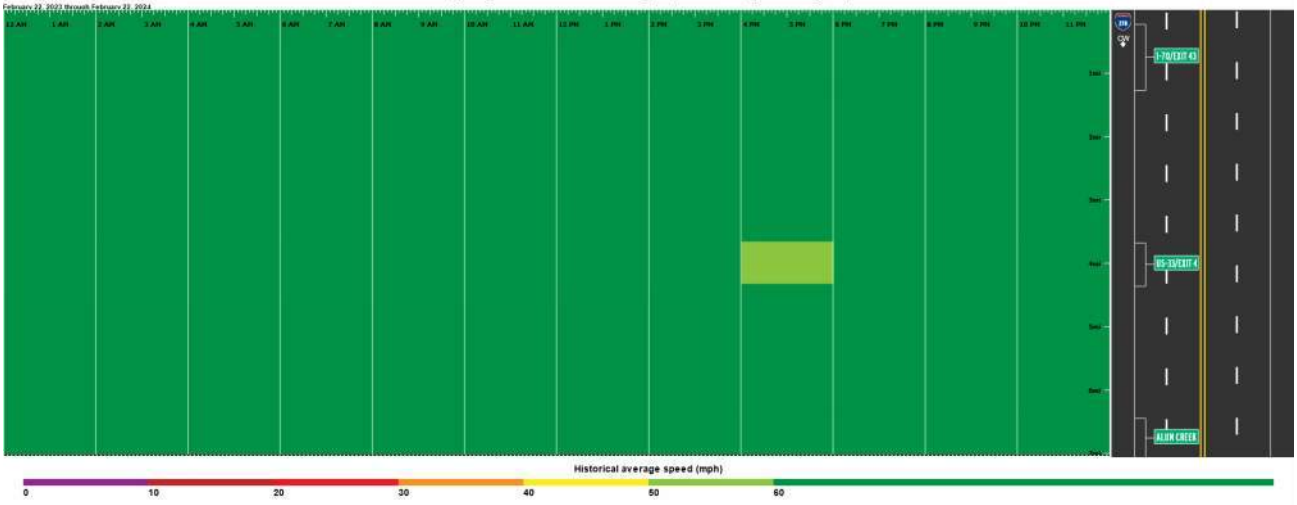
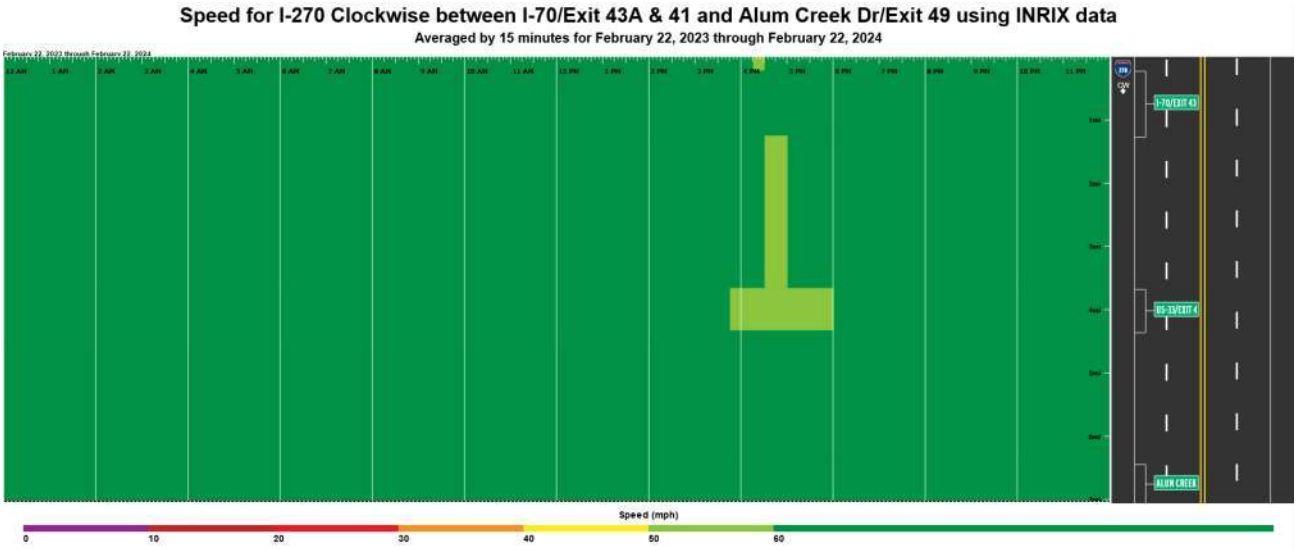


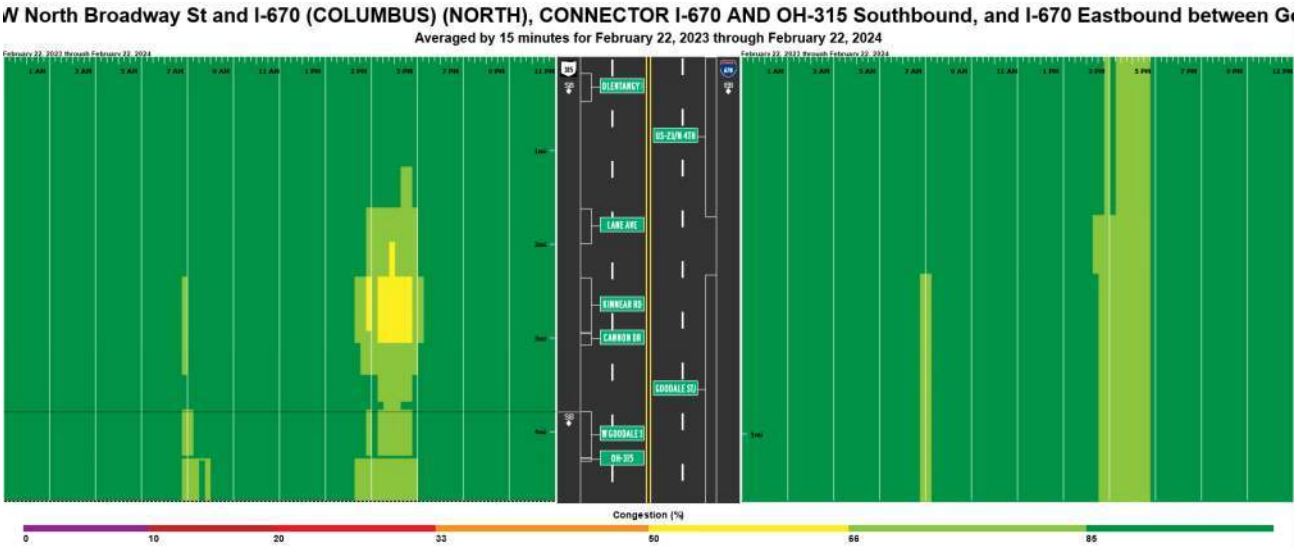
Congestion Scan for I-270 Clockwise between I-70Exit 43A 41



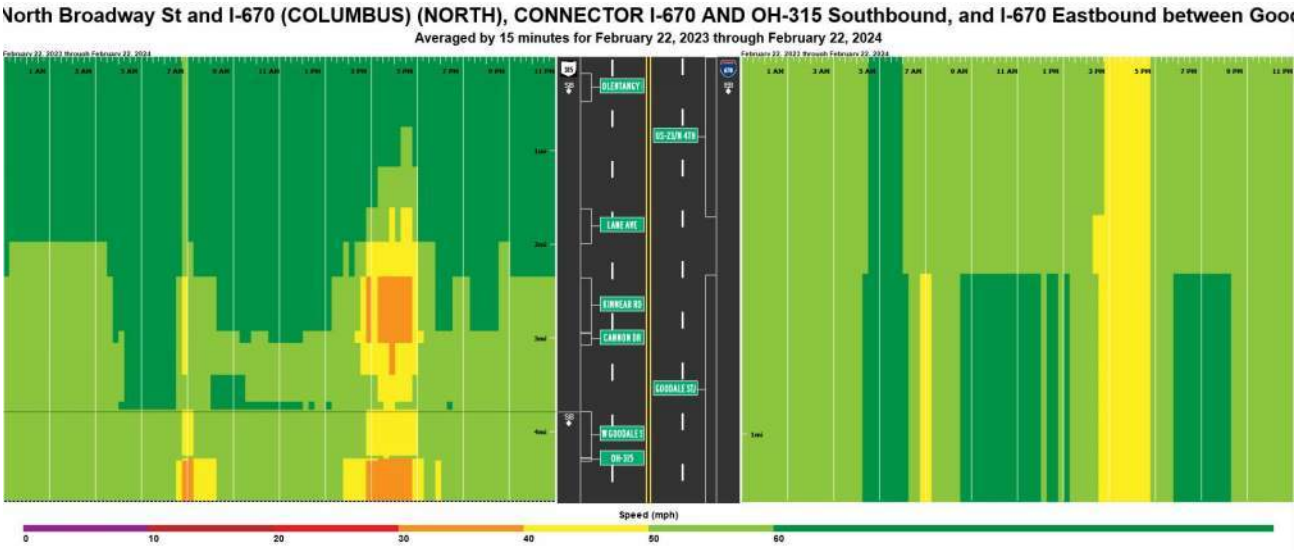
Congestion Scan for I-270 Clockwise between I-70Exit 43A 41



Congestion Scan for OH-315 Southbound between Olentangy FwyW North



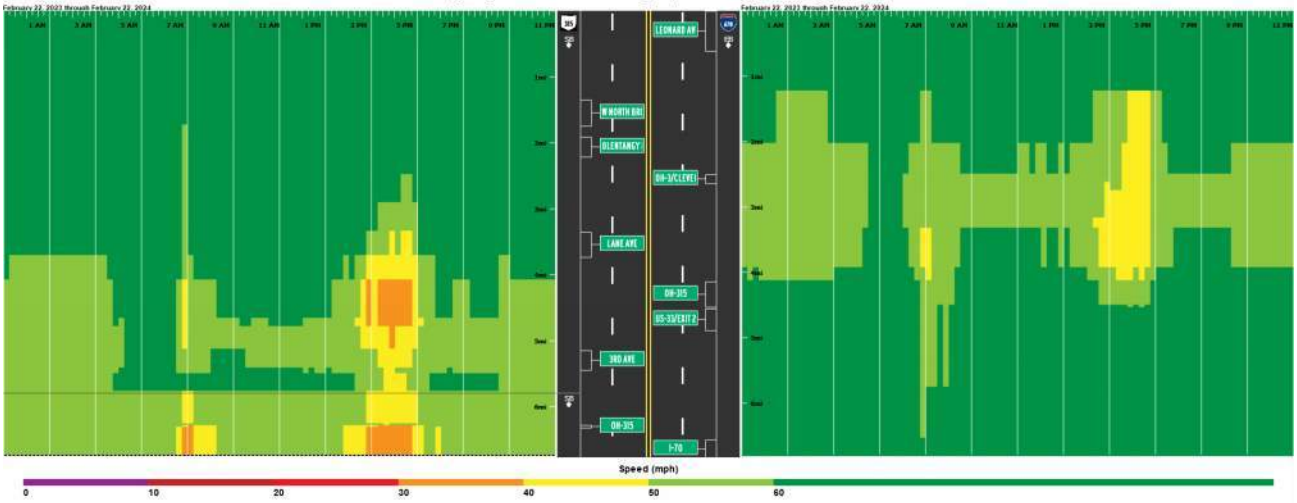
Congestion Scan for OH-315 Southbound between Olentangy Fwy W North



Congestion Scan for OH-315 Southbound between W North Broadway St

y St and I-670 (COLUMBUS) (NORTH), CONNECTOR I-670 AND OH-315 Southbound between I-670 and W Goodale St, and I-670 Eastbo

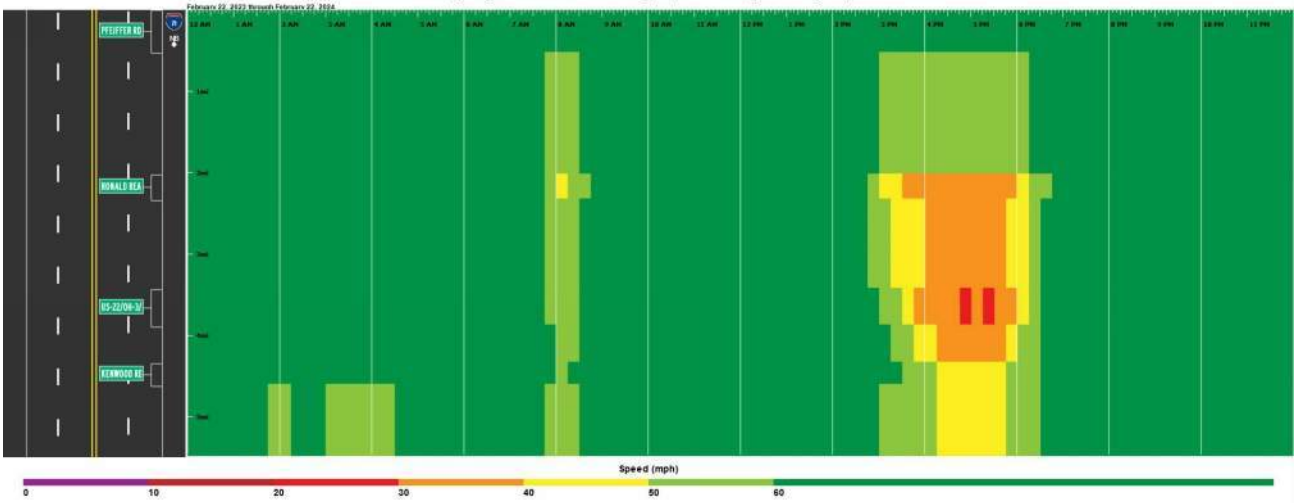
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



Congestion Scan for I-71 Northbound between Kenwood RdExit 11 and for February 22, 2023 through February 22, 2024

Speed for I-71 Northbound between Kenwood Rd/Exit 11 and Pfeiffer Rd/Exit 15 using INRIX data

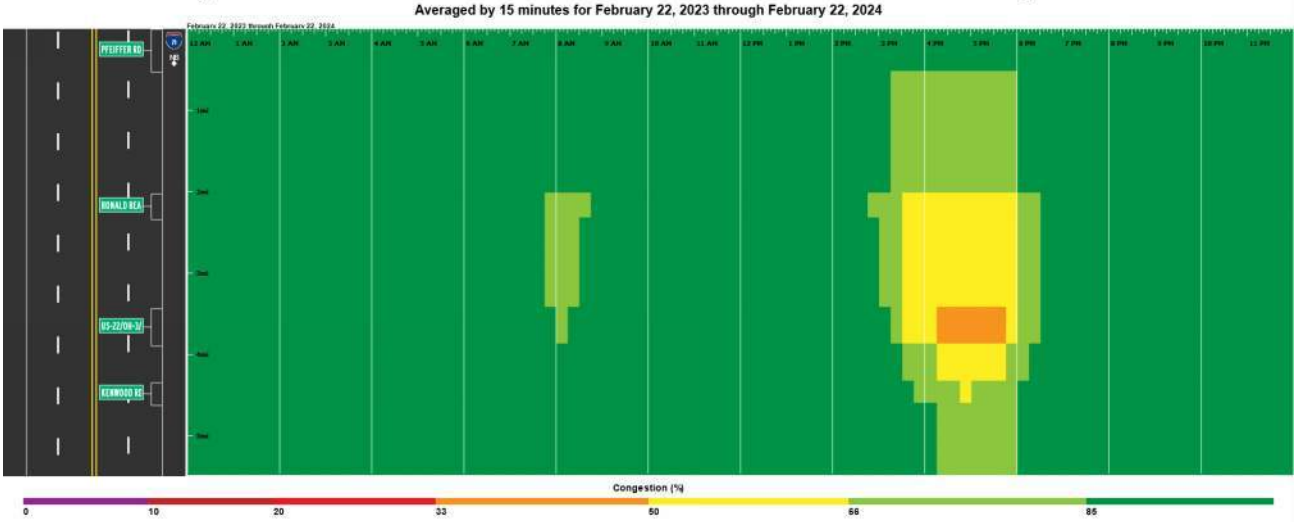
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



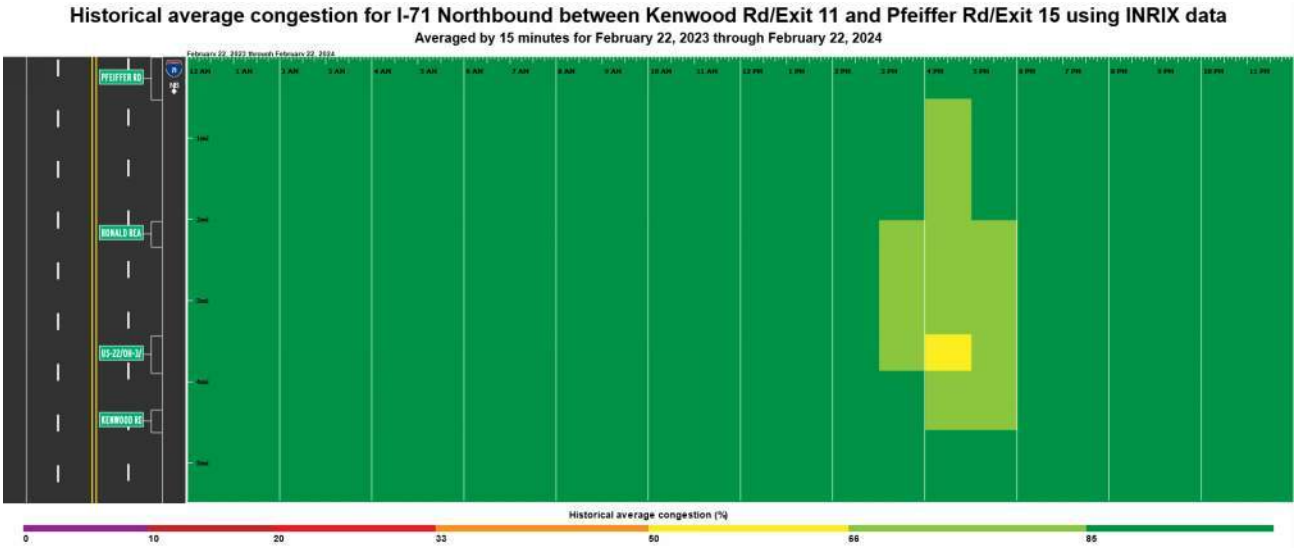
Congestion Scan for I-71 Northbound between Kenwood RdExit 11

Congestion for I-71 Northbound between Kenwood Rd/Exit 11 and Pfeiffer Rd/Exit 15 using INRIX data

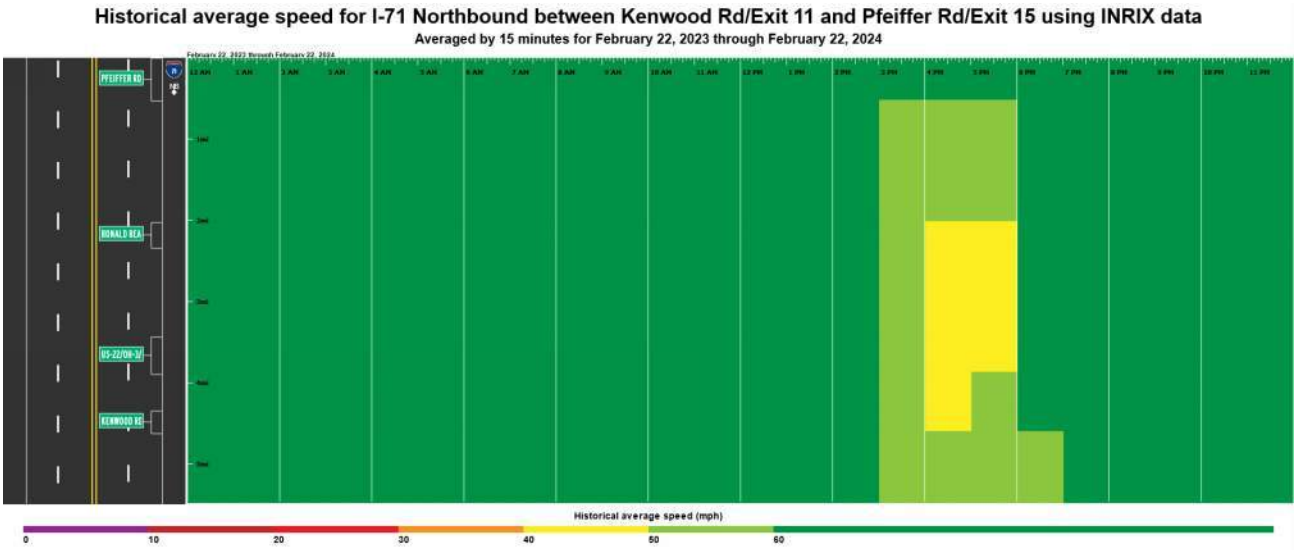
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



