Smart Work Zone

Design Standards

Version 1.1

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX A

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
CCTV	Closed-circuit Television
CMO	Construction Management Outline
DOT	Department of Transportation
FHWA	Federal Highway Administration
GPS	Global Positioning System
HAR	Highway Advisory Radio
HMS	Hybrid Message Sign
IMP	ITS Monitoring Plan
ITS	Intelligent Transportation System
MassDOT	Massachusetts Department of Transportation
MUTCD	Manual on Uniform Traffic Control Devices
PCMS	Portable Changeable Message Sign
PIP	Public Informational Plan
PTS	Portable Queue Trailer
RFID	Radio-frequency Identification
SOP	Standard Operating Procedures
SWZ	Smart Work Zone
TMP	Traffic Management Plans
TTCP	Temporary Traffic Control Plan
USDOT	United States Department of Transportation
XML	Extensible Markup Language

Acknowledgement *– The Smart Work Zone Design Standards were developed by Kanaan Consulting US, Inc. in cooperation with the MassDOT Traffic and Safety Engineering Section.*

1. INTRODUCTION

Roadway construction can cause traffic delays and safety hazards. Agencies across the country are using portable Intelligent Transportation Systems (ITS) to monitor and improve work zone performance. These Smart Work Zones (SWZ) – collections of computer, communication, and sensor technologies – are used to alert road users about construction activities so that they can slow down and take alternate routes. Agencies also use SWZ to monitor traffic conditions for planning and oversight purposes.

The Massachusetts Department of Transportation (MassDOT) first deployed a SWZ to assist with the Sagamore Bridge construction project and provide motorist information on Route 6 westbound in 2009. MassDOT's first large-scale SWZ was utilized during the Interstate 93 Fast14 project in the summer of 2011. Based on the success of these deployments, MassDOT procured a set of SWZ equipment to deploy as needed during to assist the District Construction Offices with providing real-time information feedback to motorists. In addition, MassDOT began to include SWZ specifications in other accelerated construction projects where contractors were required to deploy them as part of the traffic management plan.

MassDOT's primary goal for the SWZs is to improve customer service. Experience with the Fast 14 and pilot installations in 2012 and 2013 have indicated that motorists are less likely to become aggravated when they are made aware of delays in travel time during construction. SWZs are the most efficient way to tell motorists about traffic conditions. The use of SWZs also allows MassDOT to collect large quantities of data about traffic conditions in and around work zones for internal planning and monitoring purposes.

Figure 1: Work Zone Traffic[1]

1.1 Purpose

This document provides guidance for designing SWZ layouts that are helpful to the public and capable of collecting the data that MassDOT needs to better evaluate and plan for future construction impacts. It is organized as follows:

- Section 1 provides background and context.
- Section 2 describes SWZs and what they do.
- Section 3 explains how to use SWZs at different types of projects.

[1] Photo by Tracy Scriba, FHWA (http://www.fhwa.dot.gov/publications/publicroads/07july/05.cfm)

- Section 4 includes detailed guidance for planning the layout of SWZ equipment.

The *Smart Work Zone Standard Operating Procedures*, a companion guide to this document, provides more detail to the contractor on the deployment and operation of a SWZ. *Figure 2* shows the process as described in the two documents.

Figure 2: Process for Designing and Operating SWZs at MassDOT

1.2 Background

1.2.1 Federal Highway Administration (FHWA)

In September 2004, the FHWA updated the *Work Zone Safety and Mobility Rule* 23 CFR 630 Subpart J. The Rule applies to all state and local governments that receive Federal-aid highway funding. This state and local transportation agencies were required to comply with the provisions of the Rule by October 12, 2007. The Rule identifies ITS as a work zone strategy to minimize construction impacts upon traffic flow.

FHWA has also made available a number of resources developed by the academia, and local and state agencies for implementing various types of ITS in work zones. Such resources can be accessed through FHWA's Work Zone Mobility and Safety Program website[2].

1.2.2 Massachusetts Department of Transportation (MassDOT)

In 2010, MassDOT developed the *Work Zone Transportation Management Procedures* to ensure compliance with the 2004 FHWA *Work Zone Safety and Mobility Rule* 23 CFR 630 Subpart J. The purpose of these procedures is to establish a clear and comprehensive process for evaluating and mitigating the impacts of construction work zones on the safety and mobility of both workers and the general public. The Procedures categorize projects into one of five impact levels using evaluation criteria, such as posted speed and impacts to the traffic among others. The highest impact levels (Levels 3, 4 and Significant Projects) as defined by MassDOT's *Work Zone Transportation Management Procedures* are required to develop an ITS Monitoring Plan (IMP) as part of the Traffic Management Plan (TMP) submission.

The level of effort that is required by the ITS Monitoring Plan (IMP) is dictated by the expected traffic impacts to normal operations on the roadway. In some instances the IMP may be as simple as the use of portable changeable message signs to reflect various shoulder and lane closure activity. For large traffic impact projects, designated by either Level 4 or "significant project status", MassDOT desires to use a full SWZ system to provide real-time information to the motorists travelling in and around the work zone.

In parallel to the Design Standards covered in this document, MassDOT has developed a Smart Work Zone Concepts of Operations (ConOps), which provides the high-level operational needs for the implementation of SWZs.

Figure 3 shows the sequence of policy and guidance documentation, from general overarching work-zone framework to project-specific detailed SWZ design and operation.

[2] http://www.ops.fhwa.dot.gov/wz/its/index.htm.

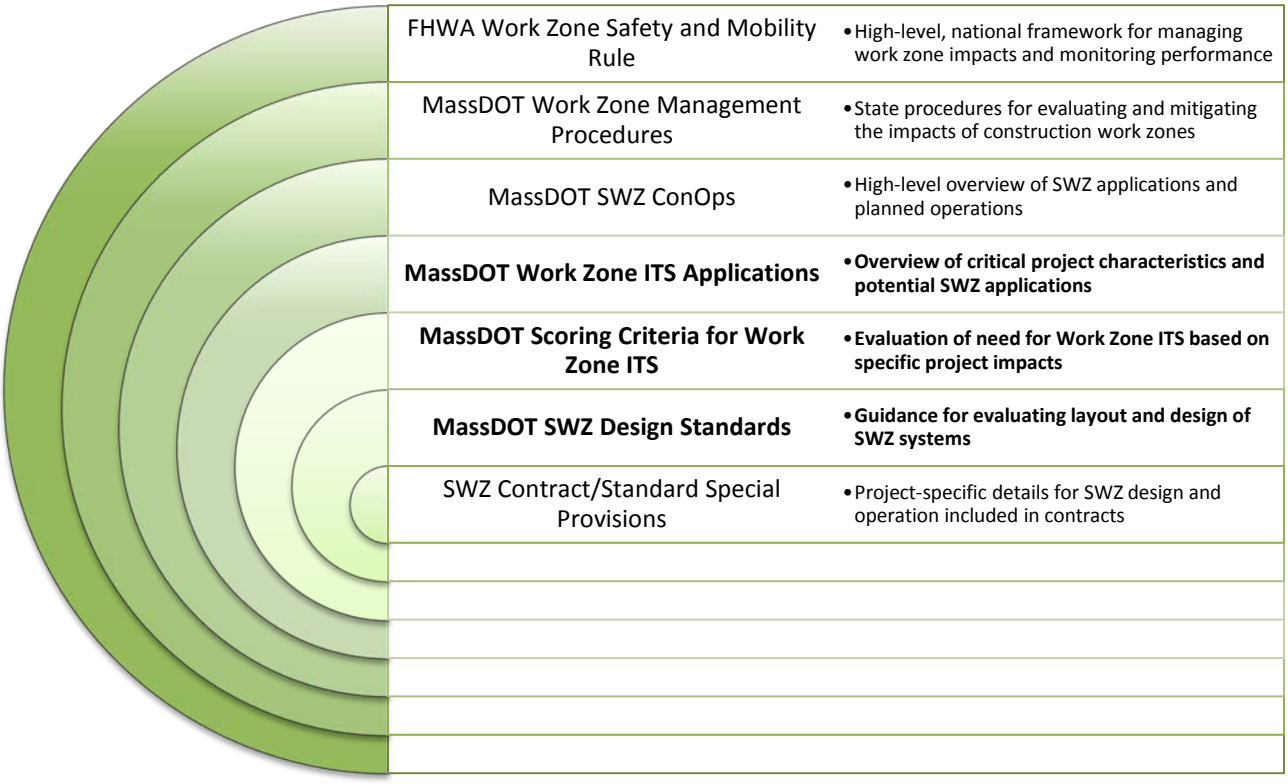


Figure 3: Context for MassDOT SWZ Design Standards

2. OVERVIEW OF SWZs

2.1 Typical Architecture

SWZs are portable combinations of equipment designed for flexible deployment in work zone environments. SWZs typically consist of four components:

- **Detection and surveillance equipment** that collect data and video near the work zone, and send them to the central processing system.
- **Central processing systems** that analyze, process, and store data. They also push messages to the public through signs and other dissemination outlets.
- **Dissemination outlets** on and off the road that make real-time information about work-zone conditions available to the public and MassDOT.
- **Ancillary systems** provide power to the equipment and communications between the components of the system.

Figure 4 shows a simplified SWZ system architecture and Section 4.2.2.4 describes SWZ components in more detail.

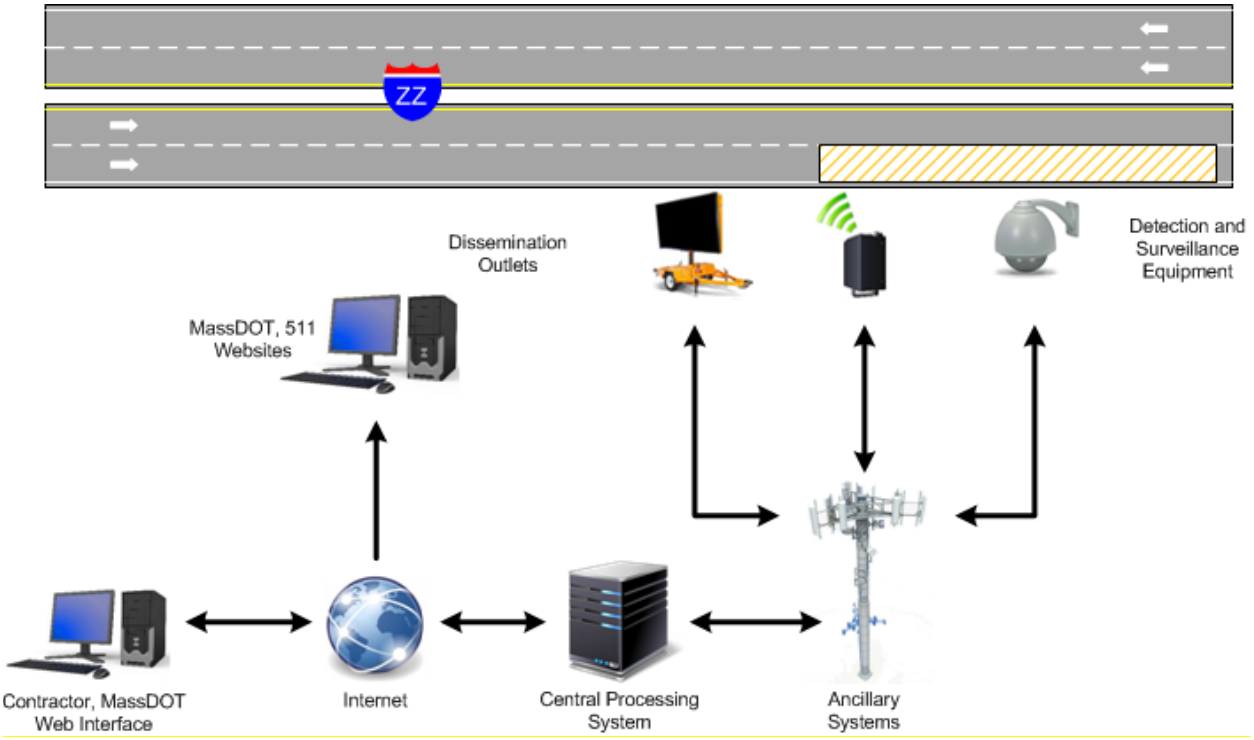


Figure 4: Typical Smart Work Zone Architecture

2.2 Assessment for Smart Work Zone Need

The SWZ systems displayed in *Figure 4* can be used for a variety of applications, depending on what an agency would like to achieve with them.

