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Connecticut Department of Transportation Smart Work Zones Guide

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Executive Summary

Smart Work Zones (SWZ) are applications of temporary Intelligent Transportation Systems (ITS) technology in work zones, utilized to help increase safety and mobility.

The SWZ Guide presents the basic guidelines for the consistent and uniform usage of SWZ in the State of Connecticut. The guide has been developed as a collaborative effort between the Bureau of Highway Operations (Highway Operations) and the Bureau of Engineering and Construction (Division of Traffic Engineering and Division of Construction Operations). Project designers remain responsible for customizing and adapting this guidance to meet specific project needs, conditions, and context. All Smart Work Zones in the State of Connecticut shall conform to standards and guidance provided in Part 6: Temporary Traffic Control of the Manual on Uniform Traffic Control Devices (MUTCD), as well as any standards and practices set by the Connecticut Department of Transportation (CTDOT). Through appropriate use of SWZ, CTDOT aims to improve safety for roadway users and work zone personnel, increase mobility within work zones, and reduce work zone traffic incidents.

This guide presents SWZ concepts, components, goals, and objectives to be pursued by CTDOT, as well as an overview of various current and future SWZ applications to be used by CTDOT. These applications currently include, but are not limited to, construction vehicle warning, excessive speed warning, intrusion detection, over dimension warning, queue warning, travel time estimation, and performance measurement.

This guide also outlines the roles and responsibilities of different entities involved in the process of SWZ implementation. Such entities include CTDOT's SWZ Determination Committee, Highway Operations, Division of Construction Operations, Division of Traffic Engineering, District Offices, Enterprise GIS Unit, Project Designer, and the Contractor. Guidelines for SWZ project-level determination and implementation are also explained in this guide.

The presented guidelines are designed to facilitate successful application of SWZ and bring about a variety of benefits including, but not limited to, increased safety to work zone personnel, emergency responders and general traffic, reduced delay, queue length, congestion and probability of secondary crashes, improved work zone travel time, travel speed and traveller information, and decreased incident clearance time.

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1 Purpose of Guide

The purpose of the smart work zones (SWZ) guide is to present basic guidelines for the **correct, consistent, and uniform usage** of SWZ in the State of Connecticut.

Smart Work Zones in the State of Connecticut shall conform to the standards and guidelines contained in Part 6: Temporary Traffic Control of the Manual on Uniform Traffic Control Devices (MUTCD)[1] (see also References for this manual), as well as those standards and practices put in place by the Connecticut Department of Transportation (CTDOT). Project designers remain responsible for customizing and adapting this guidance to specific project needs, conditions, and context.

If there are any questions on this guide, please contact CTDOT SWZ Determination Committee at DOT.SWZ.Committee@ct.gov for further clarification.

Acronyms used in this guide are defined in the table below:

ACRONYM	DEFINITION
ADT	Average Daily Traffic
BOC	Bridgeport Operations Center
CCTV	Closed-Circuit Television
CMS	Changeable Message Sign
CTDOT	Connecticut Department of Transportation
FHWA	Federal Highway Administration
ITS	Intelligent Transportation Systems
MPT	Maintenance and Protection of Traffic
MUTCD	Manual on Uniform Traffic Control Devices
NOC	Newington Operations Center
PCMS	Portable Changeable Message Sign
RWIS	Road Weather Information System
SCMQ	Smart Work Zone Changeable Message Sign/Queue Sensor Trailer
SEAFORM	Systems Engineering Analysis Form
SQT	Smart Work Zone Queue Trailer/Sensor
SVQS	Smart Work Zone Mobile Video Camera/Queue Sensor Trailer
SWZ	Smart Work Zones
TMP	Traffic Management Plan
USDOT	United States Department of Transportation

[1] Federal Highways Administration, U.S. Department of Transportation. Manual on Uniform Traffic Control Devices. 2009 Edition with Revisions 1, 2, and 3, July 2022.

2 Introduction to SWZ Technologies

2.1 SWZ Overview

Smart Work Zones are applications of temporary Intelligent Transportation Systems (ITS) technology in work zones, utilized to help increase safety and mobility. SWZ components are also sometimes referred to by other agencies as “Work Zone ITS” or “Portable Work Zone Technology”. SWZ typically collect real-time information at work zones, run a decision logic (standalone in the field or coordinated at a central location), and disseminate actionable information such as delay, travel time, queue warning, intrusion alert, etc. to end-users. Additionally, SWZ facilitate data collection for performance measurement and provide insights for operational enhancements and support adjustments.

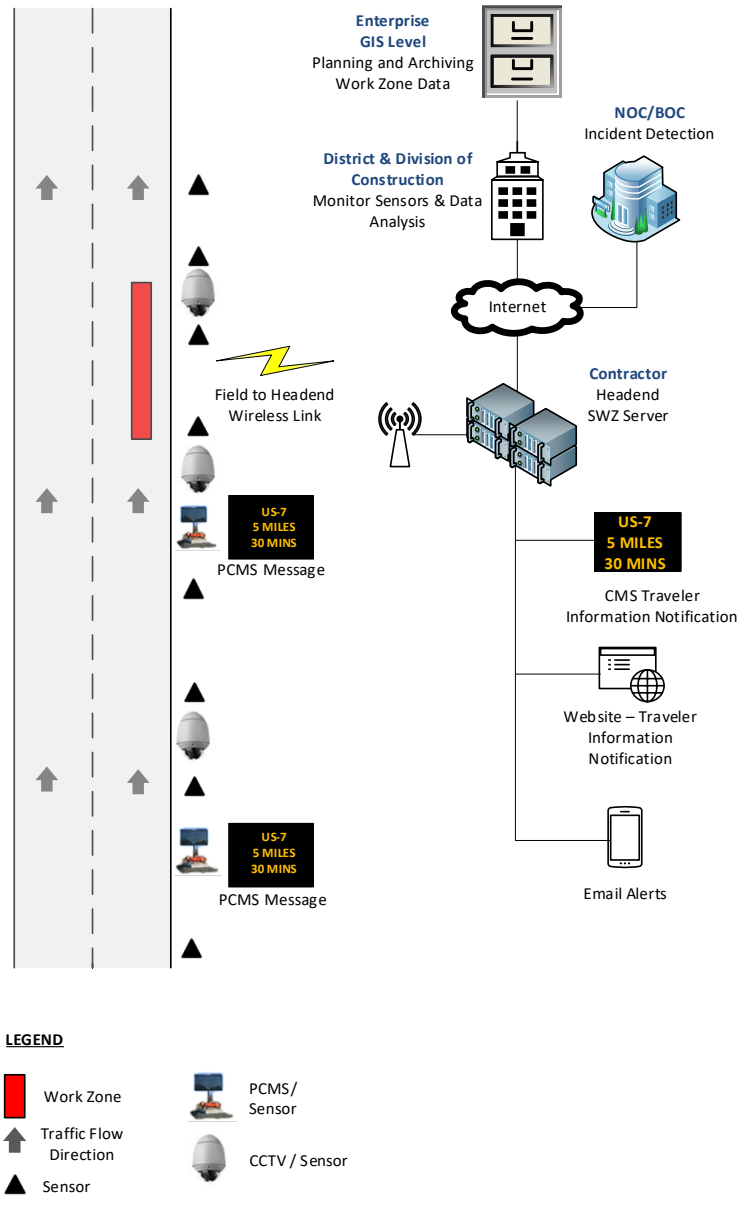


Figure 1: Example Concept of Operations Block Diagram

2.2 SWZ Components

A typical SWZ consists of field sensors or ITS equipment, communications systems, software application and electronic information distribution components.

Table 1: Description of SWZ Components

COMPONENTS	DESCRIPTION
Sensors and ITS Field Components	Sensors can be deployed along work zones to gather real time data such as traffic volume, speed, occupancy, etc. When additional monitoring of work zone conditions provides valuable information, ITS equipment such as Closed-Circuit Television (CCTV), Road Weather Information System (RWIS), etc. can be deployed. These field devices are typically portable and mounted on a trailer. There exists considerable potential for the use of real-time traffic data collected and disseminated by providers such as INRIX, HERE (formerly NAVTEQ Maps), WAZE, TomTom, etc. in place of using physical sensors.
Communications Systems	Communications Systems are used to transmit data collected at work zones to a central location for processing and dissemination, and/or communication between SWZ devices in the field. Due to the portable nature of SWZ devices, wireless cellular communications is used in SWZ deployments.
Software Application	Vendor-supplied or custom developed software applications process and analyze data collected at work zones by applying decision logic based on parameters set. A typical software application allows for: • configuration of constraints for various parameters (ex. traffic speed limits) • actions to be taken when the constraints are met (ex. display messages via Portable Changeable Message Signs (PCMS)[2] in work zones) • provision of status and location information of field devices in a map view • dissemination of actionable information to end-users via electronic information exchange means (websites, email text alerts, PCMS, etc.) and visible or audible alarms • archiving raw and processed information and retrieval of archived data
Information Distribution Equipment	The output of decision logic applied in the software application is disseminated to end-users using various information distribution methods such as PCMS, websites, email/text alerts, audible alarms, or other means. Information such as travel time through work zone, delay, queue warning and speed reduction in work zone, incidents, intrusion alert, and construction vehicle entering and exiting work zone, are often communicated to end-users as well as collected for performance monitoring and analysis.

2.3 SWZ Applications

Using the SWZ components described in Section 2.2, various work zone ITS applications can be developed to address specific work zone needs. The following table provides a short description of some of the applications which are of interest and applicable to CTDOT.

[2] CTDOT typically uses the terms Changeable Message Sign (CMS), and Portable Changeable Message Sign (PCMS). CTDOT also occasionally uses the terms Variable Message Sign (VMS), Portable Variable Message Sign (PVMS) and Dynamic Message Sign (DMS), as these are also common terms in the industry.

Table 2: Description of SWZ Applications

APPLICATION	DESCRIPTION
Construction Vehicle Warning	Construction Vehicle Warning SWZ application can be used to warn drivers of slow-moving construction or emergency vehicles, entering, or exiting the roadway. A typical system includes field sensors that activate PCMS to display notification to motorists.
Dynamic Lane Merge	The Dynamic Lane Merge SWZ application provides information to drivers to enable merging earlier or later based on current conditions in the work zone. A typical system includes field sensors to collect traffic data, PCMS to display instructions to merge traffic at specific points in a work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Excessive Speed Warning	The Excessive Speed Warning SWZ application can be used to provide warning to drivers of vehicles travelling above the speed limit in or prior to approaching a work zone. A typical system includes a PCMS, and sensor trailer that measures and displays vehicle speeds and alerts drivers to reduce potentially excessive speed.
Hazardous Conditions Warning	The Hazardous Conditions Warning SWZ application provides the motorists with real-time potentially hazardous conditions that might arise temporarily during construction such as falling debris or temporary flooding during roadway construction. A typical system includes sensors in field to collect traffic data, siren to alert motorists and construction personnel, PCMS to display dangerous/unexpected roadway conditions through work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Incident Management	The Incident Management SWZ application serves to enhance operational visibility and facilitate efficient management, expeditious response, and prompt clearance of traffic incidents. A typical system includes field sensors to collect traffic data, CCTV cameras to provide live feeds, PCMS to communicate incident related delays to end-users, communications systems, and software applications to process, analyze, disseminate, and archive data.
Intrusion Detection	The Intrusion Detection SWZ application can be used to alert work zone personnel when a vehicle enters a work zone. A typical system includes field sensors connected to speakers and/or lights to immediately notify work zone personnel of an intrusion.
Over Dimension Warning	The Over Dimension Warning SWZ application can be used to provide warnings to drivers of over height vehicles prior to entering areas with low clearance due to construction activity. A typical system includes field sensors along with flashing lights or signs and optional siren alerting drivers about over-height restrictions, and possibly PCMS to display notification of an alternate route.
Performance Measurement	The Performance Measurement SWZ application is similar to travel time estimation, except that the data collected is mainly used for the purpose of performance measurement and enables modifications to operations and support. This system is not designed to provide notifications to the general public.
Portable Signal	A Portable Signal SWZ application controls traffic in an orderly and safe manner using standard traffic signal thereby reducing delay, increasing work zone safety, controlling costs, etc. A typical system includes battery/solar powered traffic signal trailer set with signal heads, microprocessor-based controller, radio frequency transceiver module, solar panels, hydraulic lift, microwave sensor to detect vehicles,

APPLICATION	DESCRIPTION
	PCMS to display work zone conditions and portable signal ahead, and software applications to process, analyze, disseminate, and archive data.
Queue Warning	Queue Warning SWZ application provides warning information on slow or stopped traffic ahead in a work zone. A typical system includes field sensors to collect traffic data, PCMS to display delay/stopped traffic in work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Speed Advisory	The Speed Advisory SWZ application alerts the approaching traffic to slower speeds in the work zone to improve safety by encouraging drivers to slow down approaching the work zone. A Speed Advisory SWZ application is a variation of Travel Time Estimation and Stopped Traffic Warning applications. A typical system includes field sensors to collect traffic data, PCMS to display information on lower speeds in work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Stopped Traffic Warning	The Stopped Traffic Warning SWZ application serves to notify motorists of traffic congestion or stopped traffic in advance of approaching a work zone. This feature enables motorists to proactively seek alternate routes when necessary. This application could be used for projects which result in frequent occurrence of stopped traffic. This application is a variation of Queue Warning and Travel Time Estimation applications. A typical system includes field sensors to collect traffic data, PCMS to display delay/stopped traffic in work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Temporary Ramp Metering	The Temporary Ramp Metering SWZ application regulates ramp traffic entering the mainline and provides safety measures such as driver compliance, merging behavior, speed differentials, and lane changing. A typical system includes sensors in field to collect ramp and mainline traffic data, PCMS to display traffic conditions in an active work zone and display information for traffic entering mainline from the ramp, battery/solar powered portable traffic signal, ramp metering controller, communications systems, and software applications to process, analyze, disseminate, and archive data.
Travel Time Estimation	The Travel Time Estimation SWZ application provides real-time travel time information through a work zone. A typical system includes sensors in field to collect traffic data, PCMS to display travel time through work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.
Variable Speed Limit	The Variable Speed Limit SWZ application allows for reduced speed limit set through manual intervention based on current delay and traffic speeds experienced in an active work zone. Future implementation of Variable Speed Limit SWZ applications can allows for speed limits to be changed dynamically in work zones based on current delay and traffic speeds experienced in the work zone. A typical system includes field sensors to collect traffic data, a PCMS to display changing speed limits set in an active work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.

2.4 Benefits of SWZ

Work zones typically cause reduced roadway capacity, which can lead to congestion, traveler delay, and irregular traffic flow. Additionally, changing lane configurations, traffic incidents, and other factors such as slow or stopped traffic in work zones, can increase motorist confusion and

lead to safety hazards. SWZ applications provide actionable information to end users to reduce risk, delay, and congestion, and improve safety. The Federal Highway Administration (FHWA)[3] SWZ implementation guide cites various studies demonstrating benefits of using SWZ. The various applications described in Section 2.3 can be used to achieve the following benefits in a work zone:

- Increased safety to work zone personnel, emergency responders and general traffic.
- Reduced delay.
- Reduced queue length.
- Reduced congestion.
- Reduced secondary crashes.
- Improved work zone travel time.
- Improved travel speed.
- Improved traveler information.
- Decreased incident clearance time.