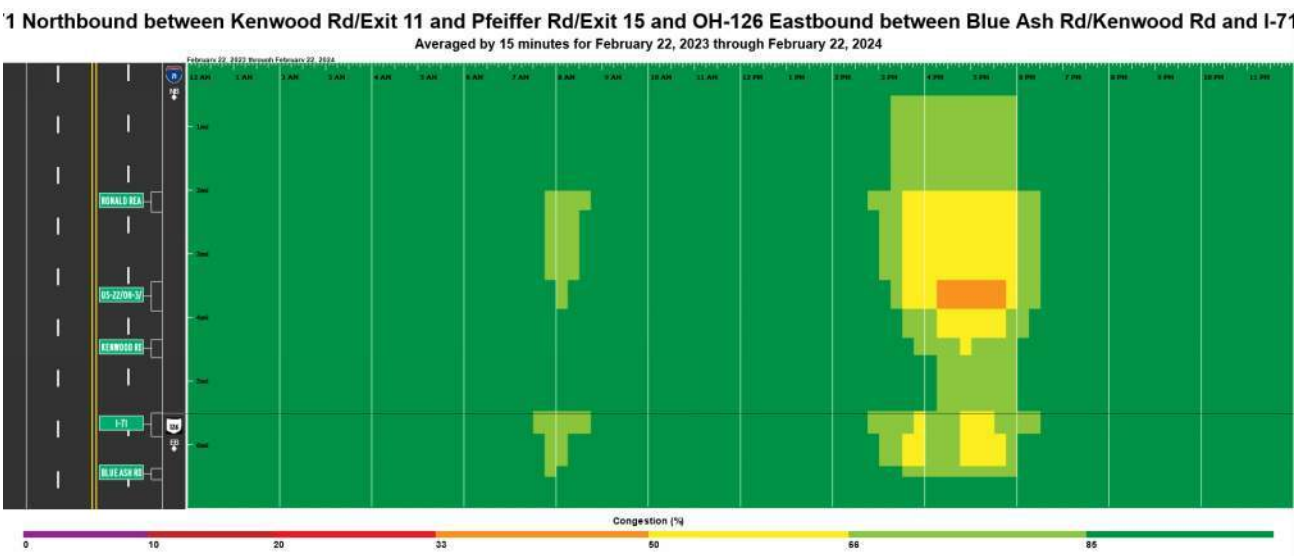
Congestion Scan for I-71 Northbound between Kenwood RdExit 11



Congestion Scan for I-71 Northbound between Kenwood RdExit 11



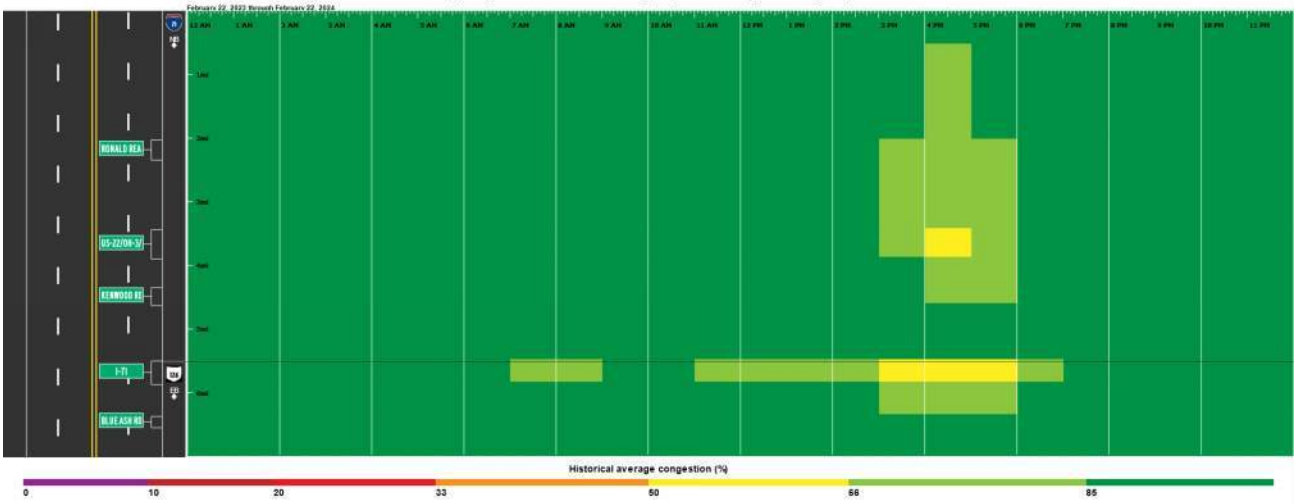
Congestion Scan for I-71 Northbound between Kenwood RdExit 11



Congestion Scan for I-71 Northbound between Kenwood RdExit 11

ion for I-71 Northbound between Kenwood Rd/Exit 11 and Pfeiffer Rd/Exit 15 and OH-126 Eastbound between Blue Ash Rd/Kenwood R

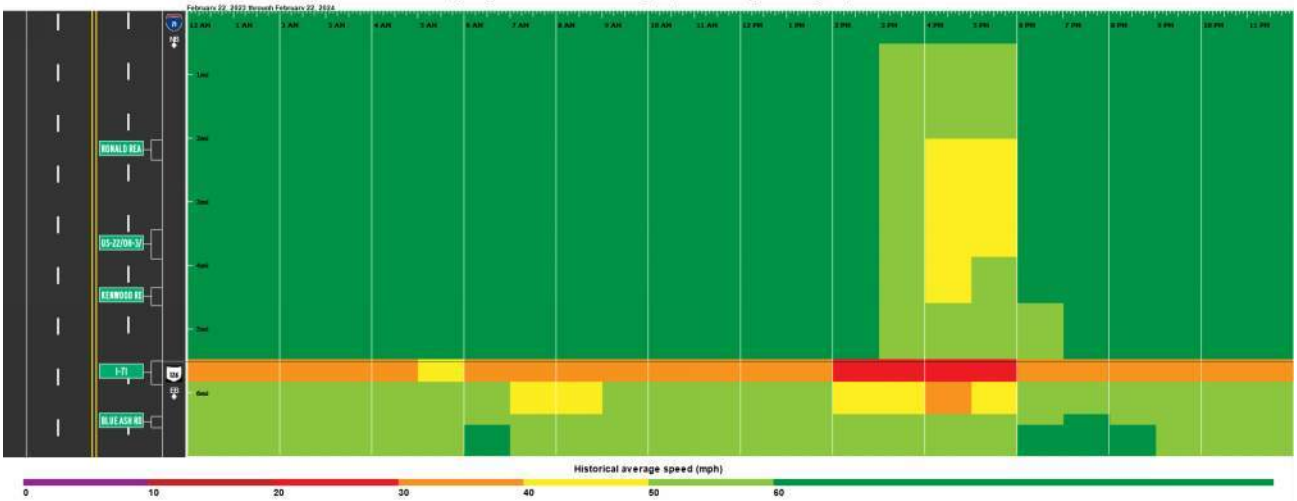
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



Congestion Scan for I-71 Northbound between Kenwood RdExit 11_Historical avg speed

l for I-71 Northbound between Kenwood Rd/Exit 11 and Pfeiffer Rd/Exit 15 and OH-126 Eastbound between Blue Ash Rd/Kenwood Rd a

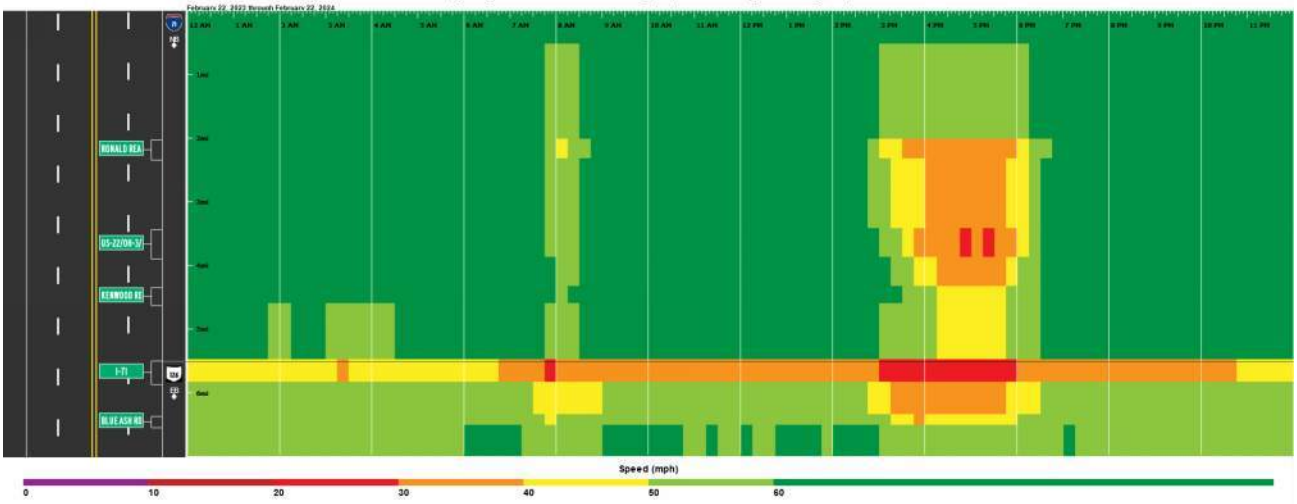
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



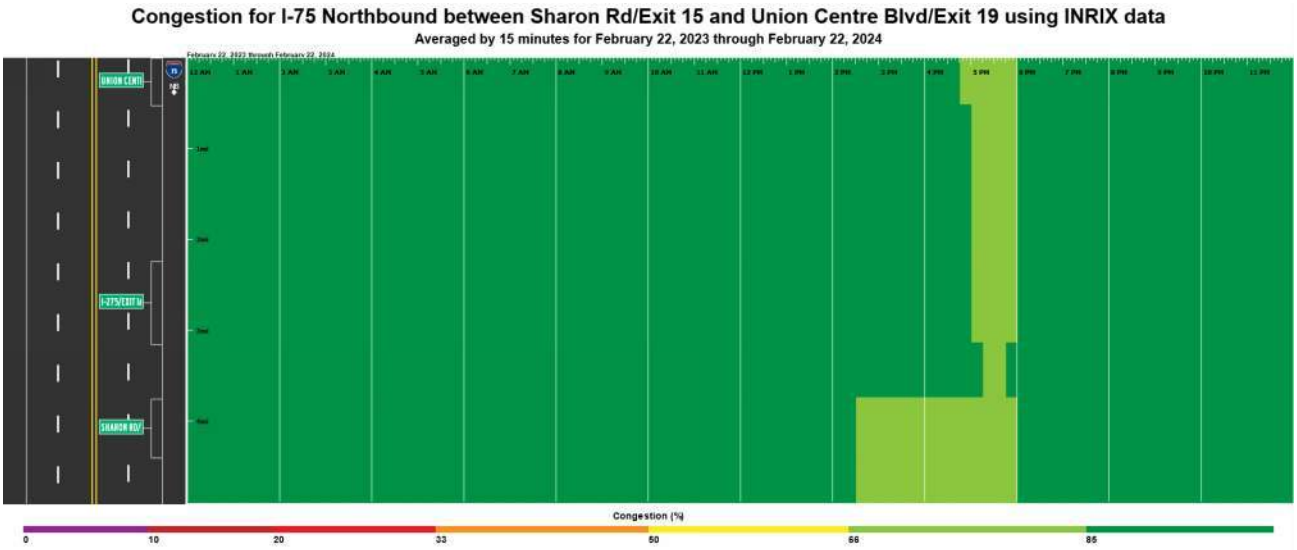
Congestion Scan for I-71 Northbound between Kenwood RdExit 11

Northbound between Kenwood Rd/Exit 11 and Pfeiffer Rd/Exit 15 and OH-126 Eastbound between Blue Ash Rd/Kenwood Rd and I-71 u

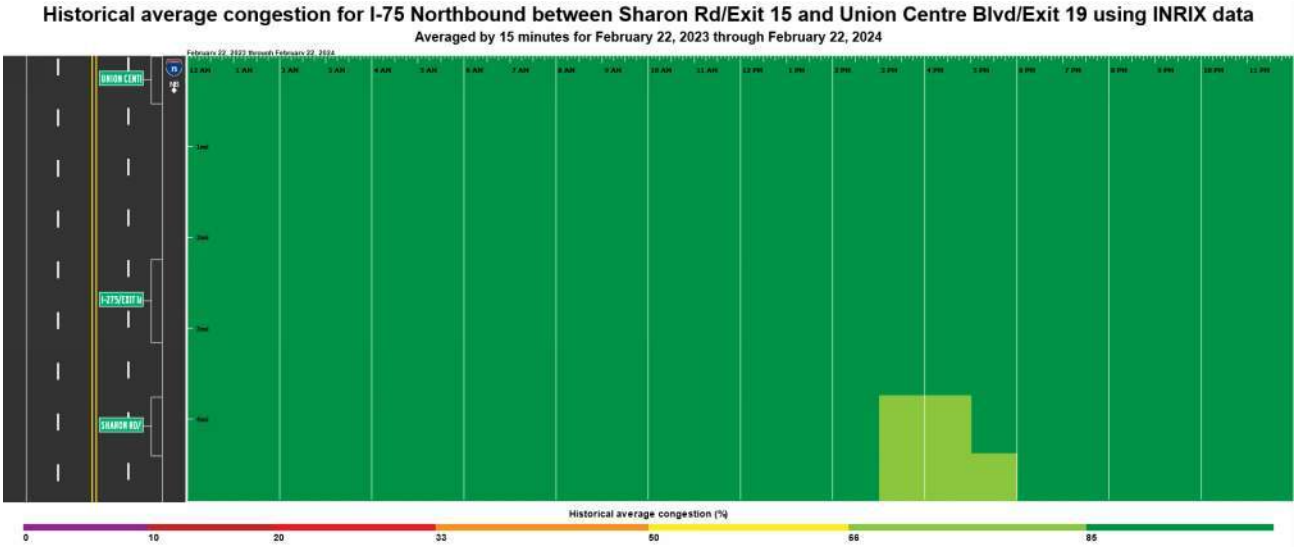
Averaged by 15 minutes for February 22, 2023 through February 22, 2024



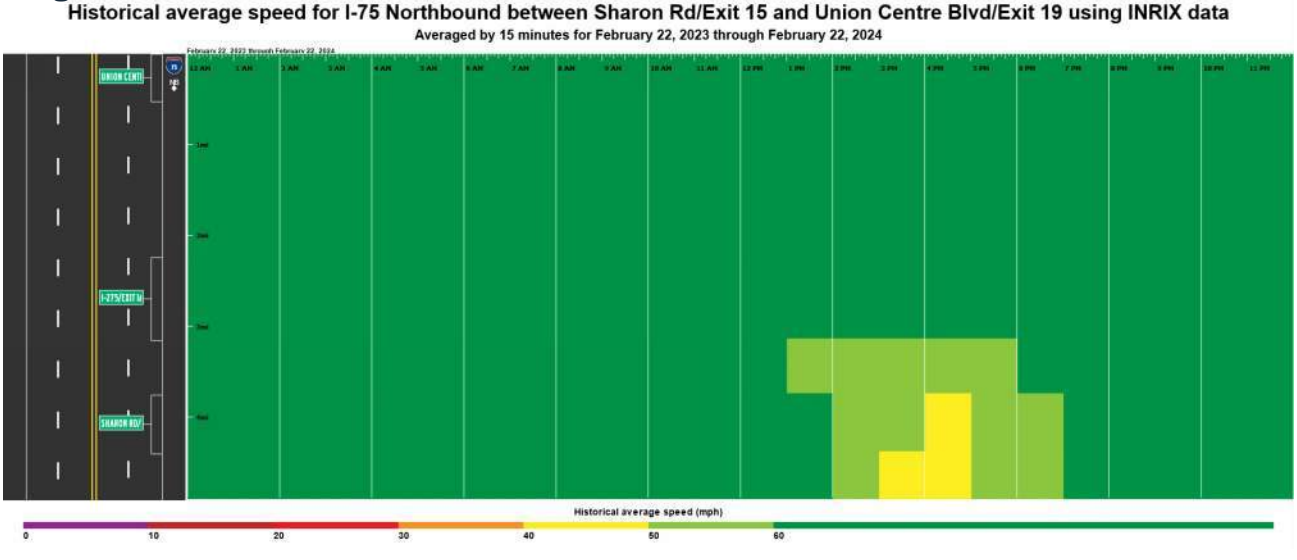
Congestion Scan for I-75 Northbound between Sharon RdExit 15



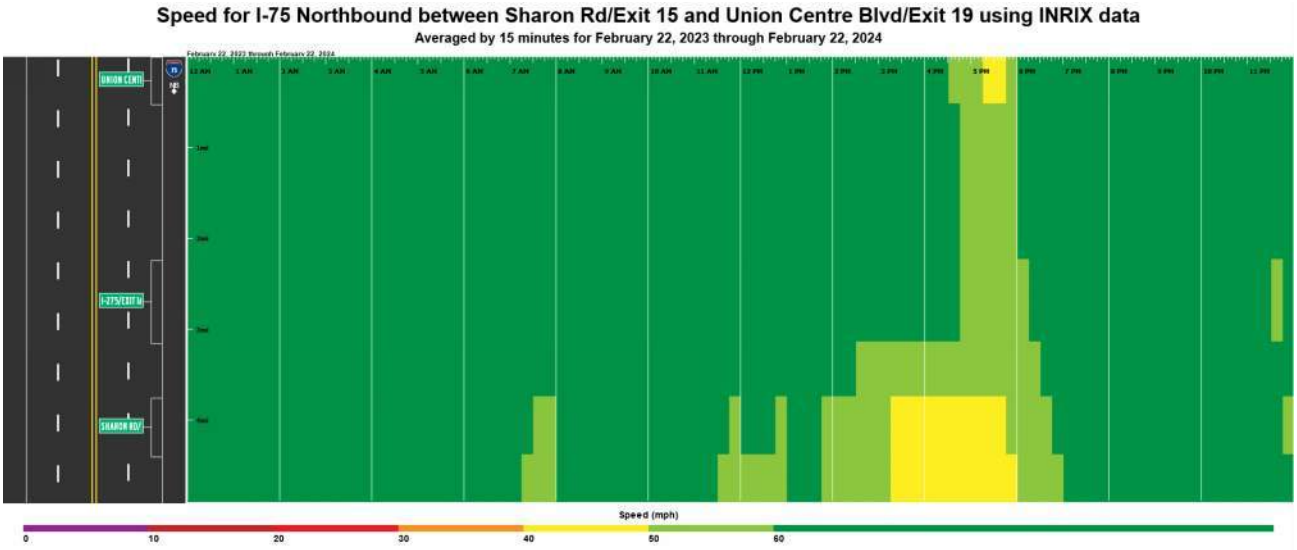
Congestion Scan for I-75 Northbound between Sharon RdExit 15



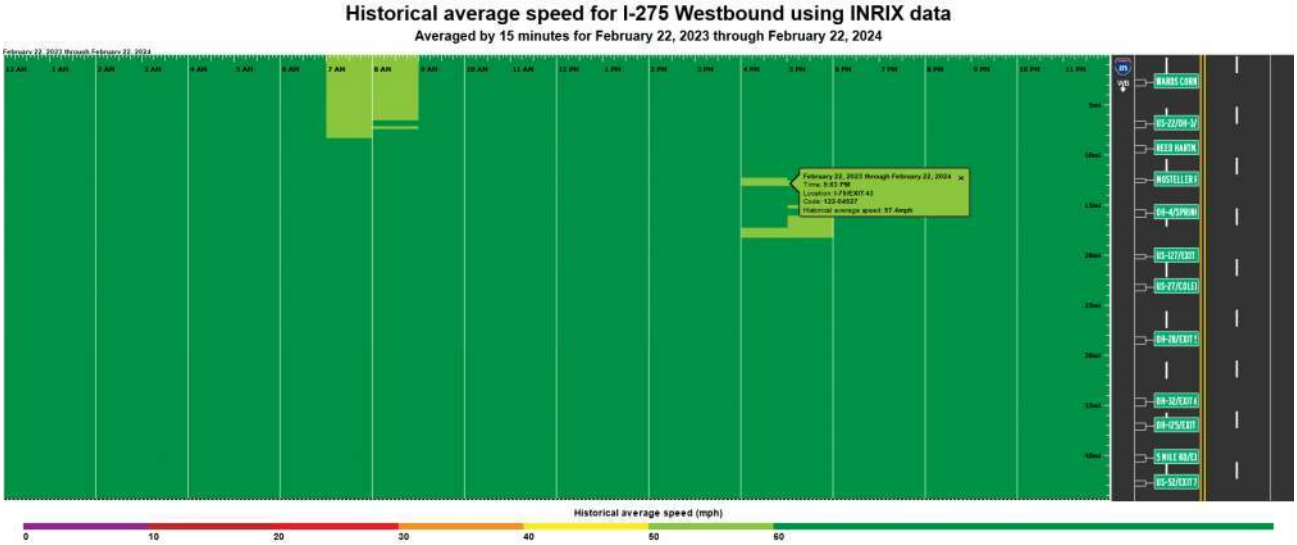
Congestion Scan for I-75 Northbound between Sharon RdExit 15



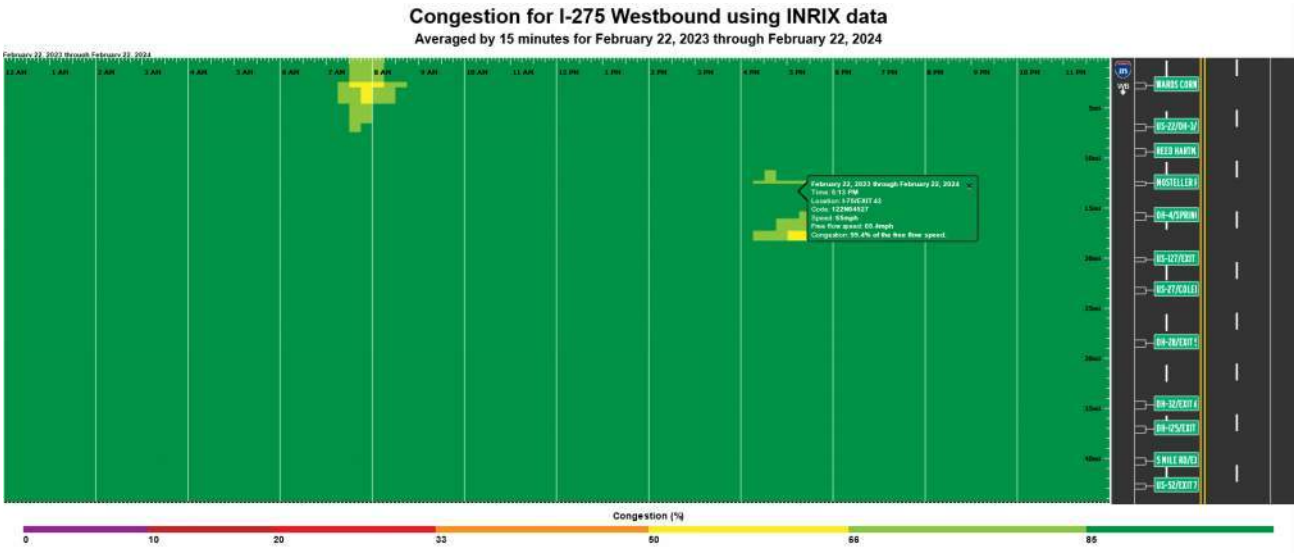
Congestion Scan for I-75 Northbound between Sharon RdExit 15



