

ITS Concept of Operations: End of Queue Warning System for Work Zone

August 2015

Prepared for: The Minnesota Department of Transportation

Acknowledgements

This document was prepared for Minnesota Department of Transportation's (MnDOT) Systems Engineering to Address Work Zone Challenges project.

Project Champion

Rashmi Brewer is the MnDOT project champion for this effort. MnDOT stakeholders were heavily involved in identifying the key challenges with using Intelligent Transportation Systems to address and enhance safety, operations, mobility and efficiency in work zones. This document covers the system requirements to address some of these challenges.

Project Management Team (MnDOT)

- Ralph Adair
- Tiffany Dagon
- Ted Ulven
- Craig Mittelstadt
- Leigh Kriewall
- Dave Mavec
- Ken Johnson
- Rashmi Brewer

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1. Introduction

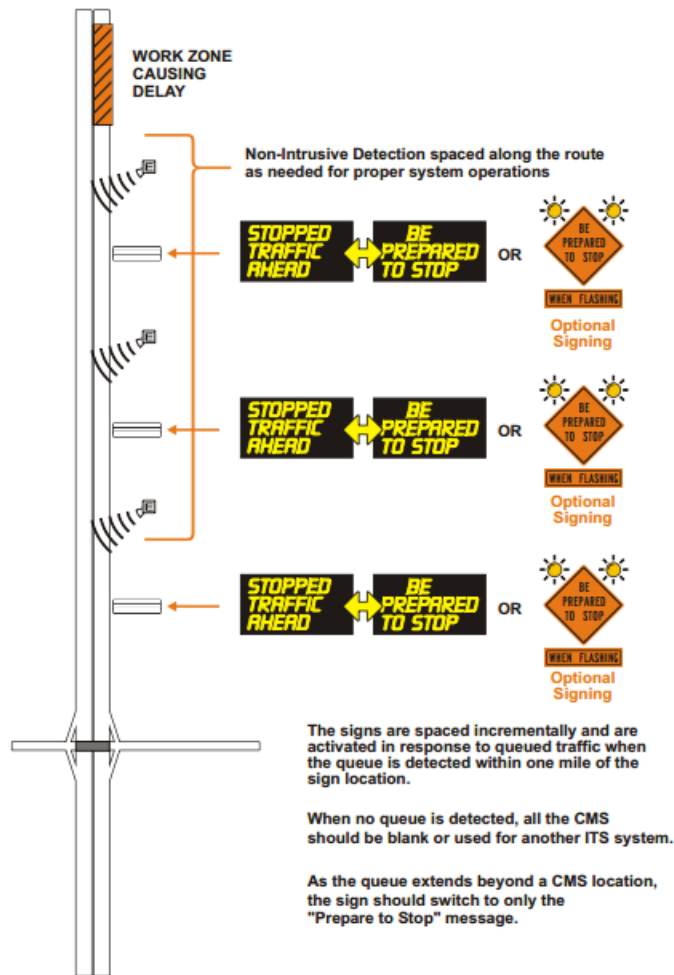
Safety is MnDOT's top priority as demonstrated in the Toward Zero Deaths (TZD) initiative to lower the number of traffic crashes, injuries, and deaths occurring on Minnesota roads. MnDOT is working to not only increase safety for drivers, yet also for those in the field working to improve our roadway system. In the state of Minnesota, 21 severe crashes occur in the work zone per year on average.

A significant number of crashes occurring in work zones are end of queue crashes. Since 2011, end of queue crashes resulted in 9 fatalities in Minnesota. It is important that drivers are aware of slowed or stopped traffic ahead in work zones to be prepared to stop safely and reduce end of queue crashes. On top of reducing end of queue crashes, advanced warning of slowed or stopped traffic ahead can detour traffic out of the work zones and ease congestion through that area. The traffic entering the work zone can be slowed to increase safety for the workers present in the work zone as well.

1.1 System Overview

Traditionally, work zones utilize a multiple queue warning system, portable changeable message signs (PCMS), permanent CMS, and/or Variable Speed Limits to inform drivers of the work zone/work zone conditions. Crash history shows that additional systems are needed to safely address the issue of end of queue crashes and inform drivers of slowed or stopped traffic ahead. Assessing the location and number of CMS signs and non-intrusive detection devices in work zones could improve the system. Messages displayed on the signs can also be researched which may lead to enhanced safety results.