3 Enterprise-Level Involvement

3.1 SWZ Goals and Objectives

CTDOT's overall SWZ goal is to improve safety for roadway users and work zone personnel, increase mobility in work zones and reduce work zone traffic incidents. SWZ goals and objectives specific to offices within CTDOT are listed below.

Highway Operations goals and objectives for SWZ are to:

- Obtain video feeds from work zones, where available, to maintain situational awareness of traffic flow and incidents in work zones.
- Obtain access to real-time traffic data to maintain situational awareness of traffic flow, traffic speeds, and incident detection.
- Coordinate SWZ with existing ITS infrastructure along state roadways.

Division of Construction Operations goals and objectives for SWZ are to:

- Gather data for performance measurement, including queue length, speed, volume, and delay information in work zones to create a knowledge base for roadways throughout the State.
- Manage queue length and alert vehicle entry and exit into/from construction zones.
- Obtain performance measure data points during construction and analyze and modify traffic management plans accordingly (take lanes earlier to expedite construction).
- Facilitate incident / crash reporting.

Division of Traffic Engineering goals and objectives for SWZ are to:

- Analyze the relationship between queue, volume, speed, and other traffic data collected in work zones with a goal of understanding how certain staging plans result in specific traffic patterns.
- Utilize volume data to develop generalized traffic diversion rates for various work zone types and patterns.

[3] Work Zone Intelligent Transportation Systems Implementation Guide. FHWA-HOP-014-008. Washington D.C.: Federal Highway Administration. January 2014, Pg.21.

- Obtain traffic data before and during staged construction to be used in developing limitation of operations for future projects, and if applicable, updating the limitations of operations for the existing project.

Federal Highway Administration goals and objectives for SWZ are to:

- Monitor and measure performance.
- Gather crash, speed, and throughput data in work zones.
- Reduce queue length.

3.2 Roles and Responsibilities

This sub-section discusses roles and responsibilities of various units within CTDOT.

SWZ Determination Committee:

- A committee consisting of representatives from the Division of Traffic Engineering, Division of Construction operations, Enterprise GIS Unit, and Highway Operations is responsible for determining whether a project meets the criteria for the application of SWZ.
- The committee evaluates types of SWZ applications that should be applied to the project during the 60% design phase and once the Maintenance and Protection of Traffic (MPT) methods have been established.
- The committee makes recommendations to the designer on types of SWZ applications to be developed and work zone performance data to be collected for the project.
- The committee reviews SWZ design submitted as part of traffic management plans (TMP) to ensure that the initial objectives for using SWZ for the project have been addressed. The committee is responsible for maintaining and updating SWZ guidelines and specifications.

Project Designer:

- The project designer prepares and submit the Smart Work Zone Determination Matrix (SWZ Matrix) to the SWZ Determination Committee, DOT.SWZ.Committee@ct.gov, if SWZ application is determined to be feasible. The submittal includes the information needed to determine whether the project meets the criteria for the application of SWZ. Information provided to the committee by the designer shall include, at a minimum, project description, project location, duration, anticipated construction staging, and preliminary cost information.
- For all projects determined to require SWZ, the designer is responsible for developing the SWZ Systems Engineering documentation with reference to the latest version of the CTDOT Systems Engineering Stewardship Update Process Guide.
- The designer is responsible for adapting SWZ application guidelines to the specific project needs and project conditions.
- The designer shall follow all Manual on Uniform Traffic Control Devices (MUTCD) and CTDOT standards, guidelines, and practices while developing project-specific customized plans.

Highway Operations:

- Owns the specifications for the SWZ bid items.
- Member of the committee that determines at project-level if SWZ should be included.
- Reviews SWZ design submitted as part of the TMP for integration with existing ITS infrastructure.

- Has access to real-time video feeds and sensor information from work zones for situational awareness and incident detection.
- Monitors operation of SWZ and reports device outages to Contractor.
- Reviews and confirms that all proposed PCMS sign locations and PCMS messages meet the MUTCD and CTDOT PCMS guidelines.

Division of Construction Operations:

- Member of the committee that determines at project-level if SWZ should be included.
- Determines if coordination is needed for lane closures and construction signage between adjacent projects and adds necessary requirements in project contract documents.
- Conducts on-site Work Zone Safety reviews and determines work zone safety standards compliance and the potential necessary changes to be made. These inspections will also include SWZ as the systems are installed.
- Reviews SWZ design submitted as part of the TMP.
- Reviews traffic control pattern change requests.

Division of Traffic Engineering:

- Member of the committee that determines at project-level if SWZ should be included.
- Reviews SWZ design submitted as part of the TMP.
- Reviews Average Daily Traffic (ADT) data and variance request from the Contractor during construction to allow lanes to be taken earlier in an effort to expedite construction.
- Reviews and confirms that all proposed PCMS sign locations and PCMS messages meet the MUTCD and CTDOT PCMS guidelines.
- Participates in on-site Work Zone Safety reviews and determines work zone safety standards compliance and the potential necessary changes to be made. These inspections will also include SWZ as the systems are installed.

District Offices:

- Responsible for monitoring daily operations of construction and SWZ in work zones.
- Review SWZ design submitted as part of traffic management plans (TMP).
- Escalate the Contractor's request for changes to the limitations of operations to the Division of Traffic Engineering for review.
- Review periodic[4] work zone traffic performance reports submitted by the Contractor.
- The Engineer is responsible for making the decision to deploy or remove the SWZ or individual devices in the field.
- The Engineer approves relocation of SWZ components in work zone. Following relocation of SWZ, Engineer confirms that SWZ components and software have been reconfigured, recalibrated, and re-tested as necessary.
- Oversee coordination of lane closures and construction signage between adjacent projects as needed.

Enterprise GIS Unit:

- Member of the committee that determines at project-level if SWZ should be included.
- Responsible for archiving work zone data.
- Utilizes archived data for planning purposes.

[4] Please refer to section 5.6 for further information on periodic work zone traffic performance reports.

Contractor:

- The Contractor's responsibilities include:
  - installation, deployment, calibration, and testing of SWZ
  - daily operations and maintenance of SWZ
  - configuration of SWZ software as directed by the Engineer and Contract requirements
  - work zone data collection, processing and archiving as directed by the Engineer and contract requirements
  - submittal of periodic work zone traffic performance reports to the District
  - responding to and fixing any failure, to provide continuous operation of SWZ as defined in the contract requirements
  - relocation, re-calibration, and re-testing of SWZ as needed (with the Engineer's approval) and as directed by the Engineer
  - removal of SWZ
- The Contractor shall request approval for the following items from the Engineer:
  - acceptance of initial SWZ testing and calibration data
  - changes to location of SWZ devices in the field
- The Contractor shall request and obtain approval for proposed PCMS sign locations and PCMS messages from the Office of Highway Operations.
- Under the direction of District Engineer, the Contractor shall coordinate lane closures and construction signage with adjacent projects as needed.

4 Project-Level SWZ Determination

Project level determination and recommendation for SWZ will be provided by a committee comprised of members from Division of Traffic Engineering, Division of Construction Operations, Enterprise GIS Unit, and Highway Operations.

4.1 Project Criteria

The Project Designer is responsible for completing the Smart Work Zone Determination Matrix and recommending a project for evaluation by the SWZ Determination Committee at the 60% Design Phase of a project. This matrix includes scoring based on various criteria specific to the project, to be completed based on information available in the Project Description/Design Report. The project designer shall utilize the latest version of the SWZ determination matrix provided by CTDOT. The project designer is also responsible for the development of Systems Engineering documentation for the SWZ project as per the latest version of CTDOT Systems Engineering Process Guide. The committee may also recommend projects for the use of SWZ based on Department needs. Once recommended, the SWZ Determination Committee shall evaluate each recommended project to determine what types of SWZ applications, if any, should be applied to the project. During the evaluation process, the committee may take into consideration the criteria listed below:

- **Project Location**
- **Stakeholders, Designer, and Department requests**
- **Current ADT – Traffic volume on the roadway**
- **Project cost** categories such as: (1) significant projects (>$50 Million), (2) medium projects ($20-$50 Million), or (3) small projects (<$20 Million) can be considered as a determining criterion; however, the decision on including SWZ applications for projects is needs-based and not solely based on dollar amounts.
- **Duration of work zone:** Large scale, long-term projects resulting in long term traffic issues due to complex traffic control layout.
- **Projects with staged construction** (e.g., bridge projects) resulting in frequent changes to traffic patterns and work zone traffic issues.
- **Extent of traffic impact** (traffic delay, increased travel time, queue length) due to temporary lane closure (e.g., mill and pave, deck patching on bridges)
- **Extent of queue length/delay** due to temporary signalization projects (e.g., alternate one-way traffic patterns around bridge projects, intersection improvements) or long-term MPT where lane/shoulder widths are reduced. Impact on traffic, businesses, other destinations, or other users (e.g., extremely long delays, high risk of speed variability, access issues) for the duration of work is also a determining criterion.
- **CTDOT's internal need for traffic data** during construction on a particular roadway. In some projects, the value gained from performance data collection and evaluation may be a driving factor to implement SWZ.
- Other roadway types and traffic conditions that should be considered during the evaluation process are listed below.
    - Traffic speed variability
    - Back of queue and other sight distance issues
    - High speeds/chronic speeding
    - Work zone congestion
    - Availability of alternate routes
    - Merging conflicts and hazards at work zone tapers
    - Work zone hazards/complex traffic control layout

- Frequently changing operating conditions for traffic
- Variable work activities
- Frequent non-peak lane closures
- Emergency route
- Oversize vehicles (percentage of heavy vehicles >10%)
- High speeds over 85th percentile
- Limited offset to median
- Construction vehicle entry/exit speed differential relative to traffic
- Crash history within the limits
- Data collection for work zone performance measures
- Change in roadway capacity
- Unusual or unpredictable weather patterns (such as snow, ice, and fog).

Based on the 2023 SWZ Engineering and Construction Directive[5] the following types of projects are exempt and do not need to complete the SWZ matrix:

- Short duration projects less than 6 months
- Traffic signals, signing and pavement marking projects at various locations
- Pavement patching, concrete sealer, bridge repairs at various locations
- Projects not located on a limited access highway

[5] https://portal.ct.gov/-/media/DOT/documents/AEC/ECD-2023-6_Smart-Work-Zone-Criteria-Matrix_20230427_signed_SAH.pdf

4.2 Project Characteristics and SWZ Applications

Based on the project needs and characteristics, the committee may recommend use of one or more specific SWZ applications. The following table shows potential situations and possible mitigation measures.

Table 3: CRITICAL PROJECT CHARACTERISTICS AND COMPONENT SELECTION

CRITICAL PROJECT CHARACTERISTICS	CONSTRUCTION VEHICLE WARNING	DYNAMIC LANE MERGE	EXCESSIVE SPEED WARNING	HAZARDOUS CONDITION WARNING	INTRUSION DETECTION	OVER DIMENSION WARNING	PORTABLE SIGNAL	SPEED ADVISORY	STOPPED TRAFFIC WARNING	TEMPORARY RAMP METERING	TRAVEL TIME ESTIMATION	VARIABLE SPEED LIMIT
Does a temporary ramp geometry have an inadequate length for the acceleration lane?									X			X
Do vehicles unintentionally follow a tall vehicle (i.e., a truck) off an exit due to the high volume of traffic or insufficient sight distance?							X					
Does the work zone cause regular, recurring delays in excess of 15 minutes?											X	
Does traffic have to reduce speed to safely negotiate a hazardous condition?			X					X				
Does construction cause temporary minimal clearance for large vehicles using the roadway?						X						
Can a construction vehicle merge lane be provided on the project or is the haul road entrance visible to drivers?	X						X		X			
Is there congestion where traffic must suddenly adjust speed or change lanes?	X							X				
Does the location of the day's work activities require a reduction in speed?												X
Is stopped or slowed traffic expected, especially where visibility is restricted?									X			
Does traffic operations have to be controlled along a two-lane, two-way highway where one lane is closed, and alternating traffic movements are necessary?							X					
Is there capacity reduction through long-term lane closures?		X							X		X	X

4.3 SWZ Applications

This section presents typical setups for various SWZ applications that are currently used by CTDOT and applications that could be considered for future deployment by CTDOT. For each application, a brief description of system overview, sample setup, and notes on considerations for design and deployment are provided.

NOTE: The sample SWZ applications shown in this section are overview representations and not detailed designs. The Designer and the Contractor are responsible to ensure all applicable CTDOT and MUTCD[6] standards, guidelines, and practices are followed in the development of SWZ plans and during field deployment.

Illustrations of SWZ applications are adapted from MUTCD standards. The legend for the icons used in the diagrams are adapted from prior CTDOT Specifications for SWZ projects[7]:

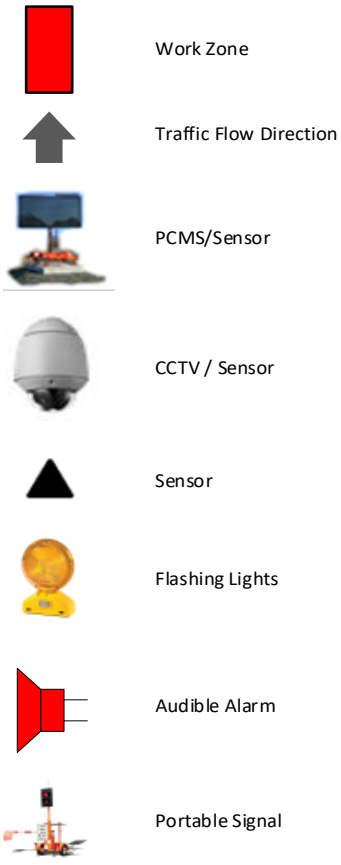


Figure 2: SWZ Components Icons

[6] Federal Highways Administration, U.S. Department of Transportation. Manual on Uniform Traffic Control Devices. 2009 Edition with Revisions 1, 2, and 3, July 2022.

[7] CTDOT Specification for Waterbury, Bridgeport and Fairfield SWZ projects.