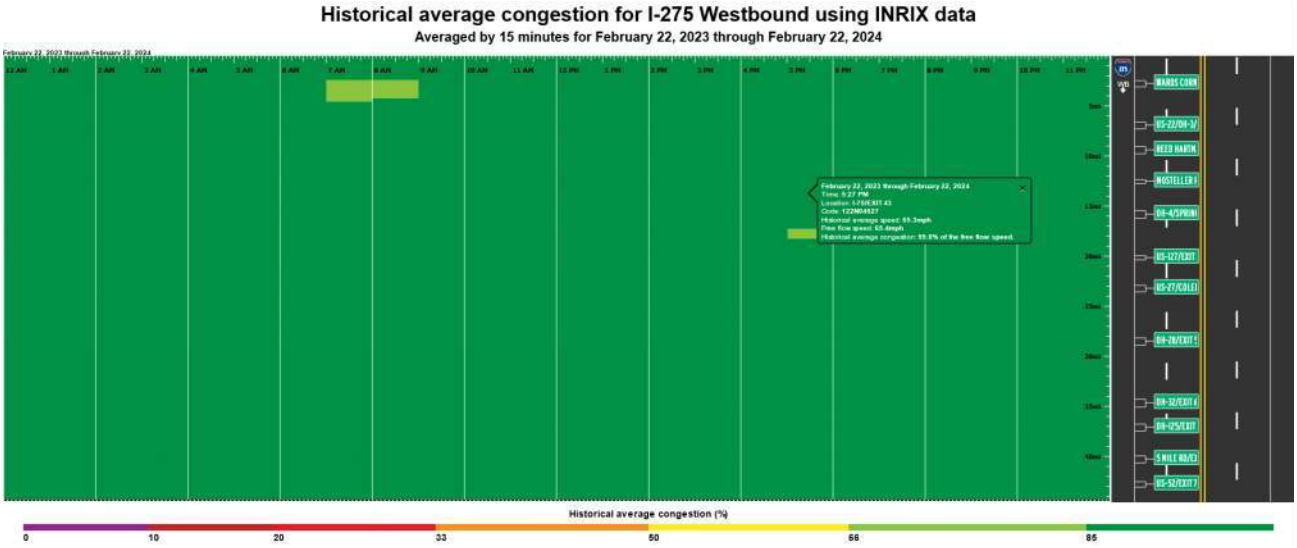
Congestion Scan for I-275 Westbound Historical avg speed



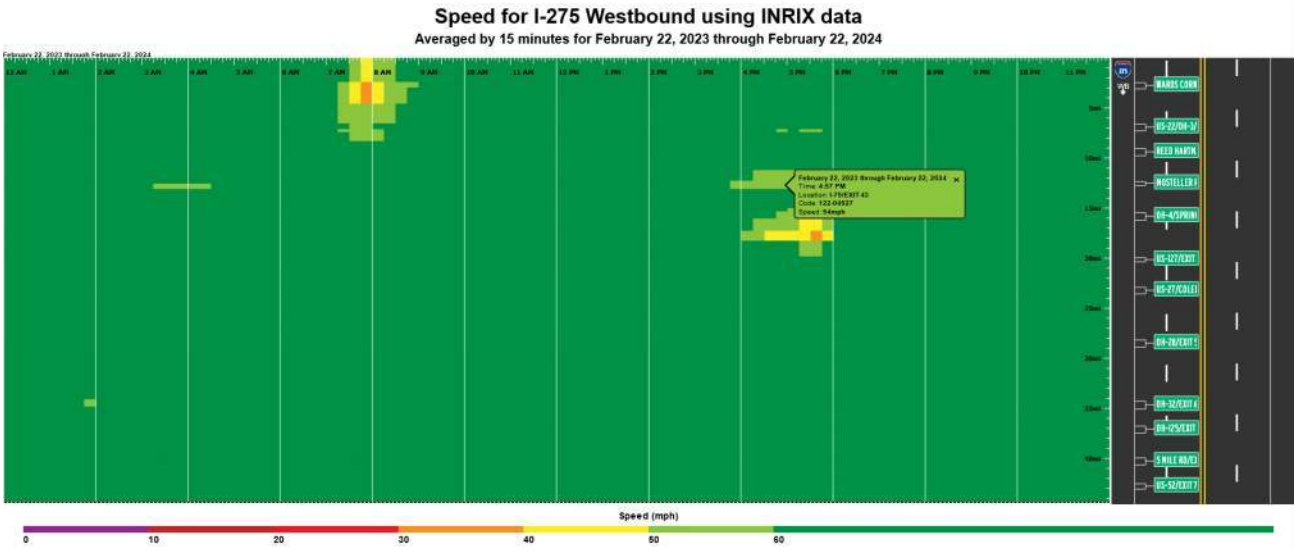
Congestion Scan for I-275 Westbound



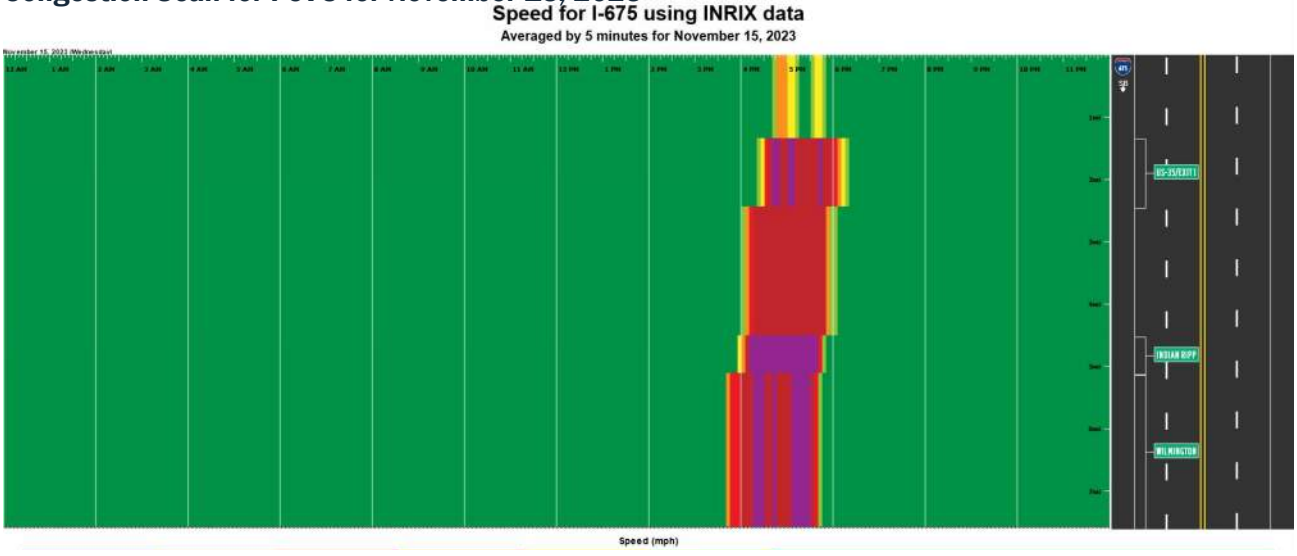
Congestion Scan for I-275 Westbound



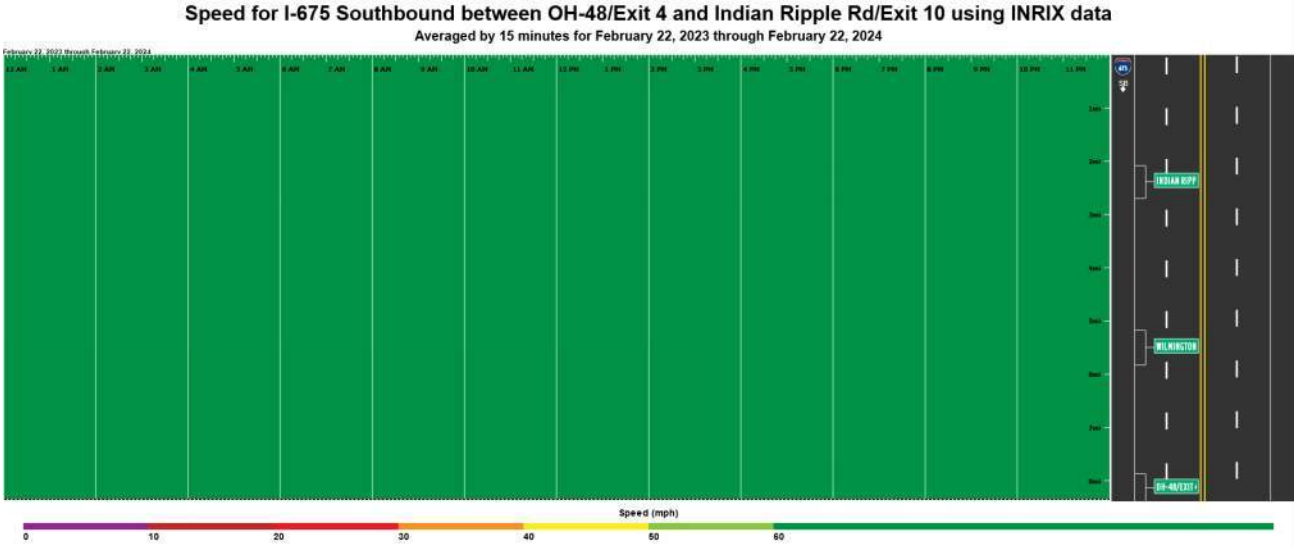
Congestion Scan for I-275 Westbound



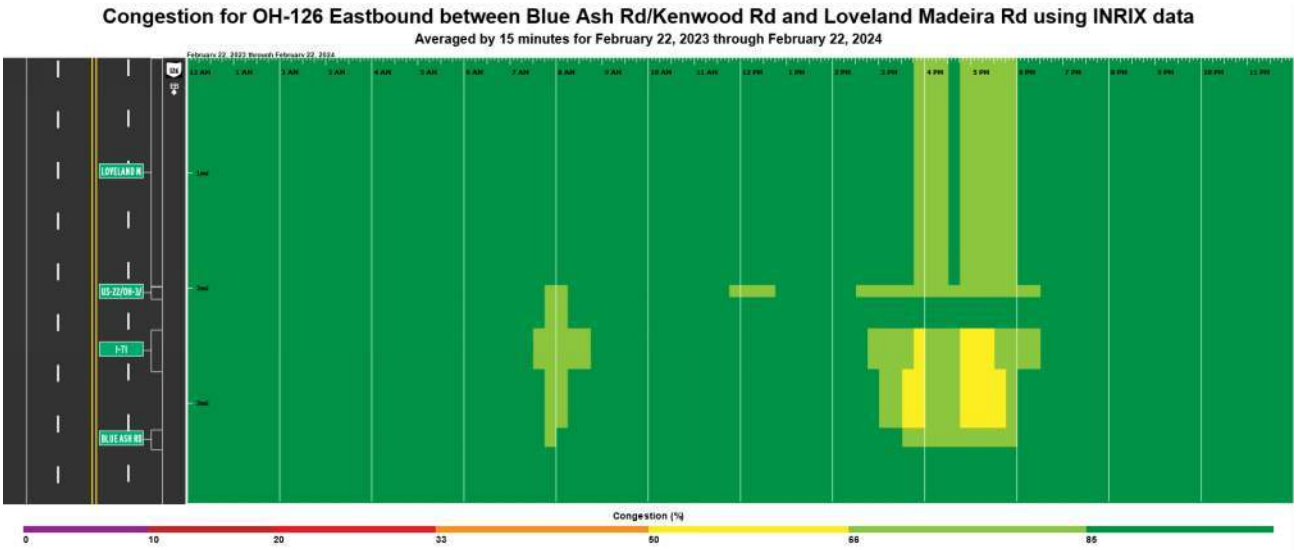
Congestion Scan for I-675 for November 15, 2023



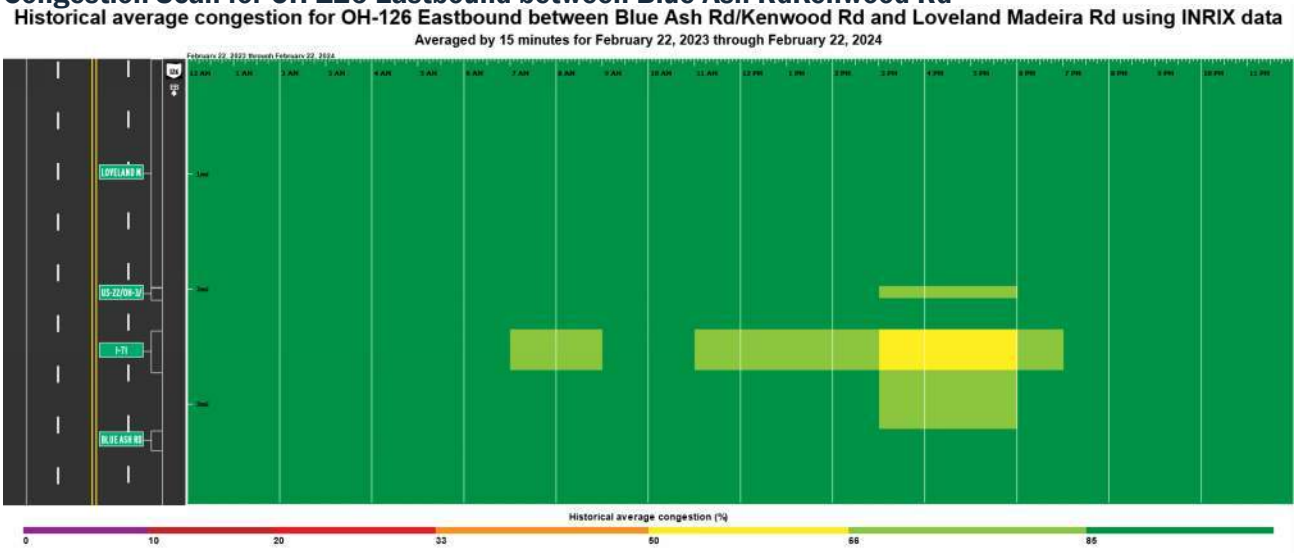
Congestion Scan for I-675 Southbound between OH-48Exit 4 and India for February 22, 2023 through February 22, 2024



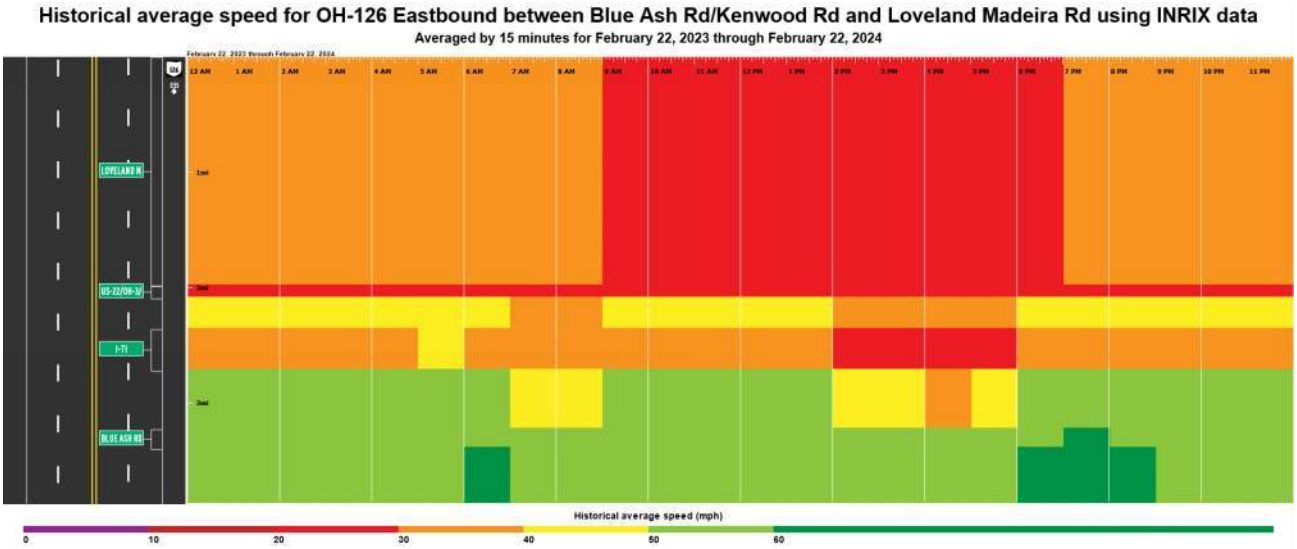
Congestion Scan for OH-126 Eastbound between Blue Ash RdKenwood Rd



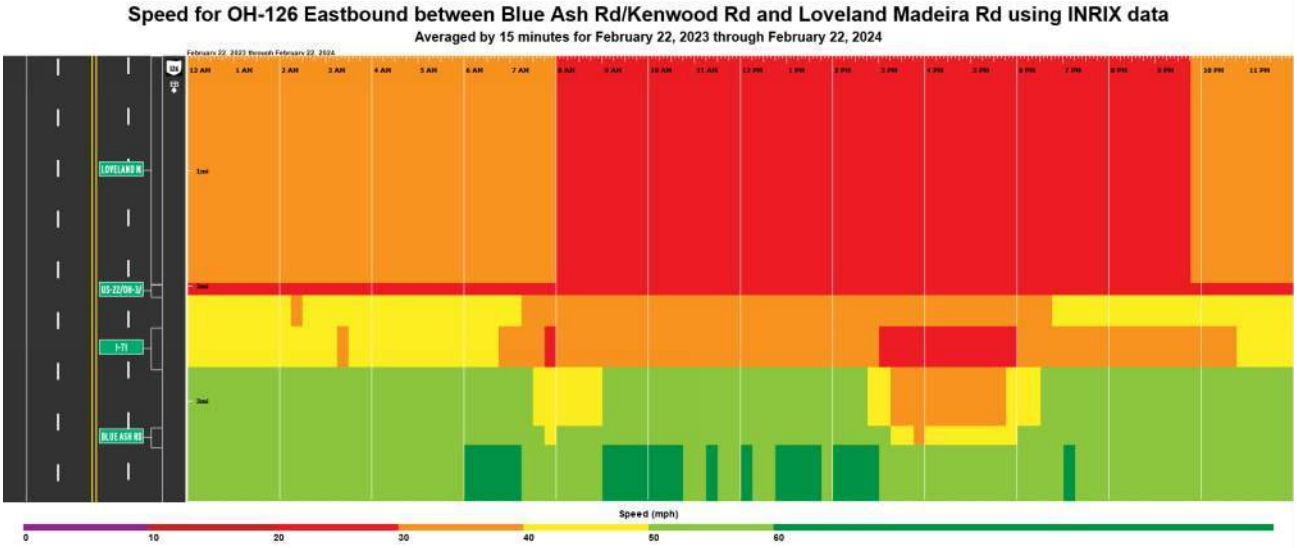
Congestion Scan for OH-126 Eastbound between Blue Ash RdKenwood Rd



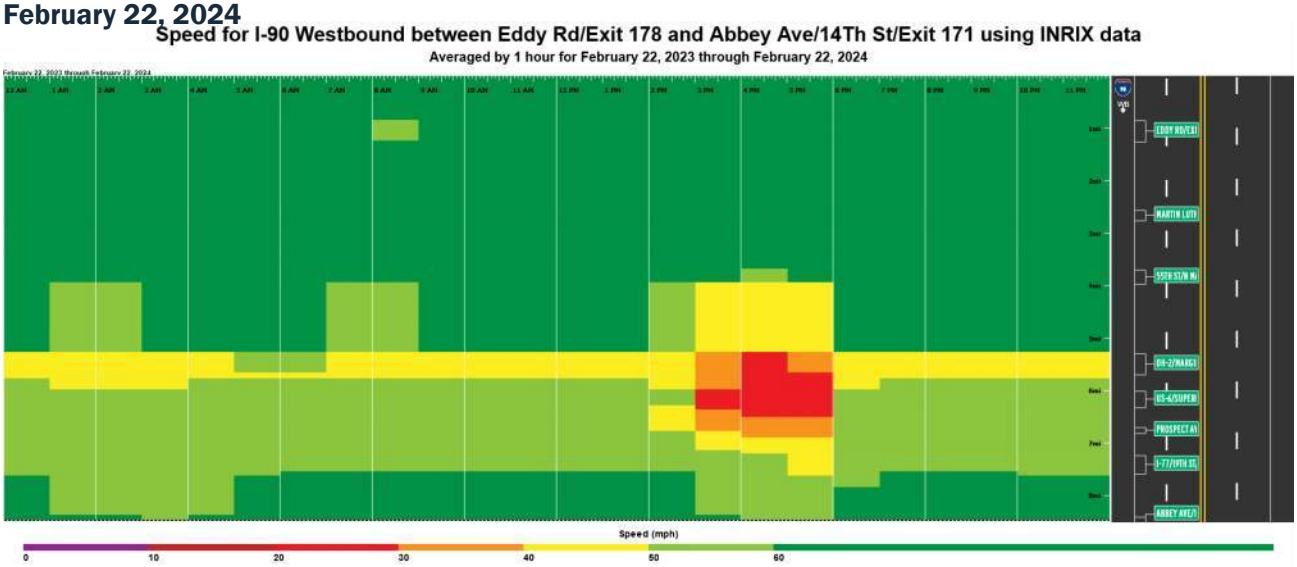
Congestion Scan for OH-126 Eastbound between Blue Ash RdKenwood Rd



Congestion Scan for OH-126 Eastbound between Blue Ash RdKenwood Rd



Congestion Scan for I-90 Westbound between Eddy RdExit 178 and Abb for February 22, 2023 through February 22, 2024



TOAST DATA

This section contains TOAST data for all locations.

