MCDOT Smart Work Zone Technical Feasibility Concept Document

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1 OVERVIEW

1.1 Vision

The Maricopa County Department of Transportation (MCDOT) desires to develop a concept for deployment of Smart Work Zone (SWZ) technology at their work zone sites. This project will support development of a feasibility concept for technical development of a SWZ system that will be implemented during the construction of the MCDOT MC-85 project from 107th Avenue to 75th Avenue. This phase of the project is anticipated to begin construction in Summer of 2017. While the concept will be piloted during the MC-85 project, this concept will be adaptable to other MCDOT work zones.

The SWZ initiative at Maricopa County began with commitment to the federal Every Day Counts (EDC) initiative from MCDOT leadership. The EDC initiative was introduced in 2009 by the Federal Highway Administration (FHWA) in cooperation with the American Association of State Highway and Transportation Officials (AASHTO) with the purpose of speeding up the delivery of highway projects and addressing the challenges presented by limited budgets. It looks to "identify and rapidly deploy proven but underutilized innovations to shorten the project delivery process, enhance roadway safety, reduce congestion and improve environmental sustainability"[1]. Smart Work Zone deployments are an example of such an innovation that helps enhance safety and reduce congestion, among other things.

1.2 Project Overview

The pilot deployment for the SWZ concept will be part of the first phase of the MC-85 construction project. The lessons learned from this initial deployment is anticipated to inform future deployments, including Phase 2 of the MC-85 project.

The MC-85 project is a good candidate for a SWZ pilot for the following reasons:

- It involves a roadway closure, lane restrictions and alternate routes so there is a variety of conditions (that have different goals) during which the technology can be deployed.
- The road is in the vicinity of the I-10, which may create unique challenges with respect to traffic volumes (including high truck volumes) and speeds.
- The project is being constructed in phases, which provides an opportunity to adjust or change elements of the deployment while still keeping some elements of the work zone and area constant.
- The project involves multiple divisions of MCDOT so that the results of the SWZ technology or data that is derived can be shared. It also helps identify the types of deployments and data that are most beneficial.

While this technical feasibility concept is designed and implemented specifically for the MC-85 project, the resulting concept will have the ability to be adapted and applied to other MCDOT work zones in the future.

[1] https://www.fhwa.dot.gov/innovation/everydaycounts/about-edc.cfm

2 CURRENT MCDOT WORK ZONE PRACTICES

2.1 Coordination and Capabilities at the Work Zone

MCDOT work zones are largely run by the project contractor with MCDOT oversight. There is at least one MCDOT inspector on-site at all times when workers are present at the work zone. The inspector's role is to supervise the work zone and track the work progress and the quality of work. The inspector also observes the traffic impacts of the work zone and can require the contractor to modify their developed traffic control plans or schedule if significant traffic congestion occurs due to the work zone. In these cases, the contractor may be required to do work at off peak times, such as during nights or weekends, to mitigate the traffic impacts caused by the work zone.

Coordination with other agencies is often required when a MCDOT work zone includes right-of-way (ROW) or land within a different agency's jurisdiction. This is not uncommon because there are many instances where the County owns a small area of land and/or a roadway within or adjacent to a different agency's boundaries. It also occurs in cases where county roads intersect with Arizona Department of Transportation (ADOT) roads. Many times, traffic control devices will have to be placed in the ROW of a different agency because of space restrictions or the need to provide advanced notification. In these cases, MCDOT has to coordinate with the local agency or ADOT to develop the traffic control plan. This coordination is especially important for plan review, because local agencies often have different standards for traffic control than MCDOT.

Another set of stakeholders that MCDOT coordinates with is law enforcement. All work zones that occur at a traffic signal require the presence of an off duty officer at the site during times when workers are actively working. The officers at the site help with traffic control and provide general monitoring of the work zone to make sure the work zone remains safe. The officer is sometimes responsible for controlling the traffic signal at the intersection or manually directing traffic; however because the officer is off duty, he or she cannot write traffic or speeding tickets. There are also times where the MCDOT inspector or the contractor will call the local sheriff to help manage a situation. The sheriff is on-duty and has the authority to issue traffic tickets to drivers, but because the sheriff is only called when there is a situation in the work zone that requires law enforcement, a sheriff often is not there for general traffic monitoring and to write tickets.

Internally, the MCDOT Public Information Office (PIO) is kept apprised of all work zone activity, as they are the ones who directly communicate with the public. PIOs attend weekly construction meetings and are provided with all available information about the work zone and its current status. The PIOs use this information to provide advanced and real-time information regarding the work zone to the public.

For projects in residential areas, flyers and mailers are distributed to residents to provide information on the work zone, such as anticipated duration, type of work, restrictions that will exist, and places to find more information. In business areas, MCDOT collects the contact information for all businesses in the area and sends them similar information as well as an opportunity for the business to sign up for updates as they become available. MCDOT also posts traffic advisories on their website, tweets about them via Twitter, and posts information on Facebook.

In addition, MCDOT will provide notifications on portable message signs prior to the start of any construction. This portable sign is deployed ten working days before the start of construction and

provides advanced warning to motorists about the upcoming construction. Portable signs are removed once construction begins and are equipped with batteries and solar power but do not include other ITS devices such as cameras or communications (i.e. wireless radios or cellular). MCDOT Maintenance owns 12 portable message signs that they use during maintenance projects, but because maintenance projects are often short in duration (less than one day), the signs are only deployed when there are workers present and are almost never left out for multiple days.

MCDOT also occasionally displays messages on permanent arterial message signs that are deployed in or around the work zone if they are available. This includes arterial message signs that are MCDOT-owned and deployed on MCDOT roads or those owned by local agencies and deployed on arterials.

The MCDOT Traffic Management Center (TMC) also assists in the work zone with both public information dissemination and traffic management. MCDOT can populate traffic maps internally and on the statewide 511 system to include information on work zone restrictions or on traffic impacts resulting from work zones. The TMC sends out alerts or updates via Twitter through their GovDelivery system. For some work zones, the TMC can also monitor the work zone using a CCTV camera that is mounted on a traffic signal and provides live-stream video. The limitation to this system is that MCDOT CCTV cameras are not available at every intersection and may not be available at all possible work zone locations. Finally, the Traffic Signal Systems Analyst, located at the TMC, is able to change the signal timing remotely at signalized intersections that have communications from the field devices to the TMC. This can help improve traffic flow (i.e. increase the length of the green indication in a certain direction to allow more vehicles to clear the intersection or improve progression). This capability is available in real time at those signals that have communications infrastructure that connects the signal to the MCDOT TMC and allows them to control it remotely. Not every MCDOT signal has this capability, so the remote changing of signal timing is not possible at all locations. TMC staff also work closely with the Signals Groups at locations where there are no communications between field devices to the TMC. To make signal timing changes at these locations, the Signals Group will manually enter the changes in signal timing at the signal cabinet.

At all work zones, there is usually a reduction in the speed limit to try to maintain the safety of the workers and drivers. For regular work zones that involve a single lane restriction, a standard 10 mph reduction in the speed limit is put in place. This is broadcasted to drivers via static speed limit signs that show the reduced speed limit in addition to other required signs (in the MUTCD) that accompany a speed limit reduction. In situations where there is a flagger at the start of the work zone and where everyone is required to stop prior to entering, MCDOT requires the contractor to incrementally reduce speeds to help control the speed of vehicles prior to the stop.

2.2 Contractor Requirements

The contractor is largely responsible for planning and executing the work zone, with MCDOT playing more of a supervisor role. The contractor is responsible for procuring any equipment that is needed for the work zone, including any intelligent transportation system (ITS) devices such as the portable message signs. Work zone technology is included as line item in the contactors budget. The contractor will rent the equipment from appropriate vendors and MCDOT will pay the daily rental cost via the contractor's lump sum contract.

While MCDOT specifies the general work zone limits, the contractor is responsible for controlling the project limits, including delineating the start and end limits for the various phases of the project if phasing

is required. The contractor also controls their own schedule for the work zone as long as it is within the agreed upon duration.

For a work zone or each phase of a multi-phase work zone, the contractor will develop and submit a traffic control plan for the equipment and devices; MCDOT does not provide design specifications or a standard template for these plans. Traffic control plans must be developed in such a way to maintain access to all driveways that might exist within the work zone, and it must be designed to allow for regular trash collection and postal services as necessary. In residential areas, there are noise restrictions that must be accommodated. If there is a planned special event to occur in conjunction with the work zone, the contractor must modify the work zone during that time to accommodate the special event and make sure that there is proper access to surrounding businesses. MCDOT will review the submitted traffic control plan, require changes as needed, and approve the plan prior to deployment of any devices in the work zone.

In general, MCDOT tries to avoid executing road closures as part of work zones. For example, if the work zone involves an intersection, the contractor will be required to work on one corner of the intersection at a time so that they can maintain access to and through the area. If the work zone does require a full closure, MCDOT will have to provide a signed detour for travelers to allow them to navigate around the work zone.

2.3 Challenges

The two biggest challenges related to work zones that were identified by MCDOT employees were:

- Lack of driver compliance with the posted speed limit and
- Difficulty maintaining access to driveways and businesses on roadways that have many access points.

The lack of speed limit compliance creates safety concerns for both workers and travelers through the work zones. As mentioned in the previous section, on-site officers at work zones are rarely tasked with ticketing for speed limit compliance as either the officer is off-duty and not authorized to write tickets or a sheriff is called to assist with a situation where the sheriff's attention is needed for the situation as opposed to monitoring speed compliance. Because of low speed limit compliance and few solutions to the issue, MCDOT often instead tries to have the contractors design the work zone traffic control for the posted speed (as opposed to the reduced speed). While this might create less efficient traffic control, it is a way to improve the safety of the work zone in light of the compliance challenge.

Access challenges in MCDOT work zones are unique to work zones that are in urban areas that have a lot of residential or businesses along the roadway in question. MCDOT is required to maintain residential and business access during construction, which often leads to complicated and robust traffic control requirements. One particular issue that was cited was related to providing necessary access while still restricting travel through certain portions of the work zone. For example, trucks require reconfiguration of traffic control to accommodate their wide turning radii. However, when a restricted lane is widened to accommodate a large construction vehicle, the lane gets widened enough that it looks like an unrestricted lane, and drivers often use it as a travel lane.

Related to access is an issue that arises when MCDOT does not have enough ROW for all traffic control equipment. This results in obstruction of a sidewalk or an additional lane of traffic in order to fit a portable message sign of another piece of equipment that is required in the work zone.

Another work zone-related issue that was identified by MCDOT included vandalism and theft of portable message signs and other electronic equipment that is used. As previously discussed, portable message signs are placed on the road 10 working days prior to the start of construction to provide advanced notification to travelers. These signs are left out on the road at all hours, and there are many reports of stolen equipment, including the tires from the portable trailer, the batteries, and the solar equipment on the trailer. There are also reports of people hacking into portable sign's computer and changing the message that is displayed on the sign.