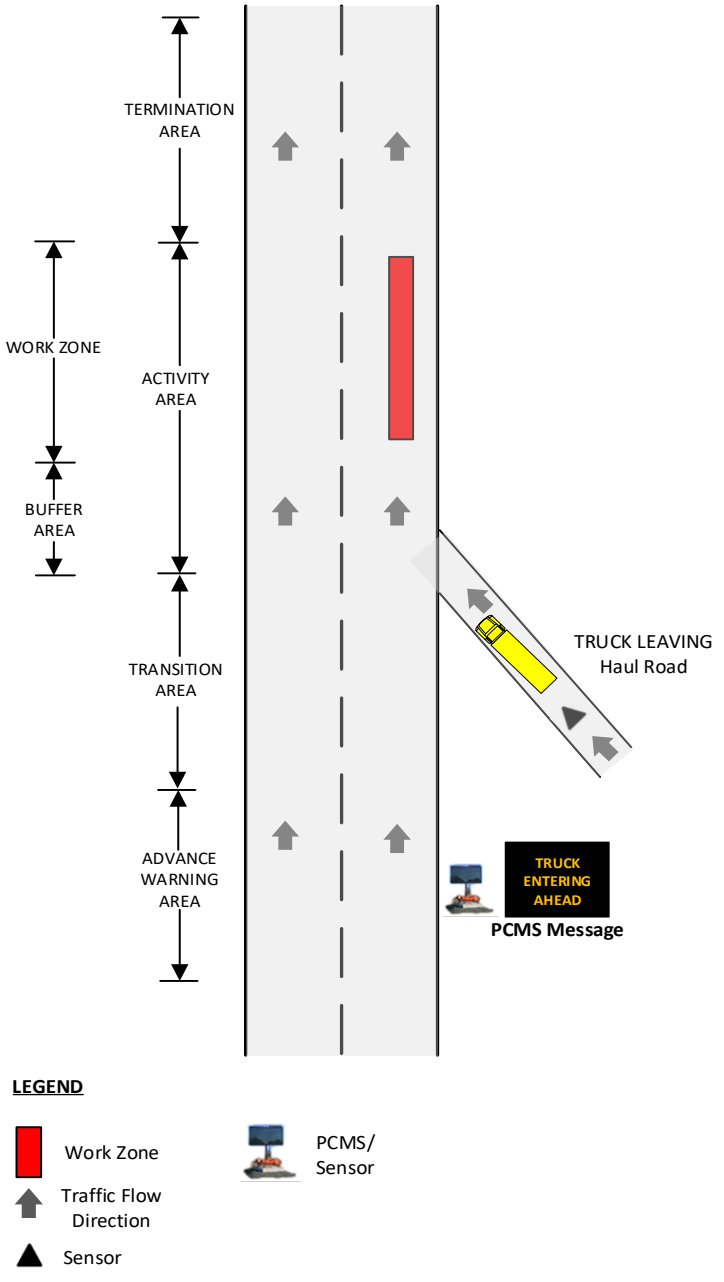
4.3.1 Current Applications

4.3.1.1 Construction Vehicle Warning

CONSTRUCTION VEHICLE WARNING

System Overview: A typical construction vehicle warning system includes sensors in field that activate PCMS to display notification of slow-moving construction or emergency vehicles, entering or exiting the roadway.

Overview Diagram:



Notes:

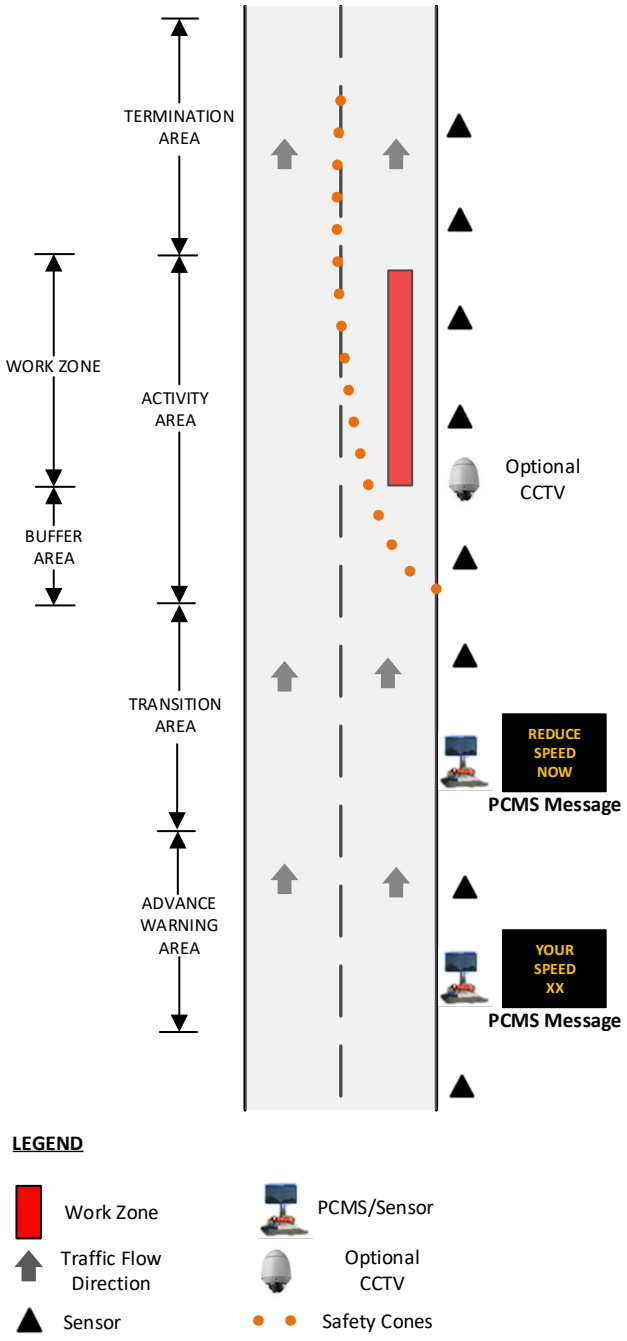
- Actual number of sensors, location of sensors, and PCMS are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS and at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.2 Excessive Speed Warning

EXCESSIVE SPEED WARNING

System Overview: A typical excessive speed warning system includes sensors to collect traffic data, PCMS and sensor trailer to measure and display vehicle speeds and alert drivers to reduce potentially excessive speed, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

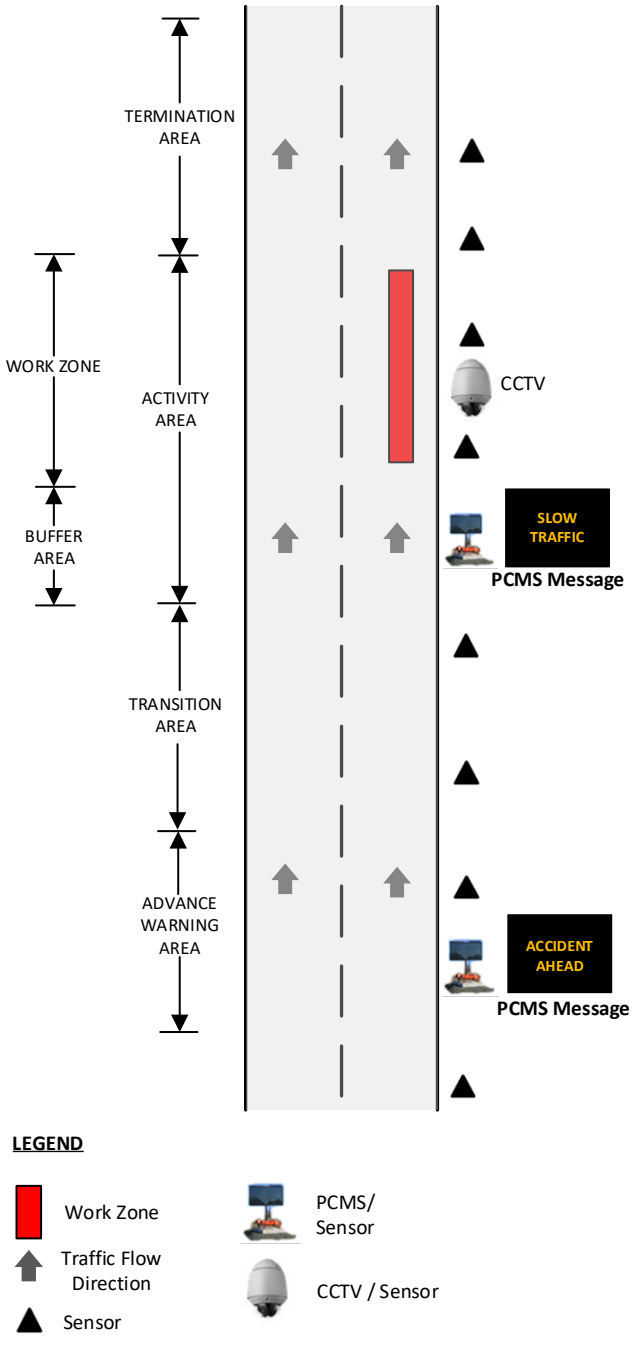
- Actual number of sensors, location of sensors and radar trailers are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications. shall comply with MUTCD and CTDOT PCMS guidelines.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.3 Incident Management

INTRUSION DETECTION

System Overview: A typical incident management system includes field sensors to collect traffic data, CCTV cameras to provide live feeds, PCMS to communicate incident related delays to end-users, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

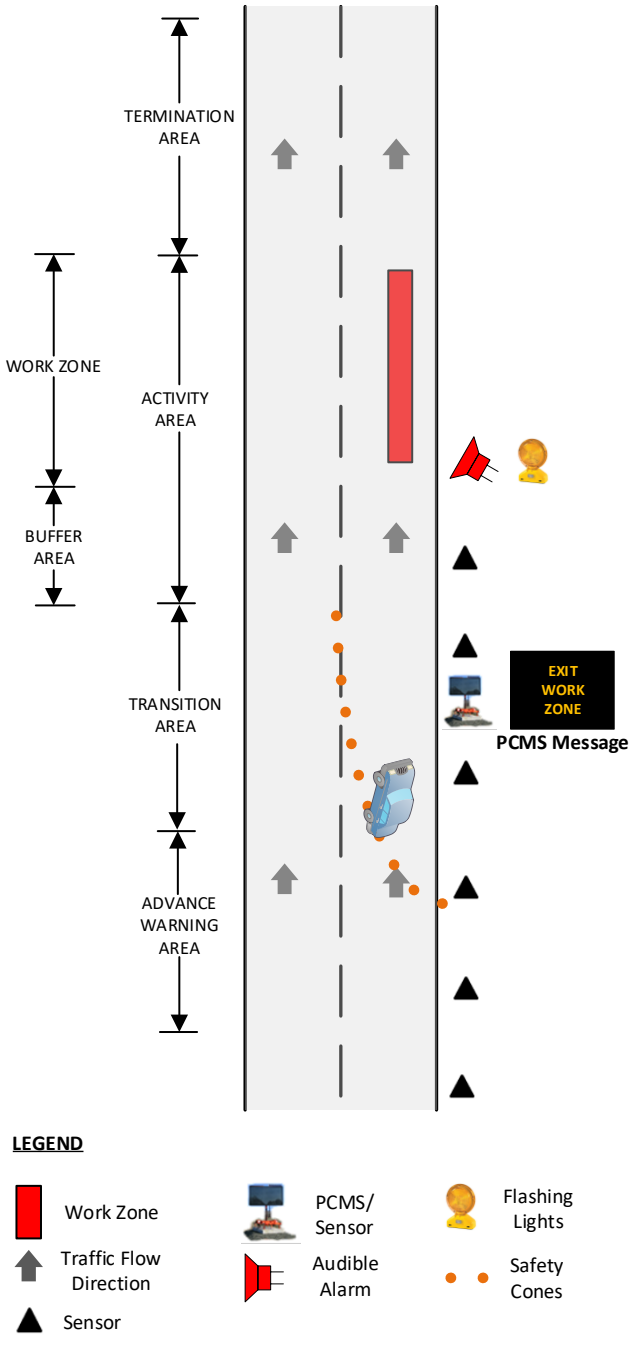
- Actual number of sensors, location of sensors, and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is required for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.4 Intrusion Detection

INTRUSION DETECTION

System Overview: A typical intrusion detection system includes sensors in field and speaker and/or light to notify work zone personnel of an intrusion, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

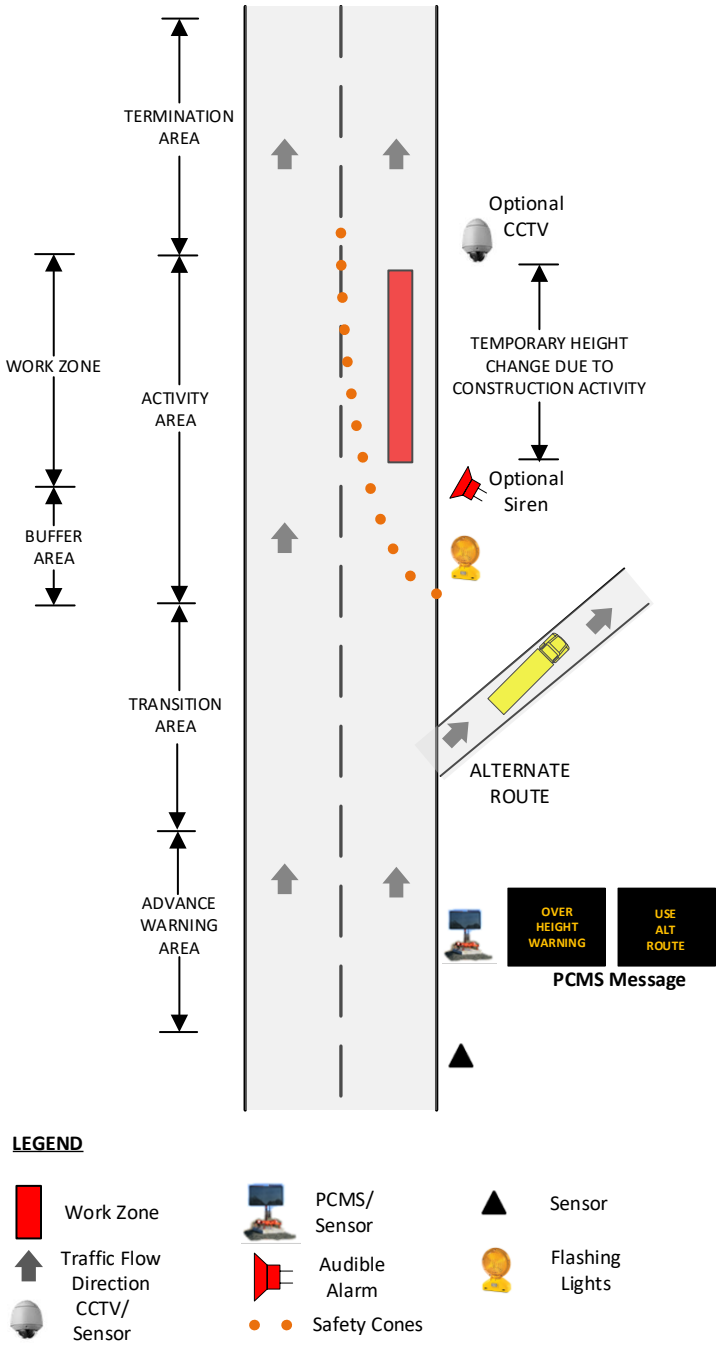
- Actual number of sensors, location of sensors, and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.5 Over Dimension Warning

OVER DIMENSION WARNING

System Overview: A typical over dimension warning system includes field sensors along with flashing lights or signs and optional siren alerting drivers about over-height restrictions, possibly PCMS to display notification of an alternate route, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