District	County	Route	Direction	Logpoint	Description	TOAST Corridor Limits	3 year Total Crashes in TOAST Corridor (from 2020-2022)	TOAST Rear End	Secondary Crashes	Incident Clearance Time (minutes)	Truck Volume
4	SUM	8	NB	4.23	Howe Ave	3.96 to 4.41	32	40.6%	18.8%	1,060	9.8%
5	LIC	70	WB	5.3	SR310/Etna	4.84 to 5.683	15	40.0%	0.0%	2,620	25.7%
6	FRA	70	EB	18.45	Approach to US 33	17 to 18.67	141	37.6%	20.0%	2,566	11.9%
6	FRA	71	SB	23.7	N Broadway/Cooke Rd	22.39 to 23.46	42	38.1%	5.9%	1,367	15.0%
6	FRA	270	SB	44.92	Refugee (ramp area from US 33)	43.45 to 46.13	52	48.1%	26.1%	1,931	13.1%
6	FRA	315	SB	3.9	Kinnear Rd (by OSU)	3.64 to 4.32	72	36.1%	10.0%	1,036	3.2%
6	FRA	670	EB	2.16	SR 315	2.13 to 3.14	53	30.2%	4.2%	n/a	8.3%
6	HAM	71	NB	13.84	SR126/Ronald Regan Hwy	12.464 to 14.157	70	42.9%	8.7%	102	9.3%
8	HAM	126	EB	19.63	IR 71 NB	18.869 to 19.691	114	69.3%	15.1%	436	3.7%
8	HAM	275	WB	26.1	IR 75	25.743 to 26.471	88	58.0%	16.7%	1,354	10.3%
8	GRE	675	SB	0	Wilmington Pike	MOT 4.951 to 7.6	46	45.7%	3.6%	1,396	9.9%
12	CUY	90	WB	18.29	East 55th to SR 2 Split	18.025 to 19.744	167	45.5%	7.7%	3,322	4.4%
12	CUY	176	NB	11.24	South of Denison to I-71/I-90 merge	11.355 to 12.666	70	35.7%	4.8%	2,012	1.7%

OVERALL COSTS

Proposed Location ID	Proposed Device	Proposed Power	Proposed Communications	Comments	Cost Estimate
LITE-D4-OH-8_NB AT HOWE AVE	Type: QWS Lite (Sign w/ beacons) Location: SLM 3.75 (NB) Existing Truss	Existing CCTV @ Tallmadge or Easton	Existing CCTV @ Tallmadge or Easton	Install overhead adjacent to the North SR 8/ East SR 59 guide sign.	$75,000
	Camera Location: SLM 4.05 (SB) Existing DMS Sign	Existing DMS sign	Existing DMS sign	Install on the existing SB DMS sign *Note: Preferred installation on NB side of SR-8 if directional bore access exists and will need increase in cost estimate.	$20,000
QWS-D5-I-70_WB BEFORE SR 310	Type: Existing QWS Panel (Ground Mounted) Location: SLM 5.50 (WB) @ Watkins Rd	N/A	N/A	Maintain existing QWS panel.	$0
	Camera Location: SLM 5.40 (WB) west of Watkins Rd	Existing QWS camera/ panel @ Watkins Rd. or TOD sign @ SLM 5.45 (WB)	Existing QWS camera/ panel @ Watkins Rd. or TOD sign @ SLM 5.45 (WB)	Install on new pole with camera looking west towards the WB off-ramp for SR310	$65,000
QWS-GRND-D6-I-70_EB AT KELTON AVE	Type: QWS Panel (Ground Mounted) Location: SLM 16.24 (EB) @ Kelton Ave. Exit ramp gore	Existing CCTV @ Kelton Ave.	Existing CCTV @ Kelton Ave.	Replace existing ground mounted Exit 103A sign with QWS and relocate existing sign further east	$150,000
	Camera Location: SLM 17.99 (EB) @ Franklin Rd	Existing CCTV @ Franklin Rd.	Existing CCTV @ Franklin Rd.	Install on existing CCTV pole with the camera looking southeast towards the off-ramp for US 33 SB.	$15,000
QWS-GRND-D6-I-71_SB AT MORSE RD	Type: QWS Panel (Ground Mounted) Location: SLM 24.12 (SB) @ Morse Rd	Existing ramp meters @ Morse Rd. entrance ramp	Existing ramp meters @ Morse Rd. entrance ramp	Install along the right-hand side of the road	$150,000
	Camera Location: Weber Rd @ IR-71 (SLM 21.87)	Existing CCTV camera	Existing CCTV camera	Install on an existing CCTV pole with camera looking towards SB IR-71 between Weber Rd. and Hudson St.	$15,000
	Camera Location: Hudson St @ IR-71 (SLM 21.09)	Existing ramp meter @ Hudson St. entrance ramp	Existing ramp meter @ Hudson St. entrance ramp	Install on an exisitng pole at the SB ramp meter at Hudson but may need a new pole (increased cost estimate to be more conservative) with camera looking towards SB IR-71	$50,000
QWS-GRND-D6-I-270_SB AT SR 317	Type: QWS Panel (Ground Mounted) Location: SLM 44.76 (SB) @ SR 317	Existing CCTV @ SR 317	Existing CCTV @ SR 317	Install across from existing CCTV camera behind guardrail on right-hand side of the road	$150,000
	Camera Location: SLM 46.09 (NB) @ US 33	Existing CCTV @ US 33	Existing CCTV @ US 33	Install on existing CCTV pole with the camera looking north/northeast towards the weave section and US 33 off-ramp	$15,000
QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE	Type: QWS Panel (Ground Mounted) Location: SLM 2.12 (EB) @ Scioto River Bridge	New power service will be needed	Existing fiber trunk line in area	Install behind guardrail along right-hand side of the road Due to sign spacing requirements, this proposed sign location may be adjusted during design phase	$150,000
	Camera Location: SLM 3.18 (EB) @ Neil Ave.	Existing CCTV @ Neil Ave	Existing CCTV @ Neil Ave	Install new camera pole and CCTV camera on EB I-670 across from existing CCTV camera on WB I-670 @ Neil Ave. with a bore across I-670 and install on a new pole (increased estimate to be more conservative). Camera looking east along EB I-670.	$100,000
	Camera Location: SLM 3.18 (EB) @ Neil Ave.	Existing CCTV @ Neil Ave	Existing CCTV @ Neil Ave	Install new camera on the new camera pole (cost estimate captured above) with camera looking west along EB I-670	$15,000
QWS-GRND-D6-OH-315_SB AT IR-670	Type: Overhead DMS (Existing) Location: SLM 7.37 (SB)	Existing	Existing	Existing full-color DMS sign at this location	$0
	Type: QWS Panel (Ground Mounted) Location: SLM 2.49 (SB) [Exit ramp to I-670 EB]	Existing CCTV on SR 315 @ IR-670 EB Flyover Ramp	Existing CCTV on SR 315 @ IR-670 EB Flyover Ramp	Install on the exit ramp to I-670 EB on the left-hand side of the road behind guardrail Existing Ohio LOGO sign will need relocated to accommodate new QWS sign	$150,000
	Camera Location: SLM 4.28 (SB) @ Lane Ave	Existing ramp meter @ Lane Ave entrance ramp	Existing ramp meter @ Lane Ave entrance ramp	Install on an exisitng pole at the SB ramp meter at Lane Ave. but may need a new pole (increased cost estimate to be more conservative) with camera looking towards SB SR-315	$50,000
	Camera Location: SLM 2.35 (SB) @ I-670 EB Flyover Ramp	Existing CCTV on SR 315 @ IR-670 EB Flyover Ramp	Existing CCTV on SR 315 @ IR-670 EB Flyover Ramp	Install on existing CCTV pole with the camera looking east down the flyover ramp to I-670 EB	$15,000

OVERALL COSTS

QWS-OVRHD-D8-I-71_SR 126	Type: Overhead DMS (Existing) Location: SLM 13.31 (NB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and truss structure	$310,000
	Type: Overhead DMS (Existing) Location: SLM 15.10 (SB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and truss structure	$310,000
	Camera Location: SLM 14.12 (NB) @ SR 126	Existing CCTV @ SR 126	Existing CCTV @ SR 126	Install on existing CCTV pole with the camera looking south of SR 126 interchange	$15,000
	Camera Location: SLM 14.12 (NB) @ SR 126	Existing CCTV @ SR 126	Existing CCTV @ SR 126	Install on existing CCTV pole with the camera looking south of SR 126 interchange	$15,000
	Camera Location: SLM 13.31 (NB) @ Kugler Road	Existing DMS sign (to be replaced)	Existing DMS sign (to be replaced)	Install on new DMS sign structure with the camera looking south along I-71 SB	$15,000
QWS-OVRHD-D8-OH-126_EB AT I-71	Type: Overhead DMS (Existing) Location: SLM 18.49 (EB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and truss structure	$310,000
	Type: QWS Lite (Sign w/ beacons) - Existing Location: SLM 18.61 (EB)	Remove	Remove	Remove existing installation (In-House)	$0
	Camera Location: SLM 19.52 @ I-71 Ramp Traffic Signal	Existing traffic signal @ I-71 Off-ramp	Existing traffic signal @ I-71 Off-ramp	Install CCTV on a traffic signal strain pole with the camera looking at the unsignalized exit lanes to I-71	$15,000
QWS-OVRHD-D8-I-275_WB AT I-75 NB	Type: Overhead DMS (Existing) Location: SLM 26.96 (WB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and truss structure	$310,000
	Camera Location: SLM 25.95 (WB)	New power service will be needed	New communications service will be needed	Install on overhead sign truss for WB I-275 to NB I-75 with the camera looking northwest along the I-75 NB entrance ramp from I-275 WB.	$70,000
QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE	Type: QWS Panel (Ground Mounted) Location: SLM 1.06 (SB) before Feedwire Rd	New power service will be needed	New communications service will be needed	Remove existing ground mounted Centerville Corp sign and replace with the QWS Note: Vegetation along ROW will need to be kept trimmed back	$150,000
	Camera Location: SLM 0.49 (NB) @ Wilmington Pike	Existing CCTV on IR-675	Existing CCTV on IR-675	Install on existing CCTV pole with the camera looking southwest torward I-675 SB exit to Wilmington Pike.	$15,000
QWS-OVRHD-D12-I-90_WB AT DOWNTOWN	Type: Overhead DMS (Existing) Location: SLM 23.73 (WB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and support	$260,000
	Type: QWS Lite (Sign w/ beacons) Location: SLM 20.27 (WB)	New power service will be needed	New communications service will be needed	Install QWS Lite on the vertical support of the "E 55th St 1/4 Mile" cantilever sign.	$50,000
	Type: Overhead DMS Location: SLM 18.66 (WB)	Existing CCTV @ Lakefront Airport	Existing CCTV @ Lakefront Airport	Remove existing overhead sign truss and replace with new truss structure full-color DMS. Signs to be replaced or re-installed on new overhead sign support truss at SLM 18.47 (WB).	$310,000
	Type: Overhead Sign Support Box Truss Location: SLM 18.47 (WB)	N/A	N/A	Remove existing cantilever and sign and replace with overhead sign support truss for the relocated signs from SLM 18.66 (WB)	$180,000
	Type: Overhead DMS (Existing) Location: SLM 17.70 (WB)	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and support	$310,000
	Camera Location: SLM 19.68 (EB) @ E. 55th St.	Existing CCTV @ E. 55th St.	Existing CCTV @ E. 55th St.	Install on existing CCTV pole with the camera looking west	$15,000
	Camera Location: SLM 18.68 (WB) @ Lakefront Airport	Existing CCTV @ Lakefront Airport	Existing CCTV @ Lakefront Airport	Install on existing CCTV pole with the camera looking west	$15,000
	Camera Location: SLM 17.70 (WB) @ Superior Ave.	Existing power service at local DMS	New communications service will be needed	Install new detection camera and pole on the south side of Superior Ave. Looking South.	$75,000
	Camera Location: SLM 17.24 (EB) @ Chester Ave	Existing CCTV @ Chester Ave	Existing CCTV @ Chester Ave	Install on existing CCTV pole with the camera looking south	$15,000
QWS-GRND-D12-OH-176_NB AT STEELYARD	Type: Overhead DMS (Existing) Location: SLM 12.15 (NB) @ Crestline Ave	Existing	Existing	Replace existing overhead DMS sign and structure with a new full-color DMS sign and support	$310,000
	Type: QWS Lite (Sign w/ beacons) Location: SLM 12.94 (NB) @ Steelyard Dr. ramp	Existing @ Dennison Ave.	Existing @ Dennison Ave.	Install along the right-hand side of the road in gore area of entrance ramp.	$30,000
	Camera Location: SLM 13.19 (NB) @ IR-71 Ramp	Existing CCTV on SR 176 @ IR-71 Ramp	Existing CCTV on SR 176 @ IR-71 Ramp	Install on existing CCTV pole with the camera looking north	$15,000

TOTAL $4,305,000

TOAST ONE PAGER

Department of Transportation

TOAST
Traffic Operations Assessment Systems Tool

Overview

ODOT's mission is to provide a transportation system that is safe, accessible, well maintained, and positioned for the future. Through our Transportation Systems Management and Operations (TSMO) plan and program, ODOT is working to maximize the efficiency, reliability, and safety of our current transportation network. As part of our TSMO initiatives, we built the Traffic Operations Assessment Systems Tool (TOAST).

TOAST is a scanning tool which scores and ranks corridors based on multiple data sets and metrics in order to help transportation professionals make data-driven decisions and determine operationally sensitive corridors throughout the state.

About the Tool

- Routes are segmented into the State Priority System with breaks at urban area boundaries, interchange center points, and road functional class changes. Where possible, data is provided directionally.
- Multiple Data Categories make up TOAST. For each category, data ranges were normalized into values of 0-10, then multiplied by a weighting factor.
- The total score for a route is calculated as a percent based on the score for each category divided by the total possible maximum score.

In general, the higher the percent, the better the route is performing, whereas the lower the percent, the more likely a route is to benefit from application of TSMO strategies.

Data Categories

Bottlenecks

A potential bottleneck is detected when speeds on a segment drop to 65% of reference speeds and cause at least a two-minute delay.

Pass-through:
any part of the bottleneck(s) impacts the corridor

Origination:
the bottleneck(s) begins in the corridor

Travel Time

Travel Time Performance:
Frequency with which motorists experience delay. Percent of time motorists can travel at or near (90%) of free-flow speed

Travel Time Index:
Impact of travel delay experienced by motorists. Ratio of the travel time during specific time of day periods to the time required to make the same trip at free-flow speeds

TSMO Safety

Rear End Percent
Percent of total crashes that are rear end

Crash Severity Impact
Impact of crashes based on severity

Traffic Incident Management

Incident Clearance
The time from report of an incident until the entire scene is cleared.

Secondary Crashes
Percent of crashes that occurred as a result of a previous incident.

Traffic Volume Data

Volume Per Lane
Volume of traffic per lane, calculated based on a weighted average for each segment.

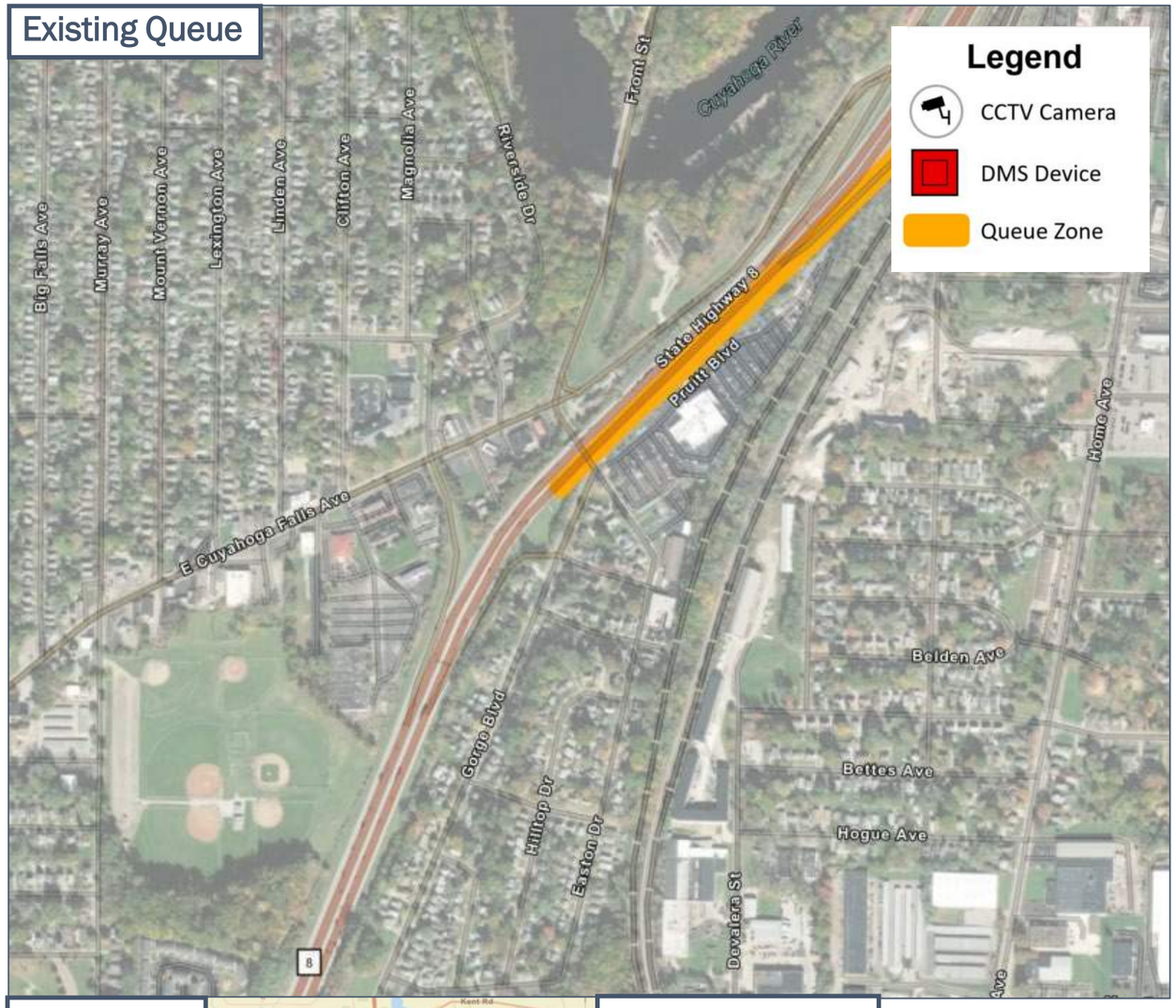
Freight Corridors
Weighted average of percent trucks (avg. daily truck volume ÷ avg. daily total volume).