Figure 1 Typical Work Zone Signage Configuration



MnDOT has prepared the Minnesota IWZ Toolbox as a guideline for Intelligent Work Zone System Selection. The IWZ Toolbox contains multiple configurations for reducing end of queue crashes, including the Travel Delay Information, Speed Advisory Information, Congestion Advisory, and Stopped Traffic Advisory systems. The figure above is an example configuration for Stopped Traffic Advisory from the IWZ Toolbox solutions, which is applicable for queue detection.

1.2 Stakeholders

The deployment and operations of an ITS system for end of queue conditions will be driven by the needs of the stakeholder groups who will interact with them. The needs have been identified for four primary groups – drivers, the industry and field personnel, transportation agencies, and Law Enforcement.

- **Drivers** on any roadway where construction occurs
- **Industry and field personnel** who may design, construct, and work on road construction throughout the state of Minnesota
- **Transportation agencies** at the state, county, and local level that will oversee, monitor, identify work zone related challenges, and research conditions in the work zones
- **Law Enforcement** who may observe operations, driver compliance, and safety of solutions in the work zones

MnDOT is working to improve safety in work zones and to reduce end of queue crashes. A Concept of Operations will clearly convey the fundamental needs and concept of the systems. This Concept of Operations details ways of improving the current systems in place. The remainder of this Concept of Operations documents the needs of the noted stakeholder groups, describes an operational concept from the stakeholder perspectives, outlines systems components, and presents common operational scenarios for this challenge.

2. Needs

Stakeholders have identified recurring work zone challenges. Stakeholders have developed the need to address these challenges to help improve safety on Minnesota’s roadways. Each challenge corresponds with an operational and system need that will determine what the system must accomplish. The following table summarizes these challenges and needs.

Table 1 Stakeholder Needs for the Challenge

Challenge	ID	Need
Drivers are unaware of slow or stopped traffic ahead in a queue created by a work zone resulting in crashes.	1	All drivers approaching a work zone need an alert to slow down regardless of where the queue is located.
End of queue crashes	2	Ability for traffic to know where queues are to adequately react, slows down, or stop.
Information dissemination when congestion breaches the work zone boundary	3	Drivers approaching a work zone need an alert if back up is outside of the advisory signs.
Drivers on roadway may not see or be aware of a stopped or slowed traffic condition ahead.	4	Drivers entering a work zone area need an alert of slowed or stopped traffic condition ahead if present.
The in place system criteria is not set up to completely address the issue or needs additional signing or detection.	5	The systems may be combined or modified to better address the issues of this challenge.
Changing work zones make it difficult to get information to calculate accurate travel times.	6	Need system that can be adjusted and calibrated frequently by field staff, yet, maintain accurate travel time info.
Continuous alerts can diminish the credibility and value of dynamic warnings for drivers.	7	Drivers, Agencies, and Law Enforcement need alerts to be specific and timely and not become nearly continuous to avoid loss of impact.
Drivers could become confused by or misunderstand the message or intent of an alert.	8	Drivers, Agencies, and Law Enforcement need Work Zone alerts to be consistent and easily understood.
Drivers travel among the states and could become confused by the intent of an alert or signage in Minnesota.	9	Drivers, Agencies, Law Enforcement and industry need work zone alerts and signage to be uniform throughout the US to the extent possible.
Drivers on surrounding roadway may not be aware of delays or congestion in the area.	10	Agencies ability to provide an alert to motorists in the vicinity to avoid area as an alternate route.