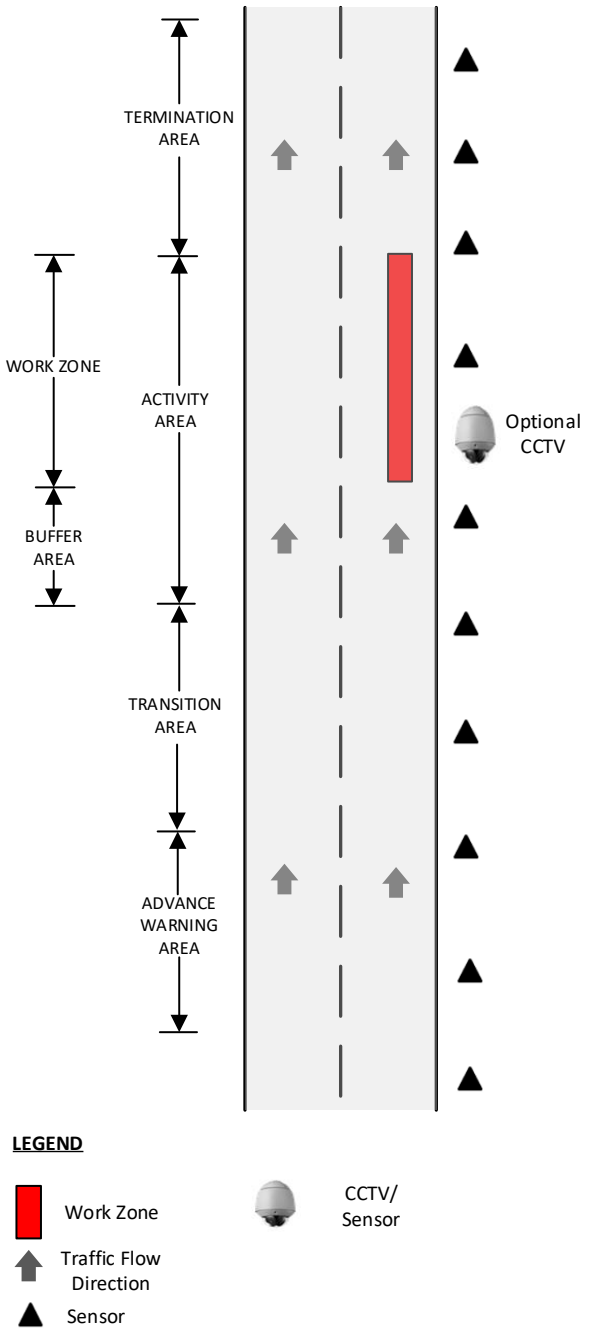
- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature, access to an alternate route, and other specifics related to the project and roadway.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- Designer shall evaluate use of audible alerts such as siren and recommend on per project basis.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.6 Performance Measurement

PERFORMANCE MEASUREMENT

System Overview: A typical performance measurement system includes sensors to collect traffic data in a work zone, communications systems, and software applications for processing, analyzing, and archiving data. The data collected is mainly used for the purpose of performance measurement and to obtain insight into traffic conditions in work zones. The information is not intended for notification, but rather to allow for modifications to current project operations and future project designs.

Overview Diagram:



Notes:

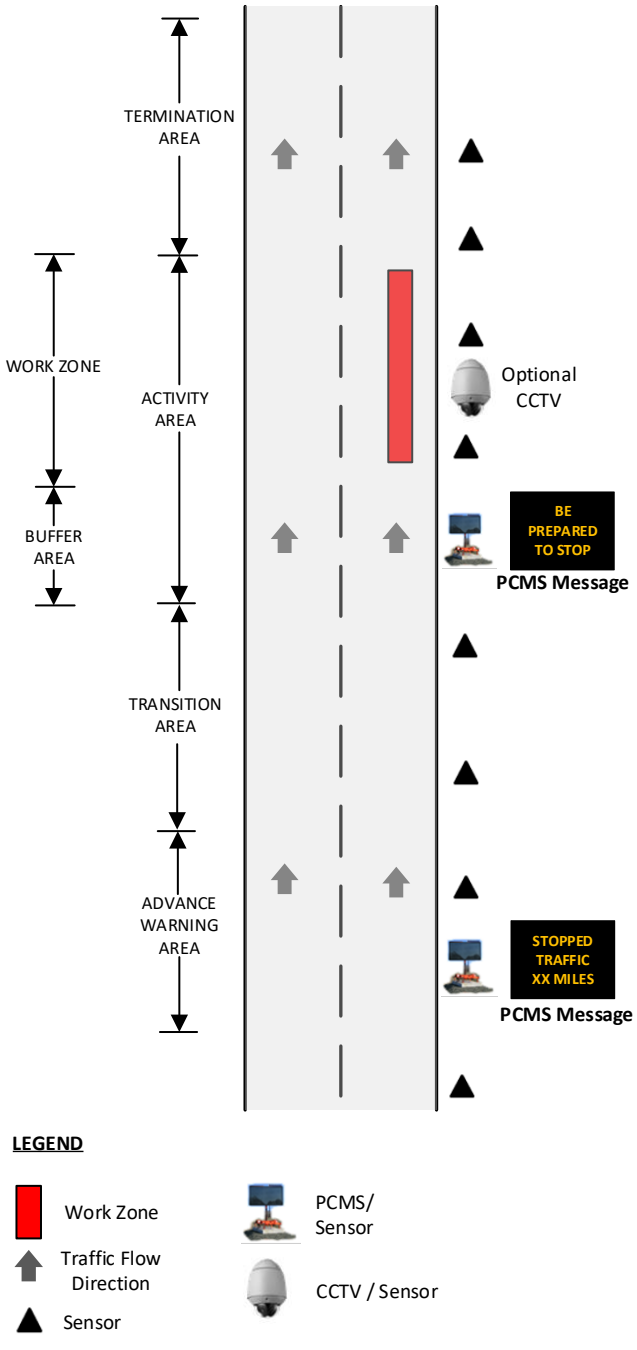
- Actual number of sensors and location of sensors are dependent on total project distance, road curvature, and other specifics related to the project and roadway
- Distance between sensors shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- CTDOT may consider the option to purchase portable sensors to implement the performance measurement SWZ application. These portable sensors could be moved to different projects and used year-round to gather data from different parts of the state as needed.
- The sensors could be moved during construction/deployment at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction sites. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design to be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.7 Queue Warning

QUEUE WARNING

System Overview: A typical queue warning system includes sensors to collect traffic data, PCMS to display delay/stopped traffic in the work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

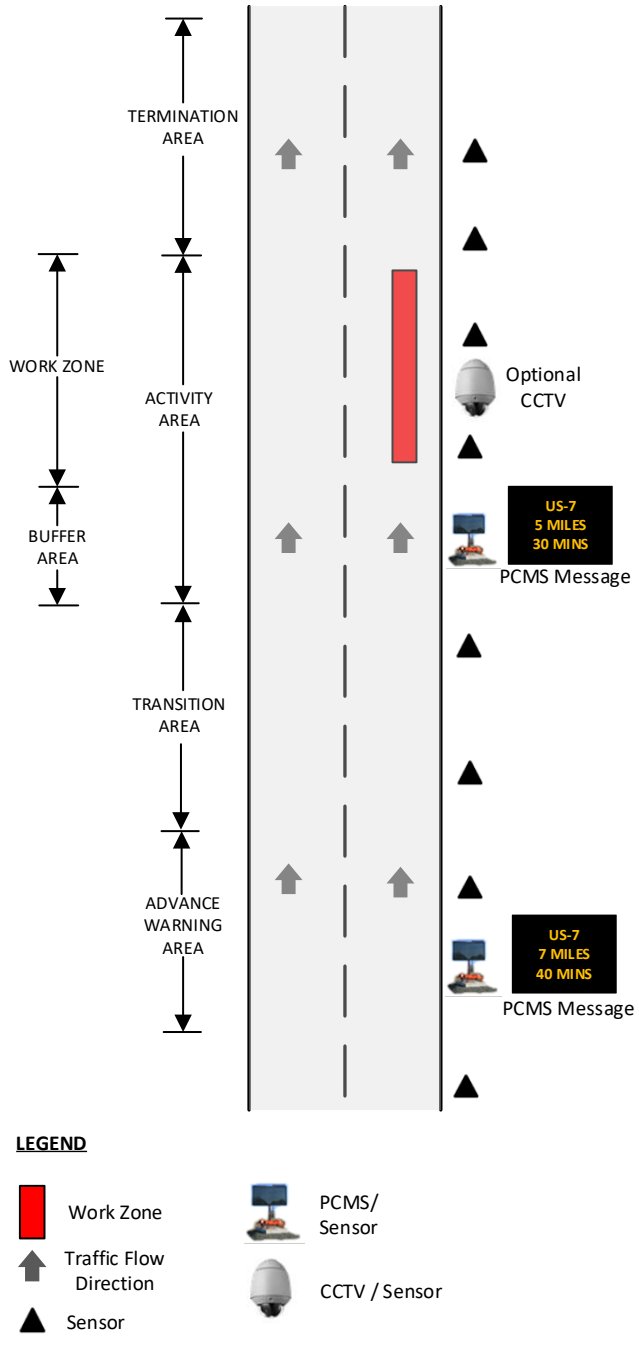
- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS might need relocation depending on the typical queue length observed during construction.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines and standards..
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS and at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.1.8 Travel Time Estimation

TRAVEL TIME ESTIMATION

System Overview: A typical travel time estimation system includes sensors in field to collect traffic data, PCMS to display current travel condition ahead of and within the work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications. shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailers at construction sites. Placement of field components shall take into consideration, requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the Contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

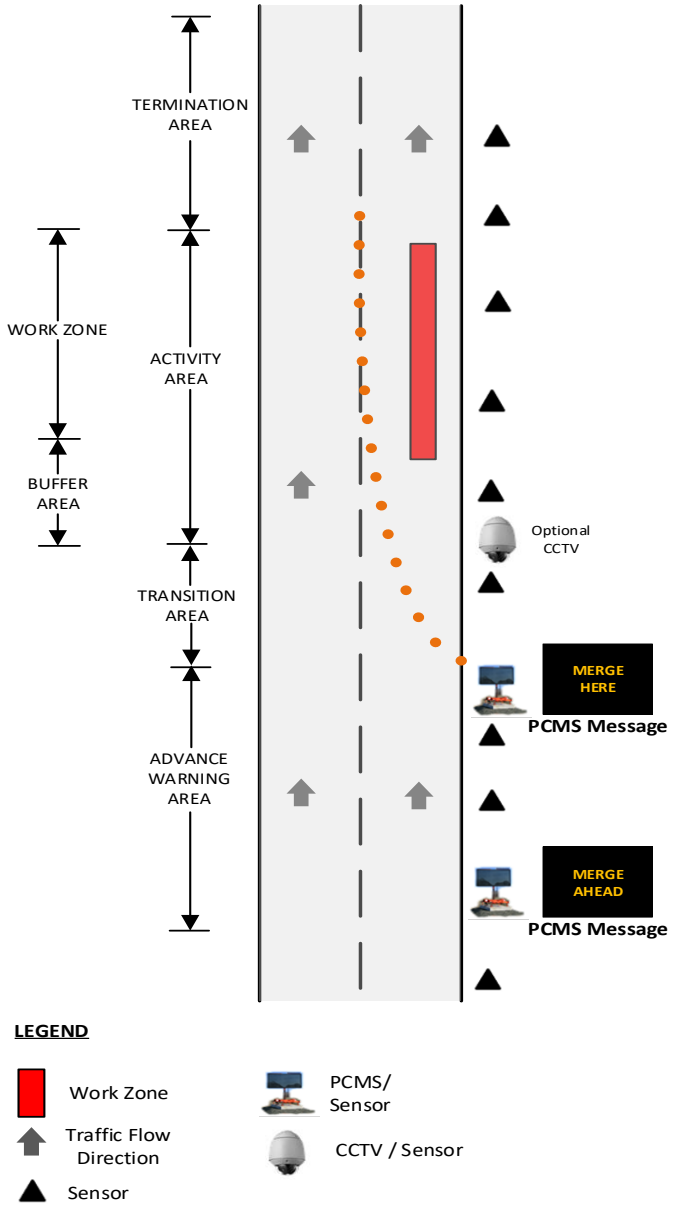
4.3.2 Future Applications

4.3.2.1 Dynamic Lane Merge

DYNAMIC LANE MERGE

System Overview: A typical dynamic lane merge system includes field sensors to collect traffic data, PCMS to display instructions for motorists to merge at specific points in a work zone, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

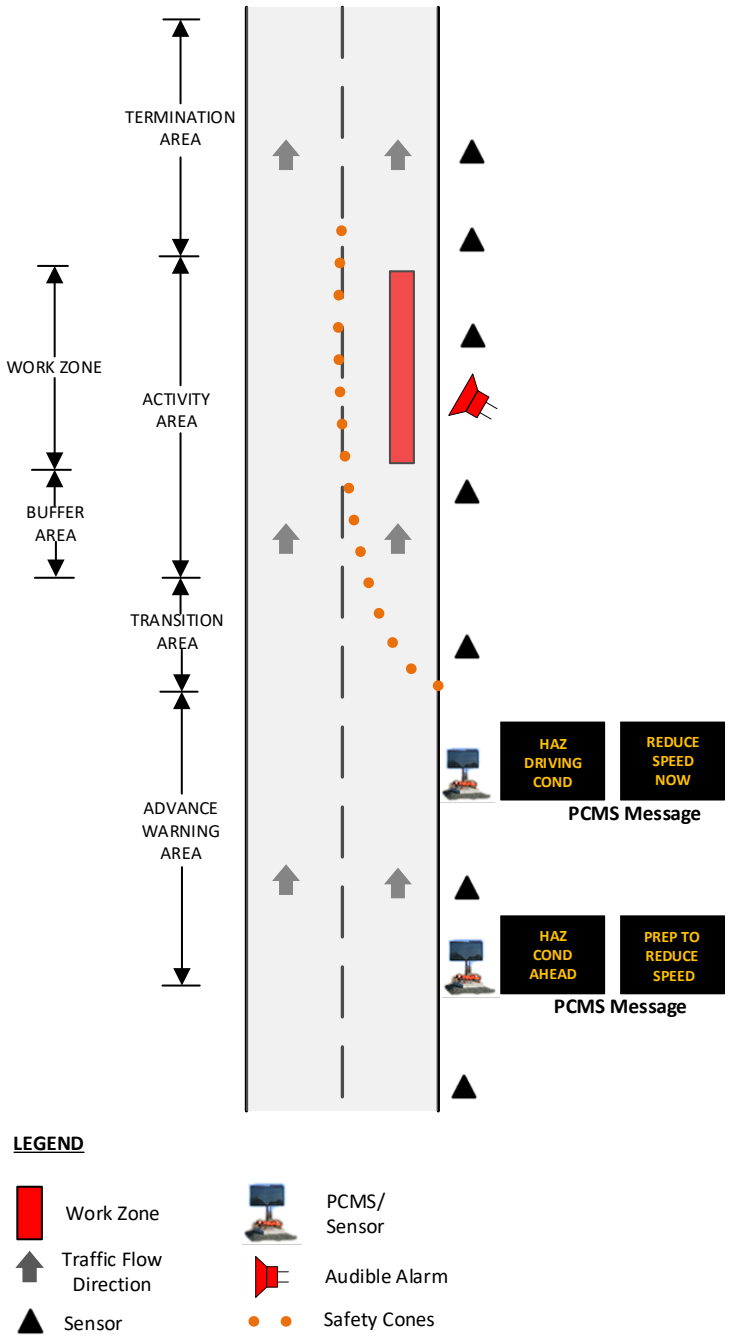
- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailers at construction sites. Placement of field components shall take into consideration, requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the Contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan

4.3.2.2 Hazardous Conditions Warning

HAZARDOUS CONDITIONS WARNING

System Overview: A hazardous conditions warning system includes sensors in the field to collect traffic data that activate PCMS to display hazardous/unexpected roadway conditions in an active work zone, a siren to alert (motorists and construction personnel), communications systems, and software application to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