LITE-D4-OH-8_NB at Howe Ave

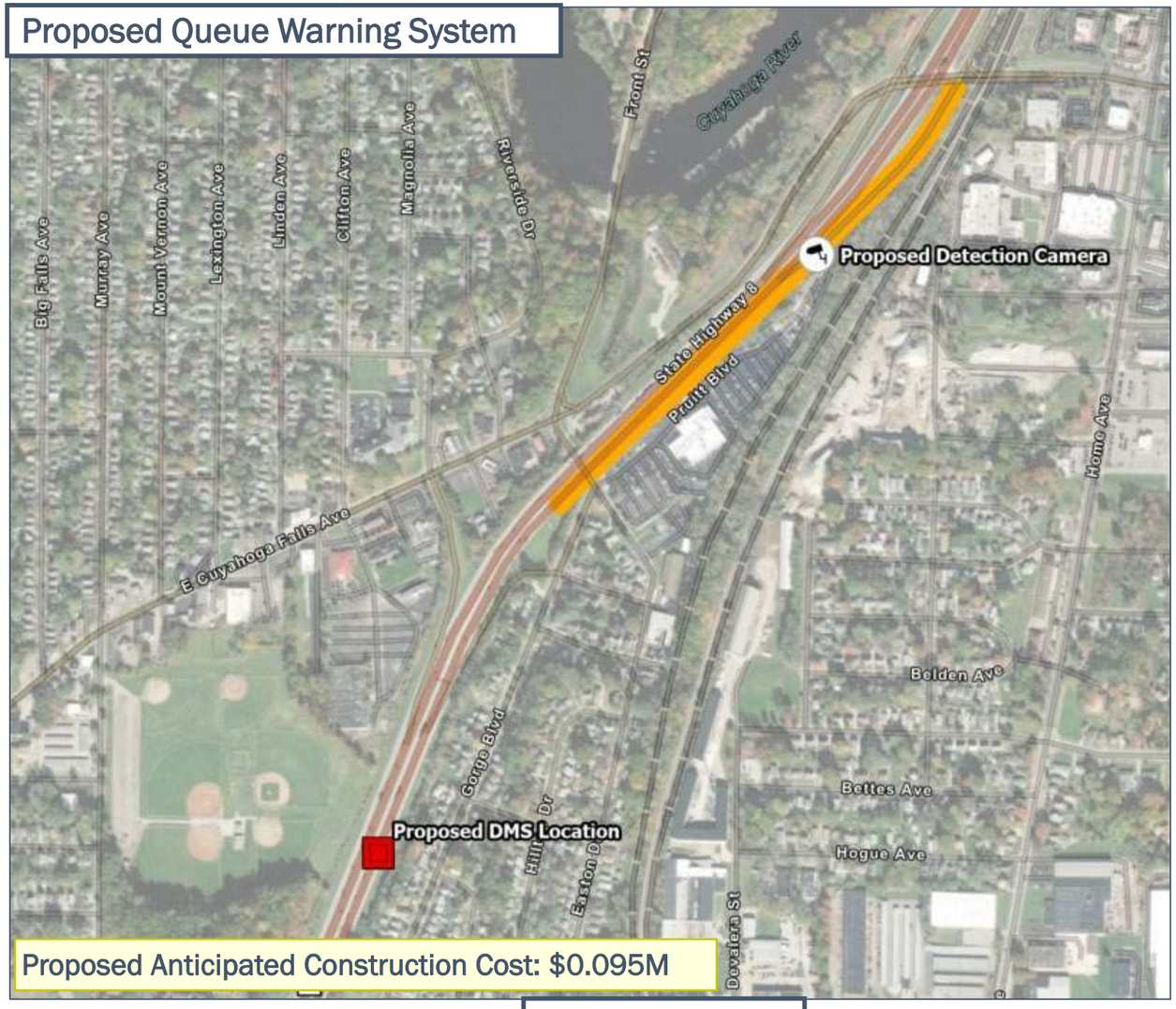
Ohio Department of Transportation

GANNETT FLEMING

Existing Queue

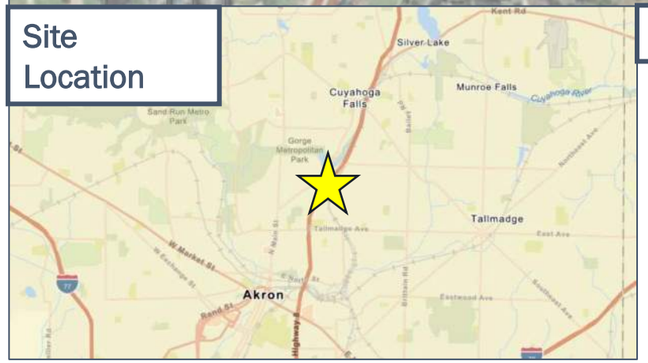


Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.095M

Site Location



Existing Conditions

- This location is a concern for safety and queuing due to its TOAST scores from the northbound exit ramp that was backing up onto the mainline.

Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$20,000
QWS Lite (Truss)	1	$75,000

Item Descriptions

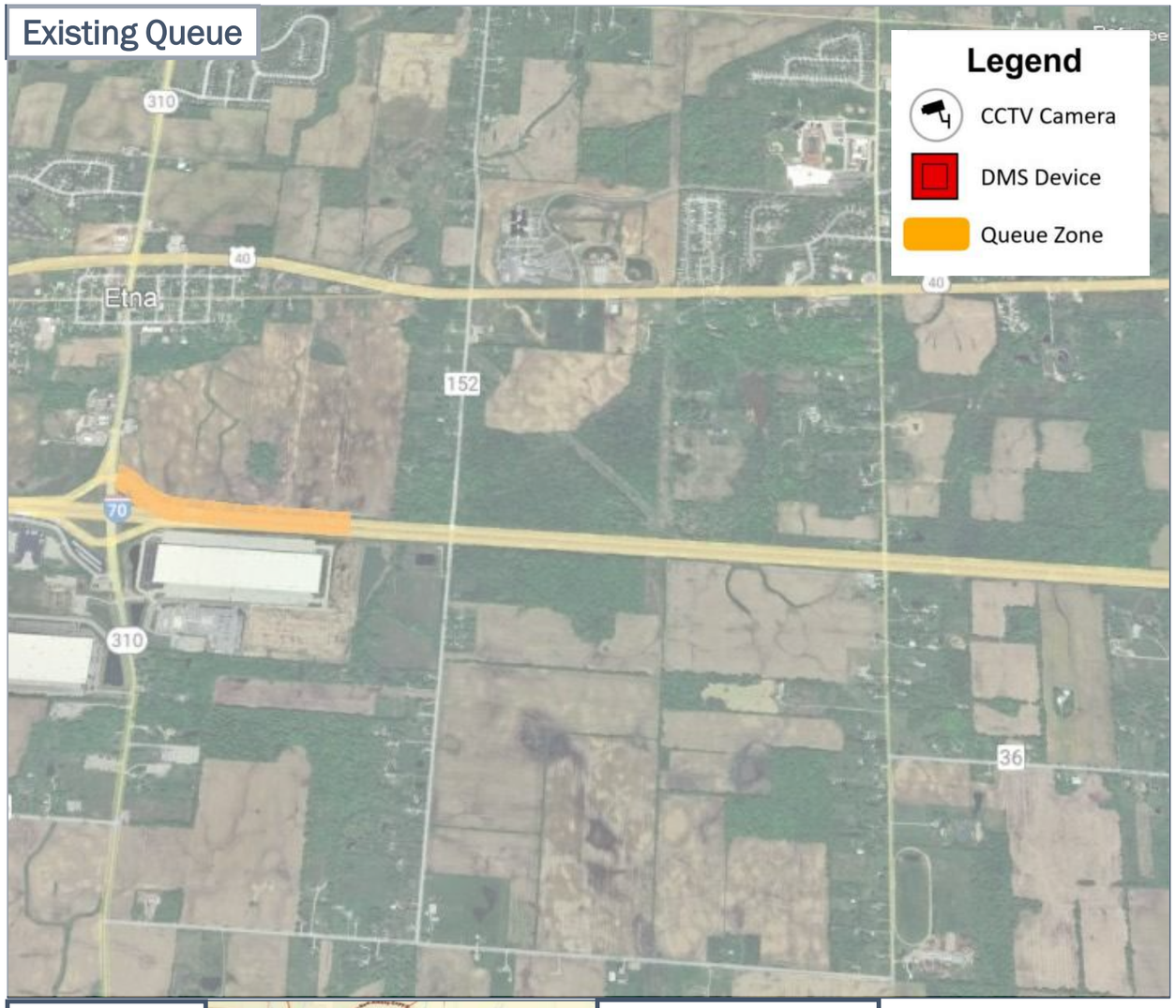
- One (1) proposed QWS Lite on a truss structure on SR-8 NB.
- One (1) proposed detection camera to be place on the existing truss structure at the beginning of the Howe Ave. ramp
- If an additional detection camera is warranted it can be placed at the same location as the proposed but facing south.

QWS-D5-I-70_WB before OH-310

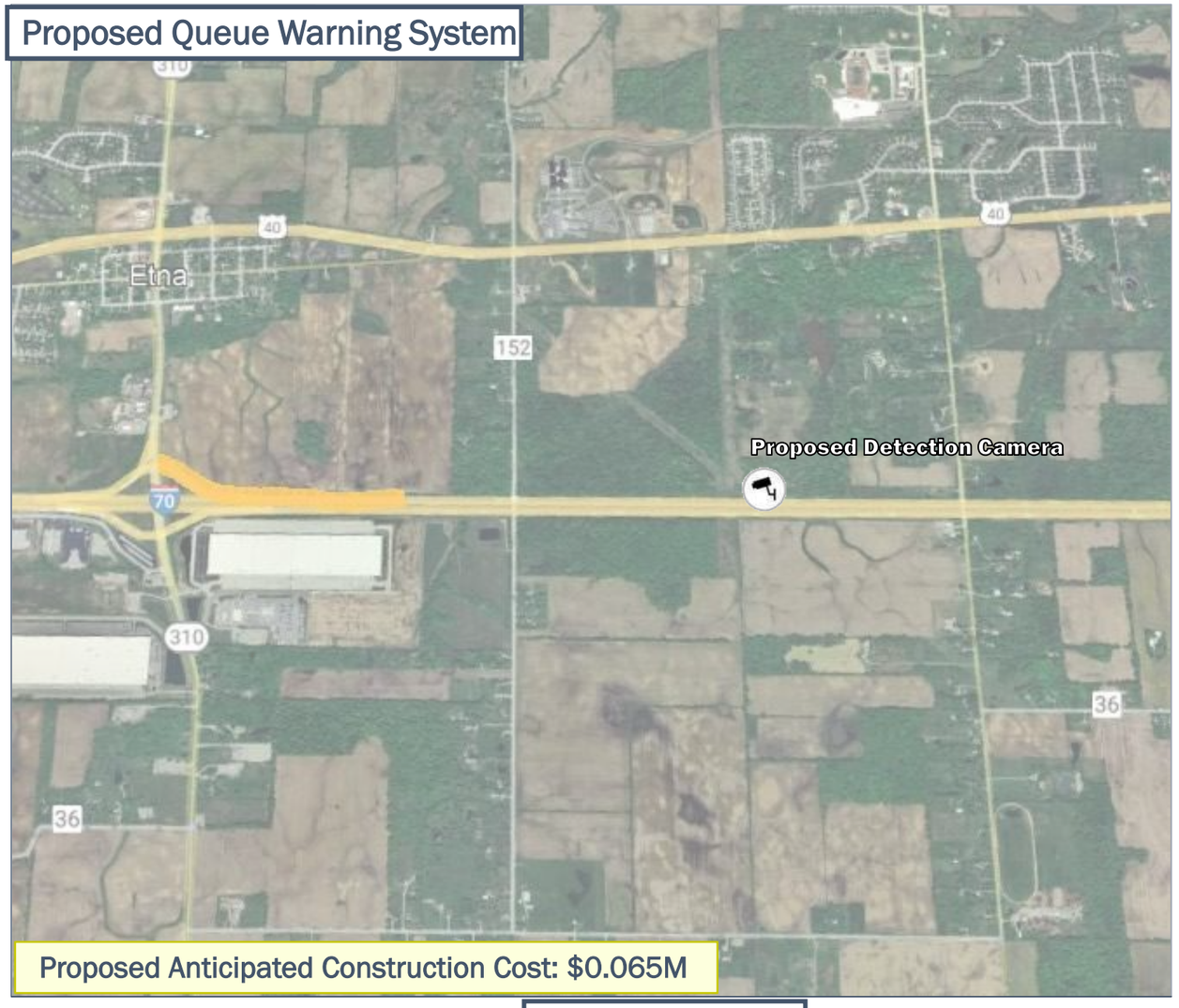
Ohio Department of Transportation

GANNETT FLEMING

Existing Queue

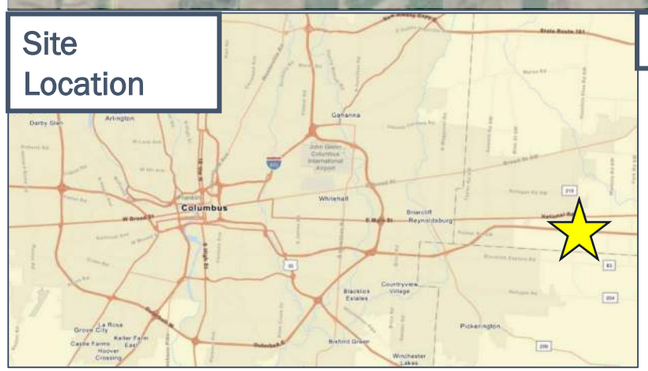


Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.065M

Site Location



Existing Conditions

- The stretch from I-70 Westbound to SR-310 is recognized as the motor crash site associated with multiple fatalities. An existing QWS system is present at this location that was installed after the crash.

Item Descriptions

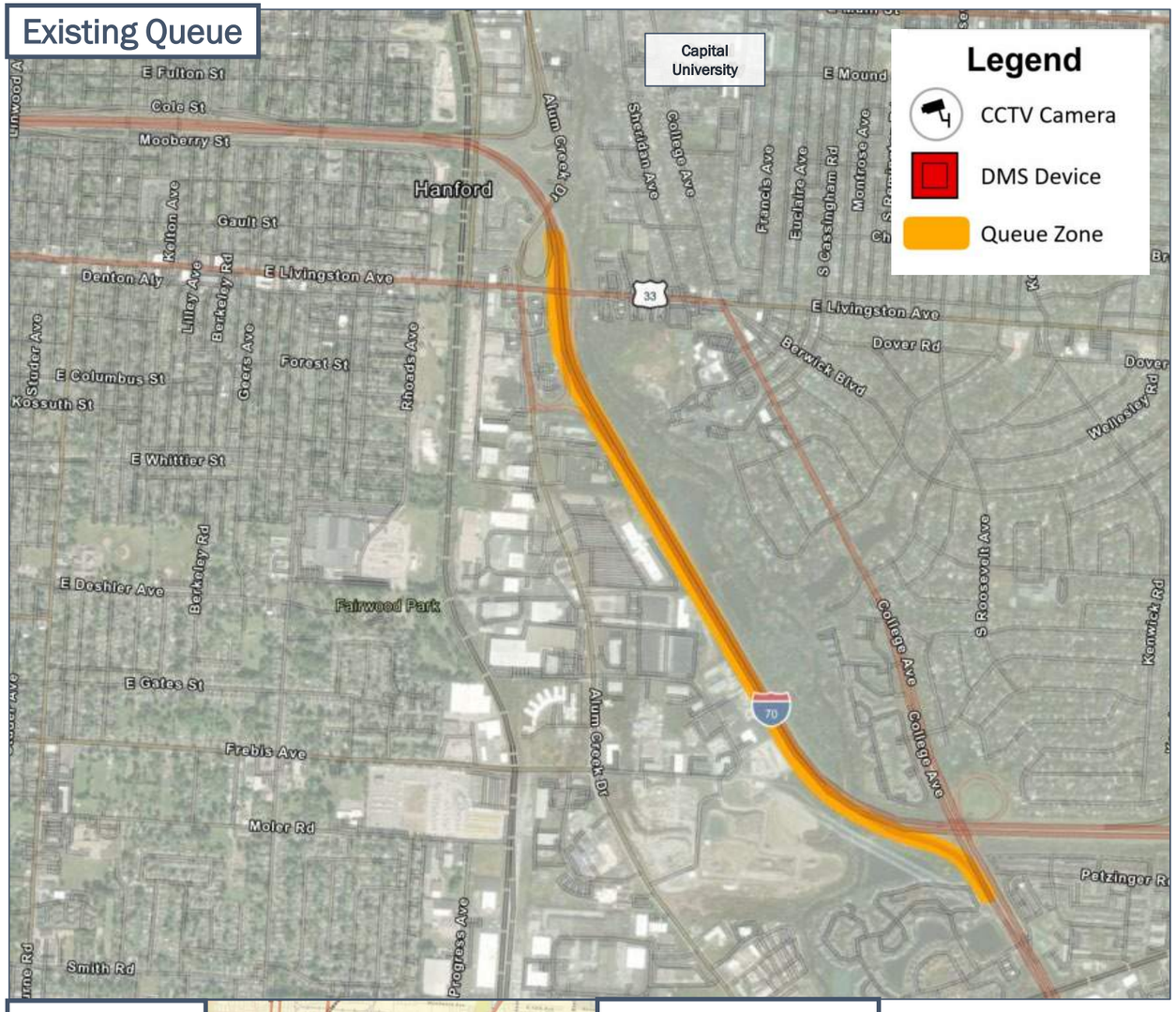
Item	Quantity	Item Total Price
Camera and new pole	1	$65,000

One existing ground mounted QWS Panel near Watkins Road Overpass

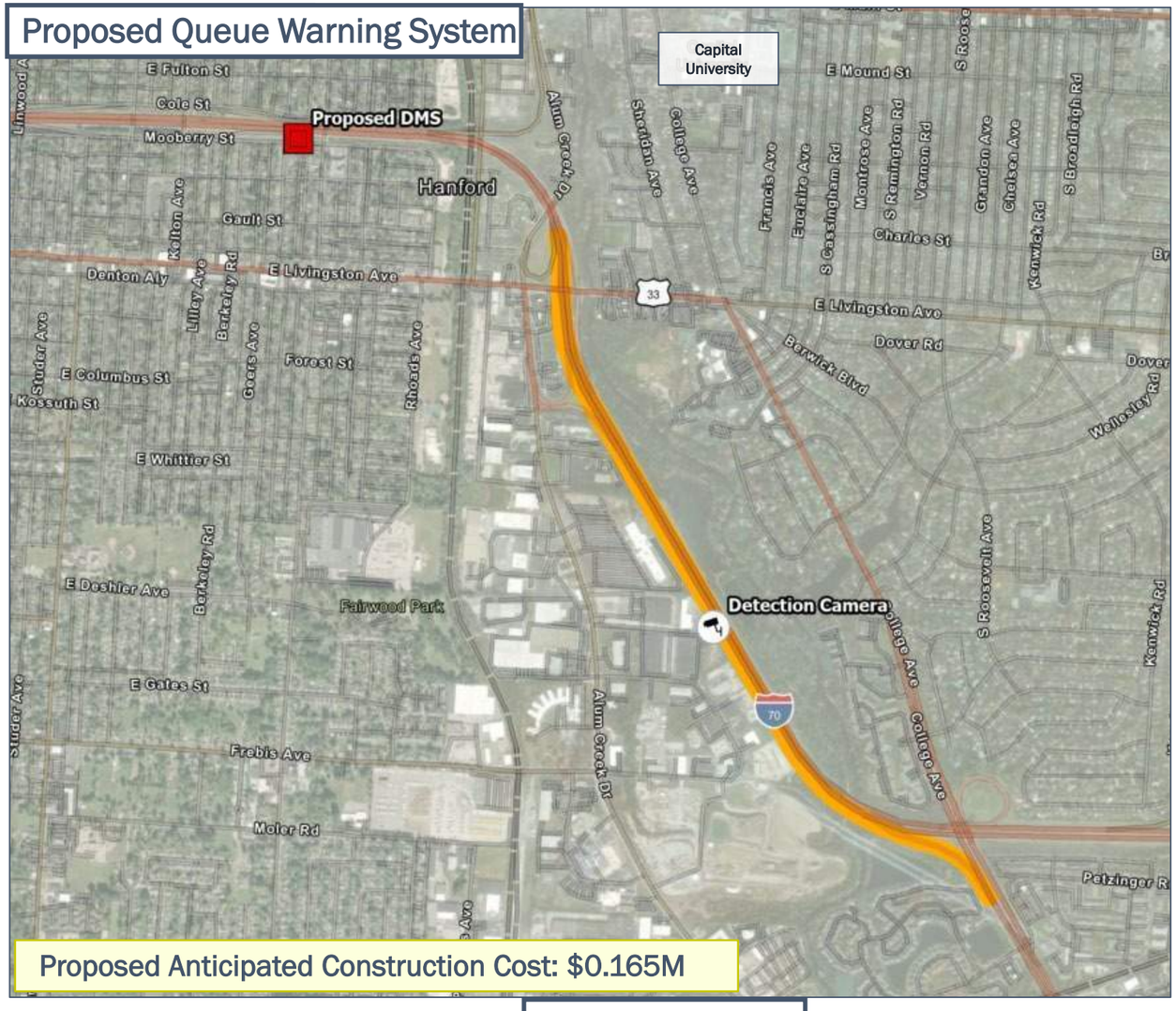
- One (1) proposed detection camera to be structurally mounted on a new pole located along I-70 WB between Watkins Road and Smoke Road. The camera will be looking southwest towards the off-ramp for SR 310.

QWS-D6-I-70_EB AT KELTON AVE

Existing Queue



Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.165M

Site Location

Existing Conditions

- Queuing frequently starts at the traffic signal of US-33 and Petzinger Rd, south of I-70, and extends back to Alum Creek Dr

Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$15,000
QWS Panel (Ground Mounted)	1	$150,000

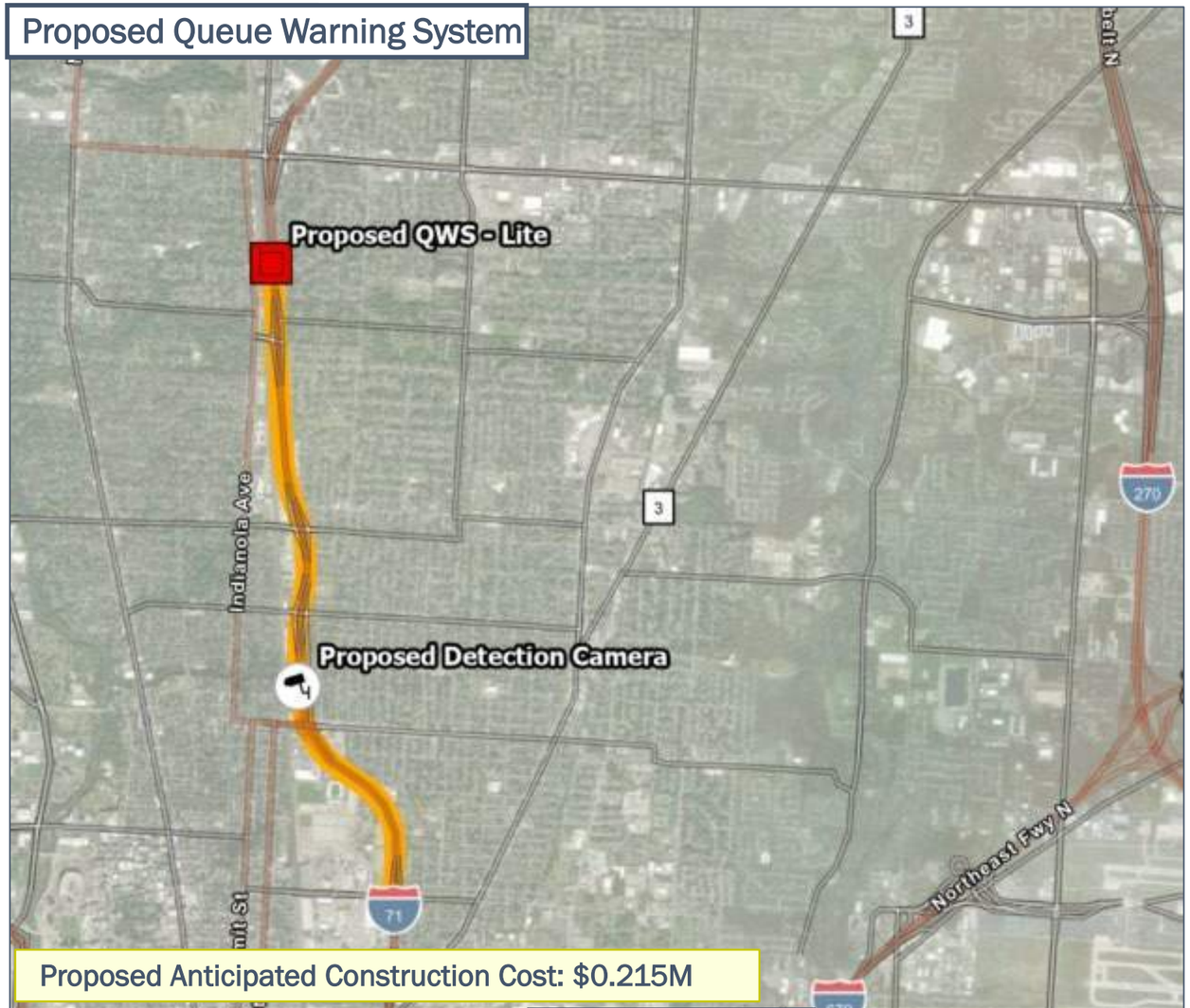
Item Descriptions

- One (1) proposed ground mounted QWS Panel at SLM 16.24 EB at Kelton Ave exit ramp gore.
- One (1) proposed detection camera to be structurally mounted on an existing CCTV pole located along I-70 SB at Franklin Rd. The camera will be looking southeast towards the off-ramp for US-33 SB.