Finally, challenges related to nighttime activity were identified. These included decreased production and identification of additional safety issues that arise in conjunction with nighttime activity, such as reduced visibility for travelers, which requires additional safety measures, such as lighting and barriers when there is active work at night.

3 GOALS AND OPPORTUNITIES

3.1 Goals for SWZ Concept

The first step in developing a SWZ concept for MCDOT is to identify the goals that MCDOT would like to achieve by implementing a SWZ. Goals provide traceability between the equipment and systems deployed and the results that are attributable to the SWZ. **Figure 1** provides an overview of the traceability process used to guide the MCDOT SWZ Concept development.

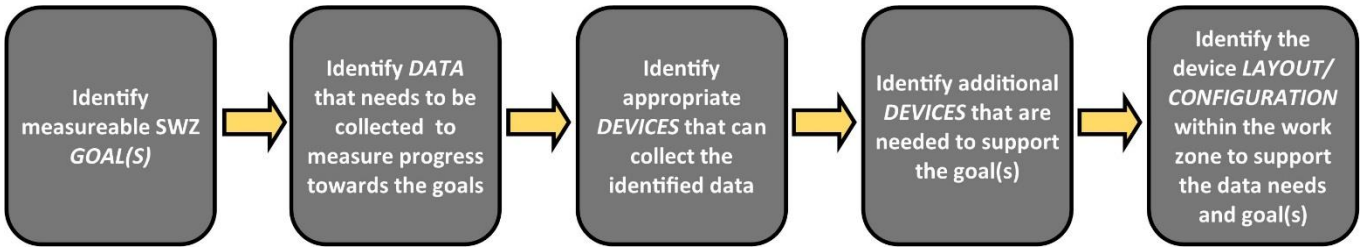


Figure 1 – Traceability in the MCDOT SWZ Concept Development Process

Goals for this SWZ concept had to be measurable and attributable to the SWZ equipment and systems. A goal was not considered if there was no data that could be collected by the SWZ components to measure progress toward that goal or if progress toward that goal could not be fully contributable to the SWZ deployment and would require other efforts outside of the scope of the SWZ.

The following goals were identified for the MCDOT SWZ Concept:

1. Improve speed limit compliance through the work zone;
2. Increase travel time reliability through the work zone;
3. Reduce number of crashes in the work zone; and
4. Reduce queues resulting from the work zone.

3.2 Proposed Functions

Table 1 provides an overview of the SWZ goals, the associated data that is needed to measure progress in these goal areas, and the devices that will be needed to collect or disseminate information.

Table 1 – MCDOT SWZ Goals, Data, and Device Needs

SWZ Goal	Data to Collect	Devices to Collect Data	Additional Devices That Could Support Goal
Improve speed limit compliance through the work zone	- Speed	- Detector - Radar	- Message sign - Variable speed limit (VSL) trailer - Speed feedback sign
Increase travel time reliability through the work zone	- Vehicle presence - Location of vehicle	- Detector - Bluetooth/ARID sensor	- Message sign - VSL trailer
Reduce crashes in the work zones	- Location of crash - Number of crashes	- None (need a crash log)	- Message sign - CCTV
Reduce queues resulting from the work zone	- Vehicle presence - Volume	- Detector - CCTV	- Message sign

This table provides full traceability from goals to devices, which help ensure that the proper devices are deployed in work zones based on MCDOT's needs. As can be seen, there is some overlap in the types of devices that are required to support different goals, which can help identify the foundational SWZ elements that MCDOT should deploy at every work zone.

Table 1 provides the outputs for the first four steps of the concept development process found in Figure 1. These four steps resulted in the identification of the devices that are needed at all work zones; however, the fifth step – identifying the device layout/configuration within the work zone to support data needs and goals – is the one step that will change based on the characteristics of the specific work zone in question.

Figure 2 provides a generalized overview of the four locations within a work zone area where devices can be deployed to collect and provide information. These four areas are defined based on their function with respect to the type of information they can provide to drivers.

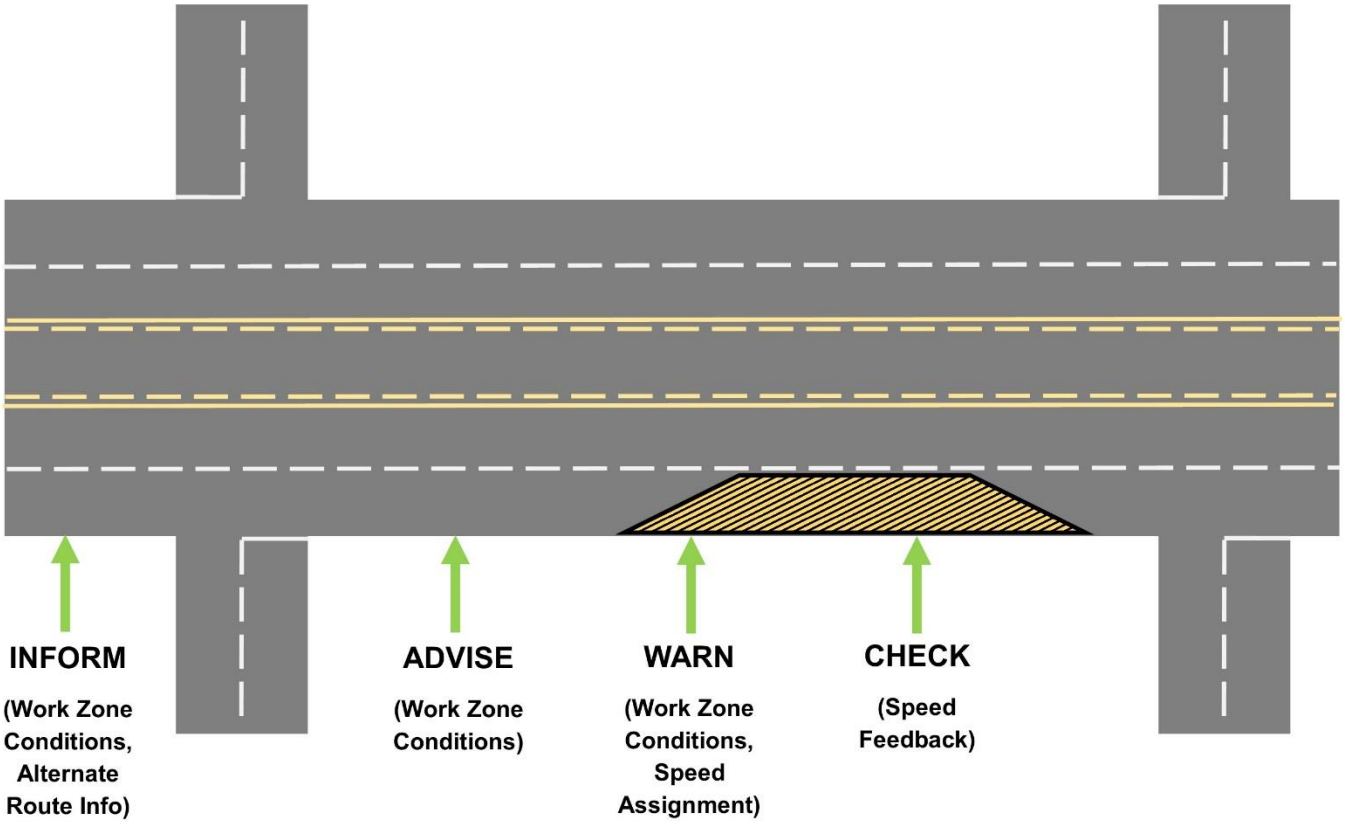


Figure 2 – General Work Zone Device Locations

The **INFORM** location is one prior to the beginning of the work zone where there is an option for drivers to take an alternate route and thus avoid the work zone entirely. Devices that are deployed in the *Inform* location provide information to drivers regarding the conditions of the work zone, such as reduced speeds, congestion or crashes, and the availability of alternate routes (if applicable) to allow drivers to make informed decisions about their routing.

The **ADVISE** location is just prior to the start of the work zone, before the beginning of any lane restrictions or active work spaces. Devices in the *Advise* location provide information regarding work zone conditions,

such a speed limit reductions or delays in the work zone. At this location, drivers do not have the choice of using an alternate route.

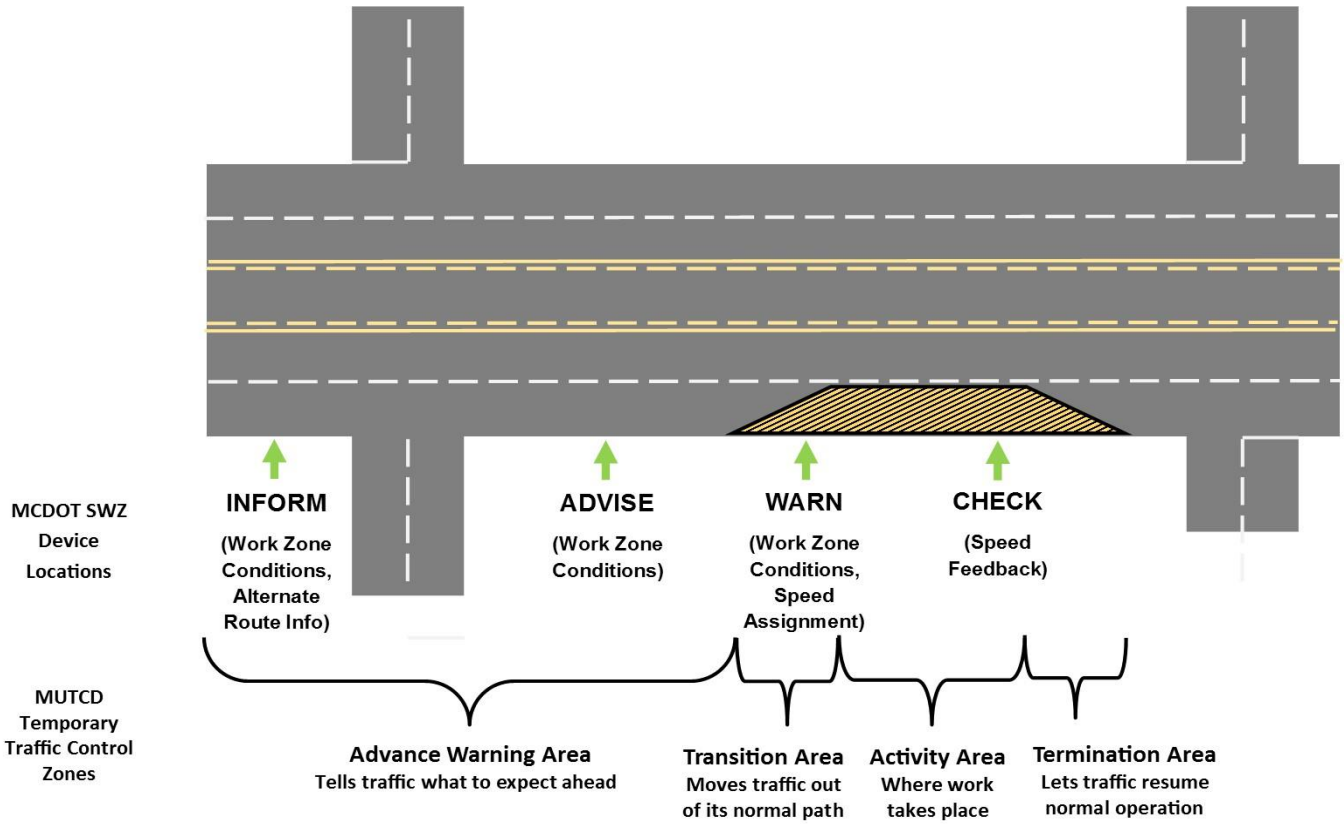
The **WARN** location is positioned at the beginning of the work zone, at the point where lane restrictions and other work zone related activities occur. Information that can be provided at the *Warn* location include work zone conditions, such as assigned speed limits, as part of traditional traffic control, or information about conditions within the work zone activity area. MCDOT can also consider deploying a speed feedback sign in conjunction with the speed limit sign at this location.