Table 1 Stakeholder Needs for the Challenge (continued)

Challenge	ID	Need
Agencies must understand and be able to quantitatively show the benefit received from a smart work zone application after deployment.	11	Need to have an acceptable standard to determine the benefits and cost for future use and agency planning purposes.
Agencies and public's understanding or preference of what data is being displayed in the field (near-time vs. real-time) is not the same.	12	Agencies should understand which type of data is most accepted and then make an effort to inform drivers as to which will be used for Work Zone ITS systems.
Long work zones create the challenge of determining when to display information and how frequently to repeat messages.	13	Need planning tools to determine where traffic is accessing long work zones and sufficient ITS systems to collect info over representative areas of long work zones to provide accurate traveler information.
Need other ways to disseminate info at correct time and location to individual drivers (i.e. connected vehicles).	14	Systems on roadside and in vehicles to collect and disseminate accurate and timely information
Getting power and communications to locations at reasonable cost and in the correct timeframe.	15	Remote locations may not have power or communications infrastructure so reliable cost effective alternative power and communication options are needed
Getting lane closure information	16	Agencies ability to provide lane closure information so that motorist can stay informed and determine most appropriate route, action, or time to travel.
Work zones are in constant transition and initial placement of devices or calibration may not be appropriate for length of project.	17	Need verification for devices when construction phases change and regularly to determine that system correctly
How to simplify use of ITS (ease of deployment, maintenance, and lower cost)	18	Design of interchangeable systems that are flexible to the work zone area or conditions

3. Operational Concept

The operational concept describes what must be done and the stakeholder roles in work zones to address the challenge. The following concept describes a sequence of operational events and the activities of each stakeholder group. The concept describes how stakeholders should interact with the system and references the initial stakeholders’.

3.1 Driver Perspective

3.1.1 Alert Driver will see a CMS as they approach a work zone **(1, 2, 3, 4)**

3.1.2 If there is congestion present in the work zone, the CMS or PCMS will indicate that there is congestion ahead or stopped traffic ahead. **(1,2,3,4)**

3.1.3 If there is slowed traffic ahead in the work zone, the CMS will indicate if there is upcoming traffic slow-down traffic ahead **(1,2,3,4)**

3.1.4 If there is stopped traffic ahead in the work zone, the CMS will indicate if there is stopped traffic ahead **(1,2,3,4)**

3.1.5 If there is no congestion in the work zone, the CMS will alert the driver of upcoming work zone and give an advisory speed limit. **(1,2,3,4)**

3.1.6 If there are alternate routes present, the CMS may indicate detour routes or suggest drivers consider other routes **(1,2,3,4)**

3.2 Transportation Agency Perspective

3.2.1 Transportation agencies will require an ITS configuration that uniformly denotes work zone traffic control conditions and advisory messages to enhance worker and traveler safety. **(8,9,12)**

3.2.2 To ensure driver recognition of the ITS configuration, transportation agencies will deploy the system consistent with warning sign standards and guidance in the MUTCD. **(8,9,12)**

3.2.3 To support driver understanding of ITS alerts across jurisdictions, transportation agencies will deploy a system with uniform placement, sign combinations, and alerts throughout their jurisdiction. **(8,9,12)**

3.2.4 Transportation agencies will develop a system that gives requirements for alerting drivers of an upcoming traffic slow-down or stopped traffic in the work zones. **(5,7,10,11,13,14,18)**

3.2.5 Transportation agencies will ensure compliance by the industry of the standards set in place **(5,7,8,9,12,18)**

3.2.6 Transportation agencies will use information obtained by the system to improve and continuously update the standards **(5,6,12,13,16,17)**

3.2.7 Transportation agencies will require uniform messages on signs to assist understanding **(8,9)**

3.3 Industry and Field Personnel Perspective

3.3.1 To ensure driver comprehension, industry will place a sufficient amount of CMS along the work zone so all drivers observe the signs. **(5)**

3.3.2 Industry will use information obtained by the detection devices to make improvements to the system **(6,12,13,17)**

3.3.3 Industry will understand the system's performance through records of system failure and vehicle detection

3.3.4 Industry will have training, documentation, and technical ability to support the system installation.

3.3.5 Industry will use multiple methods to get power and communication to locations **(15)**

3.3.6 Field personnel will monitor messaging and placement of the signs used in the system to ensure they follow warning sign standards and guidance in the MUTCD **(8,9)**

3.4 Law Enforcement Perspective

3.4.1 Law Enforcement will observe driver compliance with the messaging of the system.

4. System Components

The system components include all the physical parts of the system that work together to provide alerts to the drivers. The following is an overview of typical system components for this challenge:

- Detection: Detects slowed or stopped traffic, queue locations, or speed of traffic through the work zone. Detection may include non-intrusive detection devices
- Warning: Dynamically activates when there is a presence of queues or slowed traffic through the work zone. This may consist of CMS or static signing
- System Communication: Manages communication used to transmit data between the components, and may include cellular, radio, or other landline and wireless forms
- Data Management: Stores system performance data and may be accomplished by a variety of on or off site databases
- System Monitoring: Operates, detects, and reports fluctuations in system performance, system errors, or system failures.