QWS-GRND-D6-I-71_SB AT MORSE RD

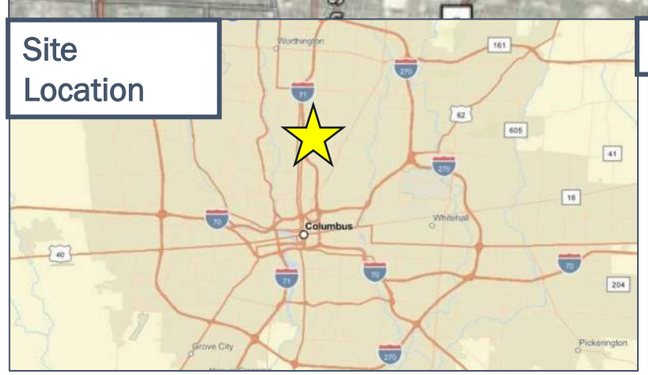
Existing Queue

Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.215M

Site Location



Existing Conditions

- Queueing begins at the sharp curve near the former Crew stadium and extends during peak hours. Ramp meters are installed in this area to help manage the flow of traffic. A SmartLane is under design to improve this section of roadway.

Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	2	$65,000
QWS Panel (Ground Mounted)	1	$150,000

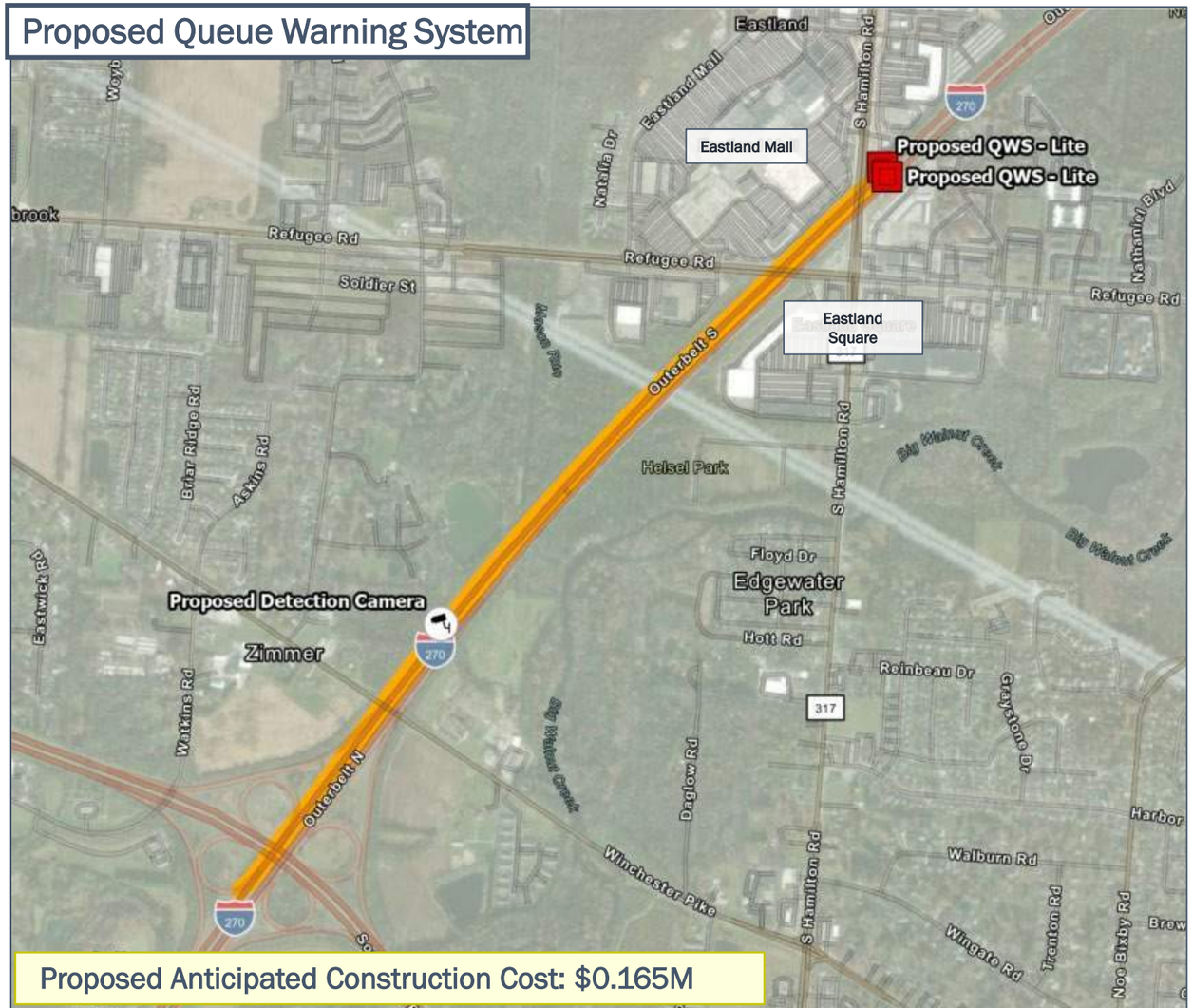
Item Descriptions

- One (1) QWS Panel proposed location at SLM 24.12 SB at Morse Rd.
- Two (2) proposed detection cameras to be structurally mounted to existing poles. One (1) on existing pole looking towards SB IR-71 between Weber Rd. and Hudson St. One (1) on existing pole at the SB Ramp Meter at Hudson St. looking towards SB IR-71.

QWS-GRND-D6-I-270_SB AT SR 317

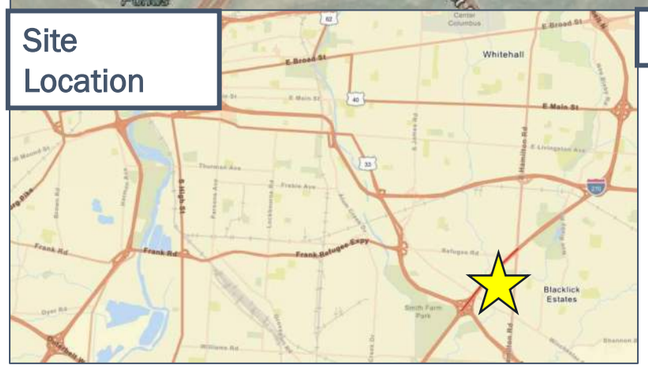
Existing Queue

Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.165M

Site Location



Existing Conditions

- The cloverleaf interchange at US-33 is contributing to congestion at this location, especially during the evening rush hour from 5:00 PM to 7:00 PM.

Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$15,000
QWS Panel (Ground Mounted)	1	$150,000

Item Descriptions

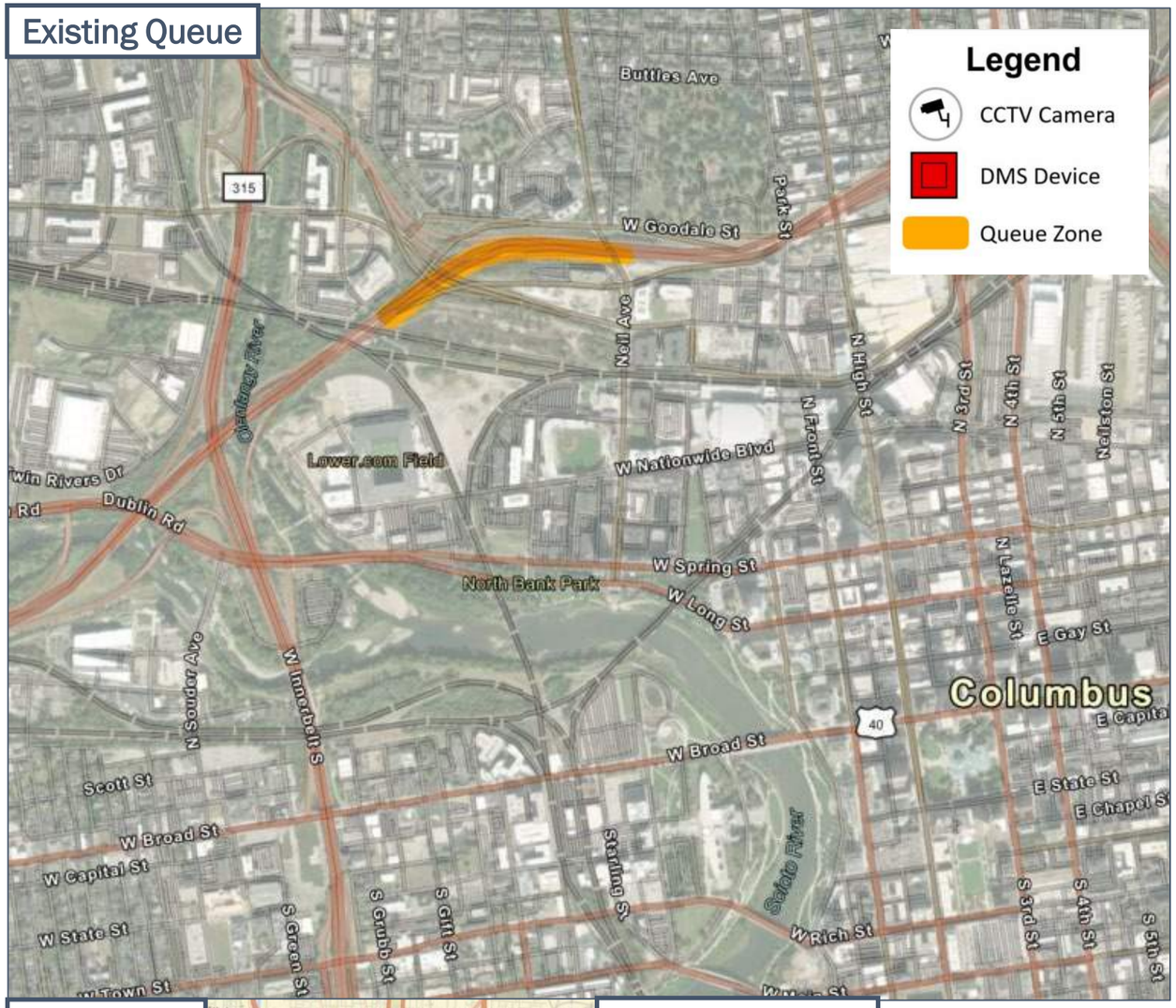
- The queues in this section start at the on-ramp to US-33 SB and back up onto I-270 SB/WB.
- One (1) proposed QWS Panel located at SLM 44.76 SB at SR 317.
- One (1) proposed detection camera installed on existing pole to be located at SLM 46.09 NB at US 33 looking north/northeast towards the weave section and US 33 off-ramp.

QWS-GRND-D6-I-670_EB AT SCIOTO RIVER BRIDGE

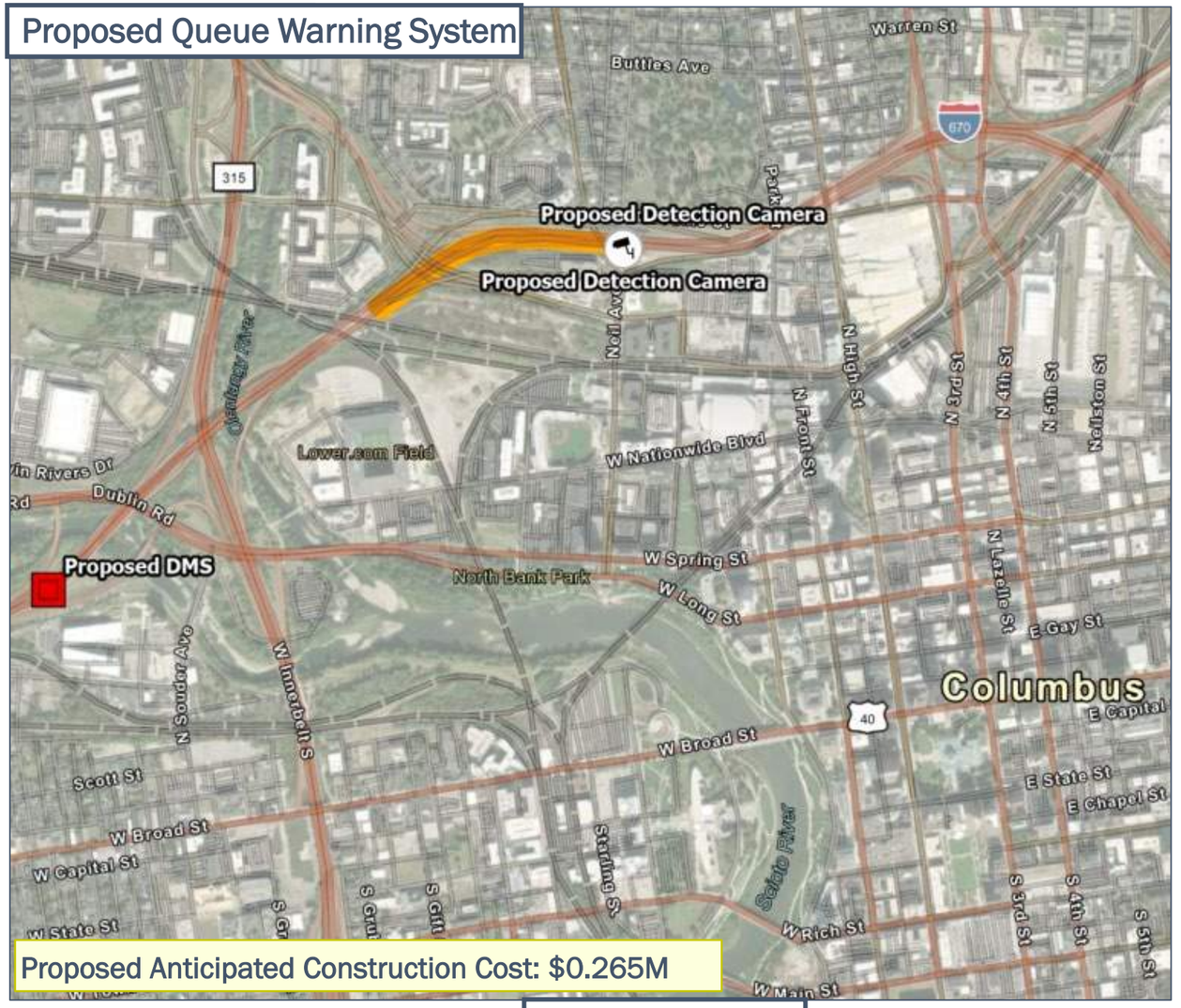
Ohio Department of Transportation

GANNETT FLEMING

Existing Queue

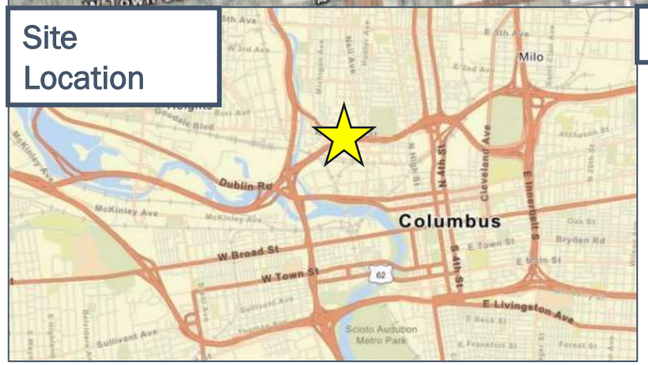


Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.265M

Site Location



Existing Conditions

- Queuing begins at approximately the 3rd and 4th street exit ramps, impacted by the influx of traffic on I-670 Eastbound and OH-315 Southbound. Queuing occurs throughout the week and during large events at the convention center.

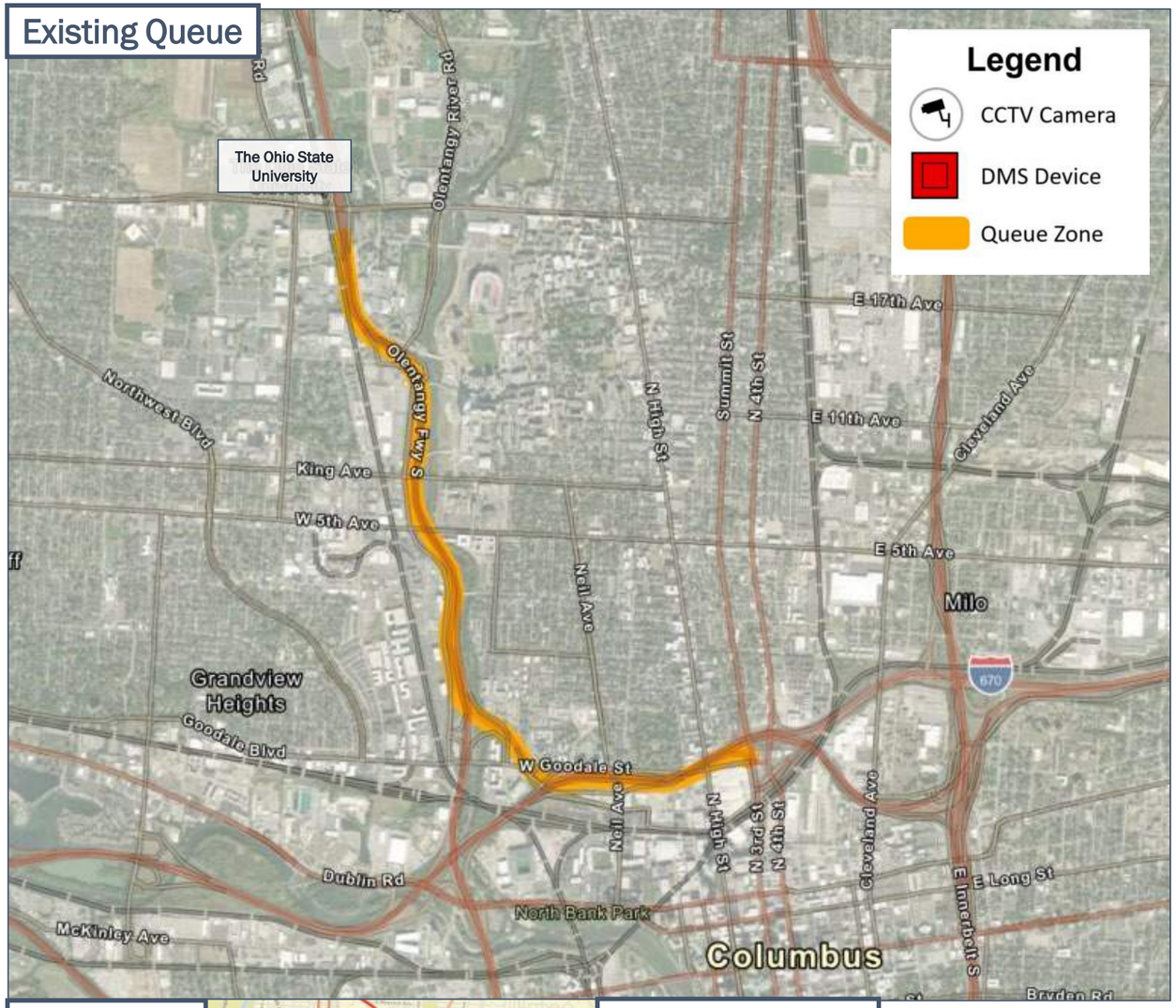
Item	Quantity	Item Total Price
Detection Camera w/pole	2	$115,000
QWS Panel (Ground Mounted)	1	$150,000

Item Descriptions

- Location 3 will work with Location 5 for queue detection. I-670 EB and SR-315 merge together for exits at 3rd St.
- One (1) proposed QWS Panel to be ground mounted at SLM 2.12 EB at Scioto River Bridge behind the guardrail along the right-hand side.
- Two (2) proposed detection cameras are to be placed on new poles at SLM 31.8 EB at Neil Ave.