- Mobility applications are used when traffic is congested around a work zone and the agency would like to help motorists go around it or plan accordingly.
- Safety applications are used when hazards are present that could cause incidents and the agency wants motorists to be aware so they can slow down or go around.
- Planning and monitoring applications are used when an agency wants work zone data for internal operations purposes.

These applications are described in the section that follows.

2.2.1 SWZ Mobility Applications

Mobility applications are used when traffic backs up. "Mobility" refers to SWZ's capability to ensure an efficient flow of traffic through the work zone, minimizing the congestion in the work zone through the reduction of traffic and/or the increase of the road capacity around the work zone. *Table 1* presents the SWZ mobility applications and Appendix A provides further detail on design standards.

Table 1: SWZ Mobility Applications

Application	Description	Benefits
Driver Alerts	Provision of simple messages notifying motorists of upcoming construction via electronic signs or other dissemination outlets.	• Drivers can plan ahead if they are notified of construction before they begin their trips or early-on during trips, which avoids frustration. • Drivers can slow down and be aware when en-route, which reduces possibility of incidents.
Travel Time and Delay Estimation	Provision of travel times and/or delay through the work zone via electronic signs or other dissemination outlets.	• Drivers know how long they will wait so they feel less frustrated. • Drivers may change routes, which relieves congestion.
Alternate Route Advisory	Provision of travel times through the work zone AND alternate routes via electronic signs or other dissemination outlets.	• Drivers know how long they will wait so they feel less frustrated. • Drivers may change routes, which relieves congestion.
Dynamic Lane Merge	Use of electronic signs to direct motorists to use all open lanes up to a metered merge point rather than merging early and causing upstream queuing.	• Road capacity is increased and aggressive merge behavior is reduced.

2.2.2 Safety Applications

Safety applications are used when hazards are present that could cause incidents. Safety refers to the SWZ's capability to minimize the number and severity of traffic-related incidents, injuries and fatalities, and asset damage in the work zone. Safety strategies are intended to maximize driver alertness and minimize surprise elements and sudden braking. *Table 2* presents the SWZ mobility applications and Appendix A provides further detail on design standards.

Table 2: SWZ Safety Applications

Application	Description	Benefits
Congestion (Queue) Warning	Warning to motorists upstream of the work zone to slow down when there is stopped or slow traffic ahead.	• Drivers can decelerate safely and gradually, which reduces risk of collision. • Drivers may decide to change routes, which relieves congestion.
Excessive Speed Warning	Warning to motorists when they are approaching the work zone at unsafe speeds	• Drivers can decelerate safely and gradually, which reduces risk of collision.
Vehicle Warning	Warning to motorists about construction vehicles merging into, entering, exiting, or crossing the roadway.	• Drivers can react appropriately, such as slowing down or changing lanes.
Clearance Warning	Warning to motorists about construction-related weight, height, or width restrictions.	• Oversize vehicles change routes, which avoid incidents in the work zone.
Hazardous Condition Warning	Warning to motorists about temporary hazardous situations such as flooding, standing water, low visibility, etc.	• Drivers can slow down. • Drivers may decide to change routes, which relieves congestion and reduces risk of incident.
Intrusion Warning	Warning to motorists and workers when an unauthorized vehicle has entered a restricted work area.	• Drivers can react appropriately and exit the work zone. • Workers and managers are notified of the entry, allowing them to respond quickly.
Enforcement	Identification of speeding drivers using License Plate Recognition technology in combination with other sensors.	• Drivers are discouraged from speeding. *This is currently not legal for use in Massachusetts.

2.2.3 Planning & Monitoring Applications

Planning and monitoring applications are used when agencies want to collect data about the work zone. SWZ data is used to develop performance reports, allocate enforcement patrols, refine guidance for allowable working hours, and ultimately deliver capital improvements more safety and efficiently. *Table 3* describes some applications and their benefits.

Table 3: SWZ Planning & Monitoring Applications

Application	Description	Benefits
Video Surveillance	Provision of real-time video, preferably online, for remote monitoring.	• Can be used to look at worksites from offsite to confirm issues and determine if interventions are required.
Traffic Data Collection	Collection of average speeds and volume data for performance measurement.	• Used for internal performance measurements and reporting to FHWA. • Used to estimate capacity of the work zone. • Helps understand traffic flow to inform work zone policy and planning for future projects.
Travel Time Data Collection	Collection of travel times and estimation of delay through the work zone for performance measurement.	• Used for internal performance measurements and reporting to FHWA • Used to monitor traffic levels and determine if interventions are required. • Helps understand traffic flow to inform work zone policy and planning for future projects.

2.2.4 Work Zone ITS Application Characteristics

To help assist the designer with the evaluation of the appropriate SWZ needs, MassDOT provides a matrix that outlines the critical project characteristics for use in selecting potential portable work zone ITS applications. The matrix is provided in **Appendix A, Exhibit 1**.

2.3 SWZ Components

SWZs are comprised of the four components described in section 2.1 -- detection and surveillance equipment, central processing systems, dissemination outlets, and ancillary systems. Within each of these categories, the specific technologies used depend on which applications the agency or contractor would like to provide. In some cases, the same set of technology can be used to provide several functions. The following section describes SWZ system components in more detail and shows which components are necessary to deploy the applications described in the previous section.

2.3.1 Detection and Surveillance Equipment

Detection and surveillance equipment are installed in the field to collect information about the work zone environment. *Table 4* presents common technologies used in SWZs with the data that they can collect. The detection and surveillance equipment are the "eyes and ears" of the smart work zone system. They must be placed intentionally, calibrated carefully, and operated reliably so that they collect accurate data for input to the processing systems.

Table 4: Detection and Surveillance Equipment Used in SWZs

Detection Equipment	Description	Data That Can Be Collected
Traffic Sensors[3]	Non-intrusive devices placed on or around the roadway to detect vehicles passing.	Volume, Speed*, Occupancy*,Classification*, Weight*, Motion*
Video cameras	Portable pan-tilt-zoom video cameras mounted temporarily on fixed structure or trailers to view an area of interest in real-time.	Volume, Images, Incidents, Motion, Occupancy, Speed
Short-Range Transmitter Receiver Systems[4]	Receivers mounted near the road that detect compatible transmitters in vehicles passing by.	Speed, Travel Time, Identification of Authorized Construction Vehicles (e.g. for entry)
Vehicle Probes	Instrumented vehicles on the roadway that provide information about location and speeds, usually through Global Positioning System (GPS).	Speed, Travel Time
Environmental	Non-intrusive sensors on or near the road designed to detect temperature, humidity, precipitation, and/or other environmental data.	Weather data, Road conditions

*Availability depends on specific technology chosen

[3] There are many different technologies, including Radar, Microwave, Pneumatic Road Tubes, Infrared, Acoustical, Ultrasonic, Magnetic, and Piezo-electric. Radar and Microwave are the most common at MassDOT.

[4] There are many different technologies. Radio Frequency Identification (RFID) and Bluetooth technology are the most common at MassDOT.

Radar and microwave are the most commonly used detection technologies at MassDOT. *Figure 5* shows examples of each.

Figure 5: Portable Traffic Sensor (PTS) (microwave) and an iCone® (radar)

Figure 6 presents examples of Portable Video Cameras (PVC) commonly used in SWZ as surveillance devices.

Figure 6: Portable Video Camera (PVC)

Table 5 shows the data requirements and commonly used detection/surveillance equipment for each application presented in this document.

Table 5: Data Requirements in SWZ Applications

			Availability of Required Data from Detection/Surveillance Equipment				
	Application	**Data Requirements**	**Traffic Sensors**	**Video cameras**	**Short-Range Transmitter Receiver Systems**	**Vehicle Probes**	**Environ-mental Sensors**
Mobility Applications	**Driver Alerts**	• No Data	-	-	-	-	-
	Travel Time and Delay Estimation	• Travel Time or Speed	✓	S	✓	S	-
	Alternate Route Advisory	• Travel Time or Speed	✓	S	✓	S	-
	Dynamic Lane Merge	• Speed • Occupancy	✓	S	✓	-	-
Safety Applications	**Congestion (Queue) Warning**	• Speed • Occupancy	✓	S	✓	-	-
	Excessive Speed Warning	• Speed	✓	S	-	-	-
	Vehicle Warning	• Motion or Identification	✓	S	✓	-	-
	Clearance Warning	• Classification • Weight • Motion	✓	S	-	-	-
	Hazardous Condition Warning	• Weather • Road Conditions	-	✓	-	-	✓
	Intrusion Warning	• Motion or Identification	✓	S	✓	-	-
	Enforcement	• Speed • License Plate Recognition or Photo	✓	✓	-	-	-
Planning & Monitoring Applications	**Video Surveillance**	• Video	-	✓	-	-	-
	Traffic Data Collection	• Speed, Volume, Occupancy, Classification, Queues	✓	S	✓	S	-
	Travel Time Data Collection	• Travel Time	S	S	✓	✓	-

✓= All or most equipment provide required data; most commonly used equipment.

S = Some systems provide required data; special central processing analytics are required.

2.3.2 Central Processing System

The central processing system is a collection of computers that is used to control and monitor field devices. It hosts the software for processing and storing data. It is typically located off-site even if some basic processing is carried out onsite within devices.

The central processing system is the "brain" behind the SWZ system and take substantial time, effort, and expense to develop. The central system requires quality input data from the detection and surveillance equipment in order to develop quality output data that will be disseminated to the public.

2.3.3 Information Dissemination System

Dissemination outlets are used to push messages to the public and MassDOT. They are the "mouth" of the SWZ system. *Table 6* shows the most common devices and systems, both on-site and off-site. Off-site dissemination systems are designed to push messages to drivers before they depart so that the can plan accordingly.

Table 6: Information Dissemination Devices/Systems Used in SWZs

Location	Device/System	Description
On-site	**Portable Changeable Message Sign (PCMS)**	Electronic signs used to display traffic conditions, travel times, incident information, and advisory messages.
	Hybrid Message Sign (HMS)	Static signs with a fixed legend and two-character electronic insert for the provision of travel times.
	Highway Advisory Radio (HAR)	Broadcasting of travel information in low band, AM frequencies, typically used in conjunction with a static signs or PCMS that tells drivers which frequency to turn to.
	Audible alarms	Acoustic alerts as a complement of visual devices for specific needs (e.g. work zone intrusion).
Off-site	**Websites and Smartphone Applications**	Publication of travel information on MassDOT, 511, and third-party websites/Smartphone Apps for pre-trip planning purposes. They may provide detailed information on speeds, delays, congestion alternate routes, PCMS messages, video images, and contractor schedules.
	SMS text messaging systems	Alerts and updates on traffic conditions sent to mobile phones of drivers and construction and MassDOT personnel.
	511 Telephone System	Travel information may be relayed to Mass 511 operator to be consulted by drivers.