4.1 System Component Support and Responsible Parties

The system will consist of systems components needed to address needs identified in Section 2 and the operational concepts described in Section 3. Each component requires deployment, operations, and

maintenance activities. This section details the deployment, operations, and maintenance functions that the industry or transportation agencies will be required to do.

Table 2 Activities Required for System Components

Component	Support Required
<i>Overall System</i>	Determine extents of where the system should be installed based on the work zone, lane configurations, and construction conditions (3.2.4)
	Design and deploy the system in accordance with relevant standards (3.2.2) (3.2.4) (3.2.5) (3.2.7)
	Incorporate inspection and maintenance of the system into standard practices requirements. (3.2.5)
<i>Detection</i>	Determine suitable detection spacing based on the work zone and expected queue lengths (3.2.4) (3.3.1) (3.3.2)
	Install detection equipment and connect power (3.3.4) (3.3.5)
	Install and integrate detection with system communication to connect detection to the warning, data management, and system monitoring (3.3.3) (3.3.4)
<i>Warning</i>	Install warning equipment and connect to power and other system requirements (3.3.4) (3.3.5)
	Inspect periodically to determine if warning is functioning properly (3.3.3)
	If warning is not functioning properly, follow procedures to troubleshoot and restore functionality. (3.3.3)
<i>System Communication</i>	Install and connect system communication equipment with other system components (3.3.4)
	Inspect periodically to determine if communication is functioning properly (3.3.3) (3.3.4)
	If system communication is not functioning properly, follow procedures to troubleshoot and restore functionality. (3.3.3)
<i>Data Management</i>	Install and connect data management equipment with other system components (3.3.3)
	Periodically download data from storage device following procedures (3.3.3)
	Inspect periodically to determine if data management is functioning properly (3.3.3) (3.3.4)
	If data management is not functioning properly, follow procedures to troubleshoot and restore functionality. (3.3.3) (3.3.4)
<i>System Monitoring</i>	Install system monitoring equipment with other system components (3.3.3)
	Inspect periodically to determine if system monitoring is functioning properly (3.3.3)
	If system monitoring is not functioning properly, follow procedures to troubleshoot and restore functionality. (3.3.3)

5. Operational Scenarios

The following operational scenarios elaborate the individual challenges that will be addressed with the implementation of the system. Each example assumes that there is a 2 lane closure along an interstate where construction crews are reconstructing a portion of the interstate. Various construction equipment is present, with approximately 6-8 individuals on site including the Contractor and Inspector.

5.1 Work Zone with Slowed Traffic

Driver approaches a work zone (see Figure 2). Driver observes a CMS indicating that there is slowed traffic ahead. Driver moves closer to the work zone and observes a CMS giving delay and traffic information, which is based on data obtained through non-intrusive detection devices spaced throughout the corridor. This sign may be before a possible detour route to give drivers another route option. Driver enters the work zone and observes another CMS giving an advisory speed based on traffic flow through the work zone. The driver would observe sufficient signage to convey the need to slow down.