QWS-GRND-D6-OH-315_SB AT IR-670

Existing Queue



Proposed Queue Warning System

Proposed Anticipated Construction Cost: $0.215M

Site Location

Existing Conditions

- This location has been identified by the TMC as an area of concern, particularly due to queuing on SR-315 Southbound in the mornings.

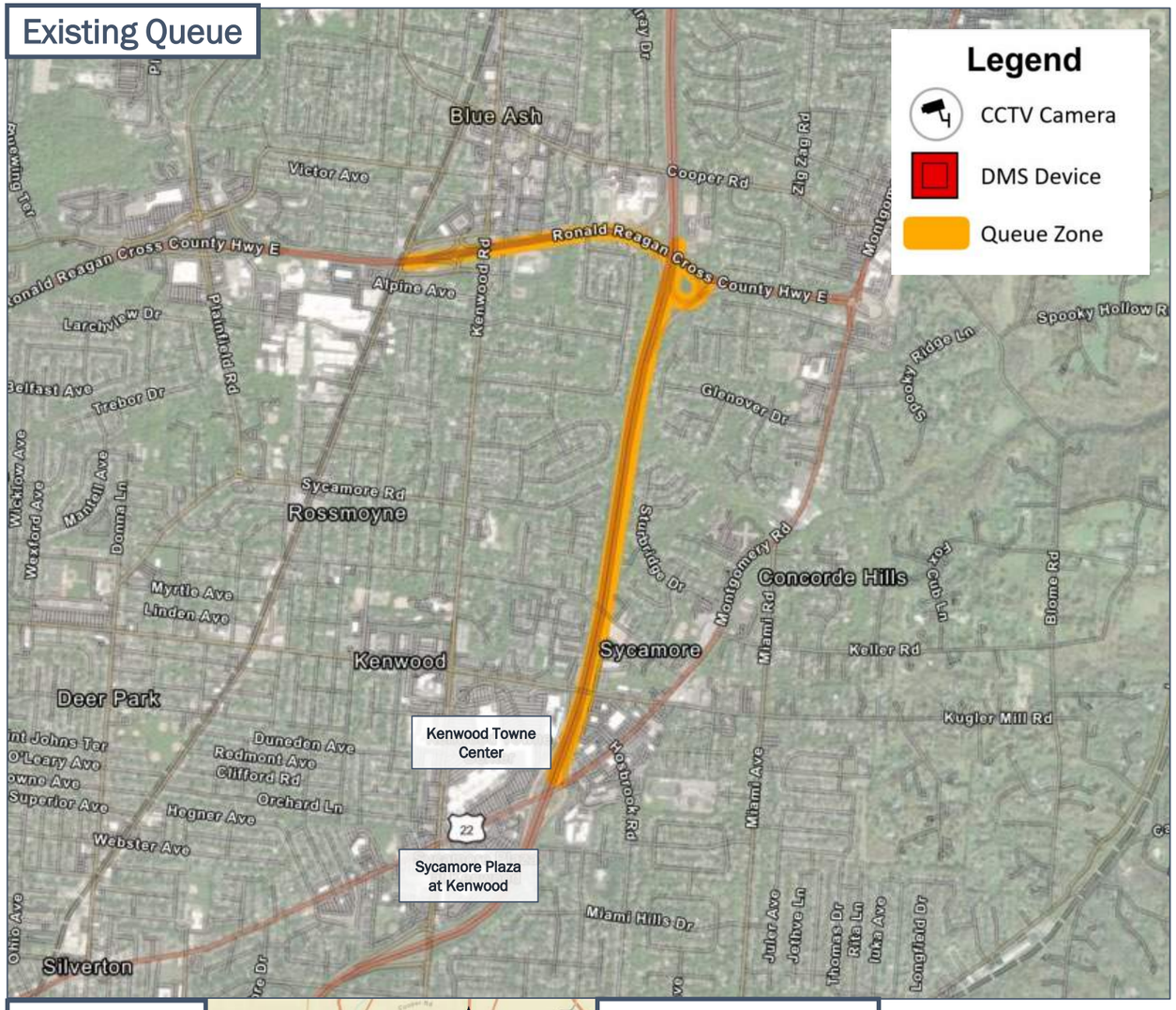
Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	2	$65,000
QWS Panel (Ground Mounted)	1	$150,000

Item Descriptions

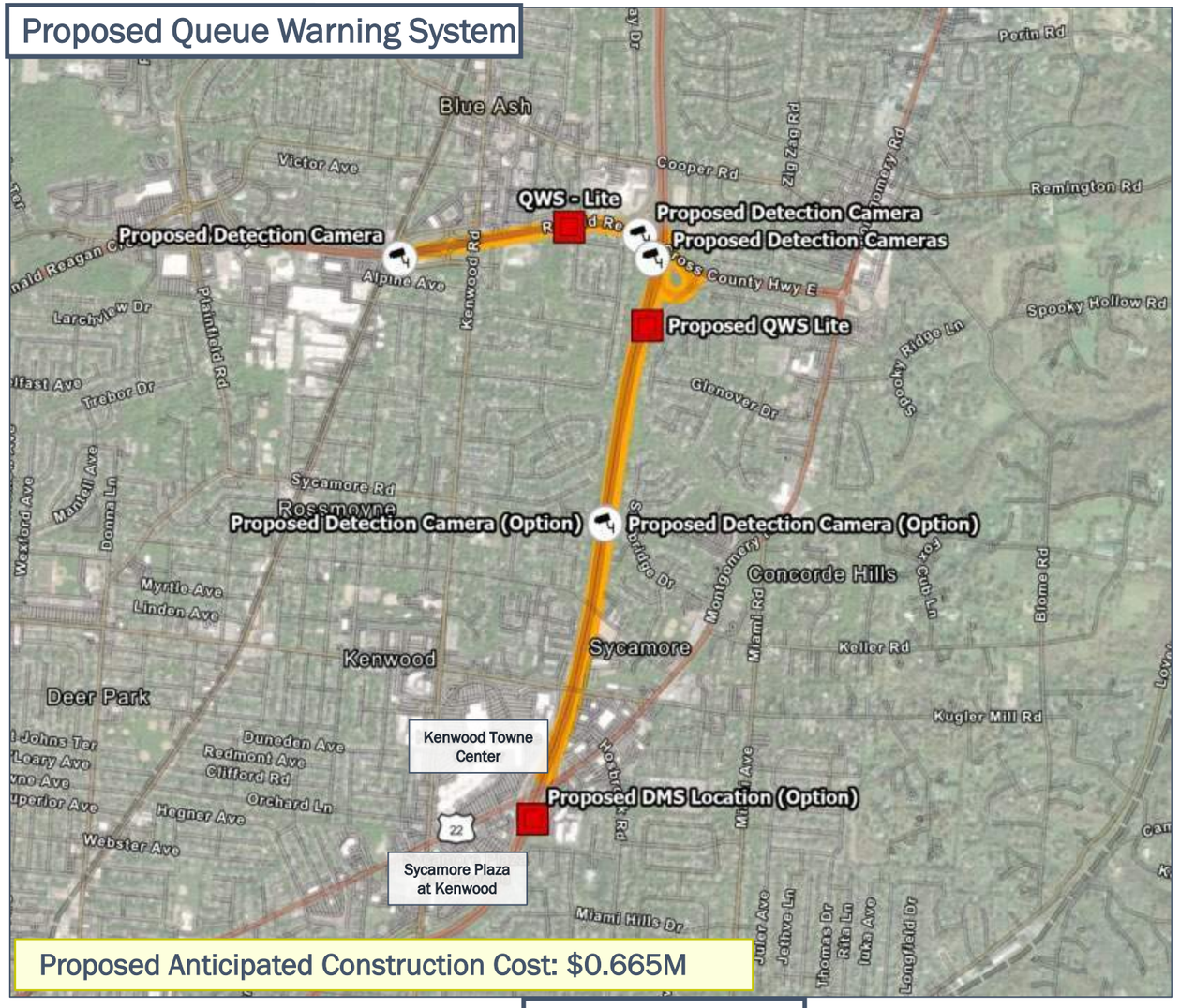
- One (1) proposed QWS Panel to be ground mounted at SLM 2.49 SB at the exit ramp to I-670 EB
- Two (2) proposed detection cameras are to be placed on existing poles at the ramp meter at Lane Ave. entrance ramp and at SR 315 at IR-670 EB Flyover Ramp.

QWS-OVRHD-D8-I-71_SR 126

Existing Queue



Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.665M

Site Location

Existing Conditions

- During the evening peak, queuing becomes a major issue in this location due to merging challenges. Specifically, on I-71 Northbound, there are often queues that back up due to vehicles merging from OH-126 Eastbound.

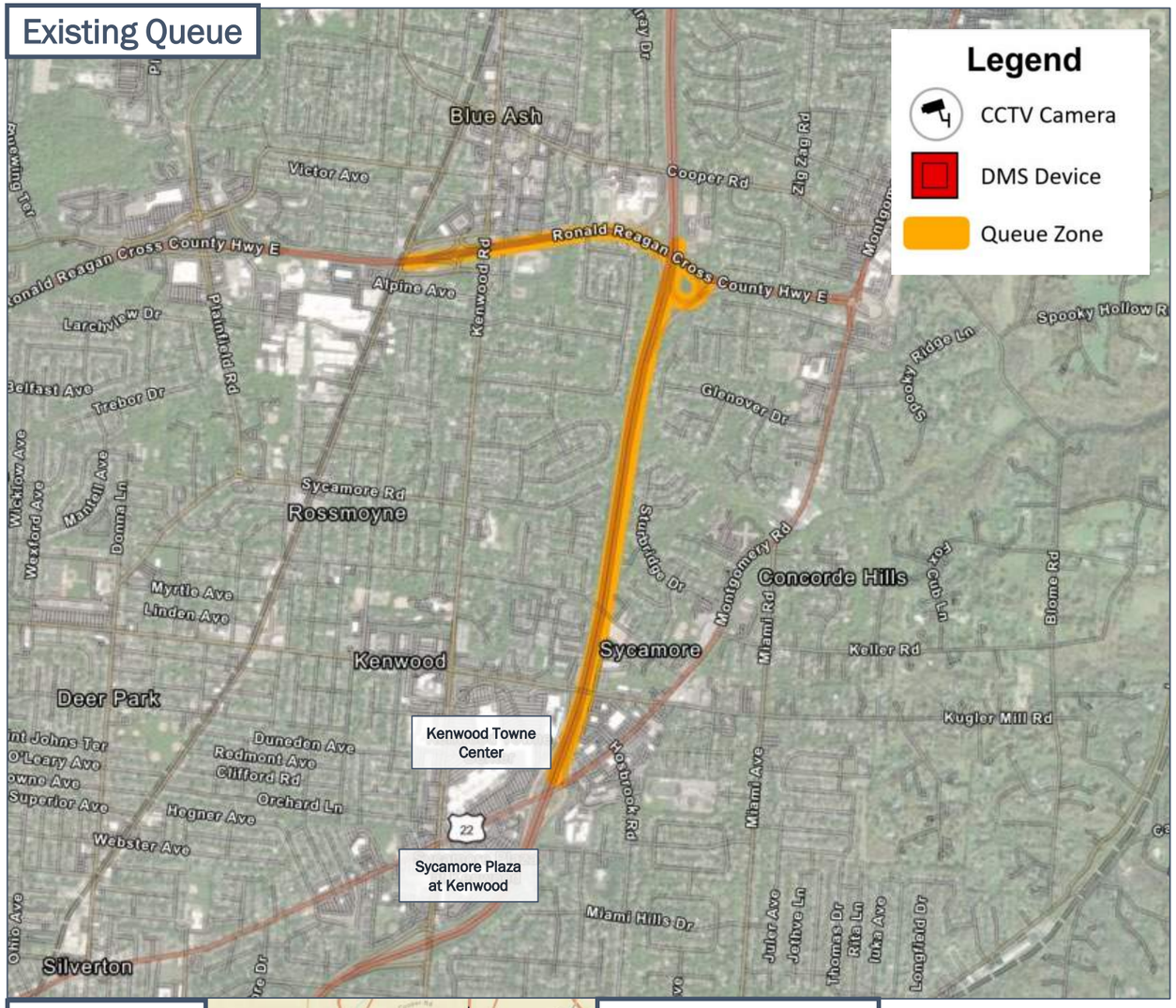
Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	3	$45,000
DMS – (Existing structure)	2	$620,000

Item Descriptions

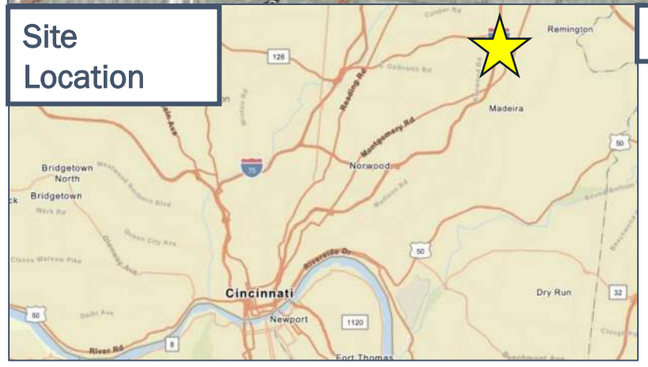
- Two (2) proposed detection cameras to be mounted on the existing pole at SLM 14.12 NB at SR 126 looking north and south.
- One (1) proposed detection cameras to be installed on existing DMS sign at SLM 13.31 NB at Kugler Rd.
- Two (2) DMS (cantilever) to be located on existing structures at SLM 13.31 NB and SLM 15.10 SB.

QWS-OVRHD-D8-OH-126_EB AT I-71

Existing Queue



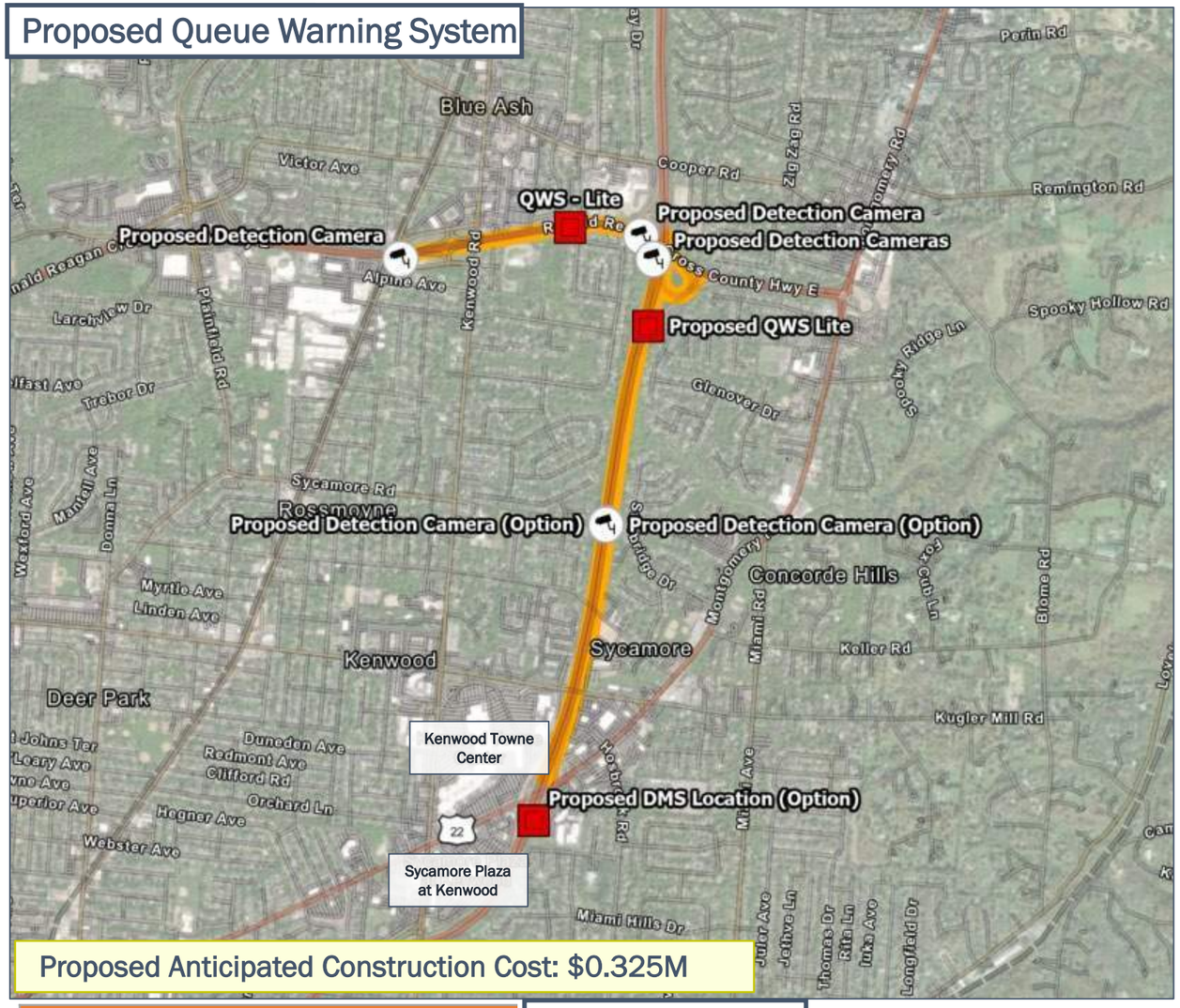
Site Location



Existing Conditions

- During the evening peak, queuing becomes a major issue in this location due to merging challenges. Specifically, on I-71 Northbound, there are often queues that back up due to vehicles merging from OH-126 Eastbound.

Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.325M

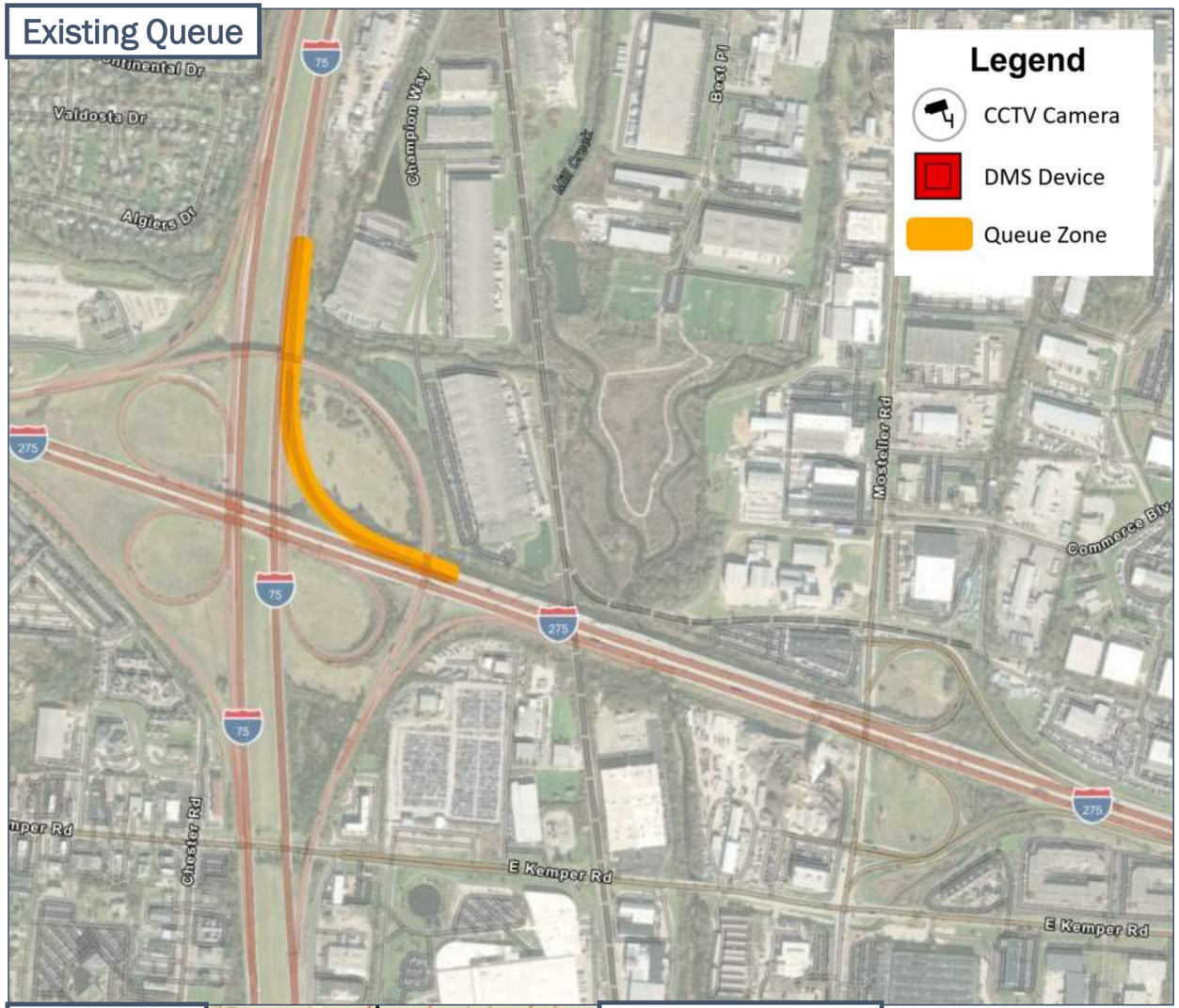
Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$15,000
DMS (Existing overhead structure)	1	$310,000