The **CHECK** location is positioned in the middle of the work zone. While information about work zone conditions is not necessary at this point, the *Check* location is a good place to provide driver feedback, such as speed feedback as compared to the work zone speed limit.

Figure 2 shows the different types of *information* that could be provided at various locations. When considering the *data* that could be collected in each location, there could be justification for collecting any of the following types of data at any of those four locations:

- Vehicle speed;
- Traffic volumes;
- Vehicle presence;
- Vehicle location; and
- Camera images.

Figure 3 provides a comparison of the SWZ device locations that have been identified for this concept as compared to the component parts of the temporary traffic control zones as identified in the MUTCD. The SWZ components will supplement the traditional traffic control put forth by the MUTCD and provide a mechanism for providing dynamic traveler information and improved data collection; however, all required signage and devices required by the MUTCD will remain. The specific location of the SWZ equipment will be determined as part of the detailed design that is developed for each specific SWZ deployment. This design process will consider the specific conditions of the work zone to identify the best locations for the recommended SWZ equipment to make sure that there is minimal encroachment within the work zone and to design the system in a way that avoids creating any hazards to workers or other work zone equipment.



Adapted from MUTCD Figure 6C-1. Component Parts of a Temporary Traffic Control Zone

Figure 3 – SWZ Device Locations Compared to MUTCD Zones

4 SWZ OPERATIONAL CONCEPT

A general SWZ concept for MCDOT was identified based on the alternatives analysis (provided in **Appendix A** for reference). This concept identifies the SWZ components that should be deployed at all MCDOT SWZ deployments, regardless of the specific characteristics of the work zone (length, location, duration, etc.).

4.1 Core SWZ System Components (For Work Zones Less Than One Mile In Length)

The recommended devices and order of core components for MCDOT work zones is not expected to change. However, it is expected that the actual location of each component in the work zone will be based on the specific characteristics of the work zone and roadway in question. **Figure 4** depicts the core components and their relevant order that should be deployed in all MCDOT work zones.

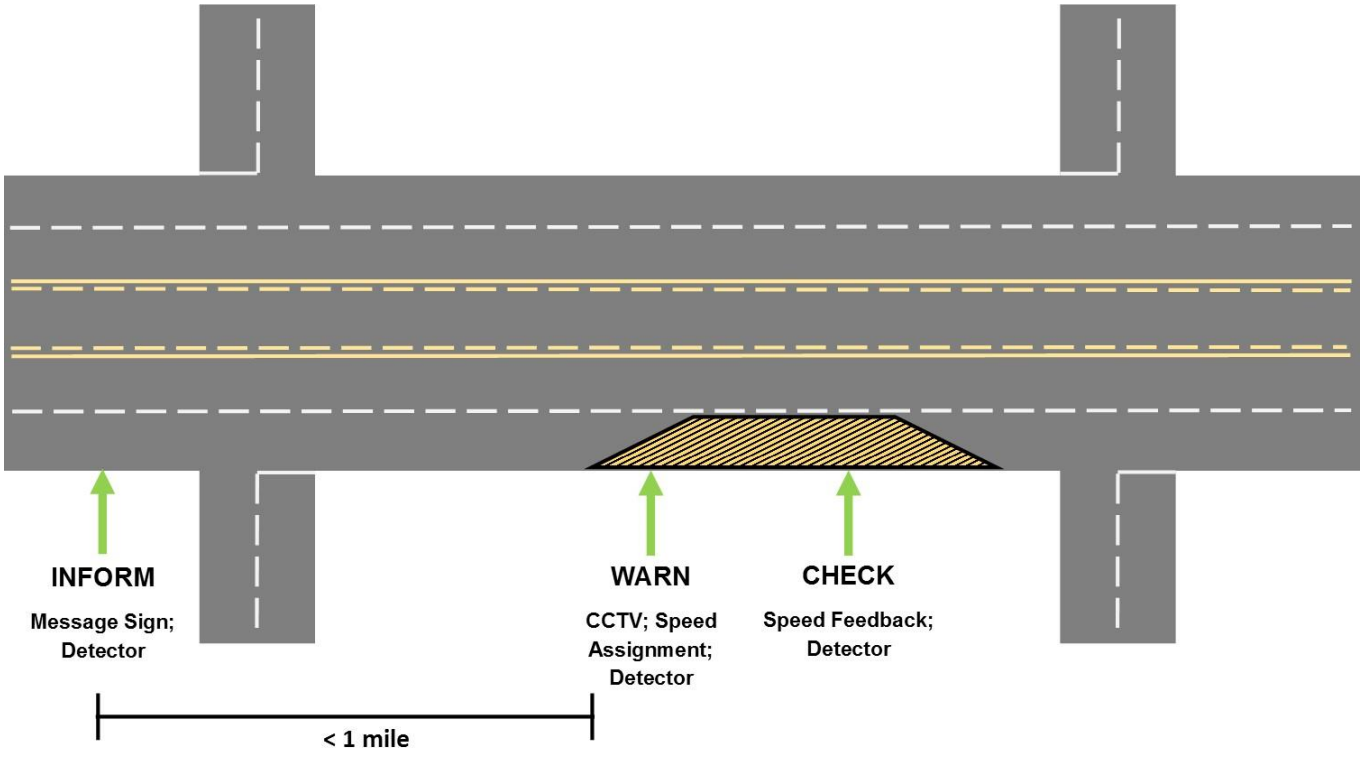


Figure 4 – Layout of MCDOT SWZ Core Components

INFORM – Provide a message sign and a detector within one mile of work zone. This provides drivers with a warning about the work zone and detection of speeds/volumes in advance of the work zone. This INFORM location and associated devices was chosen as a SWZ core component because of the potential availability of an alternate route option along MCDOT-owned corridors. In addition to being a work zone warning and detection location, this INFORM point could also provide:

- Alternate route suggestion if placed in advance of a route decision point within one mile of work zone
- Travel time through the work zone if the work zone length is longer than one mile

WARN – Provide "speed assignment" technology, such as a dynamic speed sign or a variable speed limit sign, which will designate the speed limit through the work zone. At this location, also provide a CCTV to view the work zone and traffic moving through it, as well as a detector to read speeds/volumes of vehicles entering the work zone. Dynamic speed signs are useful in work zones where the speed limit may be changed based on the level of activity in the work zone. An example of this would be that speeds are only reduced when workers are present and are otherwise returned to regular posted speeds. In work zones that do not have this variability in speed limits, an alternative to the dynamic speed sign is a static speed limit sign (both shown in the upper right figure), which is part of the traditional traffic control plan (TCP) and minimizes the need for things like power or communications that would be required for dynamic speed assignment signs.

DYNAMIC OR VARIABLE SPEED ASSIGNMENT SIGN

STATIC SPEED ASSIGNMENT SIGN

CHECK – Provide a speed feedback sign and a detector. This reminds drivers of the speed limit that was posted on the speed assignment sign at the beginning of the work zone and will detect speeds/volumes for compliance in the work zone. A speed feedback sign can include either a static or a dynamic speed limit display (both shown to the right). If the distance between the WARN and CHECK locations is less than ½ mile, the CHECK location may not be necessary but needs to be part of the traffic control design process in order to support inclusion in a SWZ implementation.

SPEED FEEDBACK SIGN (to be paired with static speed assignment sign)

DYNAMIC SPEED FEEDBACK SIGN (to be paired with dynamic or variable speed assignment sign)

The core components layout allows MCDOT to address all the major SWZ goals that have been identified.

Table 2 shows the traceability between the four goals and the SWZ core components.

Table 2 – SWZ Core Components in relation to MCDOT SWZ Goals

SWZ Goal	Relevant Core Components and Functions
Improve speed limit compliance through the work zone	• **Message sign** prior to the start of the work zone to provide information on work zone conditions to encourage people to comply with the speed limit • **Speed assignment sign** at the beginning of the work zone to display the appropriate speed limit based on work zone conditions • **Speed feedback sign** within the work zone to provide awareness to drivers of their speed in relation to the speed limit
Increase travel time reliability through the work zone	• **Message sign** to provide information on work zone conditions so people to know to slow down (if necessary) and to provide information on alternate routes to give drivers an option to avoid the work zone as to reduce the number of cars, and thus possibility of congestion, within the work zone

SWZ Goal	Relevant Core Components and Functions
Reduce crashes in the work zones	• **Message sign** to provide information on congestion or crashes in the work zone so drivers are aware of slower speeds within the work zone • **CCTV** camera to allow for quick identification and response to crashes in or near the work zone to minimize likelihood of secondary crashes • **Speed assignment sign** to reduce speed limit in work zone in response to crashes to minimize likelihood of secondary crashes • **Detectors** to detect occupancy to help with incident detection
Reduce queues resulting from the work zone	• **Message sign** to provide information on work zone conditions and on alternate routes to provide drivers with an option to avoid the work zone as to reduce the number of cars, and thus possibility of queuing, within the work zone • **Speed assignment sign** to provide appropriate speed limit within work zone to try and reduce speed variance, which causes congestion and queuing • **Detectors** to detect occupancy to help with queue detection

4.2 Additional SWZ System Components

In addition to the core components that will be deployed in all SWZs, some work zones may require additional components to accompany the core components. The need for these additional components are based on the following characteristics of the work zone: 1. the length of work zone; and 2. the distance between the beginning of the work zone and the nearest, upstream alternate route.