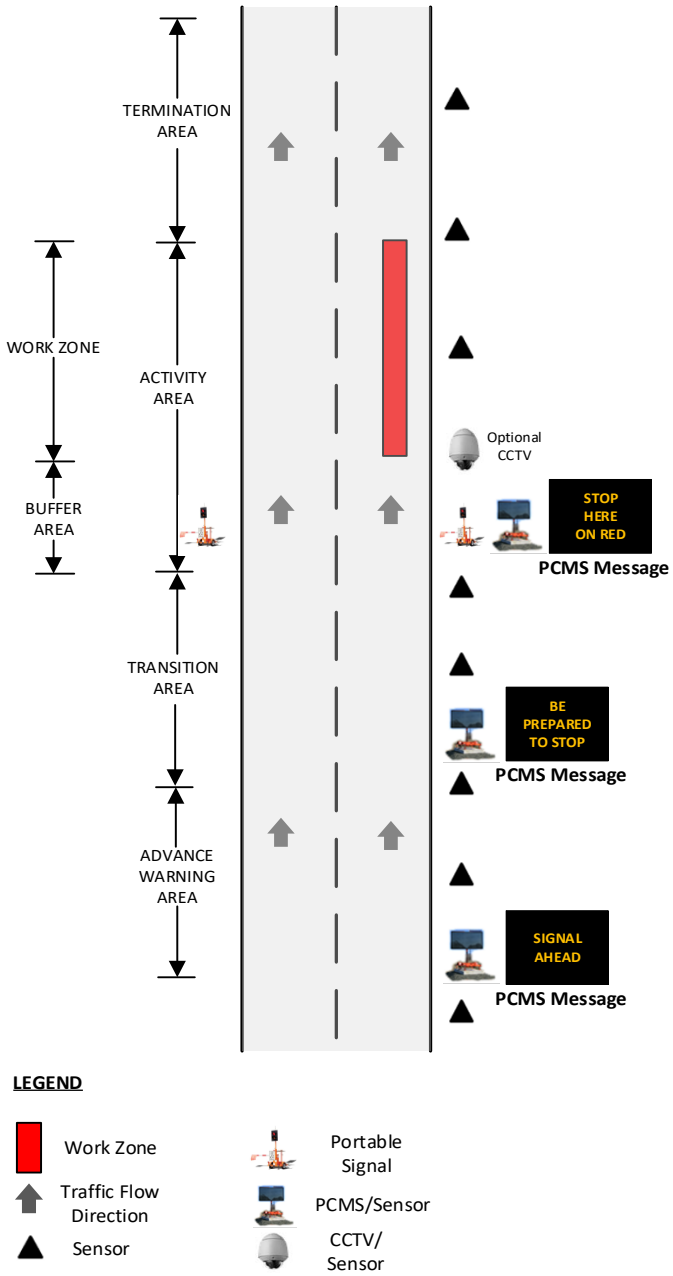
- Actual number of sensors, location of sensors, and PCMS are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailers at construction sites. Placement of field components shall take into consideration, requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the Contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan

4.3.2.3 Portable Signal

PORTABLE SIGNAL

System Overview: A typical portable signal system includes battery/solar powered traffic signal trailer set with signal heads, microprocessor-based controller, radio frequency transceiver module, solar panels, hydraulic lift, microwave sensor to detect vehicles, PCMS to display portable signal ahead, communications systems, and software applications to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

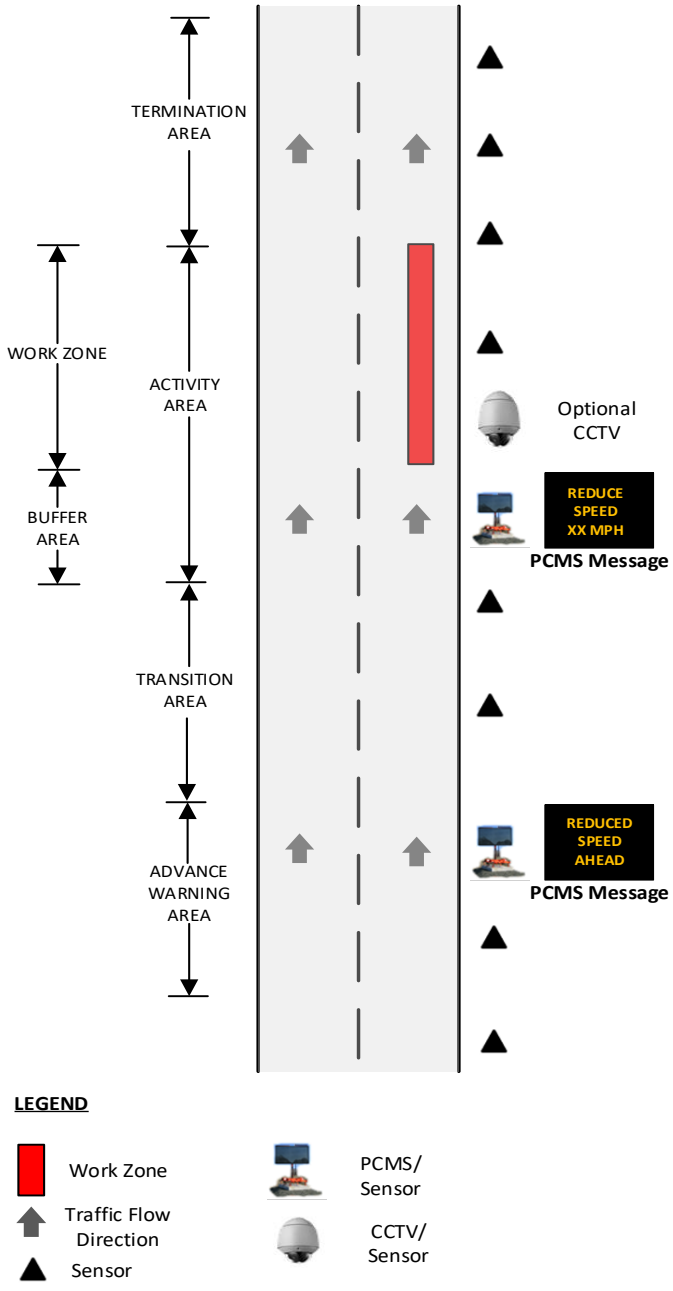
- Portable signal trailer shall be positioned horizontally, in stable shoulder areas, and clear zone space.
- Actual number of sensors, location of sensors, and PCMS are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- The Portable Signal shall meet MUTCD and CTDOT standards and guidelines.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction sites. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.2.4 Speed Advisory

SPEED ADVISORY

System Overview: A typical speed advisory system includes field sensors collecting traffic data, PCMS to display information on lower speeds in case of congestion or stopped traffic through the work zone, communications systems, and software application to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

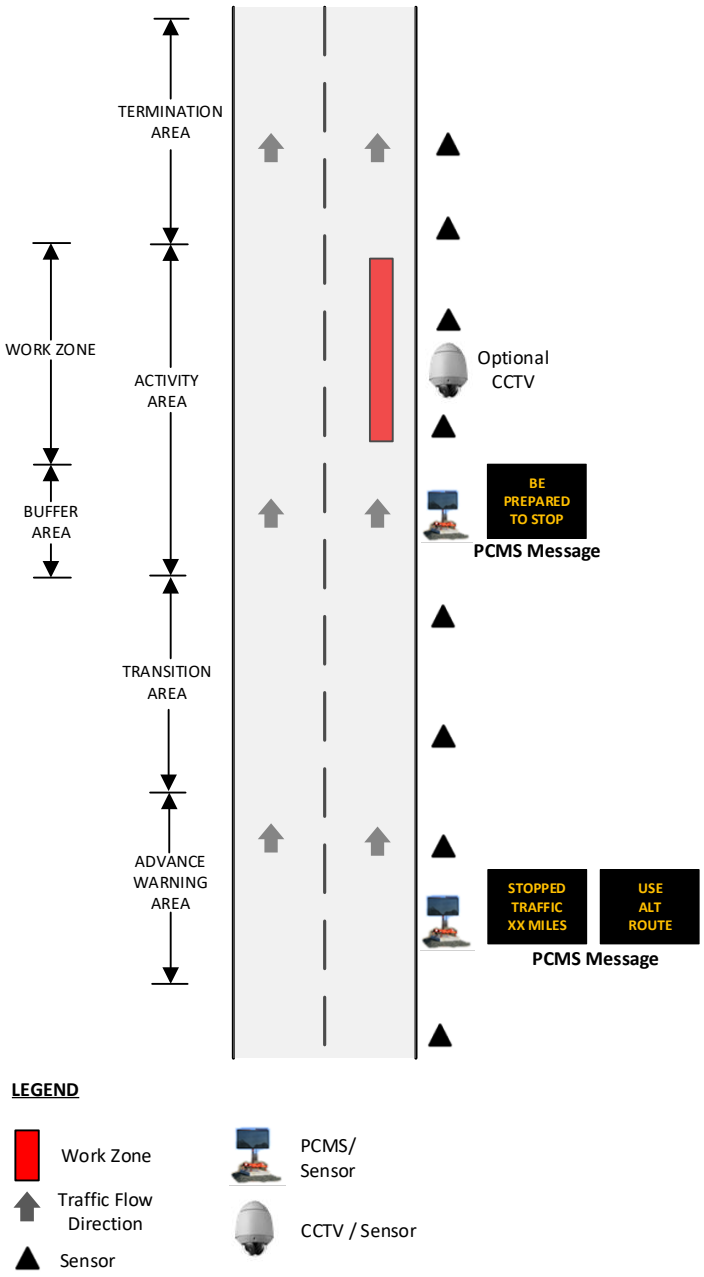
- Actual number of sensors, location of sensors and radar trailers are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan

4.3.2.5 Stopped Traffic Warning

STOPPED TRAFFIC WARNING

System Overview: A typical stopped traffic warning system includes sensors to collect traffic data, PCMS to broadcast appropriate messages in case of congestion or stopped traffic ahead of work zone, communications systems, and software applications to process, analyze, disseminate, and archive data. This application is a variation of Queue Warning and Travel Time Estimation applications.

Overview Diagram:



Notes:

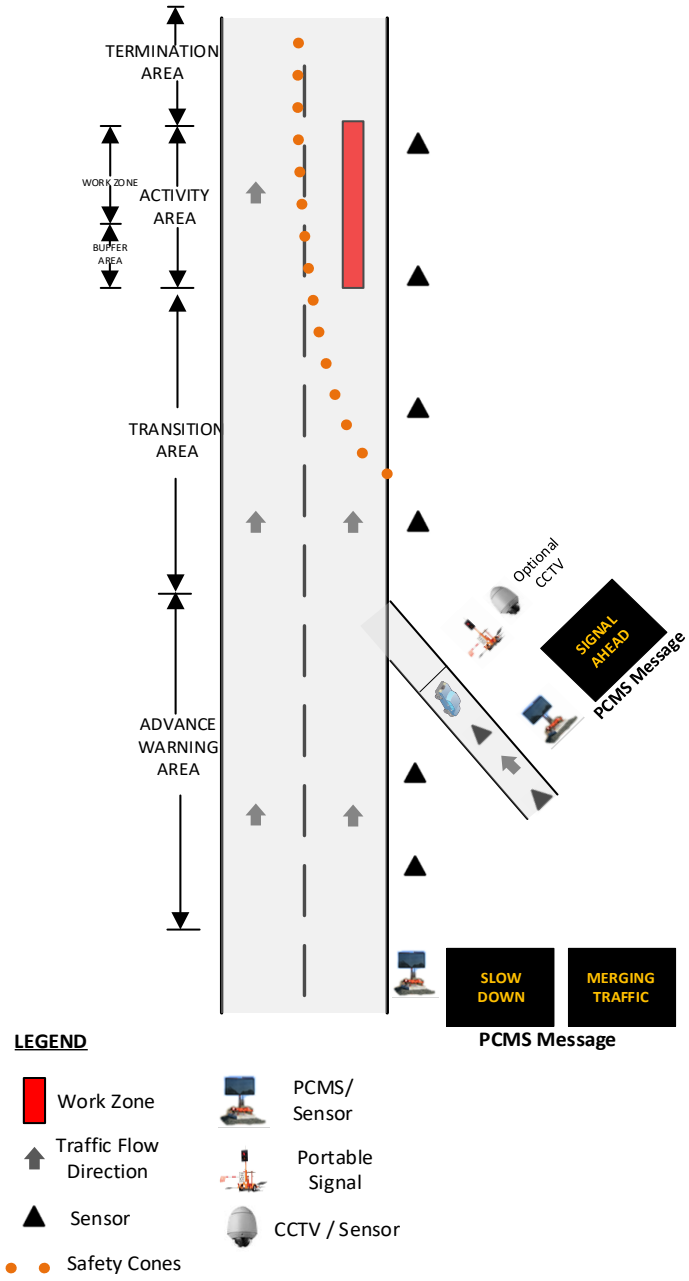
- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature, and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS might need relocation depending on the typical location where congestion or stopped traffic is observed during construction.
- PCMS message size, legibility, and other specifications shall comply with CTDOT PCMS guidelines and standards.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS and at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailer/sensor at construction site. Placement of field components shall take into consideration requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design shall be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.

4.3.2.6 Temporary Ramp Metering

TEMPORARY RAMP METERING

System Overview: A temporary ramp metering system includes field sensors collecting ramp and mainline traffic data, PCMS to display traffic conditions in an active work zone and information for traffic entering mainline from the ramp, battery/solar powered portable traffic signal, ramp metering controller, communications systems, and software application to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

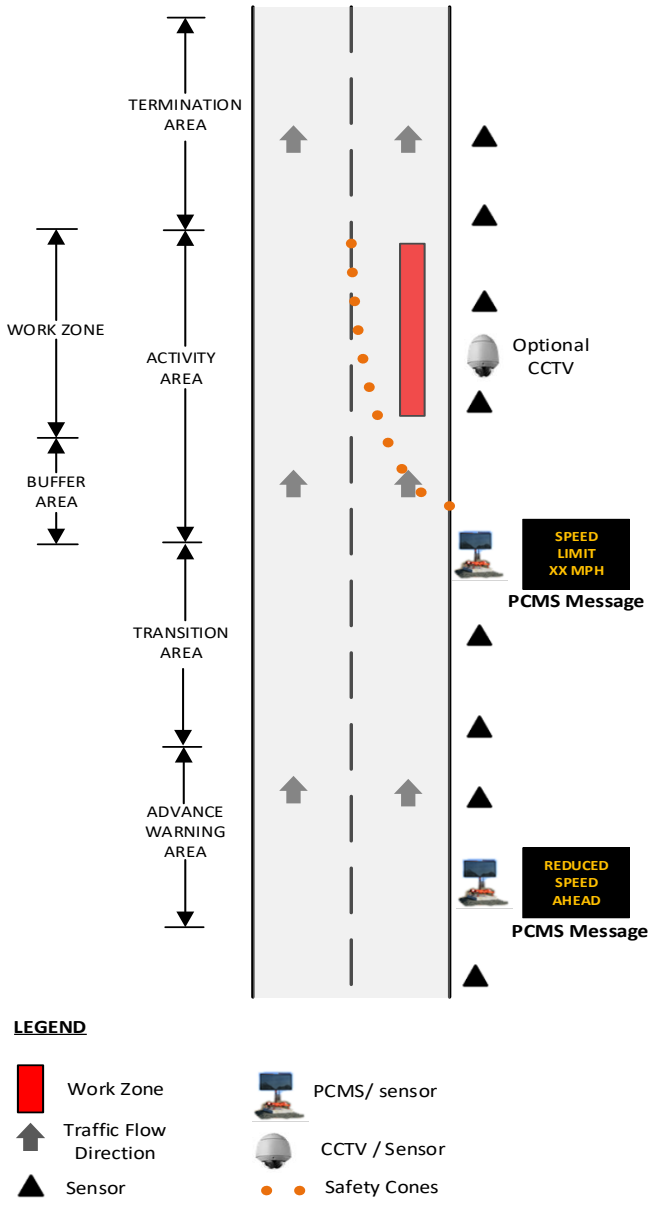
- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- CTDOT shall provide input to SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- PCMS might need relocation depending on the typical queue length observed during construction.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailers at construction sites. Placement of field components shall take into consideration, requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design should be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the Contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan.
- Ramp Control Signals shall meet all the MUTCD and CTDOT standard design specifications for traffic control signals.
- CTDOT should determine the operational strategies for ramp control signals including period of operation, metering rates, and queue management prior to the installation.