Item Descriptions

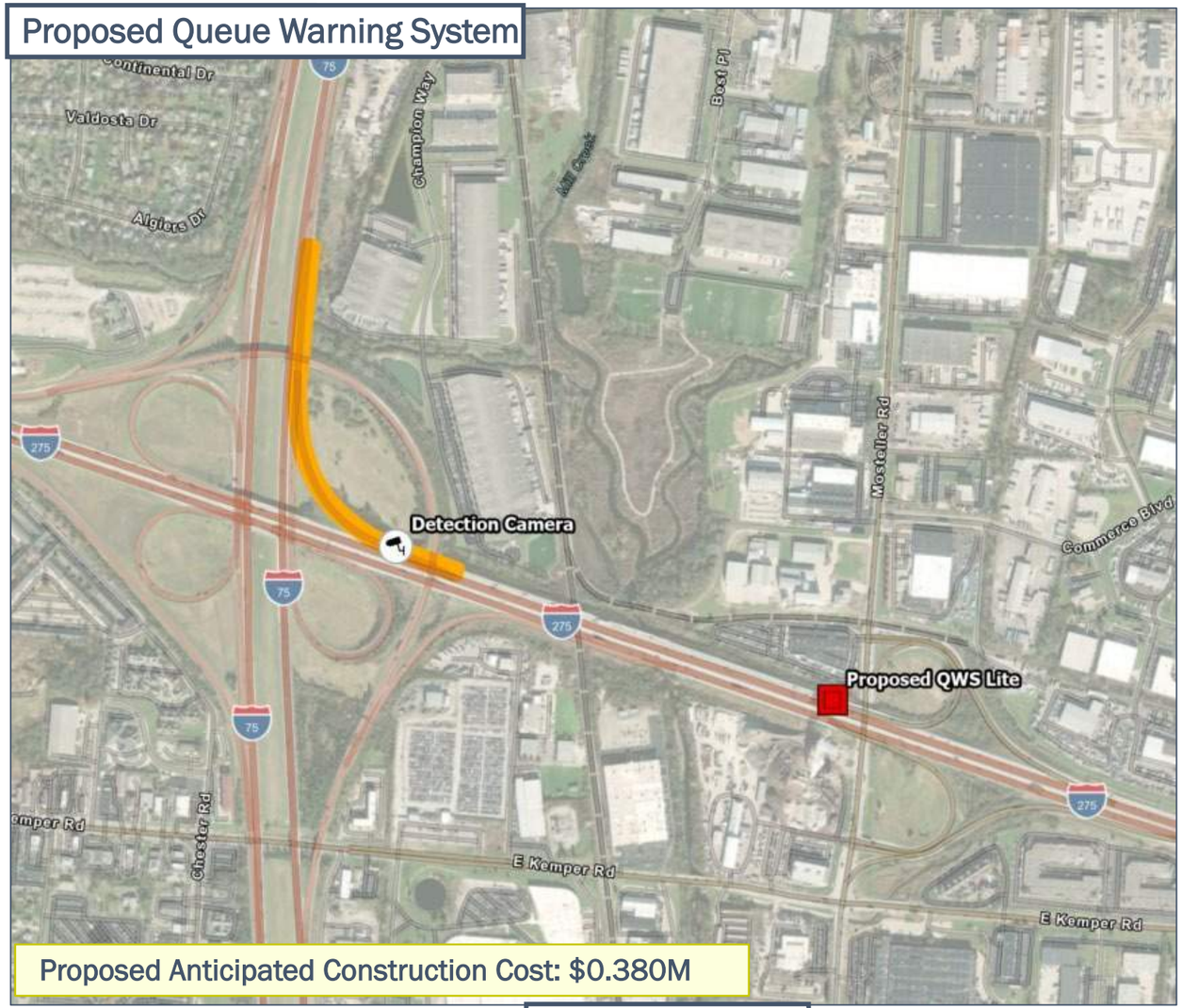
- One (1) proposed detection camera installed on existing traffic signal at I-71 off-ramp.
- One (1) proposed DMS sign replacing existing overhead DMS sign and structure at SLM 18.49 EB.

QWS-OVRHD-D8-I-275_WB AT I-75 NB

Existing Queue



Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.380M

Site Location

Existing Conditions

- I-275 Westbound and I-75 Southbound frequently experience extended queues in the evening, primarily due to slow weave points at the system interchange.

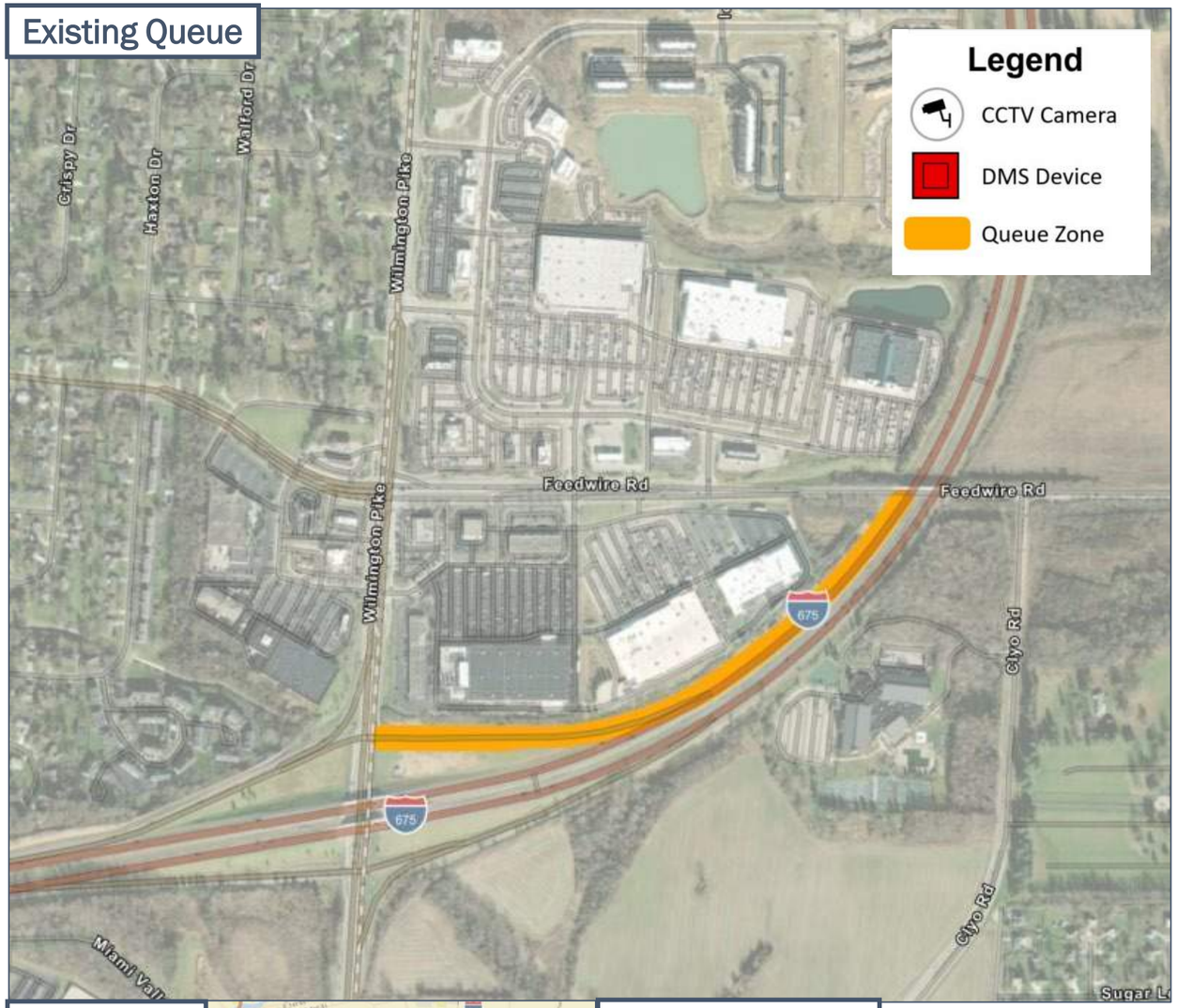
Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$70,000
DMS (Existing structure)	1	$310,000

Item Descriptions

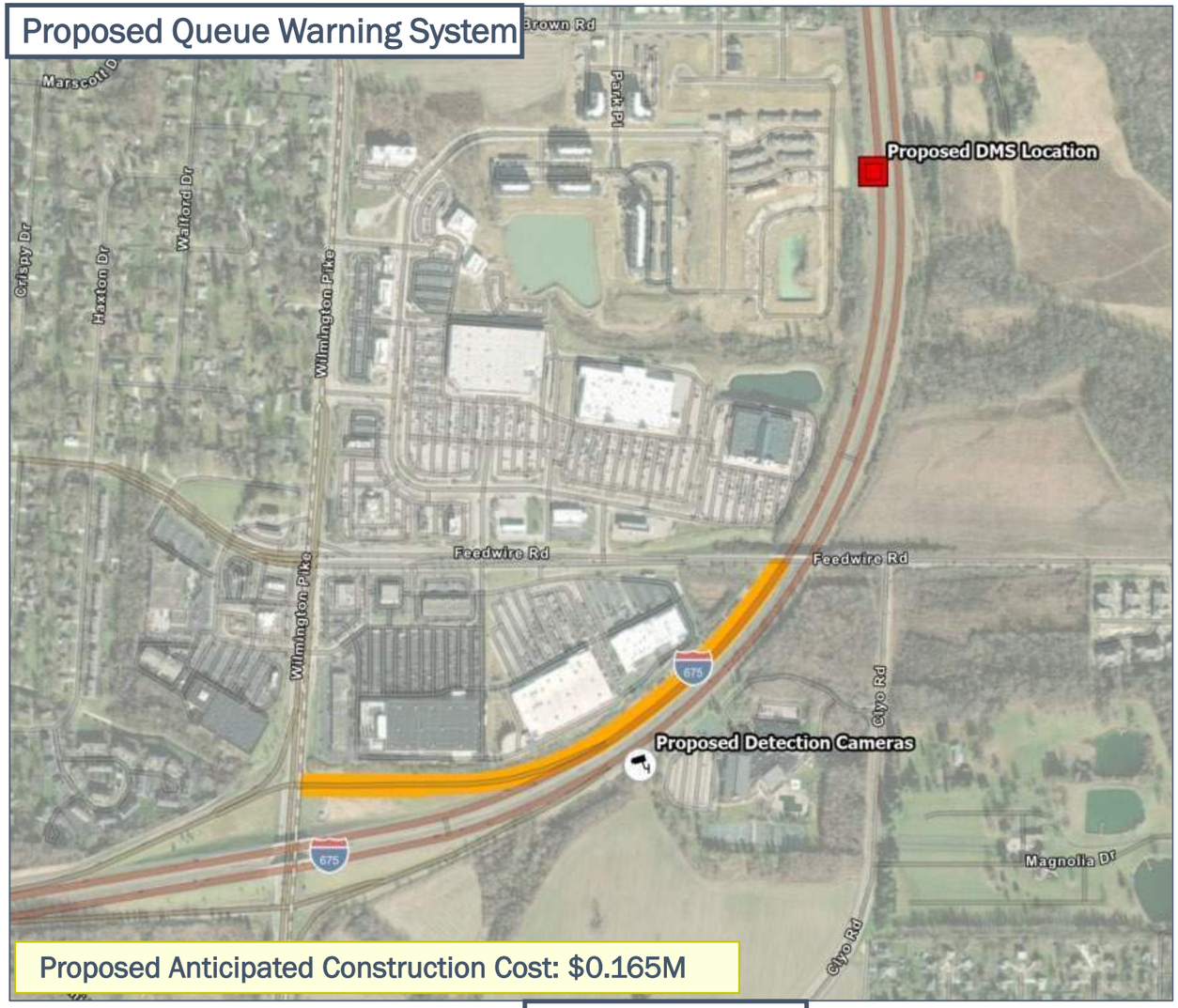
- One (1) proposed detection camera to be structurally mounted on an existing truss structure on I-275 WB at the I-71 NB on-ramp.
- One (1) proposed DMS sign to replace existing overhead DMS sign at SLM 26.96 WB.

QWS-GRND-D8-I-675_SB BEFORE WILMINGTON PIKE

Existing Queue



Proposed Queue Warning System



Proposed Anticipated Construction Cost: $0.165M

Site Location

Existing Conditions

- Queuing on I-675 Southbound during PM peak hours is a significant concern, especially as people turn left onto Wilmington Pike. Additionally, in the evenings, there are queues backing up past the Feedwire Rd exit for I-675 Southbound.

Item	Quantity	Item Total Price
Detection Camera (structurally mounted)	1	$15,000
QWS Panel (Ground Mounted)	1	$150,000

Item Descriptions

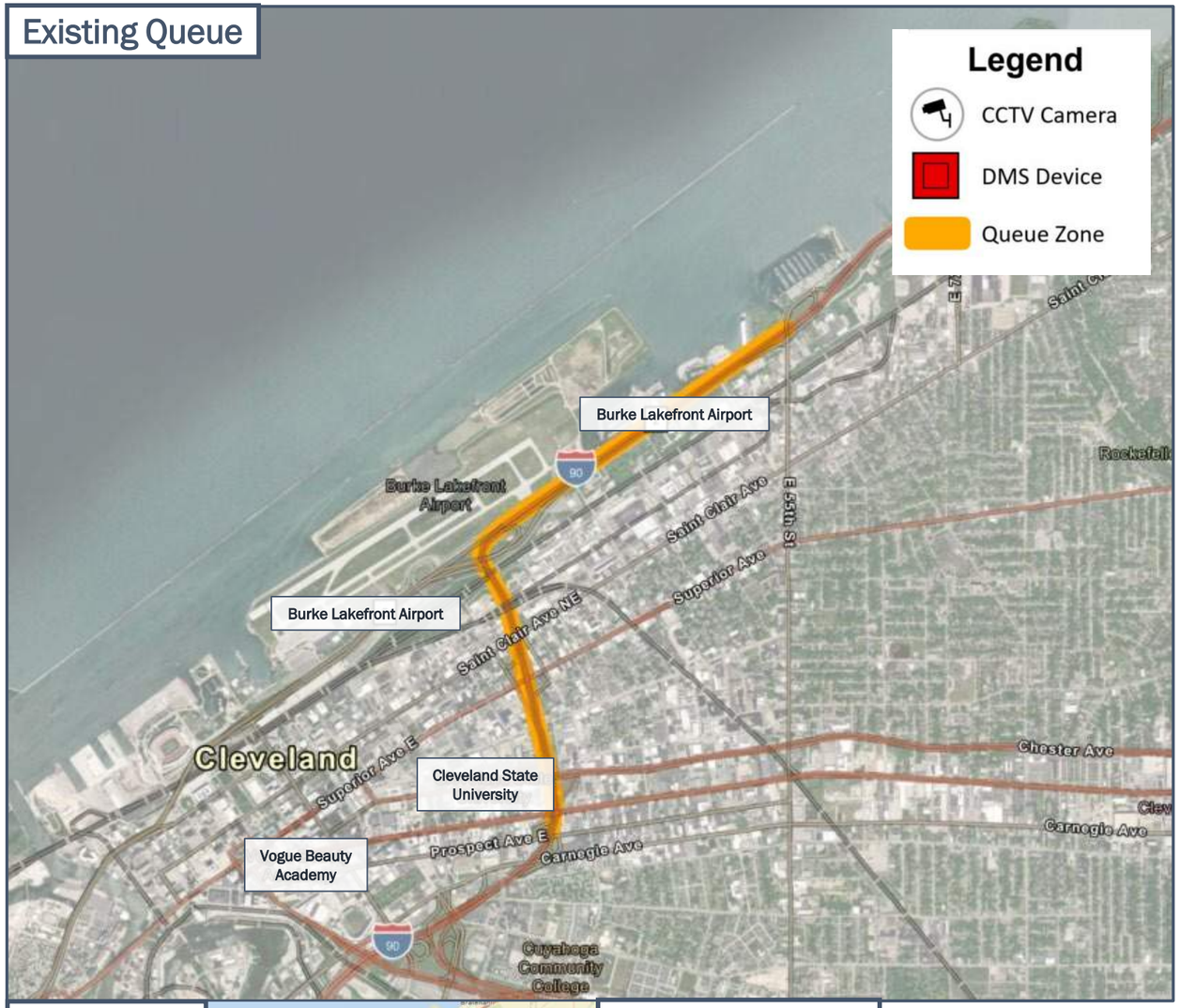
- One (1) QWS Panel to be place at SLM 1.06 SB before Feedwire Rd., removing the existing ground mounted Centerville Corp sign.
- One (1) proposed detection camera to be placed on the existing CCTV camera pole on I-675 NB at Wilmington Pike.

QWS-OVRHD-D12-I-90_WB AT DOWNTOWN

Ohio Department of Transportation

GANNETT FLEMING

Existing Queue



Proposed Queue Warning System

Proposed Anticipated Construction Cost: $1.17M

Site Location

Existing Conditions

- The Innerbelt curve poses a significant safety concern at this location and queues are a common occurrence during peak rush hours.

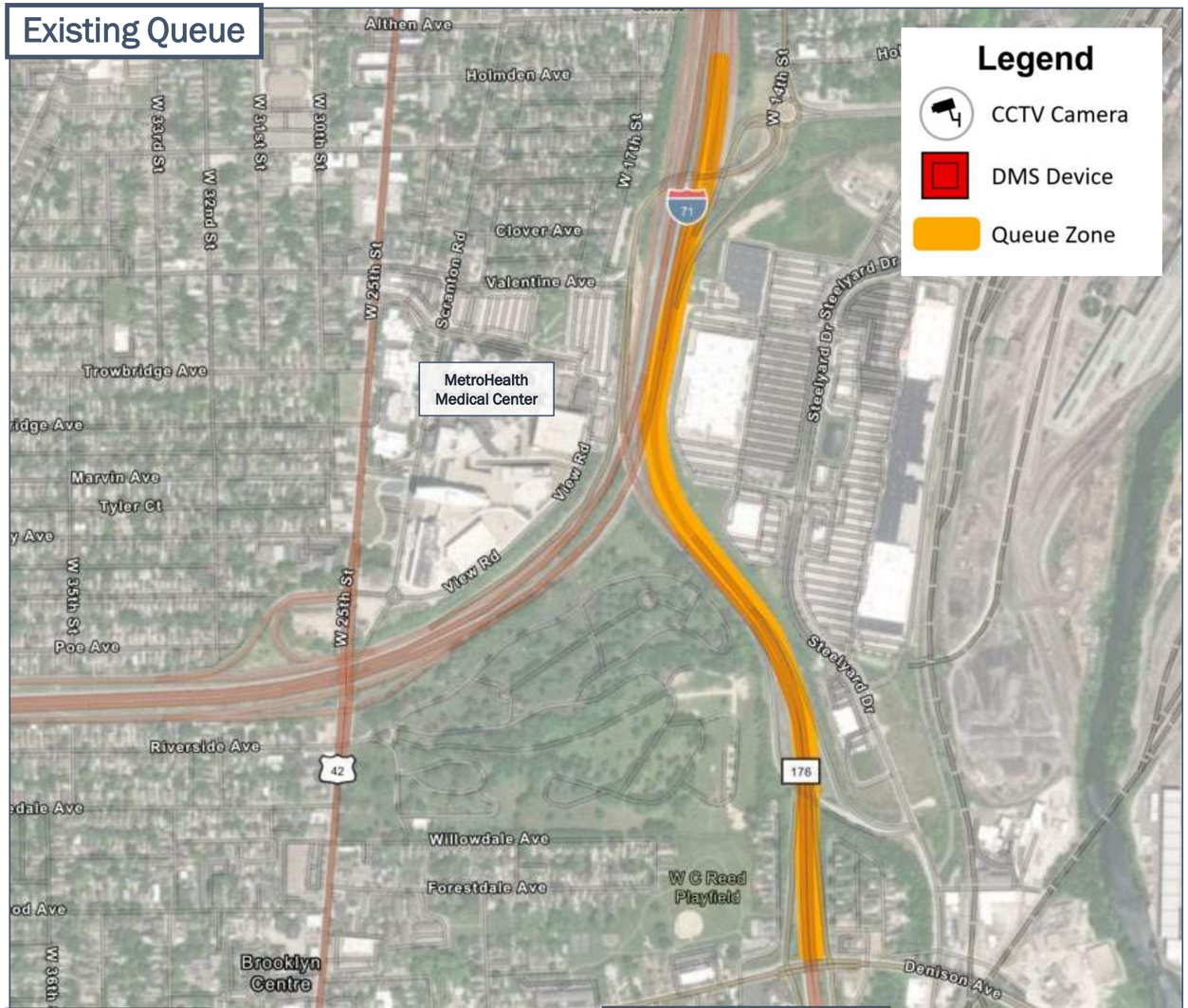
Item	Quantity	Item Total Price
Detection Camera	4	$60,000
DMS (Truss)	3	$880,000
QWS-Lite (Cantilever)	1	$50,000
Overhead Truss	1	$180,000

Item Descriptions

- Three (3) replacements of existing DMS to full color DMS signs and truss structures.
- One (1) QWS Lite to be placed on vertical support of “E 55th St ¼ Mile” cantilever sign.
- One (1) overhead sign support box truss to be installed at SLM 18.47 WB.
- Four (4) detection cameras are to be placed on existing structures.

QWS-GRND-D12-OH-176_NB AT STEELYARD

Existing Queue



Proposed Queue Warning System

Proposed Anticipated Construction Cost: $0.355M

Site Location

Existing Conditions

- During peak hours and special events, extended queues are present heading downtown, particularly on I-71 Northbound past Denison. There is a noted blind spot underneath the double-decker bridge where OH-176 and I-71 intersect that makes it challenging for drivers to know of any queues forming.

Item	Quantity	Item Total Price
Detection Camera (existing pole)	1	$15,000
DMS (replace existing)	1	$310,000
QWS - Lite	1	$30,000

Item Descriptions

- One (1) proposed QWS - Lite sign at SLM 12.94 NB at Steelyard Dr. ramp, in the gore area.
- One (1) DMS sign to replace existing DMS sign and structure at SLM 12.15 NB at Crestline Ave.
- One (1) proposed detection camera on existing pole at SLM 13.19 NB at IR-71 Ramp. .


Ohio
Department of
Transportation