4.2.1 Length of the Work Zone (Greater Than One Mile)

Work zones that are longer than one mile in length will require additional devices in order to disseminate necessary information and collect required data.

INFORM – If a work zone is more than one mile in length, the INFORM location that provides a message sign in advance of the work zone could provide the following types of information:

- Work zone alert messaging;
- Travel times through the work zone; and
- Alternate routing options if placed in advance of a routing decision point.

CHECK – If a work zone is more than one mile in length, it may require a second (or potentially third) CHECK point with devices. **Figure 5** depicts this scenario, where the SWZ core components are shown in gray and the additional CHECK location is shown in black.

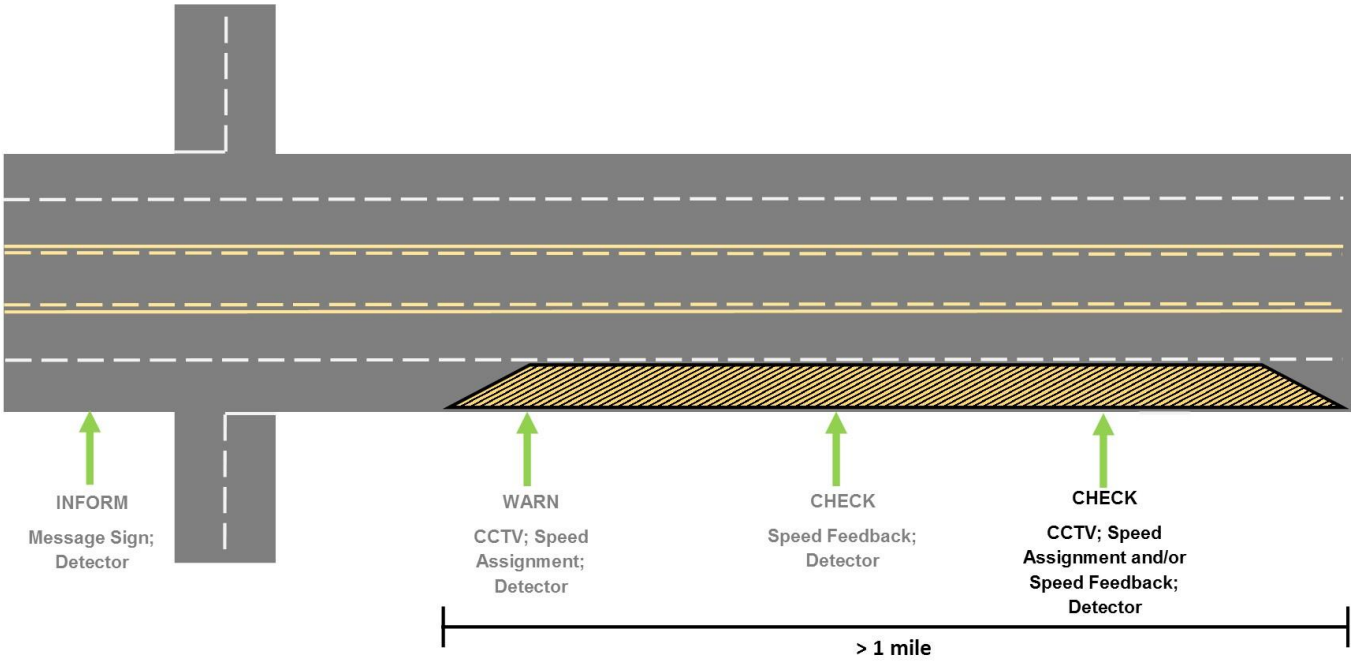


Figure 5 – Additional Components for a Work Zone Longer than One Mile

For these longer work zones, an additional CCTV camera is recommended. CCTV cameras have a typical viewing range of ½ mile in each direction when mounted at a reasonable height above the traveled way, so an additional CCTV camera would be important for providing surveillance capabilities throughout the work zone for work zones greater than one mile.

An additional VSL and/or a speed feedback sign is recommended to address the goals of improving speed compliance and reducing travel time through the work zone. An additional speed feedback sign would remind drivers of the speed limit and highlight their actual speed. A dynamic speed assignment sign would not only reinforce the speed limit, but it would also provide the contractor/MCDOT with an opportunity to adjust the speed limit in the middle of a long work zone based on the current conditions. For example, if a work zone is two miles long, but the active work zone (the space where workers are actually present) is only in the first mile, then the speed limit for the second mile, where there are fewer hazards, could be increased to help increase traffic flow through the work zone.

Additional detection of speeds and volumes will help collect a more holistic data set for the work zone and will provide information on queue presence and length, which is important for the goal of reducing queueing in the work zone.

ADDITIONAL INFORM LOCATIONS – For work zones greater than two miles in length, an additional INFORM location is recommended one mile upstream in advance of the INFORM point currently depicted as a SWZ core component. This additional and far upstream INFORM point could utilize a message sign but will not require a detector.

ADDITIONAL CHECK LOCATIONS – The number and placement of additional CHECK locations should be determined based on the actual length of the work zone.

- A work zone that is two or three miles long will likely require multiple additional CHECK locations.

- A work zone that encompasses an intersection will require a CHECK location after the intersection in order to monitor the intersection and provide information to motorists that are entering the work zone from the intersection. This additional CHECK location will need to include a message sign (**Figure 6**).

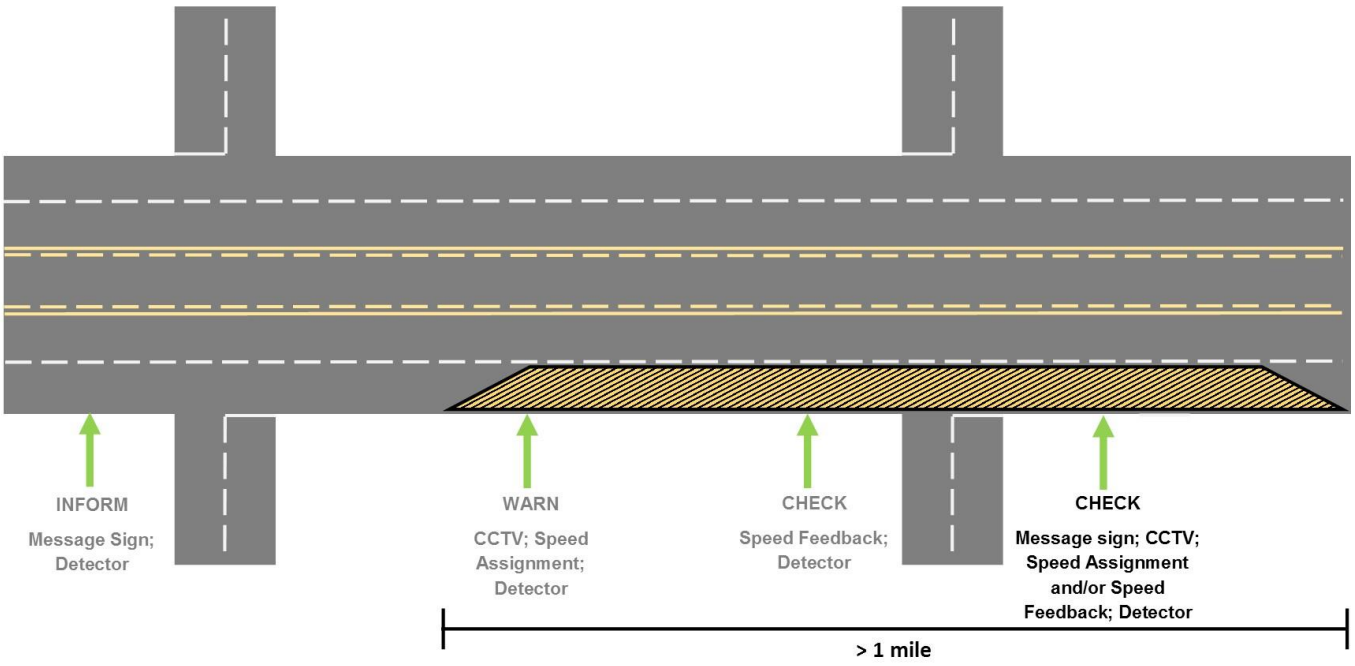


Figure 6 – Additional Components for a Work Zone Longer than One Mile with Intersections

The actual number of additional CHECK points will be dictated by the preferences and judgement of the individuals developing the traffic control plans but should consider length of the work zone, the desired camera coverage and the presence of intersections within the work zone.

4.2.2 Distance Prior to the Work Zone

The second work zone characteristic that will determine if additional devices should be deployed is the distance between the beginning of the work zone and the nearest, upstream alternate route. Generally, work zones in urban areas will have cross streets that are close to the beginning of the work zone, whereas work zones in more rural areas may not. At the INFORM location, a message sign is part of the SWZ core components in order to provide information on work zone conditions (crashes, travel time, queue/delay, speed reductions, etc.) as well as potential alternate route options, if available, so that travelers can decide to avoid driving through the work zone entirely.

ADVISE – For work zones that have more than one mile between the INFORM location and the start of the work zone and there is an alternate route option available in advance of the work zone, it is recommended that additional SWZ devices, a message sign and a detector, are deployed prior to the work zone, or what was previously identified as the ADVISE location. This is depicted in **Figure 7**.