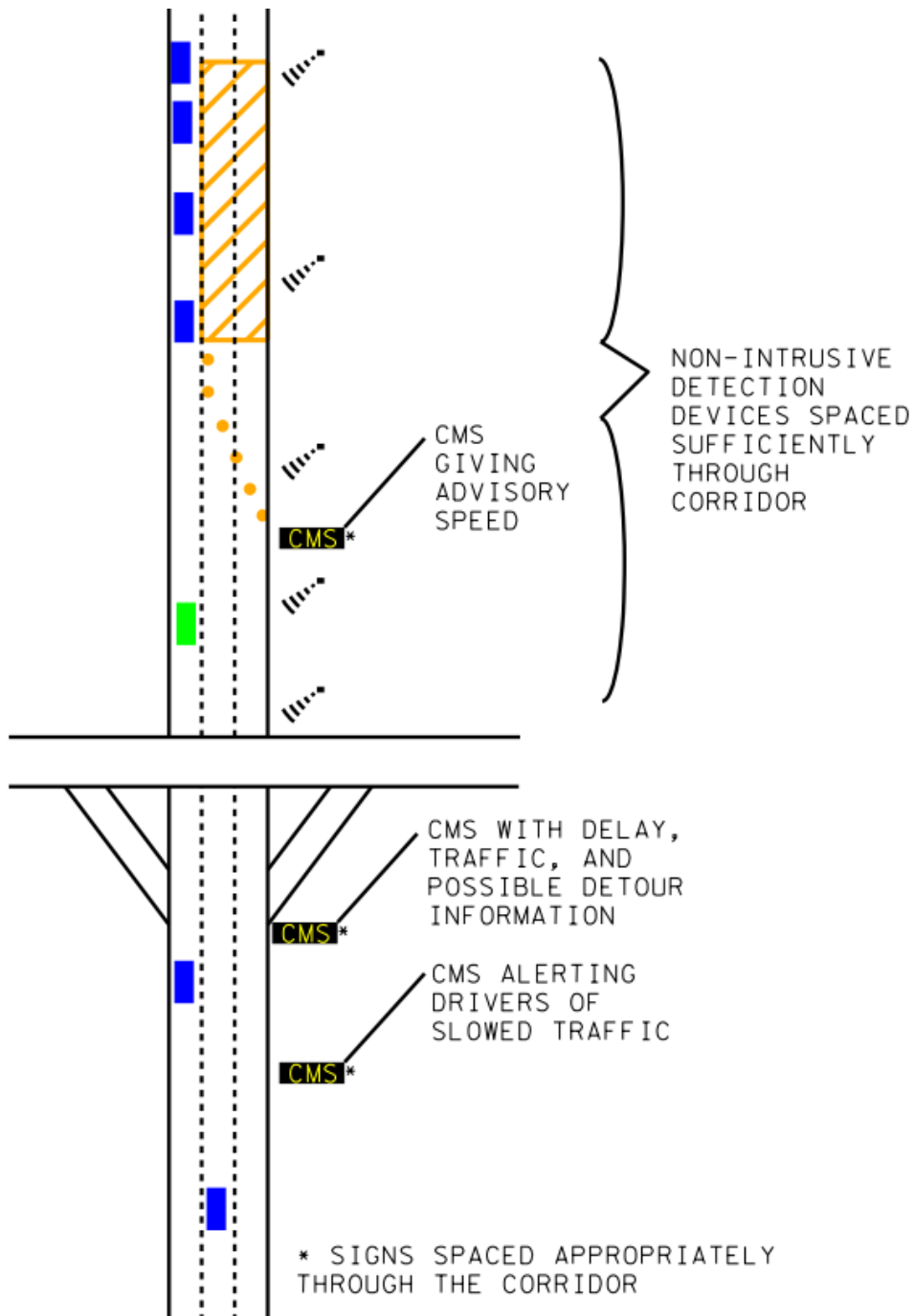


Figure 2: Approach to Work Zone with Slow Traffic

5.2 Work Zone with Stopped Traffic

Driver approaches a work zone (see Figure 3). Driver observes a CMS indicating that there is stopped traffic ahead. Driver nears the work zone and observes another CMS giving additional delay and traffic information, which is based on data obtained through non-intrusive detection devices spaced throughout the corridor. This sign may be before a possible detour route to give drivers another route option. The driver then enters the work zone and observes a CMS as a critical indicator that the motorists are traveling too fast for the stopped conditions ahead. The driver would observe sufficient signage to alert the driver of stopped traffic, delay time, and possible alternate routes.