Figure 7 shows two examples of a dissemination device used by MassDOT. They must be located intentionally and operated reliably, as they are the means through which motorists will view the system. If they do not work reliably, the motorists quickly lose interest or begin to not trust the information displayed.

Figure 7: Portable Changeable Message Sign (PCMS) and Hybrid Message Sign (HMS)

Table 7 shows the commonly used information dissemination equipment/systems for each application presented in this document.

Table 7: Dissemination Devices in SWZ Applications

		Applicability of Dissemination Devices to Applications						
	Application	**PCMS**	**HMS**	**HAR**	**Audible Alarms**	**Websites and Smartphone Applications**	**SMS Alerts**	**511**
Mobility Applications	Driver Alerts	✓	S	S	-	-	-	-
	Travel Time and Delay Estimation	✓	✓	S	-	✓	✓	✓
	Alternate Route Advisory	✓	✓	S	-	✓	✓	✓
	Dynamic Lane Merge (*Early Merge or Late Merge Options*)	✓	-	S	-	-	-	-
Safety Applications	Congestion (Queue) Warning	✓	-	S	-	✓	✓	✓
	Excessive Speed Warning	✓	✓	-	-	-	-	-
	Vehicle Warning	✓	-	-	✓	-	-	-
	Clearance Warning	✓	-	-	✓	S	S	S
	Hazardous Condition Warning	✓	-	S	-	✓	✓	S

		Applicability of Dissemination Devices to Applications						
	Application	**PCMS**	**HMS**	**HAR**	**Audible Alarms**	**Websites and Smartphone Applications**	**SMS Alerts**	**511**
Planning & Monitoring Applications	Intrusion Warning	✓	-	-	✓	-	✓*	-
	Enforcement	-	✓	S	-	-	✓*	-
	Video Surveillance	-	-	-	-	✓*	-	-
	Traffic Data Collection	✓	✓	S	-	✓*	✓*	-
	Travel Time Data Collection	✓	✓	S	-	✓*	✓*	S

* Internal only for MassDOT Staff
✓= Applicable in all or most cases; most commonly used equipment.
S = Applicable in some cases.

2.3.4 Ancillary Support Systems: Communications and power

Ancillary support systems like communications and power are the “backbone” for SWZs. Wireless communications is commonly used to exchange information between detection devices, the central processing system, and dissemination systems. On rare occasions, hard wired communications may also be used if physical connections are available in the work zone area.

Battery and solar power are typically the power choices for SWZ. As with communications, hard-wired power may be used if available in the area.

3. APPLICATION TO MASSDOT PROJECTS

MassDOT deploys SWZs for the benefit of motorists and for internal data collection purposes. SWZs can benefit any construction site, but it is not necessary or practical to deploy all SWZ functions on all jobs. To assist the designer in determining SWZ applicability for a particular project, MassDOT has provided a *Smart Work Zone Scoring Matrix* found in **Appendix A, Exhibit 2**. The following section suggests strategies for determining what types of functions to include in SWZ deployments in Massachusetts.

The *MassDOT Work Zone Transportation Management Procedures* establish that projects categorized at impact Levels 3 or 4, or Significant Project Status shall include an ITS Monitoring Plan (IMP) as part of the 75%, 100%, PS&E deliverables. The IMP can also be requested discretionally by the State Traffic Engineer for work zones outside of those levels. Suggested SWZ functions for each impact level are shown in the following table.

Table 8: SWZ Functions Based on Project Impact Levels

		Mobility Functions		Safety Functions	Planning & Monitoring Functions			
Project Impact	**Extent of ITS Coverage**	**Travel Time and Delay Notifications**	**Alternate Route Advisory**	**Congestion Warning**	**Video Surveillance**	**Site Traffic Data**	**Approach Traffic Data**	**Capacity Estimate**
Level 1 & 2	Work site	O	O	-	O	O	-	O
Level 3	Work site & vicinity	✓	✓	O	✓	✓	O	✓
Level 4 & Significant Projects	Work site, vicinity & approaches	✓	✓	✓	✓	✓	✓	✓

✓= Recommended for all, O = Recommended for some cases

In addition to the fixed suggestions for each type of project, additional SWZ equipment may be helpful if the work site has special characteristics or hazards that make it more susceptible to incidents. These are described in Table 9.

Table 9: Optional SWZ Functions Based on Hazards Present

Project Characteristics	Relevant SWZ Functions
There is a need to post information not easily conveyed by static signs, such as more than one message at the time or changeable messages according to time or traffic conditions.	**Driver Alerts**
Work zone must be established when expected traffic volumes will exceed MassDOT current average work zone capacity.	**Dynamic Lane Merge**
Any of the following situations within one mile downstream and/or upstream of the work zone: o Queue formation on tight curves or hills o Absence of buffer spaces and/or clear zones o Interaction with construction workers or police o Locations with speeding history	**Excessive Speed Warning**

Project Characteristics	Relevant SWZ Functions
More than five (5) construction vehicle merging, entering, exiting or crossing maneuvers per hour.	**Vehicle Warning**
Work zone's vertical and horizontal clearance, and weight limit are lower than the largest vehicle allowed in the original road. Also, when oversized vehicles are allowed to travel through the work zone.	**Clearance Warning**
The following conditions are expected: o Flooding or standing water o Low visibility (fog, solar or smoke) o Slippery or rough conditions o Hazards on roadway (falling rock, debris)	**Hazardous Condition Warning**
Construction traffic exits and entrances are difficult to identify, making other vehicles inadvertently follow trucks off the road. Also, where delineation between the road and restricted areas is not clear, or where protection buffers are not possible.	**Intrusion Warning**
More than 0.9 crashes per million vehicle miles traveled in the road segment between one mile upstream and one mile downstream from the work zone during the previous year.	**Enforcement**

4. LAYOUT & DESIGN GUIDELINES

The first step of SWZ design is determining the desired applications for the work zone and the equipment to be deployed, based on Sections 2 & 3. Then the layout of equipment can be designed according to the following steps:

4.1 Layout Guidelines

1. Map the location of the SWZ and vicinity.
2. Identify the following locations:
   - (a) Start of the work zone.
   - (b) End of the work zone.
   - (c) The location of merge/lane drop for closure.
   - (d) All approaches within 0.5 miles of the work activity.
   - (e) The upstream decision points nearest to the work activity (i.e. the closest viable locations where drivers could exit the highway and take a suitable alternate route before reaching the work zone).
   - (f) For Level 4 or Significant projects located on major highways or interstates, also identify any upstream intersections/interchanges with other major highways that could offer alternate routes.
   - (g) 1 point upstream of the bottleneck where traffic should be stable during most operating hours.
   - (h) 1 point downstream of the bottleneck where traffic should be stable during most operating hours.
3. Place required detection and surveillance equipment in the locations identified above as presented in *Table 10*.
4. Place PCMS as follows at the locations identified above, based on the functions to be included in the SWZ as presented in *Table 10*.

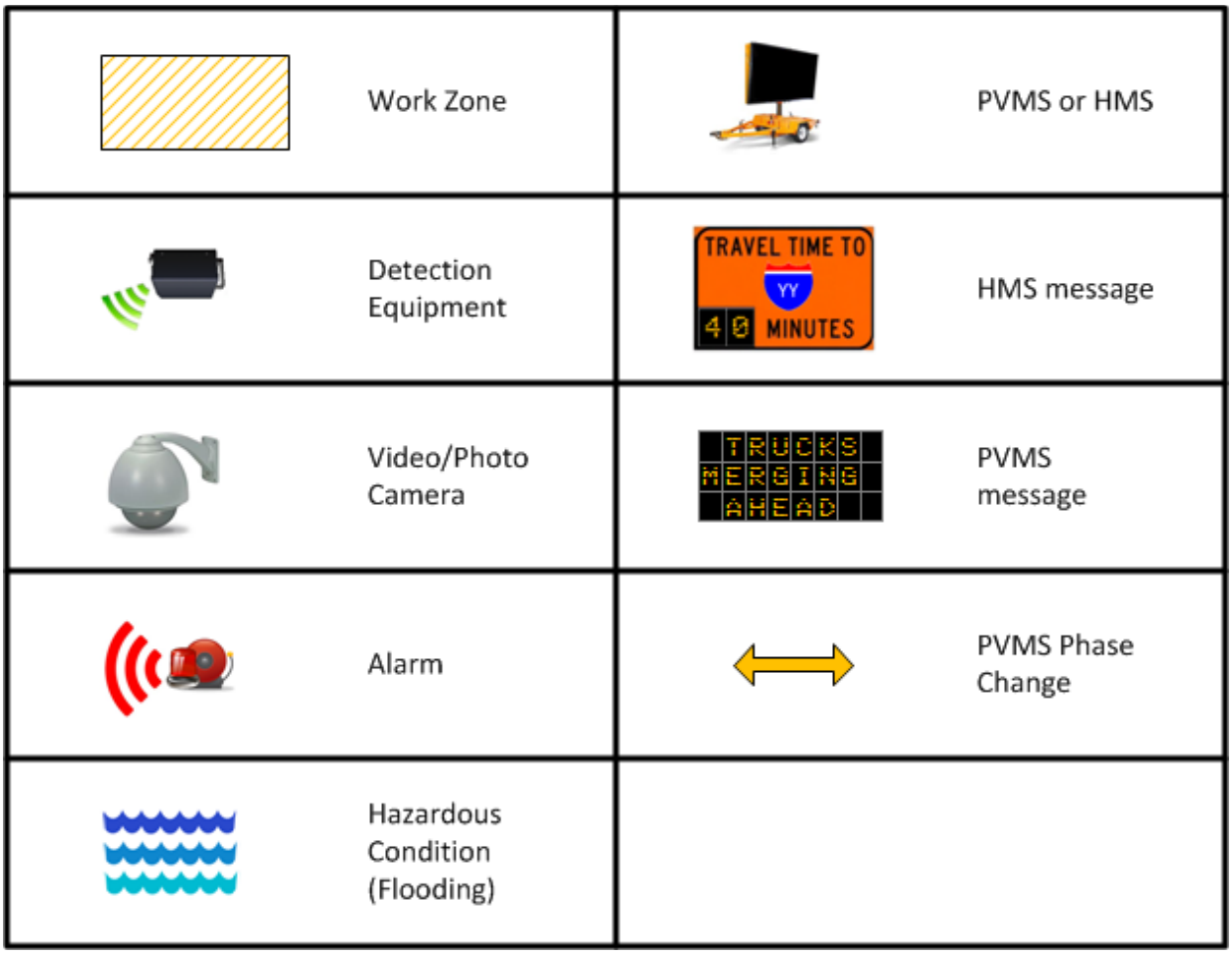
Table 10: Equipment Location

Device	Level 1 & 2	Level 3	Level 4 & Significant Project Status
Traffic detectors	(c) *	(c) (g) (h)	(c) (d) (g) (h)
Short-range receivers for travel time measurement	(a) * (b) *	(a) (b) (d) (e)	(a) (b) (d) (e) (f)
Cameras	(c) *	(a) (b) (c) (d)*	(a) (b) (c) (d)*(e)*(f)
Special detectors (e.g. hazardous conditions, intrusion warning)	Project-specific	Project-specific	Project-specific
PCMS/HMS	(a)* (d) *	(a) (d) (e) (g)	(a) (d) (e) (f) (g)

*** Optional**

Equipment should be placed according to its operating requirements and capabilities. In small work zones, some equipment (such as video) may be able to cover multiple locations. Additional design guidelines are provided in Section 4.2.