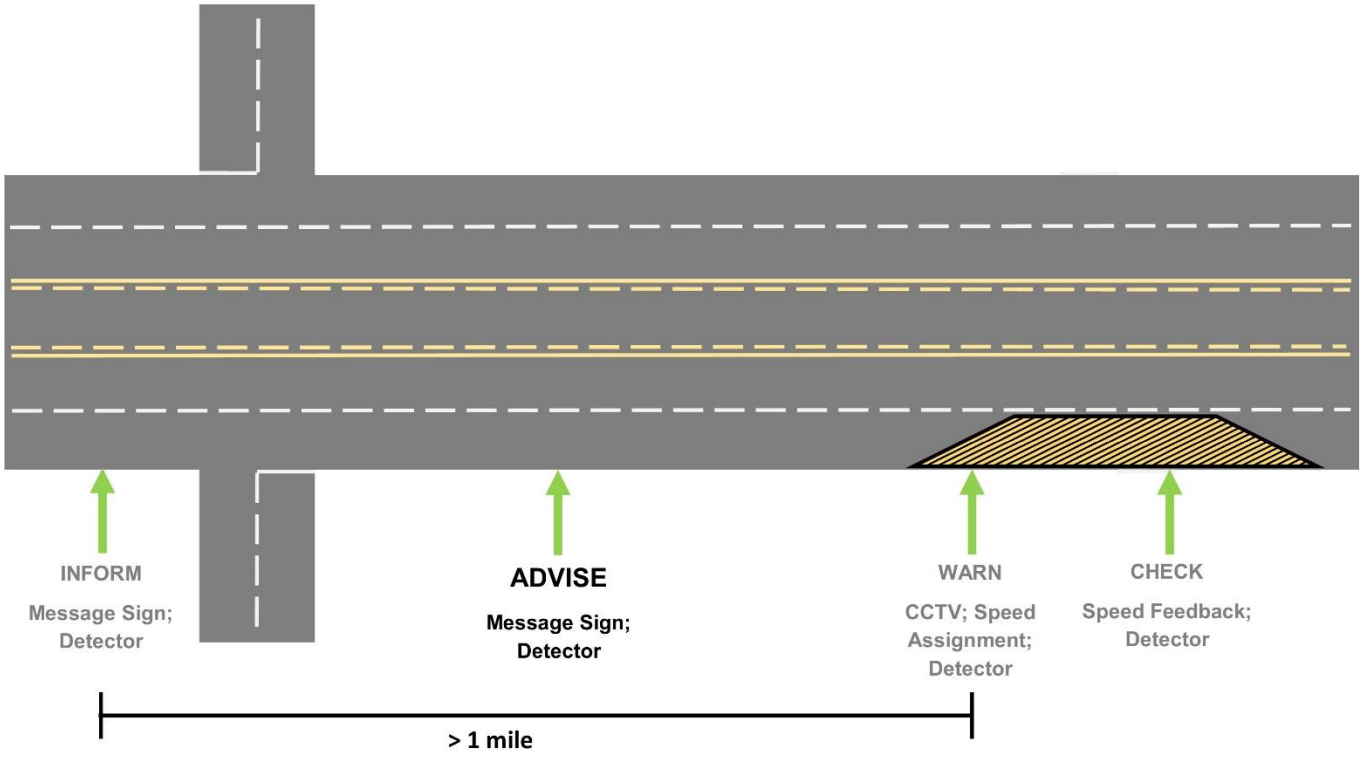


Figure 7 – Additional Components Prior to the Start of a Work Zone

Figure 7 shows the core components in gray and the recommended additional components in black. An additional message sign is recommended to provide travelers with information about work zone conditions. While there are no alternate routing options at this ADVISE point in traffic movement toward the work zone, it is important to reinforce information regarding work zone conditions to drivers who had not seen the sign prior to the alternate route, and it provides information to drivers who did not pass the INFORM location, such as those that turned onto the road from the nearest cross street.

An additional detector is recommended to help collect a more holistic data set for the work zone and provide data on queue presence and length, which is important for the goal of reducing queueing in the work zone.

ADDITIONAL ADVISE LOCATIONS – Similar to the previous scenario that required additional components, the number of ADVISE locations should be determined based on the actual length between the INFORM location and the beginning of the work zone.

- If the distance between the INFORM location and the start of the work zone is less than two miles, one ADVISE location would likely suffice to provide an additional message sign and detector.
- If the distance between the INFORM location and the start of the work zone is more than two miles, then multiple ADVISE locations might be necessary. The actual number should be based on the judgement and/or preference of the developers and approvers of the traffic control plan.

4.2.3 Major Intersecting Route within the Work Zone

While the core SWZ concept does not include any SWZ equipment on roadways that are intersecting or perpendicular to the roadway with the work zone, MCDOT might consider deploying additional INFORM locations on intersecting roadways if they are major arterials that experience significant traffic. These additional locations are indicated by the orange arrows in **Figure 8**.

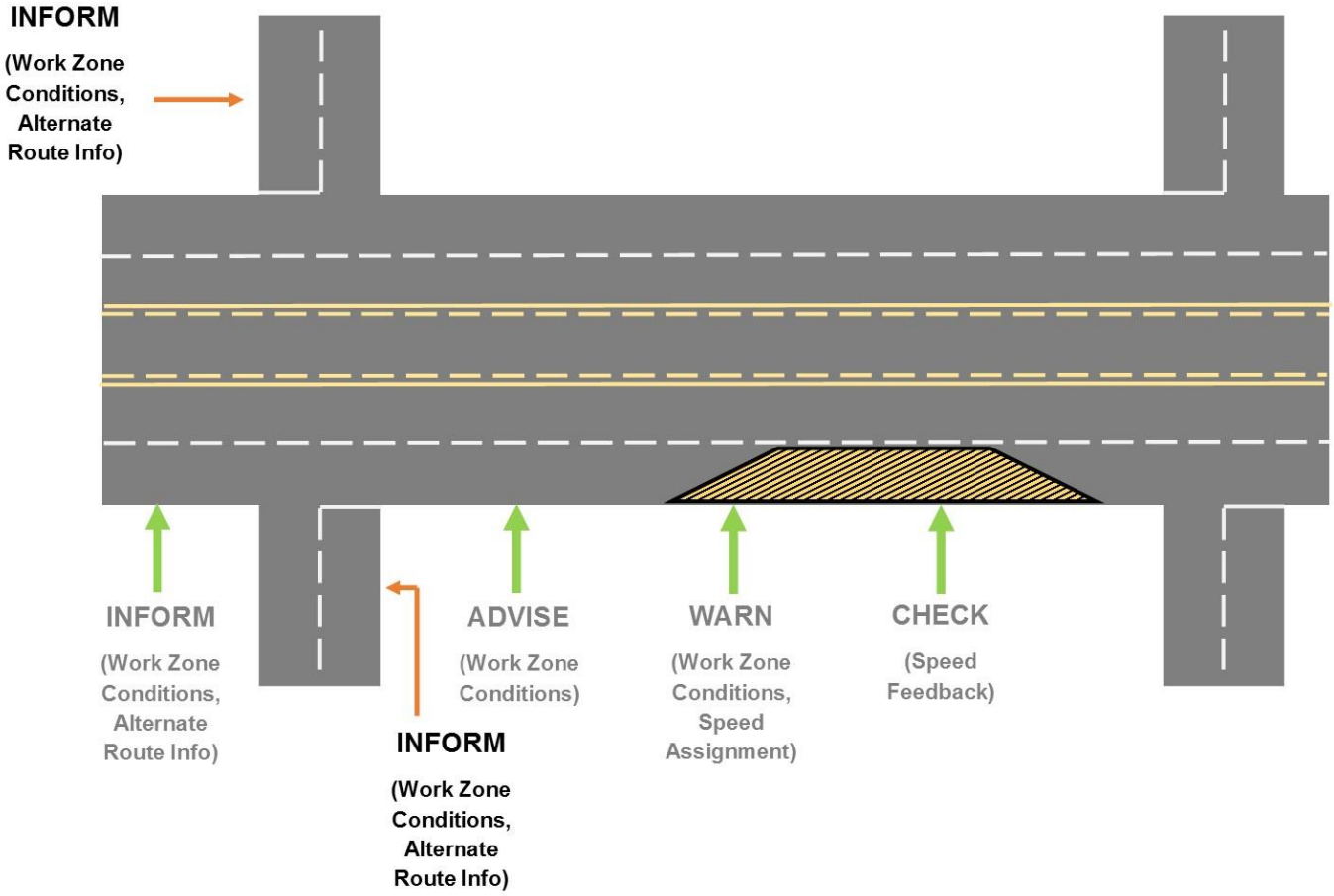


Figure 8 – Additional Components on Major Intersecting Streets

These additional INFORM locations may be deemed necessary by MCDOT in order to provide work zone condition and alternate routing information to travelers on intersecting roads, mainly those drivers planning to turn into the work zone from a perpendicular route. Providing conditions and alternate routing information to these drivers can allow them to be informed of the upcoming work zone and its impact and give them time to adjust their route to avoid the work zone if desired. This will help address all of the MCDOT SWZ goals similarly to the traditional INFORM location as it can help reduce the number of travelers within the work zone.

4.2.4 Summary of Core SWZ Components and Application Methodology

When deciding what SWZ components should be included in a deployment, there are two characteristics of the work zone that should be considered: length of the work zone; and the distance between the first location where traveler information is provided (i.e. the INFORM location) and the beginning of the work zone taper. **Table 3** provides a summary of SWZ core component applications relative to these criteria. This table should be consulted during the design of the deployment for each SWZ.

Table 3 – SWZ Core Components and Applications Summary

		LENGTH OF WORK ZONE			
		< 1 MILE	**1-2 MILES**	**> 2 MILES (WITHOUT INTERSECTION IN WORK ZONE)**	**> 2 MILES (WITH INTERSECTION IN WORK ZONE)**
DISTANCE BETWEEN INFORM LOCATION AND WORK ZONE	**> 2 MILES**	**INFORM** - message sign, detector **ADVISE** (multiple locations may be necessary) - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (may not be needed) - speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **ADVISE** (multiple locations may be necessary) - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile will be necessary) - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **ADVISE** (multiple locations may be necessary) - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile between intersections within work zone will be necessary) - message sign, CCTV, speed assignment and/or speed feedback, detector
	1-2 MILES	**INFORM** - message sign, detector **ADVISE** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (may not be needed) - speed feedback, detector	**INFORM** - message sign, detector **ADVISE** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **ADVISE** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile will be necessary) - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **ADVISE** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile between intersections within work zone will be necessary) - message sign, CCTV, speed assignment and/or speed feedback, detector
	< 1 MILE	**INFORM** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (may not be needed) - speed feedback, detector	**INFORM** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile will be necessary) - CCTV, speed feedback, detector	**ADDITIONAL INFORM** (may not be needed) - message sign **INFORM** - message sign, detector **WARN** - CCTV, speed assignment, detector **CHECK** (one per mile between intersections within work zone will be necessary) - message sign, CCTV, speed assignment and/or speed feedback, detector

4.2.5 Additional Required SWZ Components

Additional SWZ components will be needed to develop an operable, manageable, sharable, and researchable work zone. The following SWZ components will be required:

Communications – In addition to identifying the types of devices and configurations are necessary for a MCDOT SWZ, there is additional infrastructure required to collect, transmit, and process the data collected by the devices. Communications infrastructure, such as fiber, wireless radios, or cellular is typically used to connect ITS field devices to a central system.

In the case of a work zone application, the recommended technology for communications are wireless cellular devices due to the cost effectiveness, reliability in deployment, and existing knowledge of SWZ vendors for deploying such devices for communications to a web-based WZ System. Wireless radios can be used as a backup option for connection of SWZ technologies.

Work Zone Management System – A work zone management system (WZ System), provided by the vendor, functions as the central control system for the SWZ equipment. The WZ System will administer alerts when devices are malfunctioning and allow the contractor or MCDOT to remotely control the devices. It will also serve as a repository for data that is being collected and transmitted by the devices.