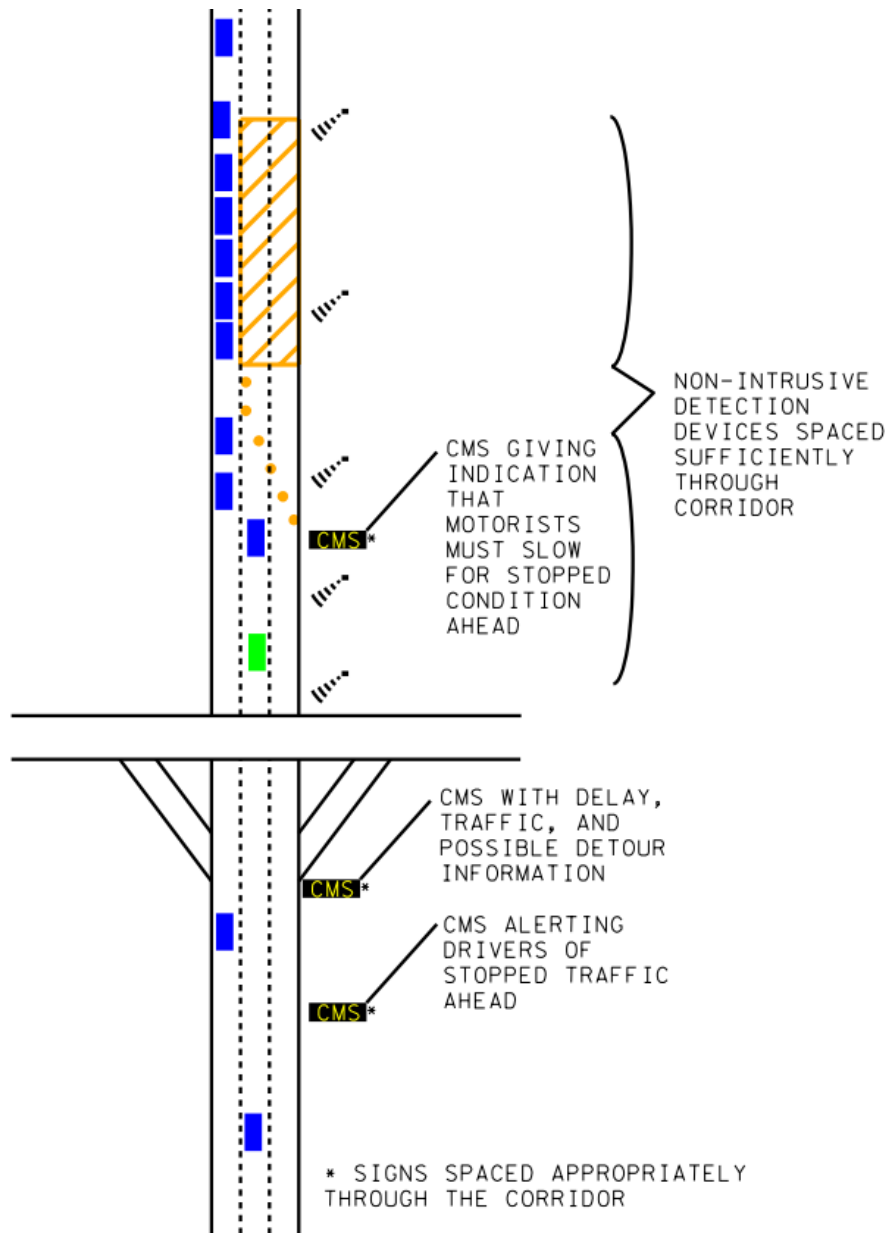


Figure 3 Approach to Work Zone with Slow Traffic

5.3 Work Zone without Congestion

Driver approaches a work zone (see Figure4). Non-intrusive detection devices pick up little congestion in the work zone, and send this information to the CMS. Driver observes a CMS indicating an advisory speed while in the work zone. Driver slows to maintain the advisory speed which keeps traffic flowing through the work zone.