A sample diagram of a layout for Level 3, Level 4 and Significant Status projects are shown in *Figure 9* and *Figure 10*. These diagrams are intended as guidelines, so dimensions are not drawn to scale. Engineering judgment is required to customize the system to a specific project.



Note: Portable Variable Message Sign (PVMS) is synonymous with Portable Changeable Message Sign (PCMS)

Figure 8: Key for Layout Diagrams

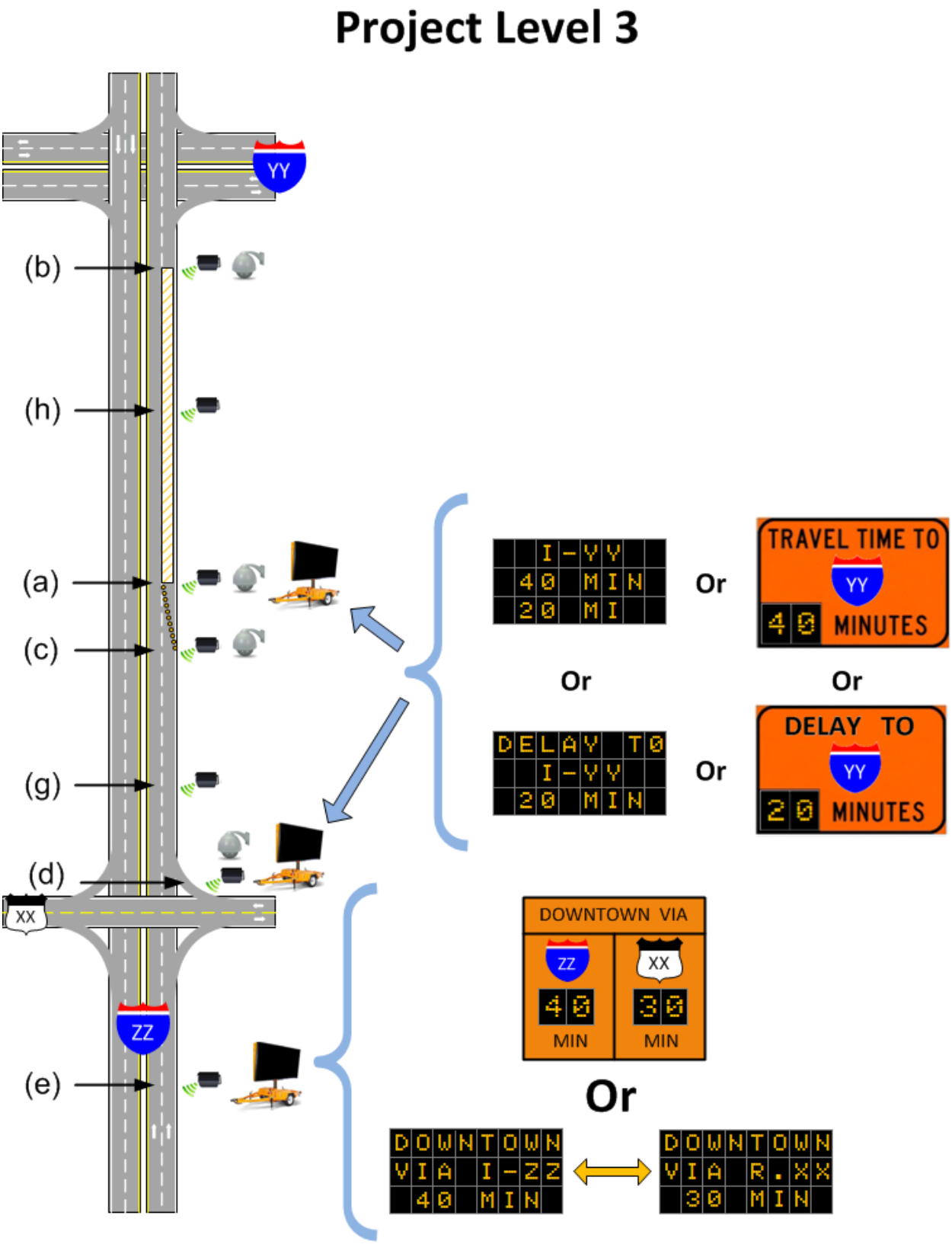


Figure 9: Typical SWZ setup for a Project Level 3

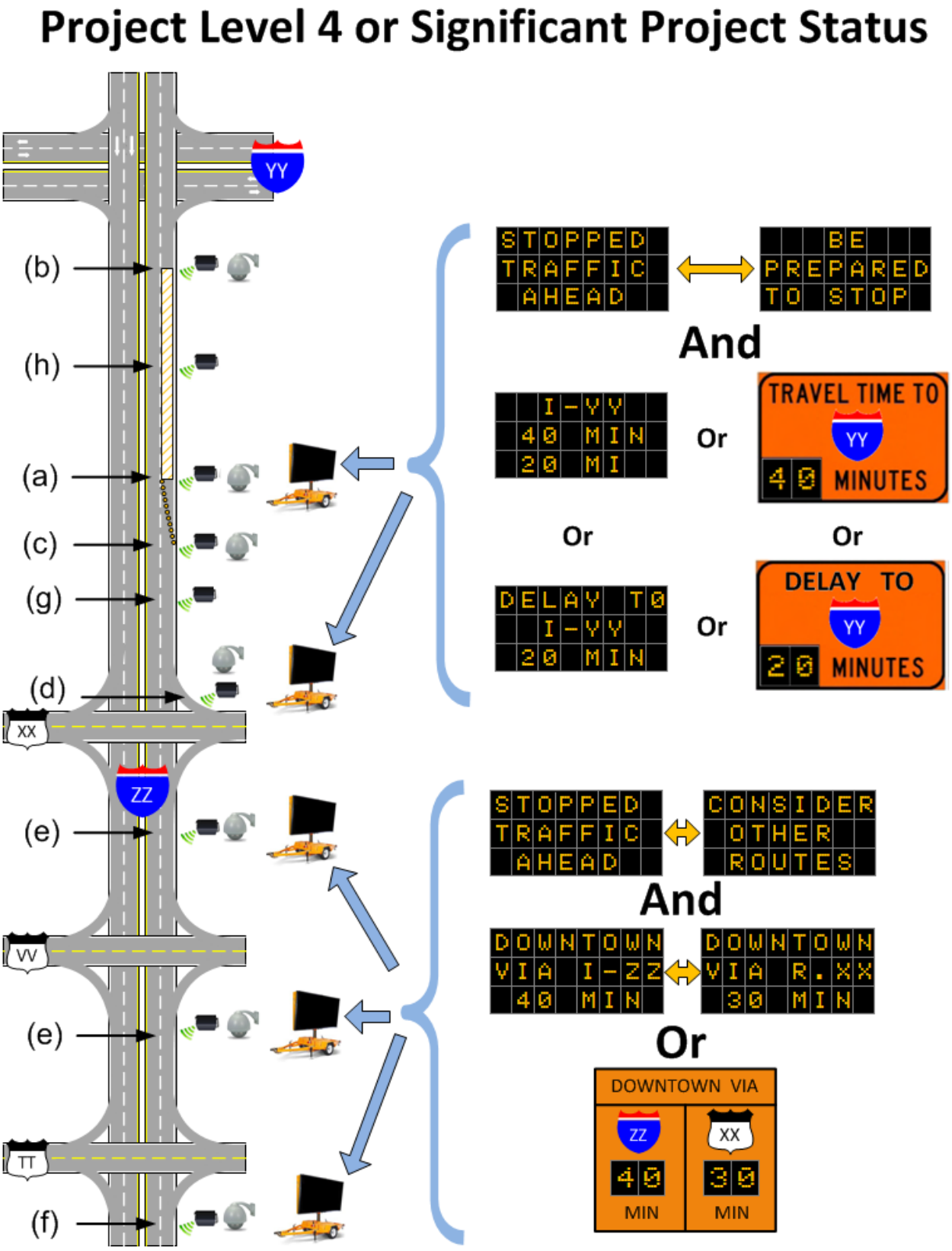


Figure 10: Typical SWZ setup for a Project Level 4 or Significant Project Status

4.2 Design Guidelines

4.2.1 General design guidelines

- Equipment should be located in accordance with manufacturers' guidance.
- Equipment must be placed outside the clear zone unless approved by MassDOT.
- Equipment should be protected by physical barriers (such as guardrails) where it is practical.
- Equipment should be placed in locations that are easy to move and access if necessary (e.g. near the end of guardrail).
- Equipment should not be placed where sight lines are blocked by other static signing on the roadside
- Equipment should be placed so as to not block existing static sign visibility
- Care should be taken to select locations for equipment that will provide adequate sunlight exposure to maximize solar power coverage.

4.2.2 Detection and Surveillance Equipment

- Place portable cameras in locations that provide good coverage of the location of interest, taking care to avoid blind spots, seasonal sun-blindness, and visual obstructions (bridges, overpasses, viaducts, foliage, buildings, etc.).
- When possible, place cameras on the outside of a highway curve because it provides better visual coverage.
- Consider travel patterns through and around the work zone when placing detectors, particularly those used for travel time. The presence of high occupancy vehicle (HOV) lanes and exits within the work zone will influence what drivers want to see on signs. For example, motorists may need differentiated data for HOV lanes or travel time to a popular exit rather than another end point. The presence of such features may also affect the data that is collected on the devices (e.g. faster traffic in an HOV lane or slower traffic in an exit lane may skew results). Sometimes such judgments can be made by reviewing the site; other times it may require additional traffic data.
- Place detectors in locations that maximize the coverage area and accuracy of collected data. The accuracy of detection equipment may be compromised by factors such as:
    - Orientation, distance, and height of the device with respect to the traffic
    - Spacing between devices
    - Extreme congestion with stop-and-go traffic conditions
    - Presence of obstructing structures such as bridges, median barriers, and signs

4.2.3 Dissemination Outlets

- Dissemination devices, such as PCMS and HMS, should not replace or block required static signs as stipulated by MUTCD and MassDOT regulations.