4.2.6 Other SWZ Components to Consider

The following list of devices are those that have applications in smart work zones, but that are not included in MCDOT SWZ core components. These devices are not considered core components, so they should not automatically be deployed in every work zone; however, there are situations where deploying these devices could be beneficial and might be considered for deployment.

Table 4 shows these other components, the reason why they are not included as a core component, and the situations where they might be considered for deployment in addition to the core components.

Table 4 – Other SWZ Core Components to Consider

SWZ Technology	Description	Reasons technology is not a core component	When to consider using the technology
Highway Advisory Radio (HAR) *[also known as Travelers' Information Station (TIS)]*	Utilizes an AM or FM radio frequency to broadcast messages to motorists. Agencies purchase a frequency where they play a recorded message that could be used to provide various types of information including traffic advisories, work zone information, evacuation plans, or other general traveler information. Drivers are made aware of the frequency via permanent or portable signs along the roadway in advance of the work zone or location for which the message is pertinent.	Tends to be relatively expensive to implement and operate as agencies have to rent the radio equipment as well as the radio frequency for the duration of the event. Additionally, radio frequencies can be unreliable and easily disrupted by other, more powerful frequencies that overpower the HAR frequency.	• When it is suspected that travelers do not have access to cell phones or internet-based GPS systems • To provide a traveler information message that is too long to fit on a dynamic message sign • Arkansas DOT used HAR to provide information on a work zone that had interstate impacts, so that travelers in neighboring Memphis, TN were provided the work zone information which would not be provided on the Tennessee DOT 511 system[2].
Portable Traffic Signals (PTS)	A traffic signal (mast arm and red-yellow-green signal head) and associated equipment that control movement of traffic through a single lane in a work zone. PTS are often deployed in lieu of a flagger, and have been found to be more effective and safer than deploying a flagger.	Many MCDOT roads already have signalized intersections so it would be unnecessary to include additional signals. Also, deploying PTS is only cost efficient when a lane closure is at least a day long[3].	• When there is limited sight distance and/or high speeds approaching a lane closure • When motorists have to wait an excessive period of time to traverse through a lane closure • Projects involving busy intersections or driveways that are not signalized[1] • When a lane is closed for a significant period of time (at least a day) and only a single lane for both directions remains open
Oversized Load Detection	Trailer-mounted detection system that identifies oversized loads and displays warning instructions on portable message signs or flashing beacons to direct the driver to an alternate route. These systems are used when work zones includes obstructions that have low clearance heights or significantly reduced lane width.	Rarely do MCDOT roads have truck restrictions due to permanent reduced height or width clearances. Further, MCDOT work zones will likely not include infrastructure that would reduce height clearances, and traffic control plans are developed in consideration with minimum widths for trucks.	• When a work zone includes infrastructure (permanent or portable) that have reduced height clearances or reduced widths below minimum requirements • When roadways are frequently used by unpermitted oversized loads[4]

[2] http://ntl.bts.gov/lib/jpodocs/repts_te/13600.html
[3] http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/3926-2.pdf
[4] http://www.atssa.com/galleries/default-file/2008july21_its_safety_and_mobility.pdf

4.3 Operational Components and Responsibilities

The green components of **Figure 9** provide the core SWZ communications links needed to manage devices from the MCDOT TMC. The yellow components are optional based on the involvement of elements that are outside of the core SWZ system. These optional components include additional MCDOT-owned equipment, coordination with other traffic management centers, coordination with the PIO office, and sharing of pre-trip information to a website.

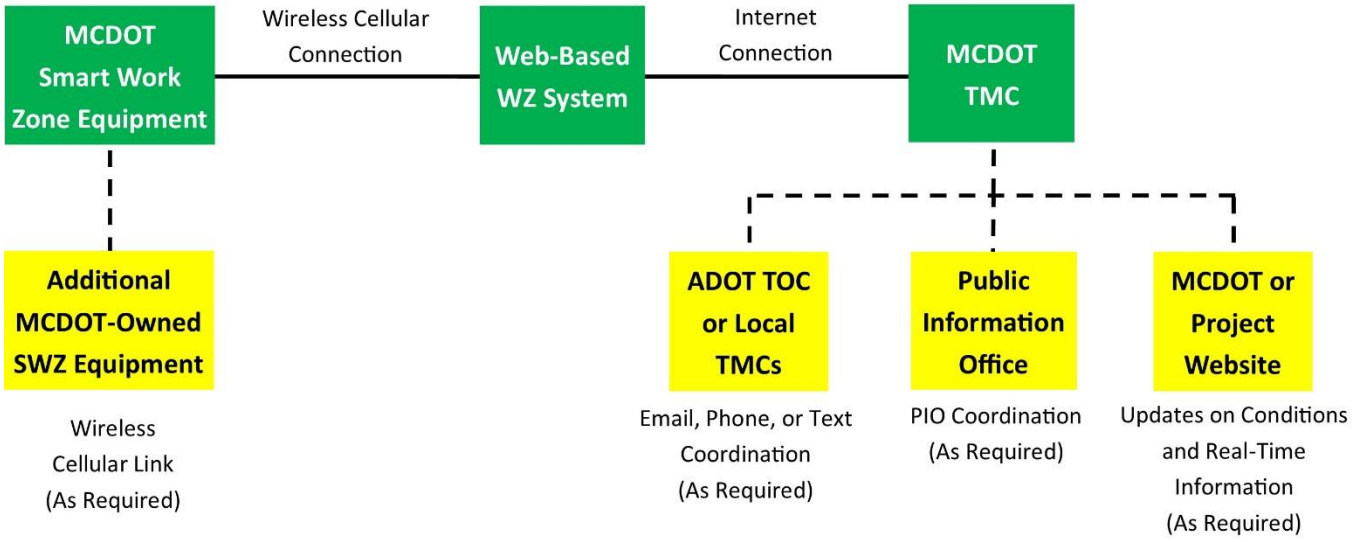


Figure 9 – SWZ Core and Optional Components

The roles and responsibilities of work zone monitoring and management are provided by the following categories:

MCDOT CONSTRUCTION MANAGER – MCDOT will have multiple responsibilities when the SWZ technologies are deployed in a MCDOT-managed work zone. These include:

- Acquiring a SWZ vendor that can supply SWZ equipment and a WZ System to manage that equipment by the Contractor. Communicate design of SWZ equipment locations to work zone Contractor for incorporation into traffic control plans for work zone phasing.
- Coordinate with MCDOT signal timing personnel (MCDOT Traffic Signal Manager and TMC Signal Analyst) to assist with optimizing the traffic signal timing along the corridor where the work zone will take place.
- The Construction Office will have access to the WZ system to view the equipment deployed in the work zone. The Construction Office should have view-only access to the WZ system and pan-tilt-zoom access to the cameras to be able to monitor the cameras and message signs to verify that the work zone is operating correctly and should coordinate with the MCDOT TMC if there are any issues or changes required to the equipment.
- Additional MCDOT-owned equipment that could supplement rented equipment by a SWZ vendor could be incorporated into the SWZ vendor design of system for use during work zone deployment.
- When deemed appropriate, coordinate with the MCDOT TMC to deploy DSRC radios to collect Connected Vehicle research data at all SWZ equipment locations that include a detector device.

MCDOT TMC – The MCDOT TMC in specific will have multiple responsibilities with the SWZ deployment, including:

- The WZ System will be provided to the MCDOT TMC by the SWZ vendor to be able to monitor and operate all SWZ components deployed in MCDOT work zones. This will include reviewing default messages, thresholds and other equipment settings prior to the start of the work zone, and operating and monitoring the equipment, especially the messages displayed on message signs and CCTV camera feeds.
- The MCDOT TMC should regularly coordinate with the MCDOT Construction Manager regarding the operation of the work zone and the SWZ equipment and should attend regular construction meetings during the duration of construction.
- The MCDOT TMC is responsible for their existing intersection and communications equipment within the work zone area. If work zone activities are expected to disrupt operations or communications equipment, MCDOT TMC staff should have a plan for fixing the equipment or having a backup plan to supplement the equipment.
- Coordination with other traffic centers such as the ADOT TOC or local jurisdiction TMCs in proximity to the work zone or impacts to traffic by the work zone will be conducted by MCDOT TMC personnel rather than a direct connect to the WZ System. Coordination will be conducted via email (direct person exchange or via subscription to GovDelivery notices), phone, or text as determined by the level of information required by the other traffic center.
- Collecting all data for a 'before' condition and an 'after' condition for analysis of work zone conditions and traffic behaviors using the SWZ deployment. This could include deployment of detectors prior to the placement of additional larger SWZ components (message signs, VSL, speed feedback signs) in order to collect the 'before' condition. Alternatively, this could include the deployment of SWZ components and only turning 'on' the detectors and not turning 'on' the other equipment in order to collect the 'before' condition. The 'after' (or 'operational') condition will be evaluated using the SWZ equipment in its full functional and intended capacity for the duration of the work zone. The analysis of the 'before' data compared with the 'after' data will help inform the deployment of SWZ equipment in future arterial work zones.
- When deemed appropriate, the MCDOT TMC should coordinate with the Construction Manager to deploy DSRC radios to collected Connected Vehicle research data at all SWZ equipment locations that include a detector device.

OTHER TRAFFIC CENTERS – Coordination with the MCDOT TMC for road condition and work zone updates. Coordination will be conducted via email (direct person exchange or via subscription to GovDelivery notices), phone, or text as determined by the level of information required by the other traffic center.

PUBLIC INFORMATION OFFICE – Public information personnel for MCDOT will stay apprised of conditions in work zone and outcomes of the use of the SWZ equipment for work zone management through attendance at weekly construction meetings and GovDelivery emails sent out by the MCDOT TMC for current road conditions.

MCDOT OR PROJECT WEBSITE – Detection information could provide updated speeds, queuing, and/or travel times to a project website or the MCDOT website for pre-trip traveler information purposes.

CONTRACTOR – Include SWZ equipment into traffic control plans for work zone phasing.

5 PERFORMANCE MEASUREMENT STRATEGY

A performance measurement strategy is important to facilitate the tracking and reporting of the performance of the SWZ system from both an operational standpoint (how well are devices working) and a benefits standpoint (are SWZ goals being achieved). The SWZ goals that were identified by MCDOT are the foundation for the performance measure strategy.

Table 5 provides an overview of the SWZ goals, the objective(s) for each goal, and an example of types of data-driven measures that can be used to measure progress towards the goal. The measures will be calculated using the data that is provided by the SWZ devices. As previously noted, the devices that were selected for inclusion were to specifically be able to measure the SWZ goals.