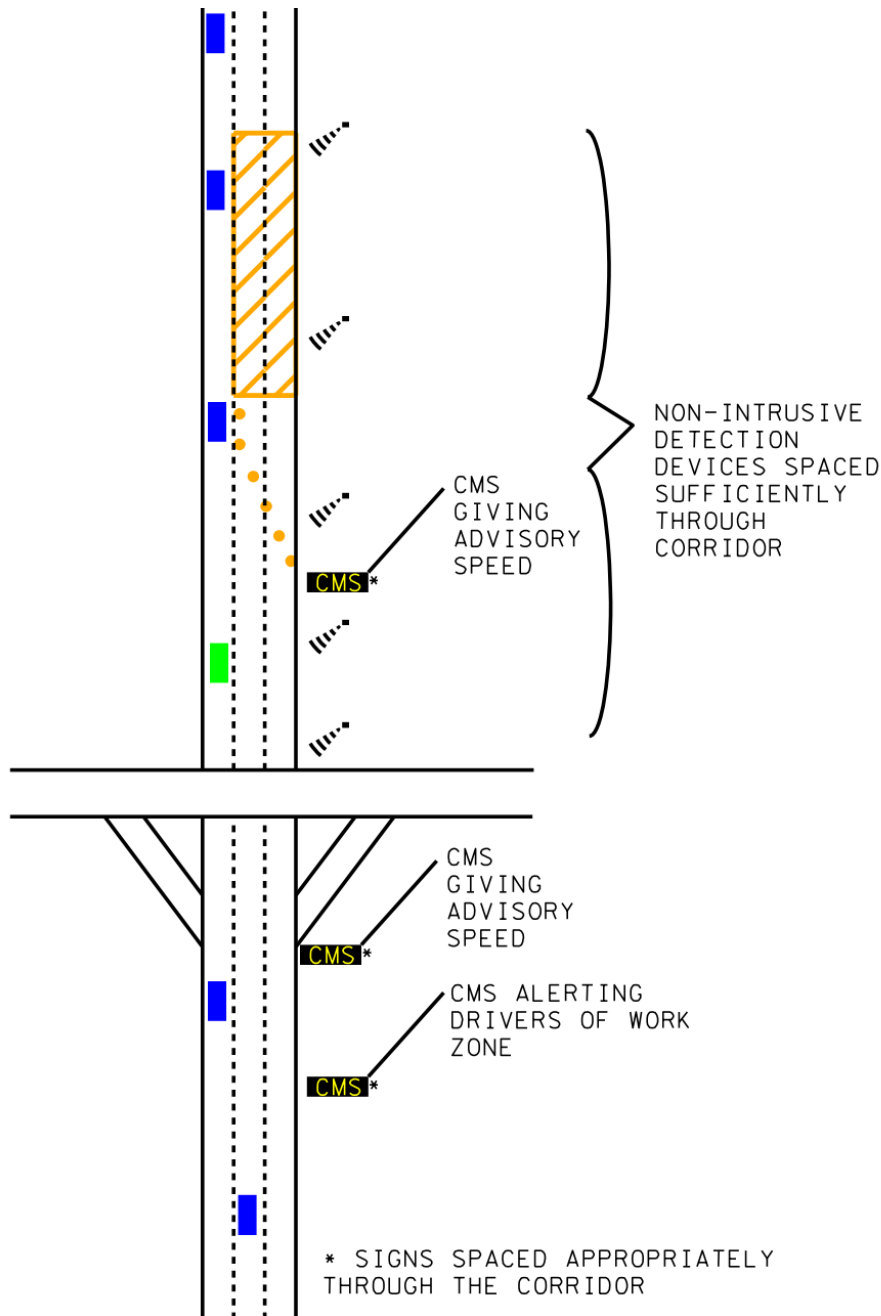


Figure 4 Approach to Work Zone with No Congestion

References

MnDOT. (2008). *Minnesota Intelligent Work Zone Toolbox: Guideline for Intelligent Work Zone System Selection*. Retrieved March 10, 2015, from the National Work Zone Safety Information Clearinghouse: <http://www.dot.state.mn.us/trafficeng/workzone/iwz/MN-IWZToolbox.pdf>

MnDOT. (2014). *SHSP, Fatal and Serious Injury Crashes: Work Zones; page 89*. Retrieved March 10, 2015: http://www.dot.state.mn.us/trafficeng/safety/shsp/Minnesota_SHSP_2014.pdf