- MassDOT normally requires a minimum spacing between signs (static and electronic). If minimum spaces are not possible, it may be necessary to strategically co-locate signs or use one sign for multiple purposes.
- MassDOT will work with the contractor to address questions surrounding the field placement of SWZ equipment.
- PCMS and HMS should be placed in locations where motorists would find them useful, typically before major decision points (e.g. exits or intersections), with enough advance warning that motorists can safely change course. In some cases, this will require engineering judgment in lieu of detailed instructions.
- Review the location of the PCMS and HMS for conditions in the field, such as:
    - Shoulder (and clear zone)
    - Nature of embankment
    - Nature of the median
    - Line of sight
    - Ground slope
    - Avoiding impacting wetlands
    - Sunlight exposure for solar panels
    - Existing roadway signs and guardrail
    - Accessibility for maintenance

5. REFERENCES

5.1 Federal/State Laws and Code

- 23 CFR 630 Subpart J-- Work Zone Safety and Mobility Rule, FHWA
  http://www.ops.fhwa.dot.gov/wz/resources/final_rule.htm

- "Final Rule on Work Zone Safety and Mobility," Federal Highway Administration (FHWA), Effective Date October 12, 2007
  http:// www.ops.fhwa.dot.gov/wz/resources/final_rule.htm

- Manual on Uniform Traffic Control Devices (MUTCD), FHWA
  http://mutcd.fhwa.dot.gov/

- SAFETEA-LU section 1201, FHWA
  http://www.fhwa.dot.gov/safetealu/factsheets/realtimesmi.htm

- Best Practices in Project Delivery Management. NCHRP Domestic Scan Team Report 07-01, Project 20-68A. TRB, National Research Council, Washington, DC. October 2009.
  http://onlinepubs.trb.org/onlinepubs/nchrp/docs/nchrp20-68a_07-01.pdf

5.2 Design Guidance

- Work Zone Intelligent Transportation Systems Implementation Guide (FHWA) January 2014
  http://www.ops.fhwa.dot.gov/publications/fhwahop14008/

- ITS Safety and Mobility Solutions--Improving Travel Through America's Work Zones,
  http://www.atssa.com/galleries/defaultile/2008July21_ITS_Safety_and_Mobility.pdf

- MassHighway Standard Details and Drawings for the Development of Temporary Traffic Control Plans, MassDOT
  http://www.massdot.state.ma.us/portals/8/docs/flaggers/tcp.pdf

- AASHTO Guidelines For Traffic Data Program, USDOT https://bookstore.transportation.org/item_details.aspx?id=1392

5.3 Supplemental Documents

- ITS in Work Zones, FHWA www.ops.fhwa.dot.gov/wz/its/
- Work Zone Analysis Series, FHWA http://ops.fhwa.dot.gov/wz/traffic_analysis/techresources.htm

- Work Zone Performance Measures Pilot Test, FHWA http://www.ops.fhwa.dot.gov/wz/resources/publications/fhwahop11022/fhwahop11022.pdf

- A Primer On Work Zone Safety And Mobility Performance Measurement, FHWA http://www.ops.fhwa.dot.gov/wz/resources/publications/fhwahop11033/fhwahop11033.pdf
- Work Zone Operations Best Practices Guidebook, FHWA http://www.ops.fhwa.dot.gov/wz/practices/best/bestpractices.htm

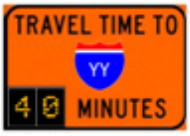
- Minnesota IWZ Toolbox, FHWA http://wwwcf.fhwa.dot.gov/exit.cfm?link=http://www.dot.state.mn.us/trafficeng/workzone/iwz/MN-IWZToolbox.pdf

- In Case Of Fire--Technology Helps Clear A Path For First Responders http://www.ops.fhwa.dot.gov/wz/resources/news/wznews_detail.asp?ID=479

APPENDIX A: TYPICAL SWZ SETUPS FOR SAFETY AND MOBILITY APPLICATIONS

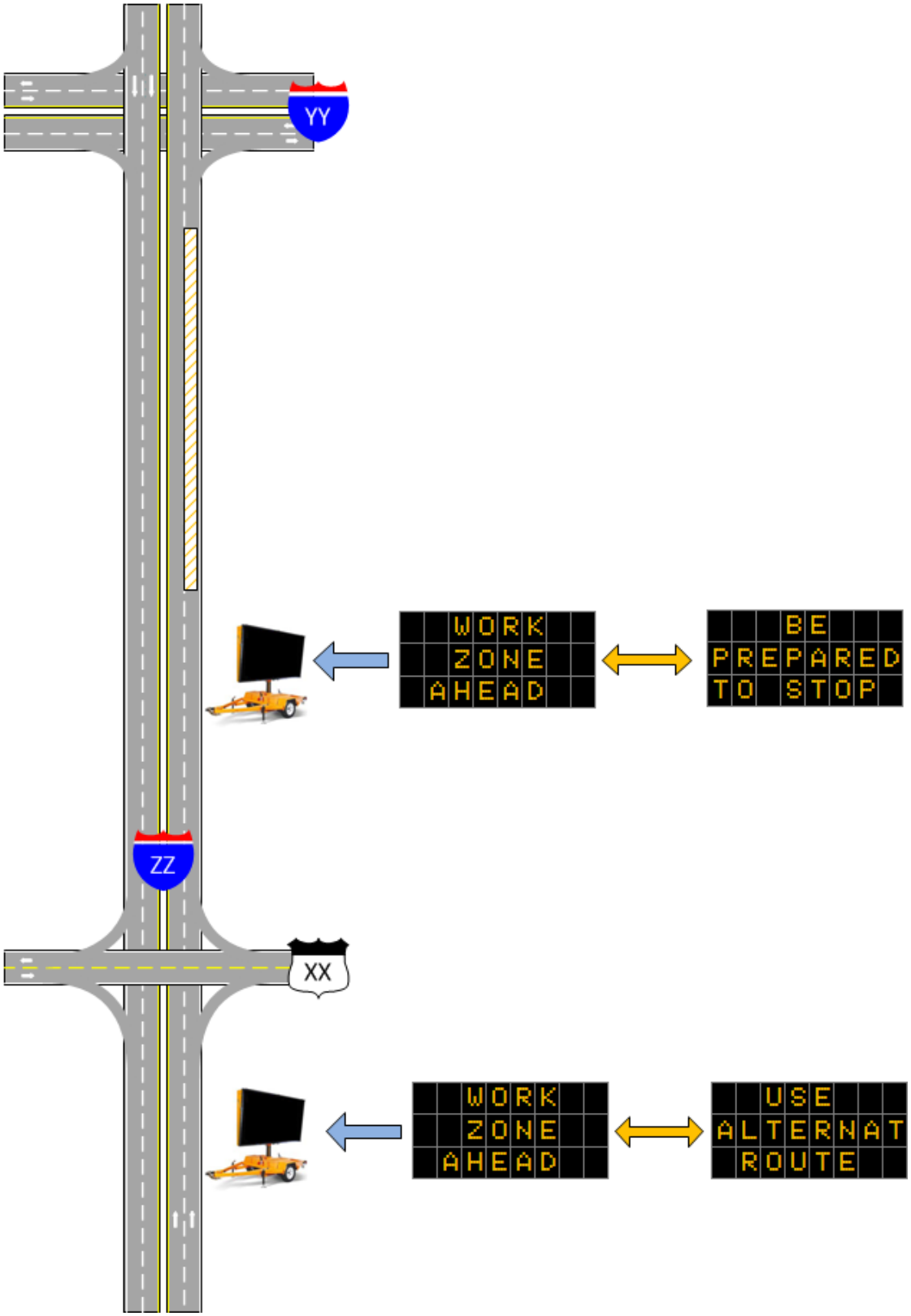
The following layout diagrams are intended to provide guidelines that should lead to practical solutions by the designer. Dimensions are not drawn to scale, and the location and quantity of devices are merely conceptual, so engineering judgment is required to customize the system to a specific project. The Massachusetts *ITS Deployment and Design Guide*, and other MassDOT and FHWA documentation provide guidance on device locations, but the designer should always keep in mind that the ITS equipment usually extends beyond the limits of the work zone.

Key for Layout Diagrams

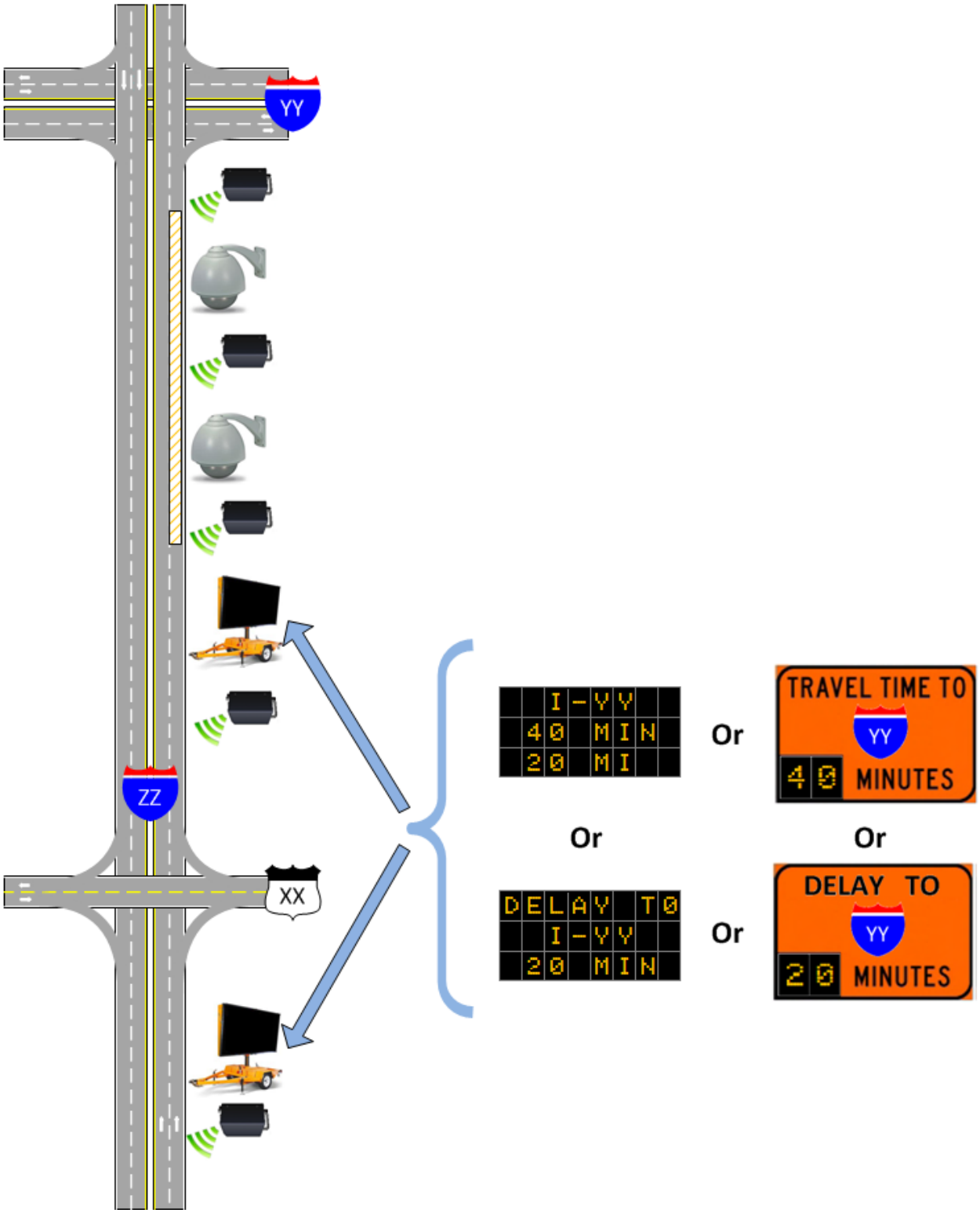
	Work Zone		PVMS or HMS
	Detection Equipment		HMS message
	Video/Photo Camera		PVMS message
	Alarm		PVMS Phase Change
	Hazardous Condition (Flooding)		

Note: Portable Variable Message Sign (PVMS) is synonymous with Portable Changeable Message Sign (PCMS)