Table 5 – MCDOT SWZ Performance Measures

SWZ Goal	Measure	Example Goal Value
Improve speed limit compliance through the work zone	% of speeds in compliance with work zone speed limit	95% speed compliance after first feedback location
Increase travel time reliability through the work zone	Travel time in minutes through work zone prior to and during deployment of SWZ equipment in work zone	15% reduction in travel time through the work zone when SWZ equipment is deployed
Reduce crashes in the work zones	Number of crashes in work zones	Zero crashes at all SWZ deployments
Reduce queues resulting from the work zone	% of time a queue forms in advance of work zone while SWZ equipment is in place	Queues due to the work zone are present no more than 5% of time

The performance measures represented in this table are anticipated to be analyzed for the first few SWZ deployments and potentially could be adjusted over time if a measure or goal value is becoming an easy or difficult target to reach. The pursuit of performance measurement is to achieve a quantifiable measure of success for the SWZ application. Thus, these measures can be used as a starting point to assist in determining that level of success.

6 APPLICATION OF SMART WORK ZONE CONCEPT

6.1 FHWA Six Step Process

This MCDOT SWZ concept will follow the FHWA six-step process for developing, designing, procuring and deploying a SWZ system. The six steps outlined by FHWA include[5]:

1. Assessment of Needs;
2. Concept Development and Feasibility;
3. Detailed System Planning and Design;
4. Procurement;
5. System Development; and
6. System Operation, Maintenance, and Evaluation.

This Technical Feasibility Concept will cover steps 1 and 2 of this process. Step 3 is completed for each, specific work zone; for the MC-85 project a SWZ concept has been developed in a separate document titled Smart Work Zone Concept – MC-85 Application, and a detailed design will be developed based on this concept. Steps 4 through 6 will be done by MCDOT prior to the initiation of the MC-85 project. Considerations for Steps 4 through 6 are found in this section and involve working with the project contractor to procure a SWZ vendor who will provide, help operate and manage the SWZ equipment for the project. MCDOT will use the data and reports provided by the SWZ system and equipment in order to undergo evaluation of the SWZ deployment.

6.2 Considerations for MCDOT to Deploy the SWZ Concept

This section outlines how to apply this concept to an actual work zone during planning and design. Applications of items 1 through 3 are found in the addendum of this concept in order to document the use of smart work zones in MCDOT road work projects:

1. **Technologies** – MCDOT to identify technologies that will need to be applied for work zone phasing. Utilize Table 3 – SWZ Core Components and Applications Summary – as guidance. The presence of alternate routing options or intersections in advance of or within the work zone will need to be specifically considered during SWZ technology placement.
2. **Optional Components** – MCDOT to identify optional components that are desired for work zones including connection to and coordination with local TMCs, potential involvement of the PIO office, and availability of data and the location to send the data for website pre-trip traveler information.
3. **Performance Measurement** – MCDOT to identify data and information that will be required to complete performance measurement analysis for the work zone.

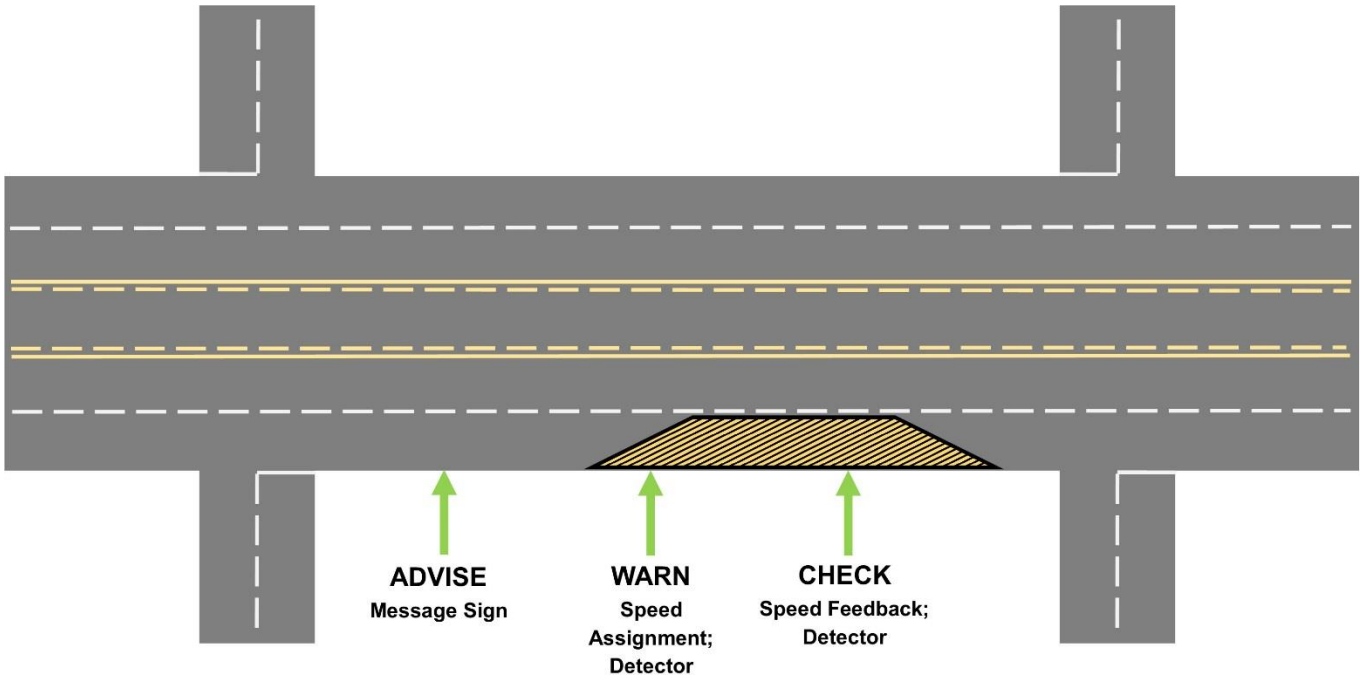
[5] FHWA (2014). Work Zone Intelligent Transportation Systems Implementation Guide. http://www.ops.fhwa.dot.gov/publications/fhwahop14008/

Items 4 through 10 require development of specific scoping documents and MCDOT processes for application of a SWZ system in an active work zone:

4. MCDOT to prepare the required scope for the SWZ to assist in Vendor-selection for renting SWZ as necessary. MCDOT to consider integrating any MCDOT-owned SWZ equipment into this scope so Vendor integrates this equipment into their systems so that it functions as one SWZ system.
5. MCDOT to select SWZ Vendor (through selection of the construction Contractor).
6. Vendor prepares design and layout of SWZ components.
7. Contractor for work zone to incorporate SWZ design into traffic control plans.
8. Vendor and Contractor collaborate on mobilization of SWZ components in advance of and use of SWZ system during work zone phasing.
9. Vendor and Contractor collaborate on demobilization of SWZ components.
10. MCDOT to conduct post-SWZ data analysis for performance measurement.

APPENDIX A – SWZ ALTERNATIVES SCENARIOS DISCUSSION

Identifying the devices that should be deployed at each location is based on the type of information that would need to be provided and types of data that would be needed to be collected based on the identified goals. For example, **Figure A1** provides the devices, data and information that could be provided at each location in order to address Goal #1 – improve speed limit compliance through the work zone. As seen in the figure, neither information dissemination nor data collection are needed at the INFORM location in order to make progress towards the goal. Additionally, providing real-time camera feeds would also be unnecessary to address the goal, and thus the use of CCTV cameras would not be required for this scenario.



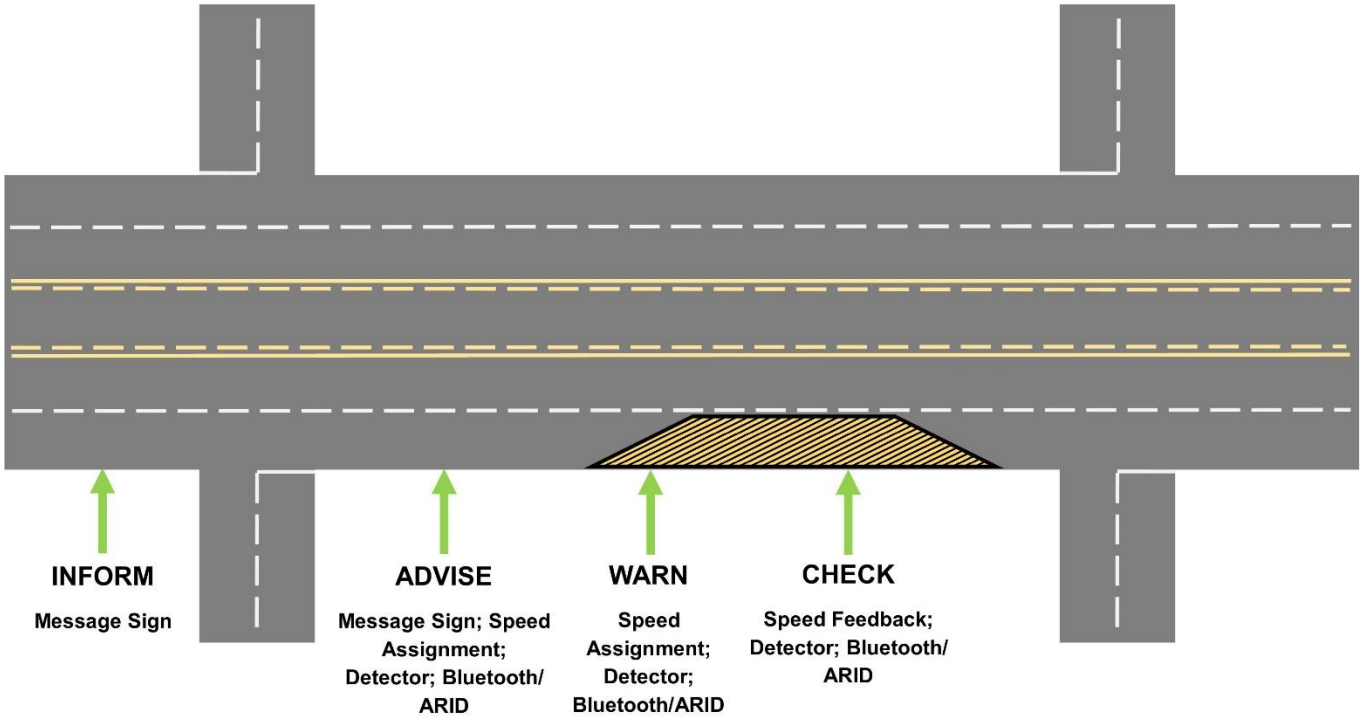
ADVISE— use a message sign to provide information on work zone conditions to encourage drivers to reduce speeds to comply with the work zone speed limit (message examples: reduce speed ahead; speed enforced ahead; workers present ahead)

WARN — use speed assignment sign to show the driver's real-time speed (collected by radar) in comparison to the work zone speed limit OR use a VSL to show the current work zone speed limit; use a detector to collect information on vehicle speed, volume and presence

CHECK—use speed feedback sign to show the driver's real-time speed (collected by radar) in comparison to the work zone speed limit; use a detector to collect information on vehicle speed, volume and presence

Figure A1 – Work Zone Layout to Address SWZ Goal #1 – Improve Speed Limit Compliance

Figures A2 – A4 provide graphics that depict the types of information dissemination, data needs and device layouts that would be required to address SWZ Goals 2, 3 and 4.