4.3.2.7 Variable Speed Limit

VARIABLE SPEED LIMIT

System Overview: A variable speed limit system includes field sensors collecting traffic data, a PCMS and sensor trailer to measure and display reduced speed limit set in an active work zone, communications systems, and software application to process, analyze, disseminate, and archive data.

Overview Diagram:



Notes:

- Actual number of sensors, location of sensors and PCMS are dependent on total project distance, road curvature and other specifics related to the project and roadway.
- Distance between sensors and trailers shall be as specified in the special provisions of the project.
- CCTV camera is optional for this application. If visibility into work zone conditions is needed, CCTV on a trailer could be included as part of SWZ or an existing CCTV feed can be utilized.
- PCMS message size, legibility, and other specifications shall comply with MUTCD and CTDOT PCMS guidelines.
- CTDOT shall provide input to the SWZ specification regarding what message shall be displayed on the PCMS at what threshold. During construction/deployment these initial requirements could be modified at the Engineer's discretion.
- As SWZ are considered to be part of temporary traffic control, the Contractor shall follow all applicable MUTCD and CTDOT standards and guidelines for placement of SWZ trailers at construction sites. Placement of field components shall take into consideration, requirements for off the road distance, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Final design should be approved by CTDOT.
- Construction signage is not shown in this overview drawing and the Contractor shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing the project specific customized plan

4.4 Integration of Existing Permanent ITS

If permanent ITS infrastructure such as CCTV and CMS (Changeable Message Signs) exist within the project limits, integration with this existing infrastructure should be taken into consideration as part of SWZ design. Existing ITS may provide additional video feed and information dissemination points but may not completely eliminate the need for CCTV or PCMS as part of SWZ design, as the existing field equipment may not be located at the right locations within the work zone. Additionally, existing CMS may have other operational uses, and may not be available for dedicated work zone use.

4.5 Typical SWZ Deployment Cost

SWZ deployment costs usually comprise three to five percent of total project cost. They depend on the costs of purchasing or leasing the equipment, the duration of the project, the extent of changes to construction staging, and operation and maintenance, among other factors. A project's general complexity and total SWZ applications used also will increase its costs.

The following sample cost information for smart work zone deployment items used in CTDOT projects is compiled from 7 projects from 2018 through 2022 with a total of 30 bids (excluding nominal 1-dollar bids for specific items). The cost details provided here should be used for planning purposes only and not for determining the exact cost of a deployment.

Table 4: SWZ deployment items

ITEM	NAME	UNIT	PROJECTS	BIDS	MINIMUM	MAXIMUM	MEAN	MEDIAN
1131021	Smart Work Zone Operations	month	7	30	$1,000	$12,397	$3,189	$2,588
1131022	Smart Work Zone Trailer Relocation	each	7	30	$488	$2,773	$1,425	$1,005
1131025	Smart Work Zone Mobile Video Camera/Queue Sensor Trailer (SVQS)	month	2	6	$775	$1,200	$993	$993
1131026	Smart Work Zone Changeable Message Sign/Queue Sensor Trailer (SCMQ)	month	2	6	$750	$878	$816	$820
1131027	Smart Work Zone Queue Trailer/Sensor (SQT)	month	1	2	$555	$600	$578	$578

5 Guidelines for Implementation of SWZ

This section defines guidelines for implementation of SWZ in the state of Connecticut. The process defined in this section allows for customization of generic SWZ applications presented in Section 4.3 to address needs and constraints specific to each project. CTDOT SWZ will closely follow federal guidelines and the Systems Engineering process for implementation of work zone ITS / SWZ. The SWZ implementation process defined in this section is presented in Appendix A in table format.

5.1 Design

The Project Designer shall complete the Smart Work Zone Determination Matrix and recommend the project for evaluation by the SWZ Determination Committee at the 60% Design Phase of a project. As part of the 60% engineering design phase and once the MPT methods have been established, the SWZ Determination Committee shall evaluate which types of SWZ applications should be applied to the project. The committee shall make a recommendation to the designer on types of SWZ applications to be developed for the project.

For all projects determined to require SWZ, the designer shall develop applicable CTDOT Systems Engineering documentation for the SWZ. Consistent with the October 2021 Stewardship and Oversight Implementation Manual[8] program responsibilities, the designer shall be responsible for following the federally required Systems Engineering process and documenting its efforts using CTDOT Systems Engineering documentation. If guidance in properly filling out the Systems Engineering documentation is needed, the person filling out the paperwork can contact the CTDOT Office of Highway Operations.

The designer shall customize the generic SWZ application to take into consideration project-specific details such as: project length/distance, roadway geometry, traffic conditions, and other project needs. Based on this project information the designer shall determine the number and placement of sensors, PCMS, and other SWZ equipment, including an assessment of the availability of integrating the SWZ with existing ITS. The designer shall follow all MUTCD and CTDOT standards, guidelines, and practices while developing a project-specific customized plan.

The SWZ design shall be included as part of the Transportation Management Plan (TMP) for the project (as part of the detailed design). As part of TMP review, various offices within CTDOT shall review and ensure construction staging is taken into consideration in development of SWZ design. The designer shall follow all applicable MUTCD and CTDOT guidelines for placement of SWZ trailers and signage at the construction site. Placement of field components shall take into consideration, clear zone requirements in the Standard Specifications Form 818, position of SWZ equipment in relation to other highway signs, curvature of highway, ramps, etc. Detailed design shall be circulated to the various CTDOT offices for review and comment, including representatives from the SWZ Determination Committee. Final design shall be approved by CTDOT.

5.2 Procurement

SWZ shall be procured under project contract as contract bid items. CTDOT has developed the following contract bid items and specifications for procurement of SWZ.

[8] 2021 Stewardship & Oversight Implementation Manual, Federal Highway Administration and Connecticut Department of Transportation, October 2021.

- ITEM 1131021A – Smart Work Zone Operations
- ITEM 1131022A – Smart Work Zone Trailer Relocation
- ITEM 1131025A – Smart Work Zone Mobile Video Camera/Queue Sensor Trailer (SVQS)
- ITEM 1131026A – Smart Work Zone Changeable Message Sign/Queue Sensor Trailer (SCMQ)
- ITEM 1131027A – Smart Work Zone Queue Trailer/Sensor (SQT)

Please note that this may not be a complete list of SWZ contract bid items and specifications. CTDOT Highway Operations ITS Engineering and Support should be contacted for information on any additional SWZ components. CTDOT Highway Operations ITS Engineering and Support is responsible for maintaining these specification items.

These items shall provide a fully operational SWZ that includes vehicle trailers with sensors, Changeable Message signs (CMS), cameras, website, communications equipment, service, and maintenance as defined in the specifications. Included in the operational responsibilities of the Contractor/Vendor is the assumption of all trailer license plates, communication costs such as FCC licensing, cellular telephone, wireless data networks, satellite and internet subscription charges, solar system support and battery charging, and maintenance. Specifications for SWZ items must be customized by the designer during design stage to meet project specific criteria and needs.

5.3 Deployment

The District and the Engineer oversee the deployment of SWZ. The Contractor shall coordinate deployment of SWZ with the District and the Engineer. Initial SWZ deployment is included as part of the following CTDOT contract bid items.

- ITEM 1131025A – Smart Work Zone Mobile Video Camera/Queue Sensor Trailer (SVQS)
- ITEM 1131026A – Smart Work Zone Changeable Message Sign/Queue Sensor Trailer (SCMQ)
- ITEM 1131027A – Smart Work Zone Queue Trailer/Sensor (SQT)

Please note that this may not be a complete list of SWZ contract bid items and specifications. CTDOT Highway Operations ITS Engineering and Support should be contacted for information on any additional SWZ components. CTDOT Highway Operations ITS Engineering and Support is responsible for maintaining these specification items.

The specification of each item provides detailed guidelines for SWZ deployment, scheduling, initial placement of equipment in work zones, calibration, testing, system demonstration, and acceptance of system prior to commencement of construction activity. While initial deployment is covered under items listed above, relocation of SWZ equipment during construction period is cover by the following bid item.

- Item 1131022A – Smart Work Zone Trailer Relocation

The specifications require the Contractor to complete calibration and testing of SWZ prior to initial acceptance of the deployment. If the SWZ trailer is re-located, the Contractor shall re-calibrate and test the system after each re-location. The Contractor shall obtain approval from the Engineer after each re-location, on the basis of new calibration data and testing results. The Contractor shall also notify the Highway Operations ITS Engineering and Support whenever a

SWZ is deployed or re-located to ensure situational awareness at the Operations Centers is maintained.

5.4 Operations and Data Collection

The Contractor is responsible for SWZ operation, maintenance and data collection during construction. CTDOT has developed the following contract bid item and specification for SWZ Operations.

- ITEM 1131021A– Smart Work Zone Operations

Please note that this may not be a complete list of SWZ contract bid items and specifications. CTDOT Highway Operations ITS Engineering and Support should be contacted for information on any additional SWZ components. CTDOT Highway Operations ITS Engineering and Support is responsible for maintaining these specification items.

The Contractor shall gather, analyze, report/disseminate and archive work zone traffic data as specified in the specifications.

- Real-time traffic data such as speed, volume, count, etc. are gathered in by the SWZ at pre-configured intervals as defined in the specifications.
- The Contractor shall continuously monitor operational status of field equipment and address any outages within the duration specified in the specifications.
- The Contractor shall periodically (at a minimum on a weekly basis), review traffic queue length and delay information to make appropriate changes to location of sensors, trailers, and/or deployment of additional PCMS with approval from CTDOT.
- Throughout the duration of construction, the Contractor may evaluate traffic operations and when feasible request from the Office of Construction and District Construction variance in the hourly limitations of operation in order to expedite construction.
- The Contractor shall coordinate with the Engineer on frequency of data reporting. Typically, the reporting will be on a monthly basis.
- The Contractor shall generate and submit to the Engineer a periodic work zone traffic performance report as defined in Section 5.6 utilizing work zone traffic data collected with SWZ.
- Upon project completion as per the specifications for SWZ, the Contractor shall submit full set of work zone data collected for the project. In addition to raw data set, the Contractor shall also include electronic copy of weekly reports and raw data for the week submitted to the department for archiving.
- In addition to supplying archived data in the format as specified in contract documents, the department may request the Contractor or an external Consultant to provide reports using archived data in graphical format. Appendix B shows examples of such data analysis reports.

5.5 Security

The Contractor shall meet the following security requirements.

- The Contractor shall secure physical equipment in field with a padlock and secure software access to field devices with a high-level password.
- The SWZ operator control functions shall be high-level password protected.

- The Project SWZ website shall allow password-protected project staff to manually override the automated messaging in order to display a message at any time.

5.6 Maintenance and Evaluation

The Contractor is responsible for maintenance of SWZ for the duration of construction. Maintenance activities may include snow and ice removal from solar panels, maintaining batteries charged, repositioning or calibration of field equipment as needed, etc.

Data collected in work zones during construction can be used to evaluate SWZ operational performance and work zone traffic performance. When SWZ fails to meet the operational performance limits set in the contract documents, the Contractor may incur loss of payment based on terms laid out in the specifications / contract document. Evaluation of SWZ performance could also include measurement of work zone traffic performance such as number of incidents in work zone, maximum queue length, the number of lanes to remain open, maximum traveler delay, etc.

Periodic Work Zone Traffic Performance Report:

The Contractor shall generate and submit to the Engineer a periodic work zone traffic performance report, utilizing the data collected with SWZ. Short term traffic performance reports shall be submitted as part of periodic construction progress meetings. The report shall include the following:

- Periodic work zone traffic data in graphical format (plot as applicable, dependent on SWZ application selected). **The data should be submitted monthly in the Work Zone Data Exchange format provided by FHWA for all the following fields except the speed trailers, which should be submitted weekly.**
    - Per Location – Sensor - Traffic Speed: Plot average traffic speed in 15-minute intervals with threshold of 45mph marked horizontally. The 85th percentile speed serves as a guide to set and adjust the posted speed limit for a roadway. Additionally, this data can be compared against historical speed data for that roadway.
    - Project Segment – Traffic Volume: Plot average traffic volume in 15-minute intervals. A minimum of four 15-minute intervals should be used. Additionally, this data can be compared against historical traffic volume for that roadway.
    - Project Segment - Travel Time: Plot average travel time in 15-minute intervals. Additionally, this data can be compared against historical travel time for that roadway.
    - Project Segment - Delay: Plot average delay in 15-minute intervals.
    - Project Segment - Queue Length: Plot average queue length in 15-minute intervals, if queue warning system is deployed. The 95th percentile queue is generally estimated for the period when traffic is stopped.
    - Project Segment – Number of Incidents: Plot number of incidents in 15-minute interval. Data for primary and secondary incidents (if any) shall be reported separately. This reporting is required for all SWZ applications.
    - Per Location (PCMS) – Message Logs: Submit a log of messages displayed on the PCMS and the time stamp at which the message was displayed. A short analysis and statement on accuracy of messages displayed shall be submitted along with the log, identifying any issues. If any issues (example: unexpected message such as “slow traffic” when there was no congestion reported at that

same time, inferred from low volume, etc.) are identified, the Contractor shall submit a plan of action to remedy the issue identified.

- Construction staging information for the reporting period. In the event of construction staging changes during the reporting period, the data for the two different staging plans shall be submitted separately.
- The report shall include a brief note describing any significant change in performance from prior period.
- Upon project completion as per the specifications for SWZ, the Contractor shall submit the full set of work zone data collected for the project. In addition to raw data set, the Contractor shall also include electronic copy of periodic reports and raw data for the period submitted to the department for archiving.

5.7 Removal

The Contractor is responsible for the removal of SWZ as part of removal of temporary traffic control. This should be coordinated with District and Division of Construction Operations. Division of Construction Operations or Office of Traffic could consider using the existing resources in field to gather useful post construction data prior to removal of SWZ. As per CTDOT requirements, the Contractor is required to complete CON 500 at the end of each project and the District emails the completed form to DCO. The SWZ Committee and the Highway Operations Center will be included in the CON-500 distribution list upon removal of a SWZ and project completion.