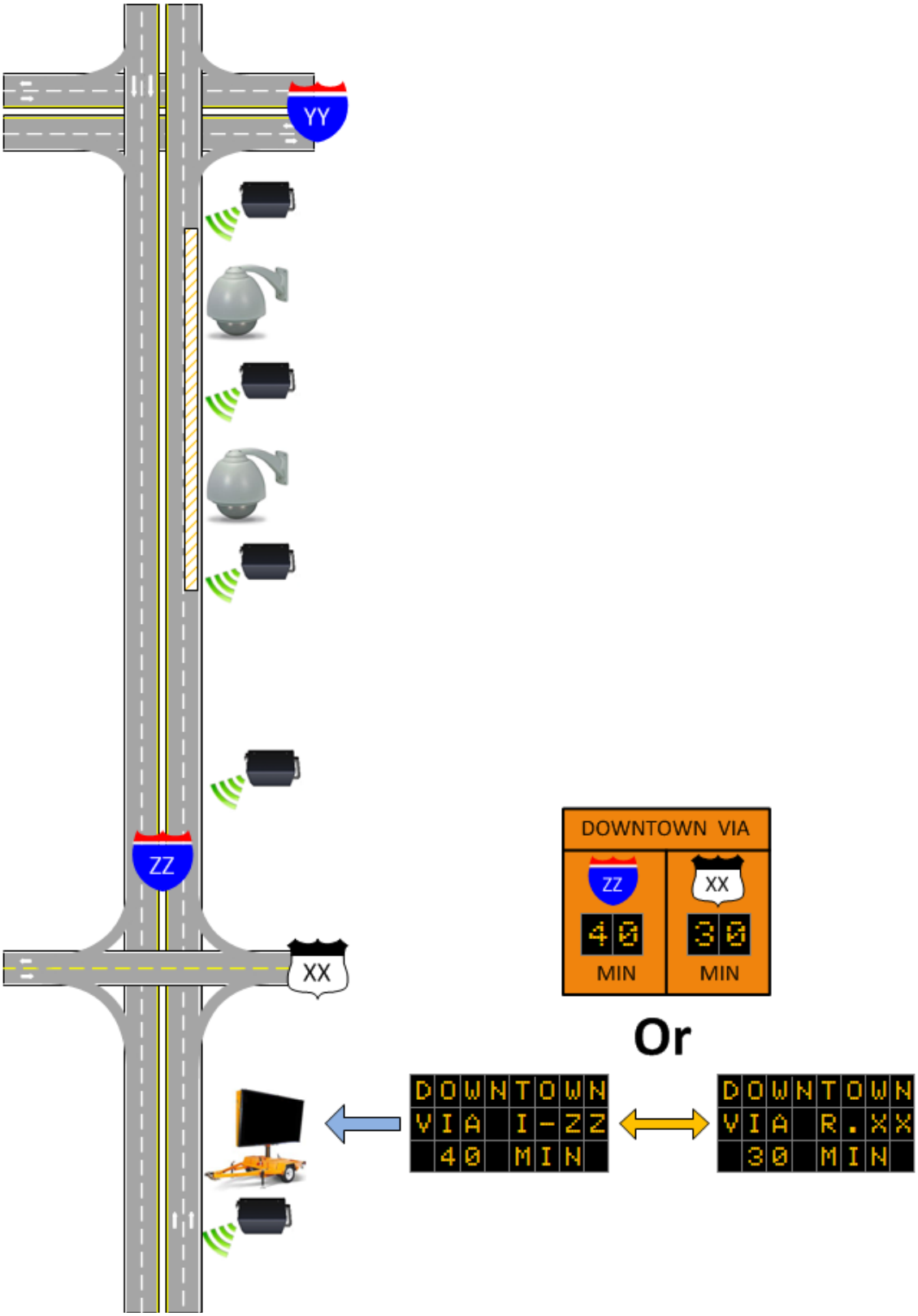
Driver Alerts



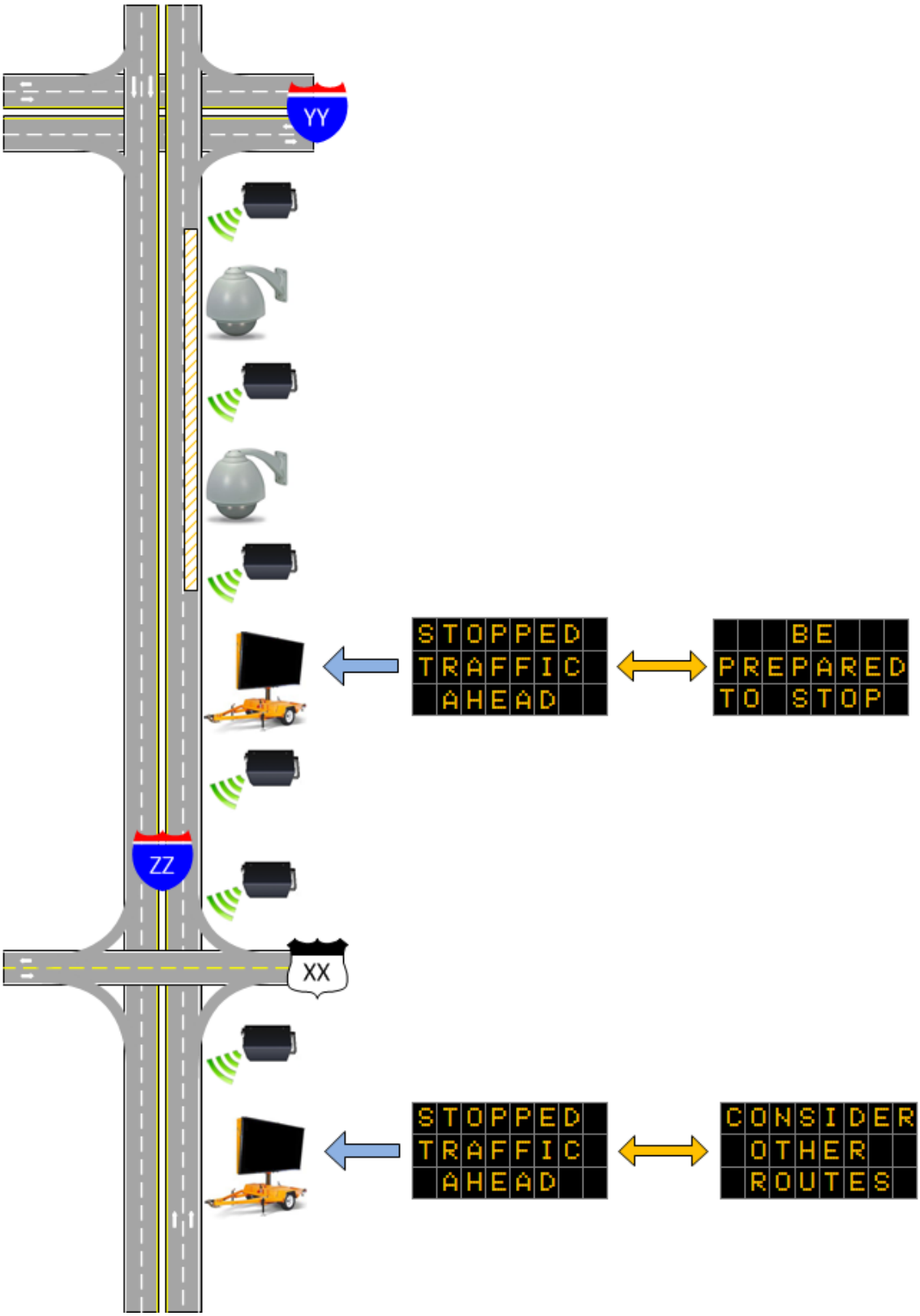
Travel Time and Delay Estimation



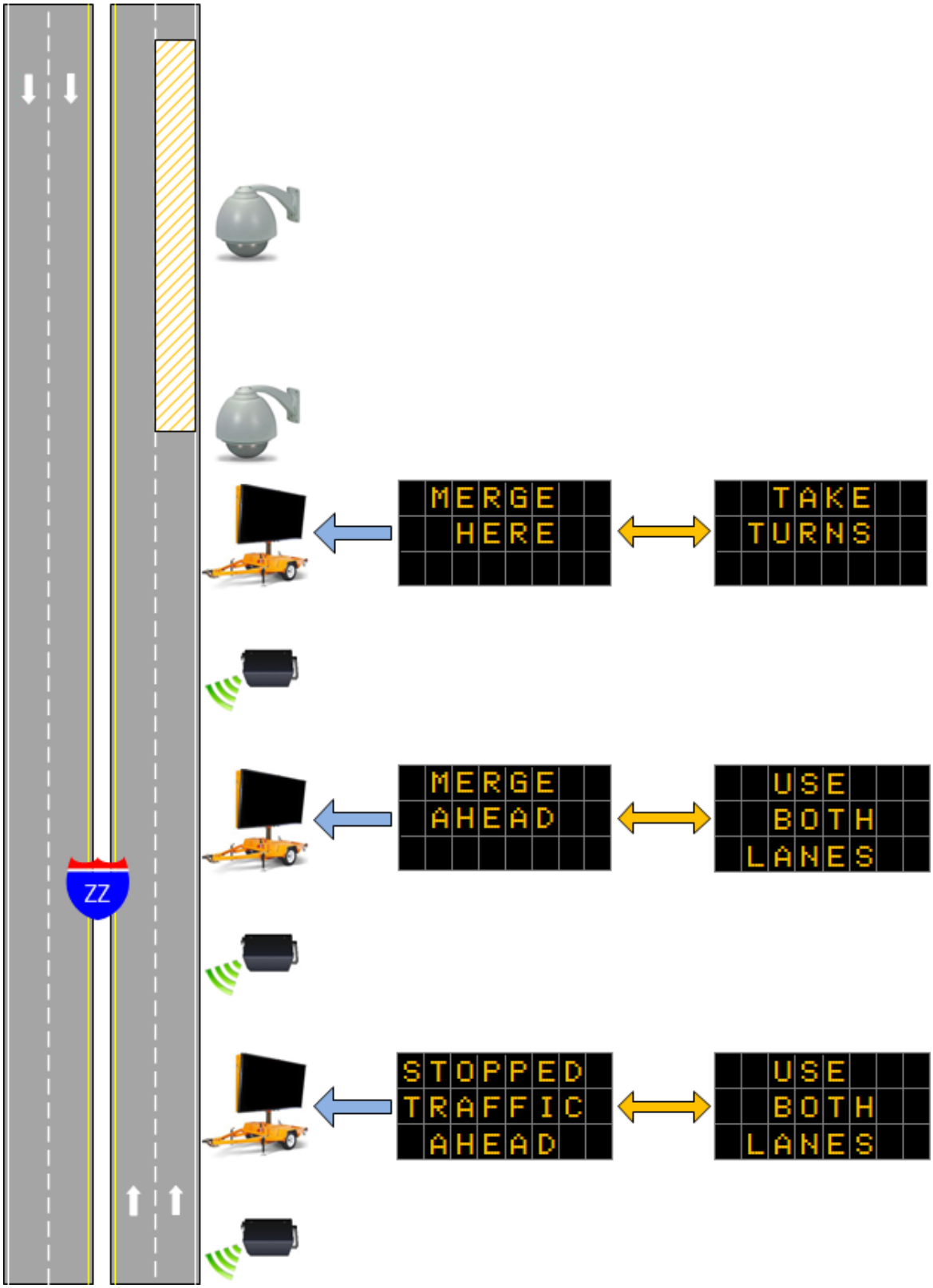
Alternate Route Advisory



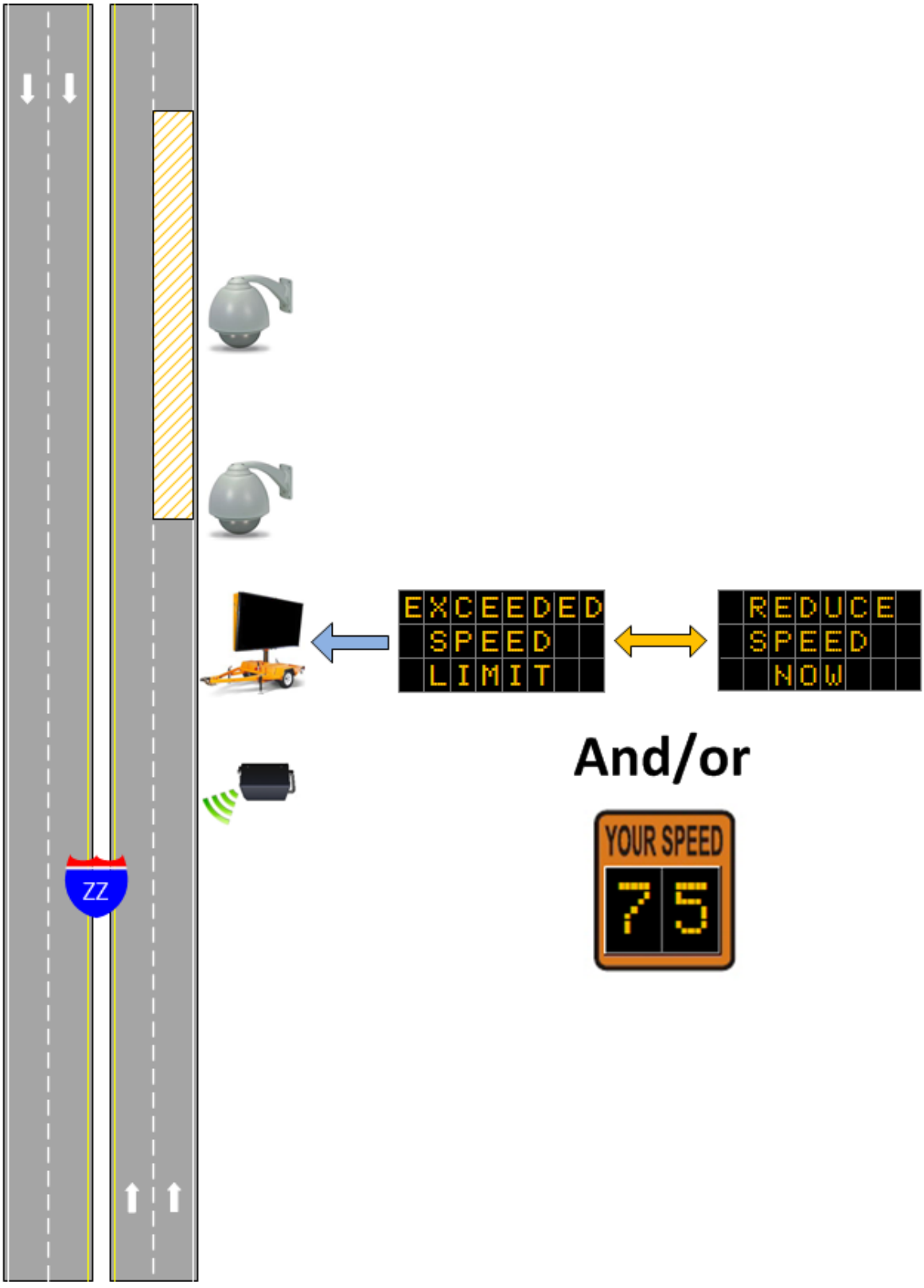