INFORM — use a message sign to provide information about work zone conditions (including travel time through the work zone) and about alternate routes to encourage drivers to consider using an alternate route to avoid the work zone (example messages: work zone ahead, consider using alternate route)

ADVISE— use a message sign to warn drivers about reduced speeds or hazards to try and reduce collisions and smooth out speeds through the work zone (which is set based on current conditions and may be lower, higher or the same as the previous speed limit; use a speed assignment sign to provide the current work zone speed limit; use a detector to collect information on vehicle speeds to inform the speed limit, as well as collect traffic volumes and presence; use a Bluetooth/ARID device to collect vehicle location to calculate travel time in the work zone.

WARN — use a speed assignment sign to provide the current work zone speed limit (which is set based on current conditions and may be lower, higher or the same as the previous speed limit); use a detector to collect information on vehicle speeds to inform the speed limit, as well as collect traffic volumes and presence; use a Bluetooth/ARID device to collect vehicle location to calculate travel time in the work zone.

CHECK— use a speed feedback sign to provide the current work zone speed limit (which is set based on current conditions and may be lower, higher or the same as the previous speed limit); use a detector to collect information on vehicle speeds to inform the speed limit, as well as collect traffic volumes and presence; use a Bluetooth/ARID device to collect vehicle location to calculate travel time in the work zone.

Figure A2 – Work Zone Layout to Address SWZ Goal #2 – Improve Travel Time Reliability

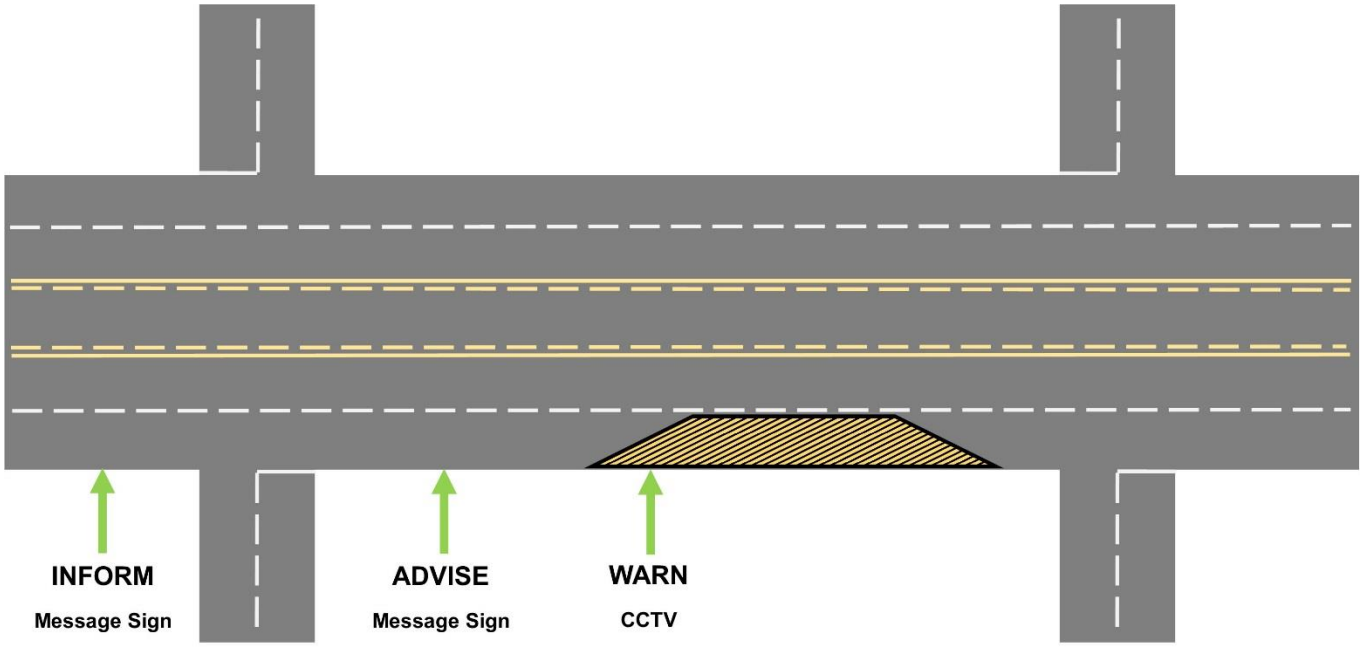
In order to make progress towards Goal #2 – increase travel time reliability, the SWZ applications must achieve two objectives:

1. Reducing the number of cars that go through the work zone, thus reducing the chance that congestion or crashes might occur; and
2. Reducing any causes for delay, such as congestion or crashes, for cars that do drive through the work zone.

Additionally, this SWZ application must also be able to compute travel time (given the nature of the goal), but MCDOT can choose whether or not to display that information to the public.

The first objective is achieved by using portable message signs to display alternate route information, which helps divert some portion of vehicles from entering the work zone. The second objective is

achieved using the portable message sign to provide information about work zone conditions to improve situational awareness and avoid crashes, secondary crashes, or other activities that might result in travel delay. Travel times are computed by data provided by Bluetooth or ARID devices.



INFORM — use a message sign to provide information about work zone conditions and about alternate routes to encourage drivers to consider using an alternate route to avoid the work zone (example messages: work zone ahead, consider using alternate route; crash ahead, use alternate route)

ADVISE— use a message sign to warn drivers about reduced speeds or hazards to try and reduce collisions or secondary collisions

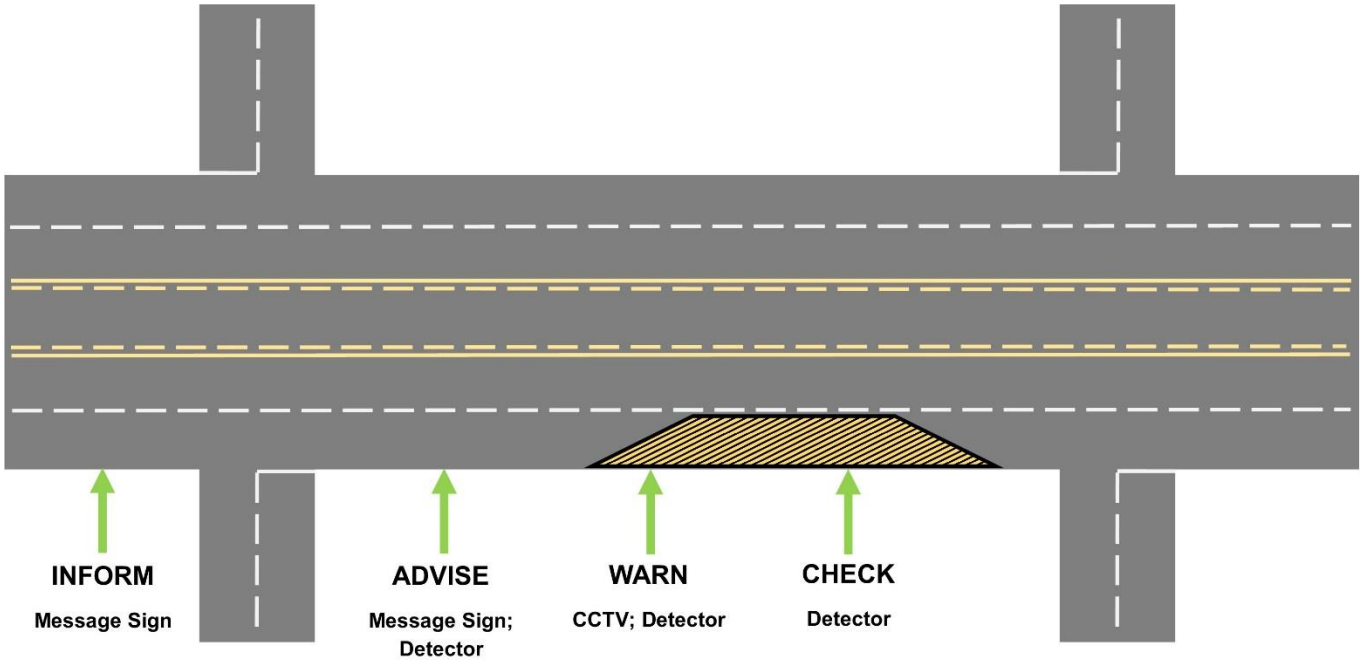
WARN — monitor CCTV camera feed for quicker incident identification and response to reduce the likelihood of secondary crashes

Figure A3 – Work Zone Layout to Address SWZ Goal #3 – Reduce Crashes

For Goal #3 – reduce crashes, the main objective is to identify, respond to, and clear incidents as quickly as possible to minimize the chances for secondary crashes. This is mainly done by:

1. Informing drivers of work zone conditions and hazards (such as crashes) so that they know to slow down and be cautious;
2. Providing information on alternate routes to reduce the number of cars that go through the work zone, thus reducing the chance that congestion or crashes might occur; and
3. Quickly identifying and responding to incidents that do occur.

The goal of reducing crashes can also be supported by other SWZ goals, such as improving compliance with the speed limit or reducing queue, so these goals can go hand-in-hand in a SWZ deployment.



INFORM — use a message sign to provide information about work zone conditions (including queues) and about alternate routes to encourage drivers to consider using an alternate route to avoid the work zone (example messages: work zone ahead, consider using alternate route)

ADVISE— use a message sign to warn drivers about queues through the work zone; use detector to collect speed, volume and presence data to detect queue and calculate queue length to inform the message on the message sign

WARN — monitor CCTV feed to confirm presence of queue and reason for queue; use detector to collect speed, volume and presence data to detect queue and calculate queue length to inform the message on the message sign

CHECK—use detector to collect speed, volume and presence data to detect queue and calculate queue length to inform the message on the message sign

Figure A4 – Work Zone Layout to Address SWZ Goal #4 – Reduce Queues

The objectives for Goal #4 – reduce queues have overlap with some of the other goals as well as some additional objectives. These objectives include:

1. Providing information about work zone conditions, including the presence of a queue, so that drivers know to slow down and to facilitate a more consistent speed; and
2. Providing information on alternate routes to reduce the number of cars that go through the work zone, thus reducing possibility of congestion.

Based on the four scenarios, there are multiple overlaps in objectives and the types of devices that would be required at a location, meaning that a single device could provide the necessary data or information to address multiple SWZ goals. It is this core set of infrastructure that could be included in other MCDOT work zones.