REFERENCES

1. *Work Zone Intelligent Transportation Systems Implementation Guide.* FHWA-HOP-014-008. Washington D.C.: Federal Highway Administration. January 2014.
2. Federal Highways Administration, U.S. Department of Transportation. *Manual on Uniform Traffic Control Devices*. 2009 Edition with Revisions 1, 2, and 3, July 2022.
3. Federal Highways Administration, U.S. Department of Transportation. Portable Changeable Message Sign Handbook. FHWA-RD-03-066.
4. New Hampshire Work Zone ITS Toolbox, Work Zone ITS Guideline for Smart Work Zone System Selection, 2011 Edition
5. Iowa DOT, Traffic Critical Projects Program 2019 Final Report.
6. CTDOT Specification for Waterbury and Bridgeport Fairfield PWZMS projects (used to development version 1 of SWZ guide).
7. CTDOT Specifications for SWZ projects.
8. Case study: Massachusetts Department of Transportation Technology Applications on the Callahan Tunnel Project.
9. Portable Work Zone Management Systems (ITS in Work Zones) Technology Review and Workshop Presentation: Background Material, IBI Group Memorandum dated August 22, 2016.
10. 2021 Stewardship & Oversight Implementation Manual, Federal Highway Administration and Connecticut Department of Transportation, October 2021.

APPENDIX A – SWZ Implementation Plan

Table A1: Mapping Between CTDOT SWZ Guidelines and FHWA WZ ITS Guidelines Six-Steps

FHWA WORK ZONE ITS GUIDELINES SIX-STEPS	CTDOT SWZ GUIDELINES	CTDOT UNIT
Step 1: Assessment of Needs	5.1 Design	Designer, Highway Operations, District, Construction, Traffic
Step 2: Concept Development and Feasibility		Designer, Highway Operations, District, Construction, Traffic
Step 3: Detailed System Planning and Design		Designer, Highway Operations, District, Construction, Traffic
Step 4: Procurement	5.2 Procurement	District, Construction, Contractor
Step 5: System Deployment	5.3 Deployment	District, Construction, Contractor
Step 6: System Operation, Maintenance and Evaluation	5.4 Operations and Data Collection 5.5 Security 5.6 Maintenance and Evaluation 5.7 Removal	Highway Operations, District, Construction, Contractor District, Construction, Contractor District, Construction, Contractor District, Construction, Contractor

PROCESS	ACTIONS IN EACH STAGE
Assess Needs of the Project	• As part of the preliminary engineering and once MPT methods have been established, the SWZ Determination Committee shall evaluate applicability of SWZ for the project.
Feasibility Review and Concept Development	• SWZ Determination Matrix is prepared by Design Engineer and submitted to SWZ Determination Committee for review at the 60% Design Phase of a project if deemed feasible by the matrix. • SWZ Determination Committee conducts a review and makes recommendations on use of SWZ and SWZ application types to be deployed and provides a special provision to the designer.
Detailed Planning and Design	• SWZ detailed plan is developed by the designer and included as part of TMP. TMP is reviewed as part of standard design review process. SWZ aspects are reviewed to ensure that SWZ objectives have been addressed. • Systems Engineering documentation for the SWZ project as per the latest version of CTDOT Systems Engineering Process Guide is developed.
Procurement	• Equipment is procured as items in project contract bid process. • Items for deployment, relocation, and operations are also included in the contract bid process.
System Deployment and Acceptance	• The Contractor deploys system under District oversight. • The Contractor is responsible for initial placement of equipment in work zones, calibration, testing, system demonstration and acceptance of system prior to commencement of construction activity.
System Operation	• The Contractor is responsible for operations, including maintaining security.
Maintenance	• The Contractor maintains equipment and websites as defined in the contract documents.
Data Collection	• Automated system collects field data and archives. • The Contractor has responsibility to collect and generate periodic work zone traffic performance reports for submittal to CTDOT.

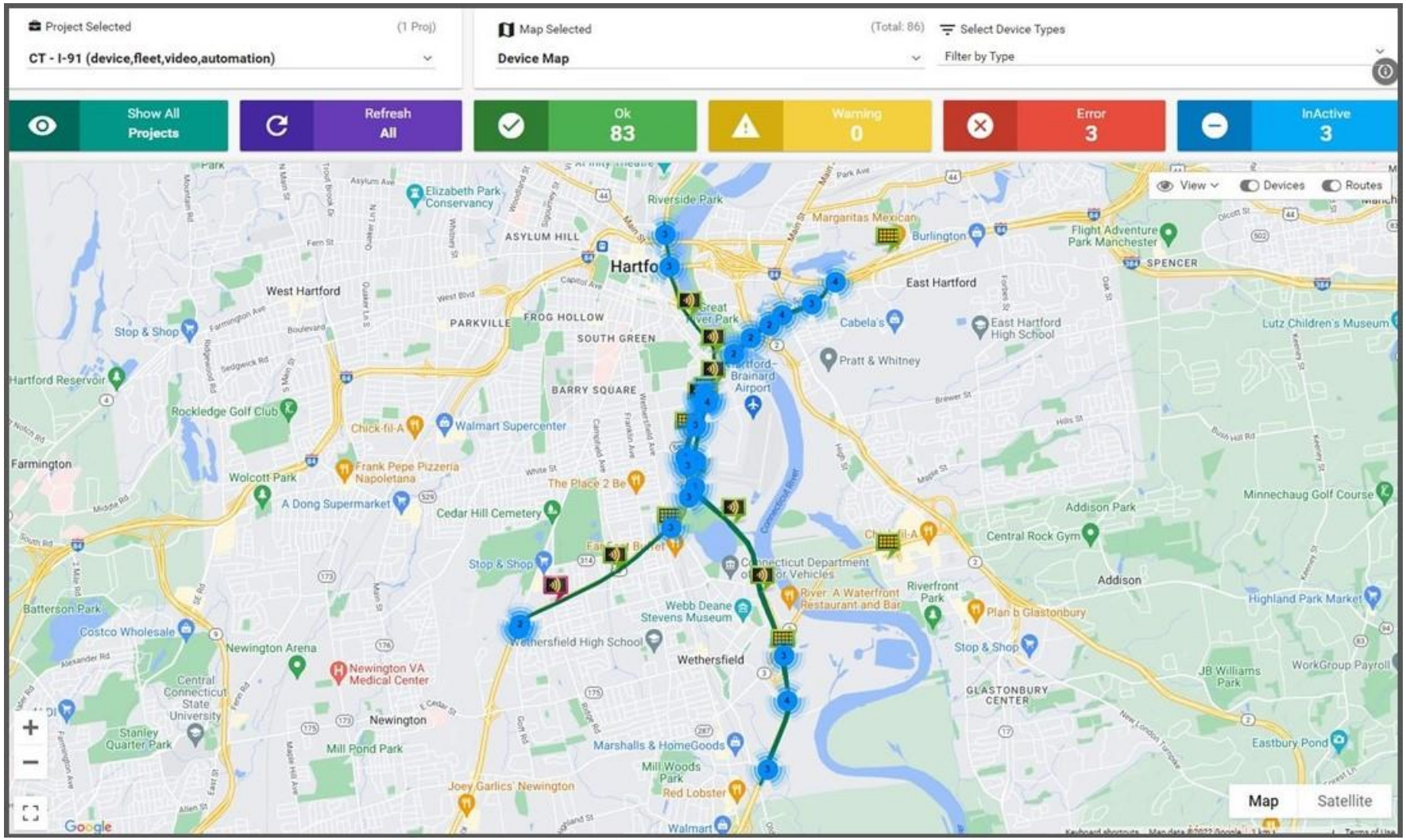
Appendix B – Data Analysis Examples

SWZ systems collect data in real-time and archives for the duration of SWZ deployment. Typically, the Contractor is not responsible for analysis and DOTs have required the Contractor to provide information in a specific format. As part of SWZ specifications, the Contractor is required to supply vendor software for the SWZ which includes data analysis and reporting functionality.

Many of the vendor provided software has ability to process and present the short-term/near-term and historical data in graphical format. Speed, volume, travel time information can be plotted graphically or presented in table format over a day/week/month/custom time frame. Additional reports such as number of times a particular type of message was posted on the PCMS, operational status of a sensor over a period of time can be generated from raw information. Comprehensive report using historical data with custom plots requires development of custom data analysis tools which is typically not covered under the scope of the Contactor's work.

This appendix contains sample screenshots from various SWZ software systems used by CTDOT that shows SWZ device locations, and performance data plots and reports that the systems can provide. These websites contain graphics with near real-time performance information displaying delay and queue length, speed heat map, sensor performance, volume, etc. CTDOT uses the plots and reports functions in these software systems to generate periodic reports and analyze work zone data.

Source: SALANDER Vendor SWZ Website SWZ Component Map Interface in Hartford, CT



Source: SALANDER Vendor SWZ Website List of SWZ Component Interface in Hartford CT

Project Selected (1 Proj)
CT - I-91 (device,fleet,video,automation)

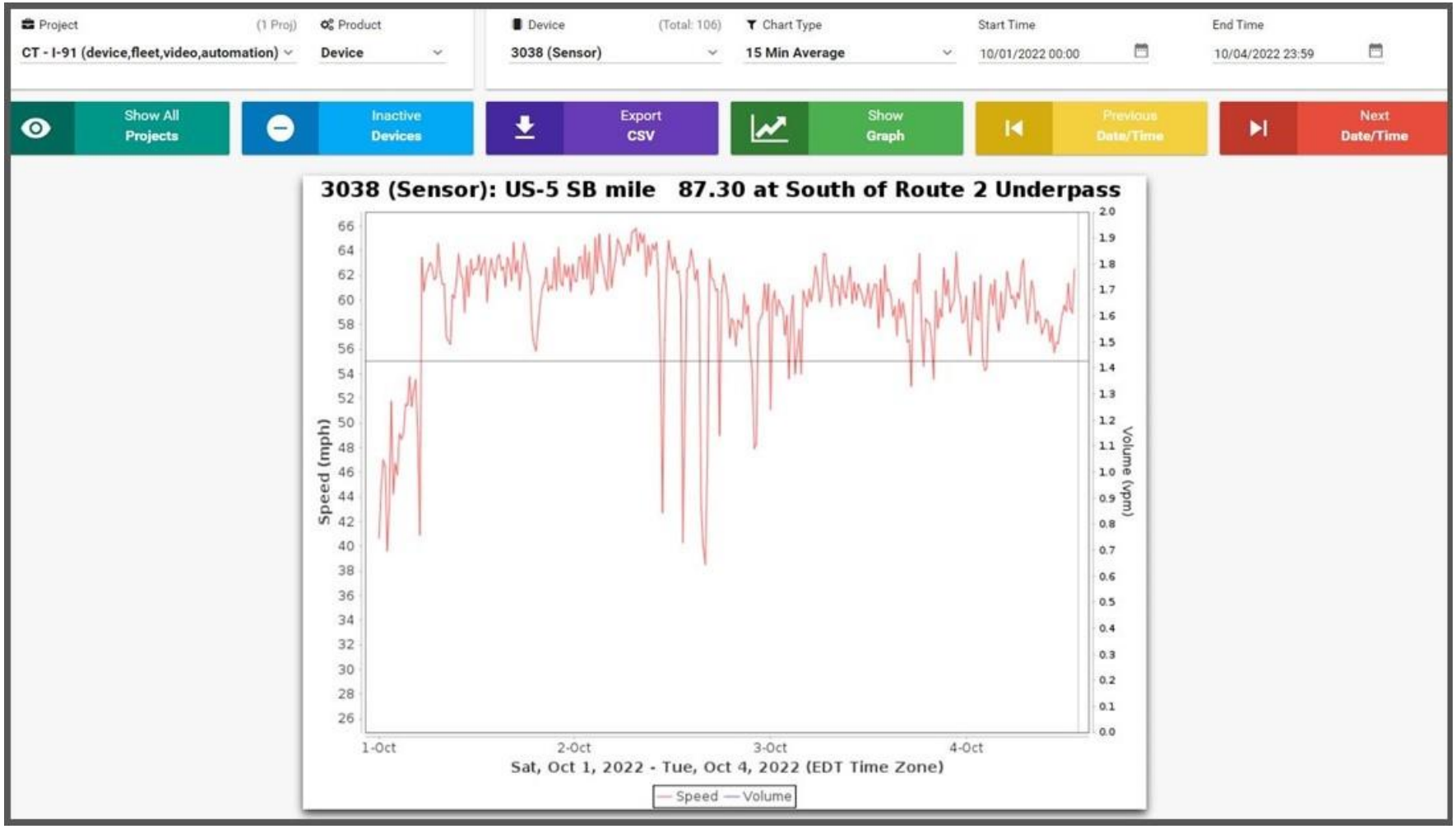
List Selected (Total: 86)
Device List

Select Device Types
Filter by Type

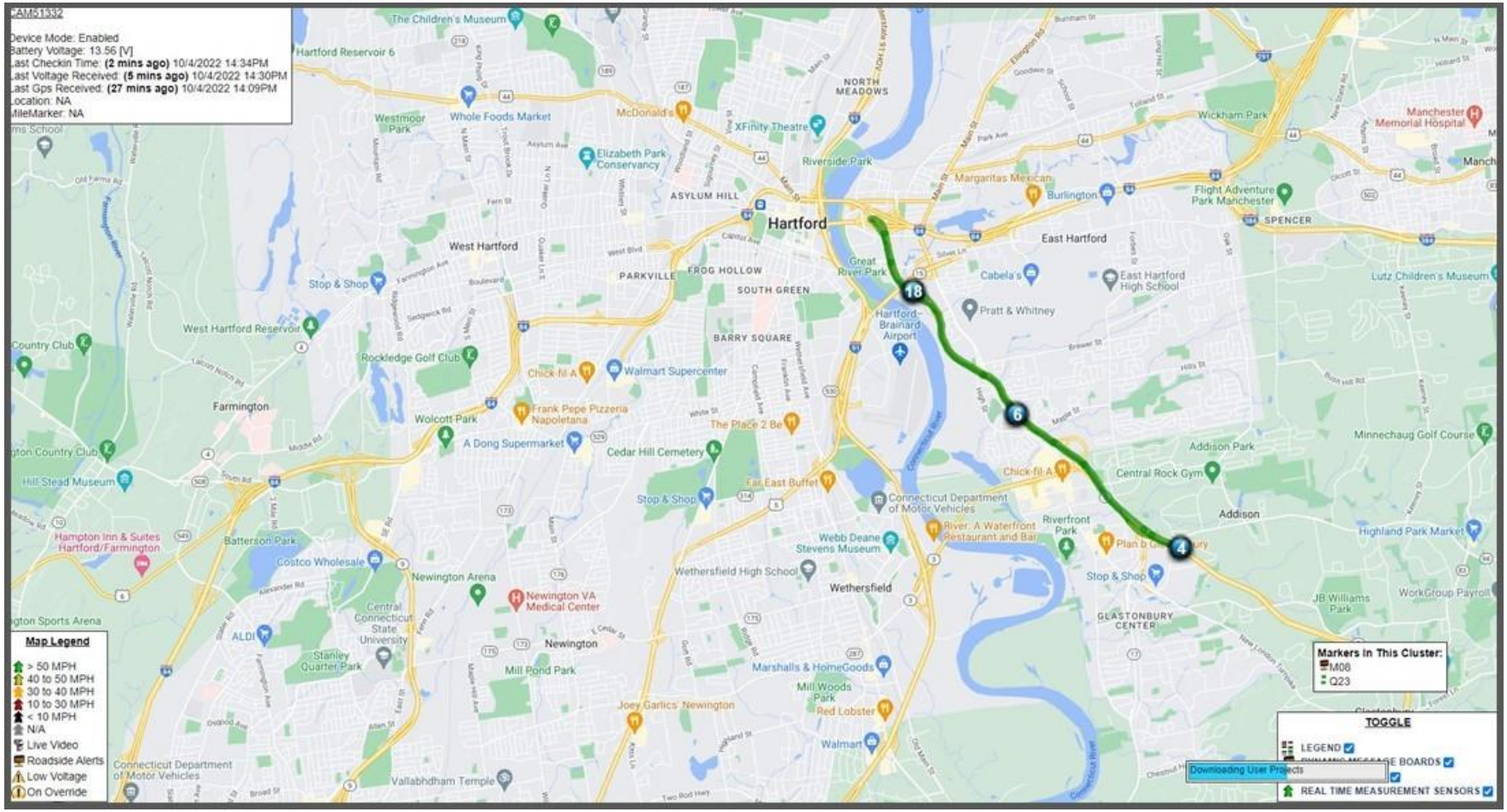
Show All Projects | Refresh All | Ok 82 | Warning 1 | Error 3 | InActive 3