Congestion Warning



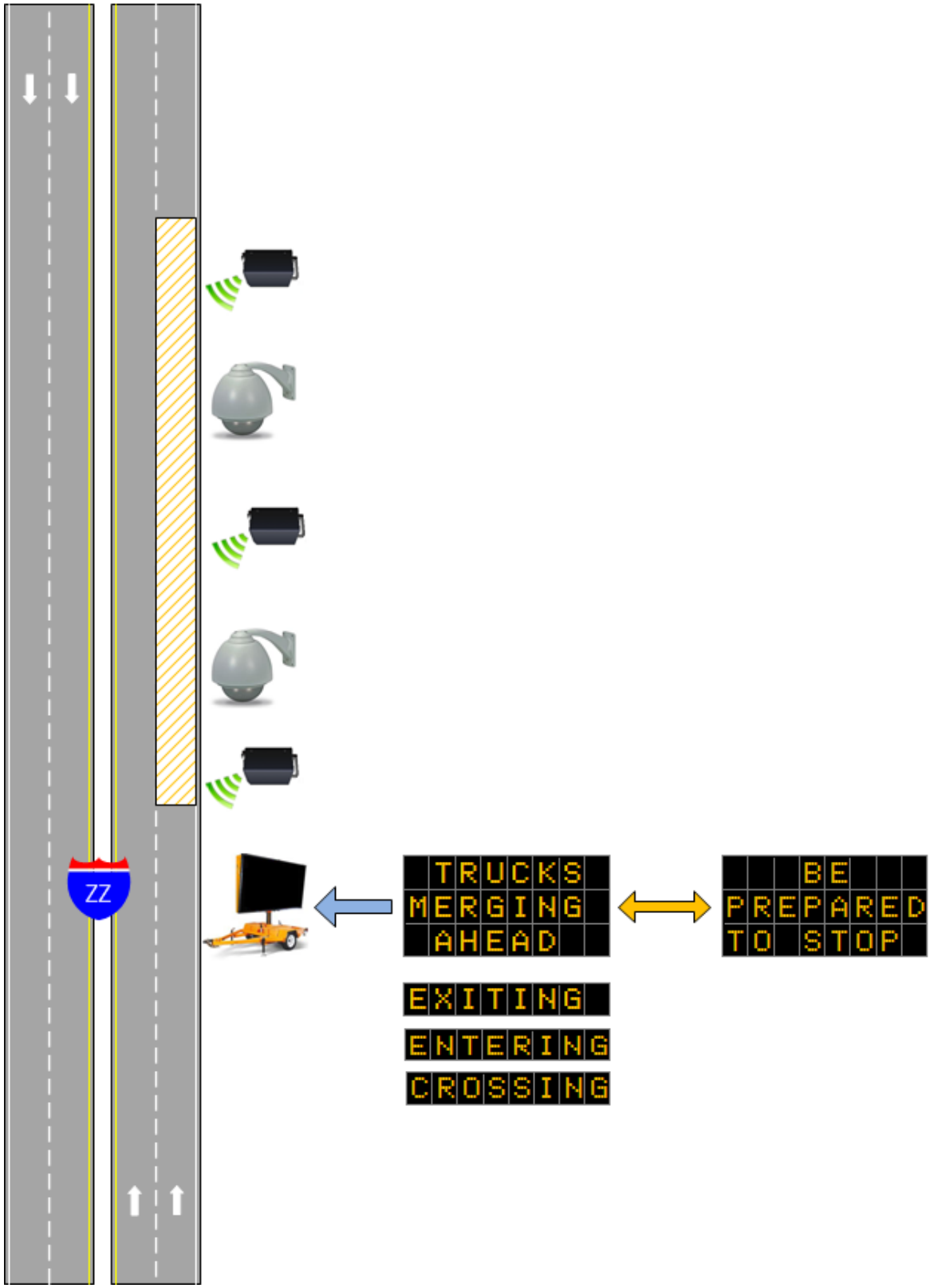
Dynamic Lane Merge



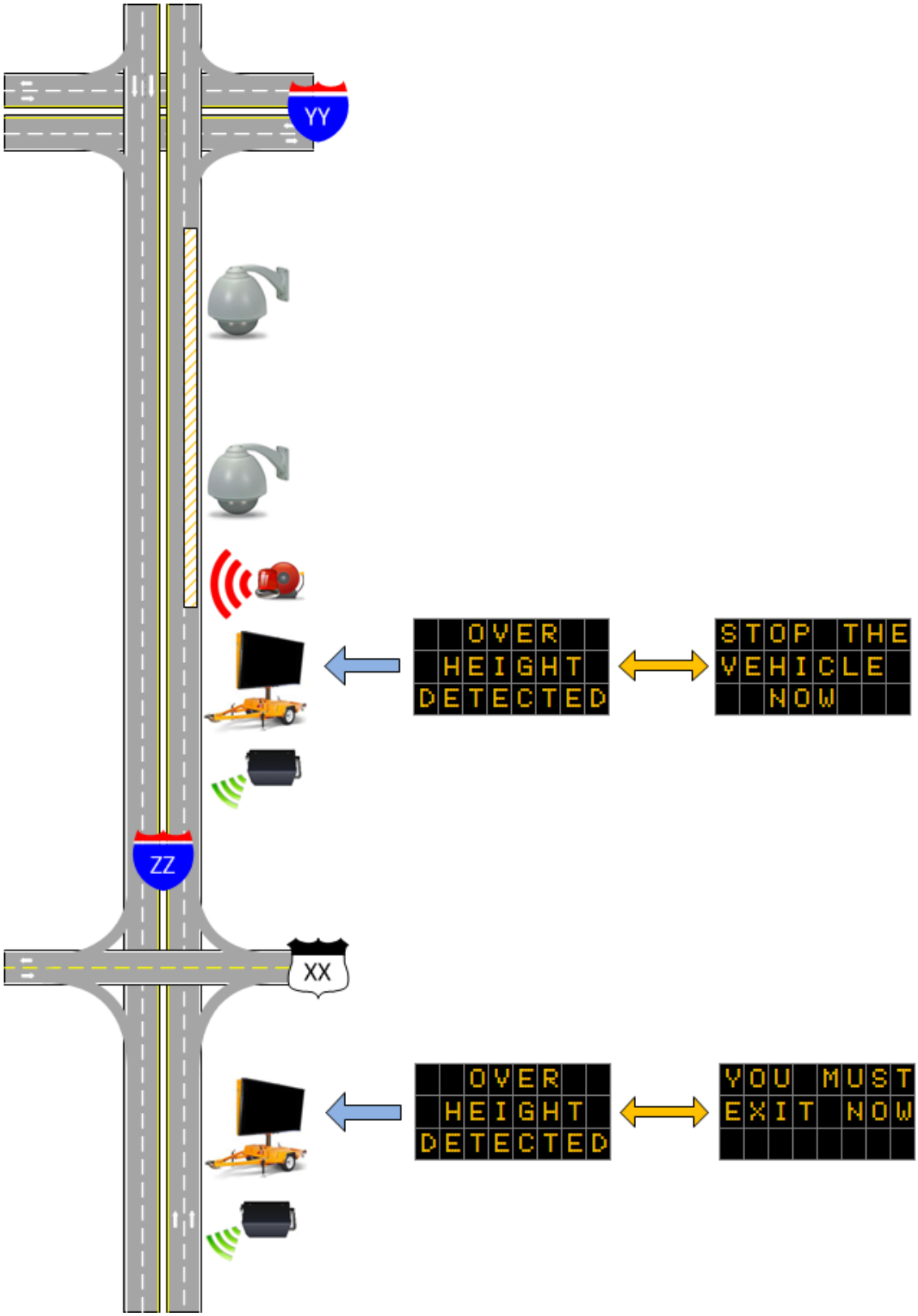
Excessive Speed Warning



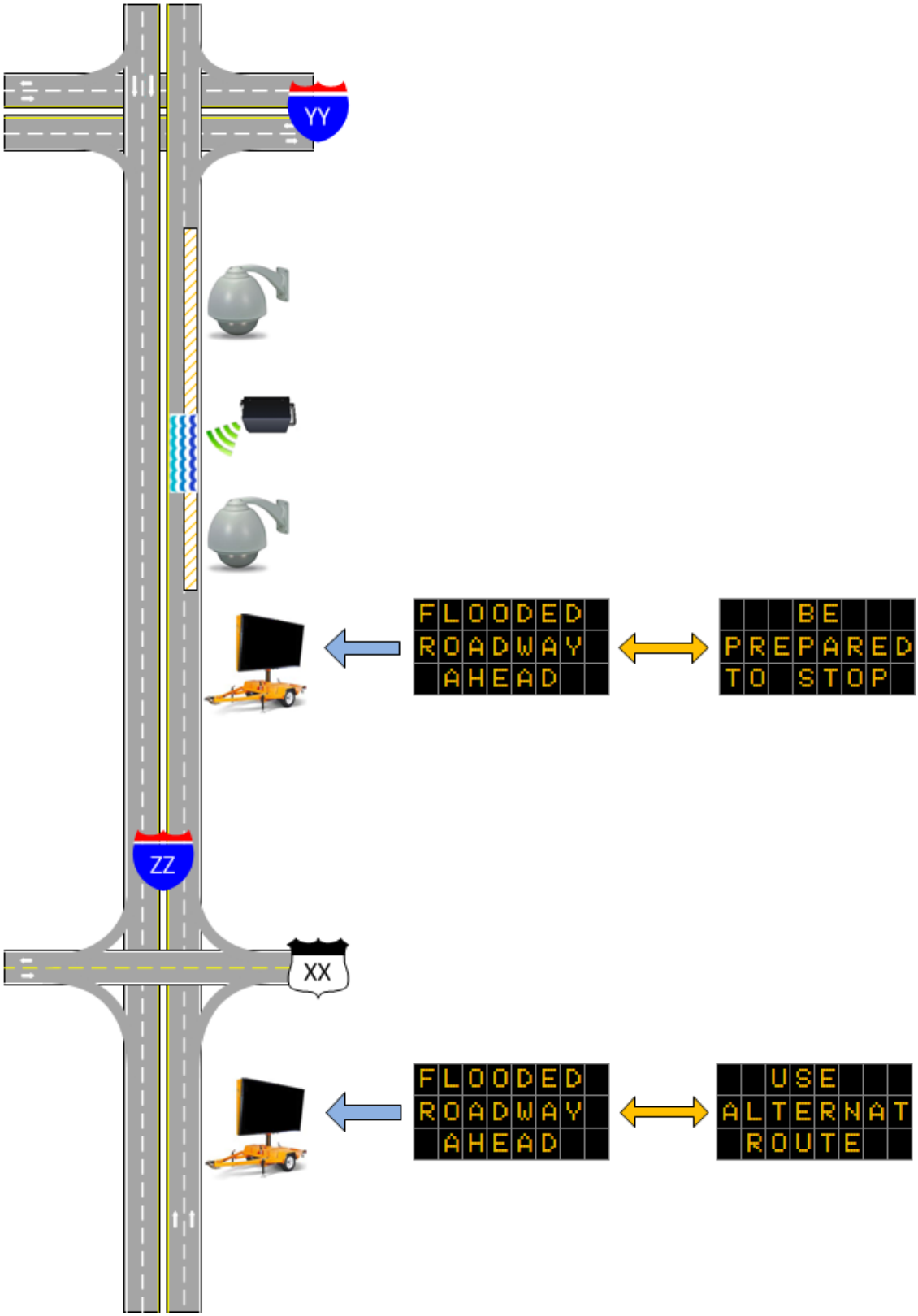
Vehicle Warning