Device	Location	Status	Device Info
SVMQ-1 (1-57-158) (Sign)	Brookside Ln at Roberts St in East Hartford	Ok	TO EXIT 25 RT 3 N
SVMQ-7 NB (Sensor)	I-91 NB mile 33.20 at at Exit 25S	Ok	65 mph
SVQS-2 NB (Sensor)	I-91 NB mile 33.60	Ok	70 mph
SVQS-2 (Camera)	I-91 NB mile 33.60 at EX 25/26	Ok	
SVMQ-2 (1-57-159) (Sign)	I-91 NB mile 33.60 at Exit 25	Ok	TO EXIT 27
2605 (Sensor)	I-91 NB mile 34.20 at Marsh St on ramp	Ok	65 mph
3000 (Sensor)	I-91 NB mile 35.00 at Wethersfield Cove	Ok	65 mph
SVQS-3 NB (Sensor)	I-91 NB mile 35.70	Ok	63 mph
SVMQ-3 (1-57-160) (Sign)	I-91 NB mile 35.70 at EX 27 Between On/Off Ramp	Ok	TO EXIT 29 RT15 COB
SVQS-3 (Camera)	I-91 NB mile 35.70 at EX 27 Between On/Off Ramp	Ok	
SVQS-4 (Camera)	I-91 NB mile 35.90	Ok	
SVQS-4 NB (Sensor)	I-91 NB mile 35.90	Ok	62 mph
SVQS-8 NB (Sensor)	I-91 NB mile 36.00	Ok	67 mph

Source: SALANDER Vendor SWZ Website Data Analysis Interface in Hartford CT

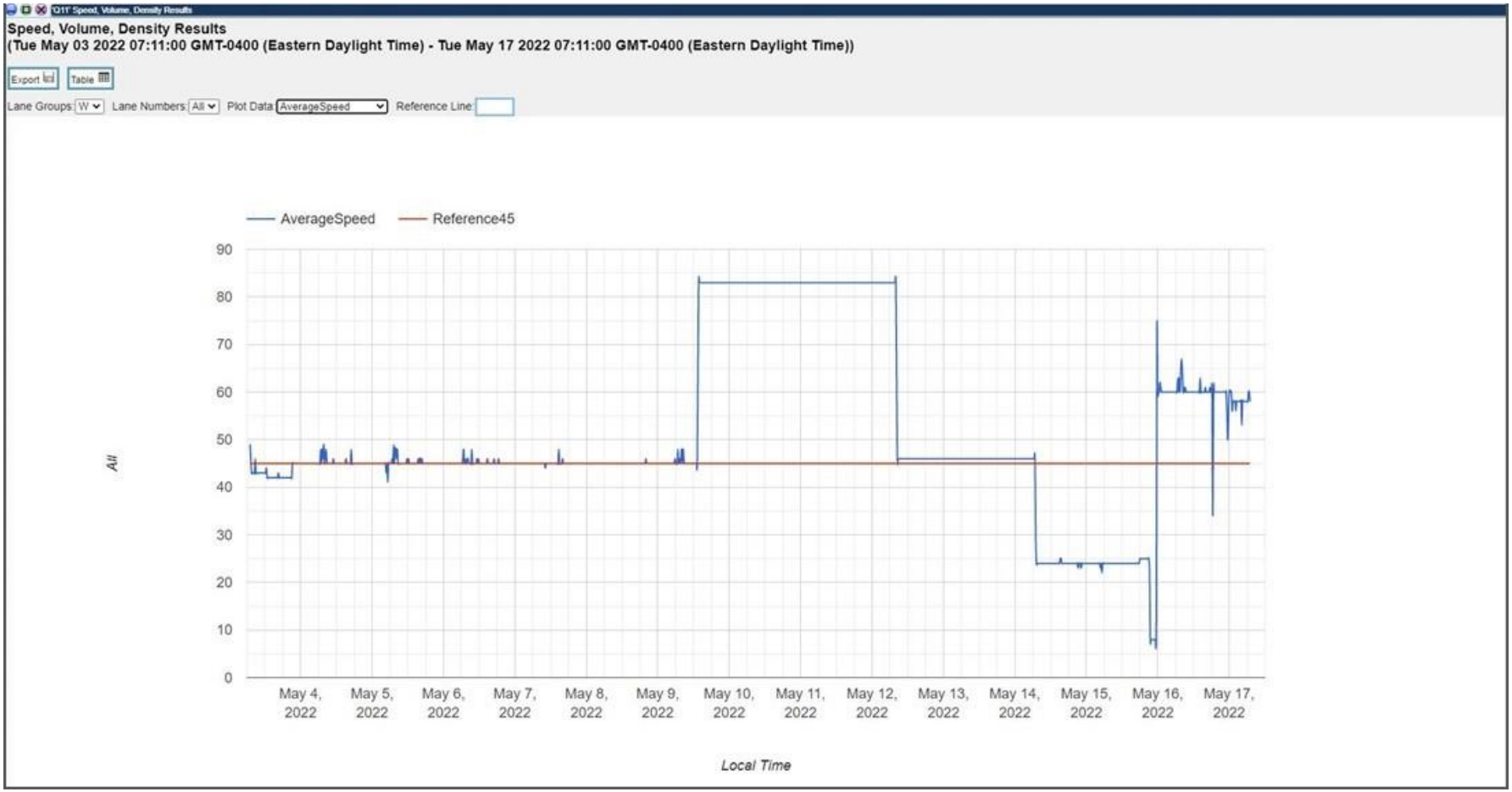


Source: ASTI Vendor - SWZ Website Map Interface in Hartford CT



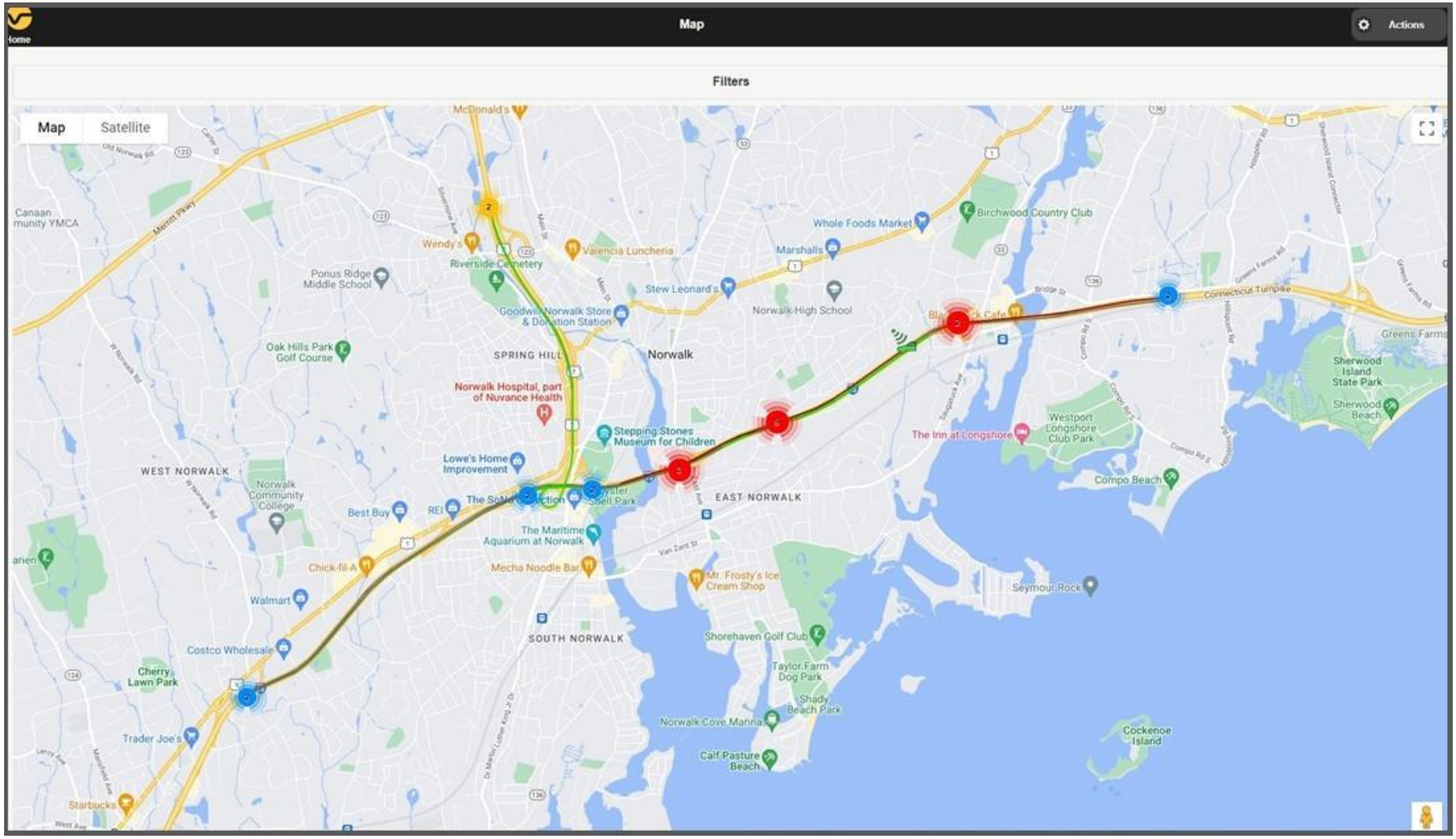
Source: ASTI Vendor - SWZ Website Data Analysis Interface in Hartford CT

Source: ASTI Vendor - SWZ Website Data Analysis Interface in Hartford CT

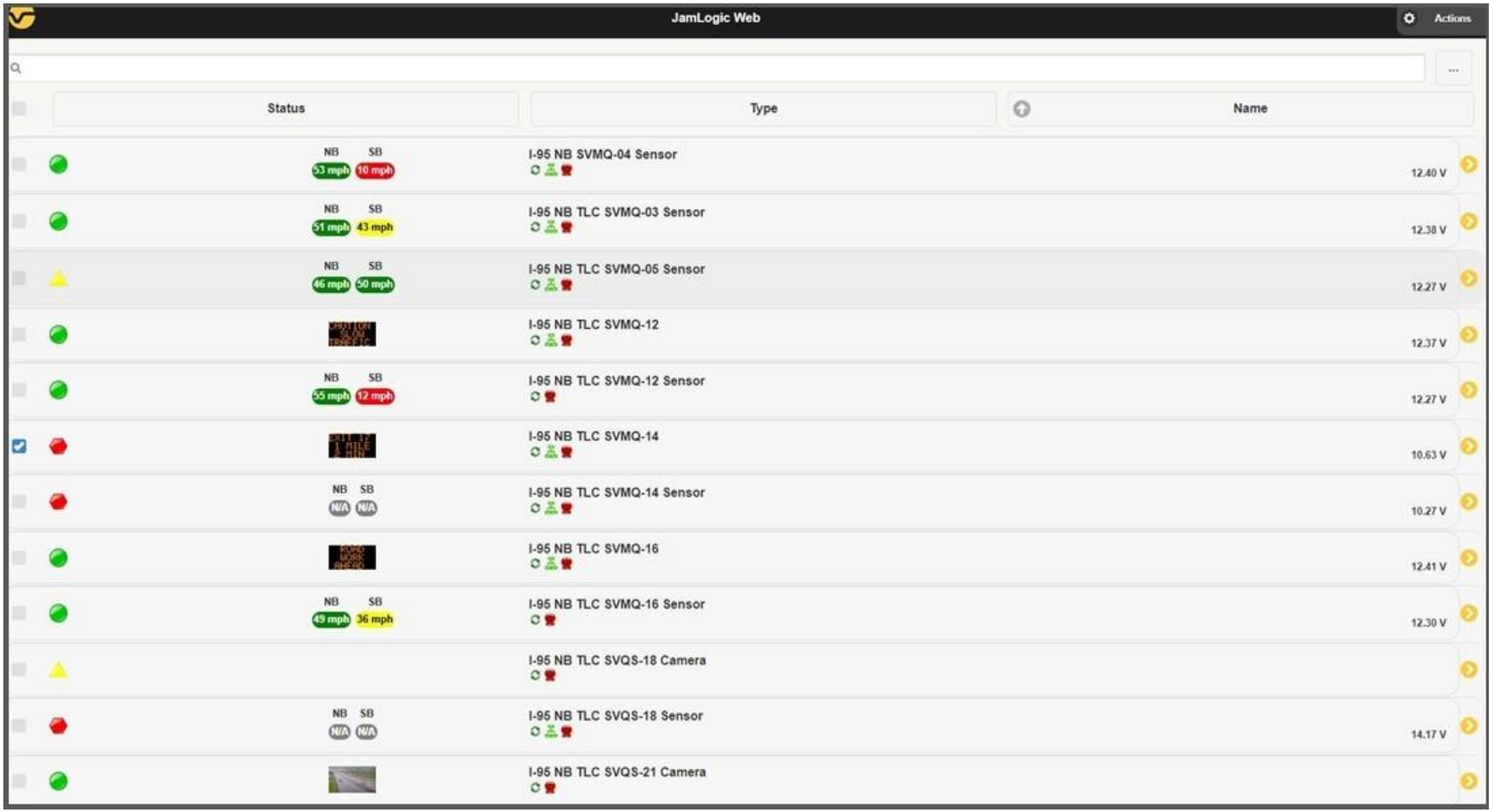


Source: ASTI Vendor - SWZ Website Data Analysis Interface in Hartford CT

Source: JamLogic Vendor - SWZ Website Map Interface in Westport CT



Source: JamLogic Vendor – SWZ Component Website Interface in Westport CT



Source: JamLogic Vendor - SWZ Website Data Analysis Interface in Westport CT