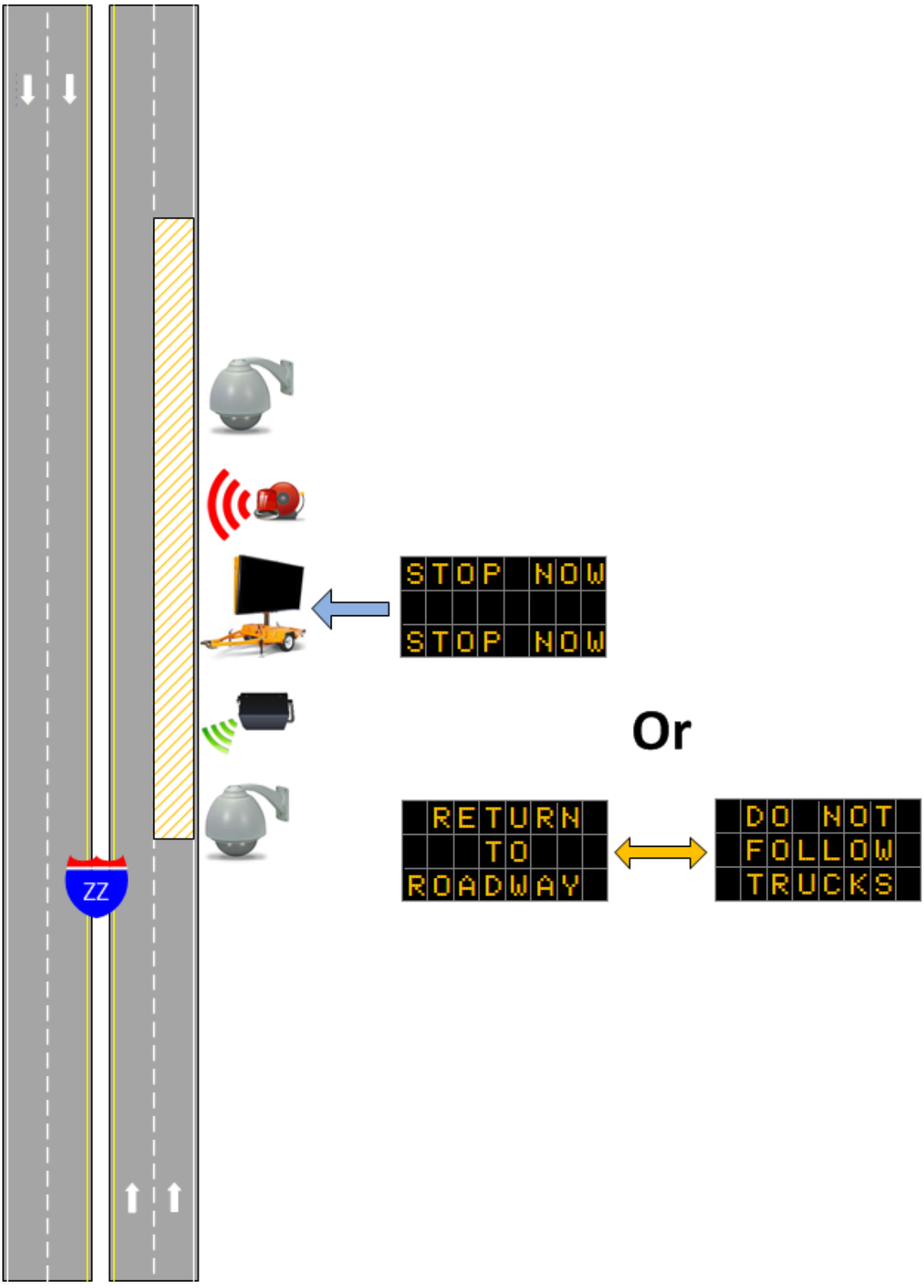
Clearance Warning



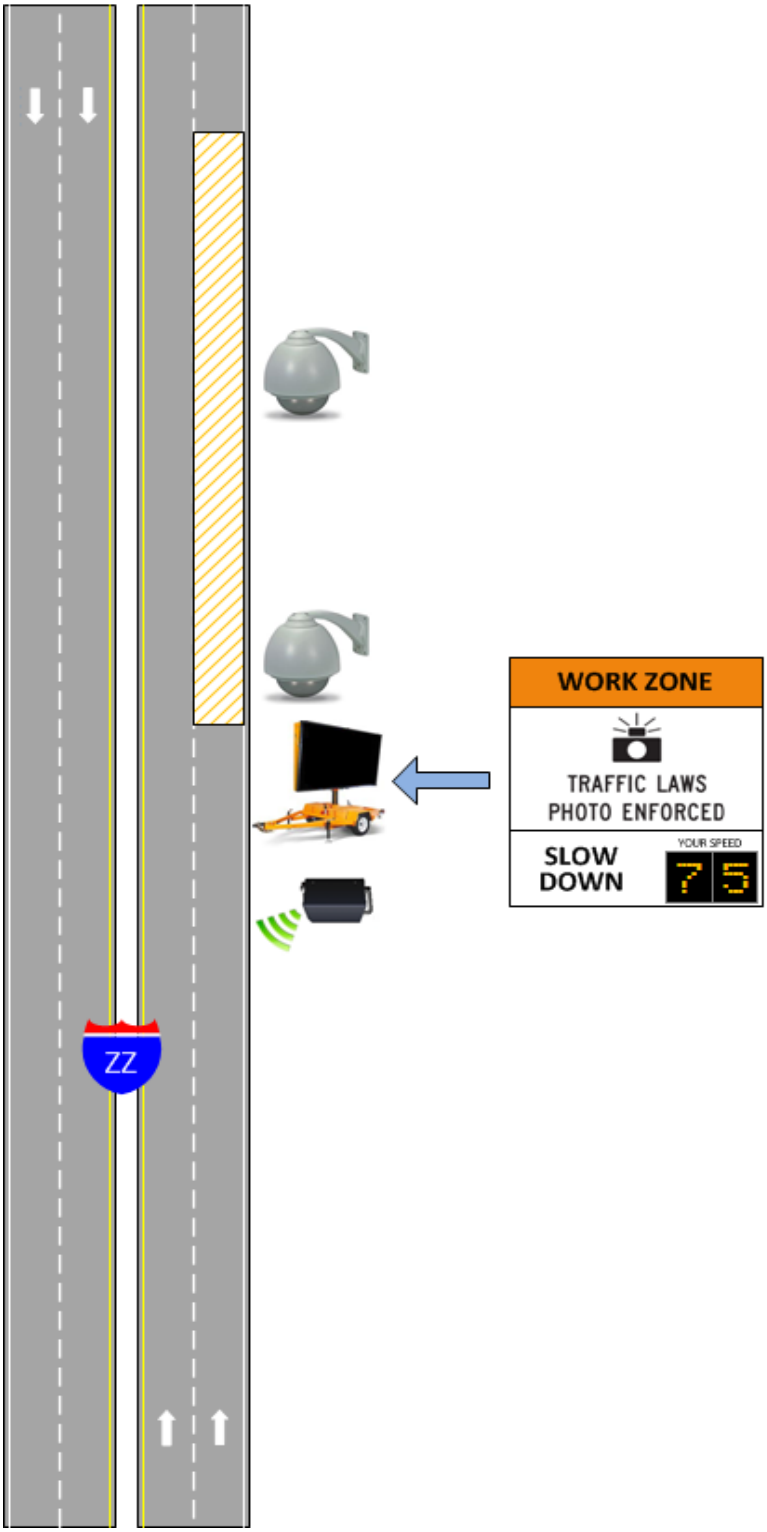
Hazardous Condition Warning



Intrusion Warning



Enforcement



Note: The use of Photo Enforcement is not allowed under Massachusetts General Laws