Utah Department of Transportation

Use of Variable Speed Limits in Construction Zones

Concept of Operations

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Prepared for:

Prepared by:

In association with:

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1 OVERVIEW

The Utah Department of Transportation (UDOT) is looking to implement smart work zone technology to manage the prudent reduction of speeds within work zones while minimizing the effects of the work zone on the traveling public. Specifically, technology related to portable variable speed limit (PVSL) signs will be investigated to help significantly reduce regulatory speed limits in active construction work zones and address the objective of improving safety for the construction personnel and traveling public within work zones.

The desired system is one that involves dynamic management of traffic through active work zones, or work areas where personnel are on site and exposed to the danger of errant vehicles. The system that is envisioned is one that dynamically manages traffic speeds through active work zones by providing accurate and reliable information on speed restrictions and travel times based on real time traffic and construction conditions. A primary goal of real-time traffic management and information dissemination is to build and maintain driver trust regarding legitimacy of posted speed limits through active work zones and encourage greater compliance with reduced speed areas.

This project effort includes the preliminary engineering, contractor specifications, detailed drawings of the system requirements and recommendations, acquisition, implementation, performance monitoring, data collection, analysis and reporting on the use of PVSL in four test work zones.

This document, known as a Concept of Operations (ConOps), summarizes the recommended concept for a PVSL system and sets the groundwork for the overall system and technical course for the project. Its purpose is to convey a high-level view of the system to be developed and help stakeholders form a comprehensive and shared understanding of the needs, goals and functions of the system. The ConOps is the first part of a larger systems engineering process that is followed when developing, testing and implementing a new system or technology.

1.1 Systems Engineering Planning Process

This section describes the intended execution of the systems engineering processes used to develop the project. Figure 1-1 is an example of a 'Vee' diagram which is used to describe the systems engineering process. As seen in the figure, the Concept of Operations (this document) is the first step of the systems engineering process for projects that involve the development, testing and implementation of a new system. This project includes almost all items within the overall systems engineering process from Concept of Operations through Operations and Maintenance.

This project will ultimately develop a PVSL System that can be operated on site by the Resident Engineer (RE) or Contractor and will be tested by UDOT on 4 specific work projects in the upcoming two construction seasons to verify that the goals and objectives of the system are met.

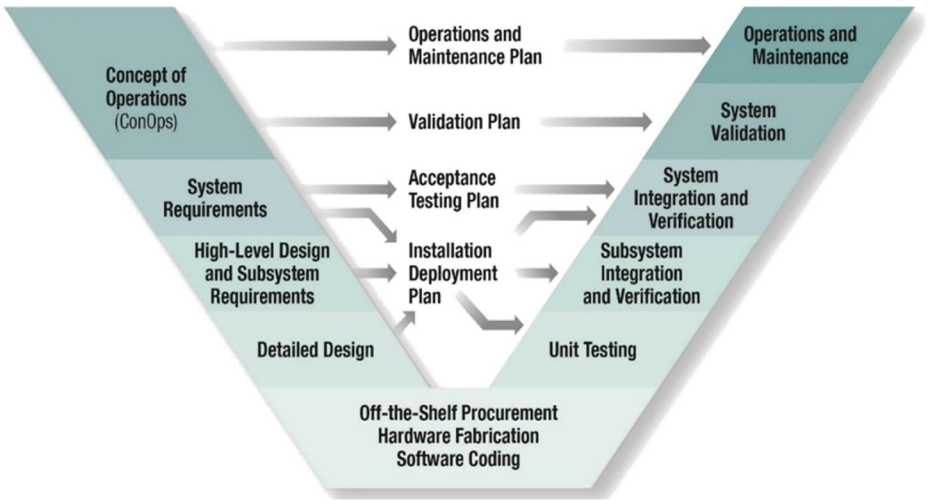


Figure 1-1: Systems Engineering Outputs within the 'Vee' Diagram

The steps being undertaken as part of the ConOps development include Technical Advisory Committee (TAC) meetings, stakeholder workshops, and systematic development of the following (all of these will be discussed in further detail within this document):

- Operational Parameters and Limits – defines the thresholds for various elements of the system and its functions such as the highest and lowest allowable speed limit or the required minimum spacing between work zone elements. (Section 4.2)
- Stakeholder Roles and Responsibilities Matrix – defines the roles and responsibilities for various functions and processes related to the system with respect to the different audiences who will interface with the system, such as UDOT, the Contractor, or the public. (Section 5)
- User and System Needs – helps define specific aspects of functions that the system must include based on the foundational needs that led to the need for this project. Developing a system based on identified needs also helps provide traceability between the ultimate system and its intended purpose. (Section 6)
- Operational Scenarios – provides graphical depictions of different situations that may be encountered to facilitate holistic decision making for the system in all conditions. (Section 8)
- Goals/Objectives/Performance Metrics – defines the overall goals of the project that can be measured and tracked in the form of data-driven metrics. (Section 9)

1.2 ConOps Development Purpose

The beginning processes for conducting Systems Engineering involves establishing needs of the stakeholders, relationships to other projects/programs, and identifying how the system will operate, before moving into steps toward designing the system – all of which are captured in a ConOps. This ConOps document describes the functionality of the PVSL System from a customer and stakeholder perspective. The final ConOps will be used to support the design and development of the PVSL construction site control system, procurement of devices for the system, integration of the system for testing, and testing of the system in actual work zones in Utah over a two year period. This ConOps document is a living document that will be refined during the course of this project as needs warrant updates.

A series of technical workshops were conducted with selected UDOT stakeholders prior, and the input and findings elicited during these meetings provided the foundation for the development of a draft ConOps. This draft has been distributed to stakeholders for review and comment. Additionally, the draft requirements developed as part of this

ConOps will be updated and circulated for a final review by stakeholders prior to commencing with system development.

Technical objectives for this project which will be managed and carefully considered throughout the course of development include:

- Defining the system from a need- and user-based standpoint;
- Designing the PVSL System platform and integration such that expansions to the system to include new functionality (device types, PVSL applications, expansion to new types of work zone characteristics not originally tested, etc.) at a later date can be accommodated without complete replacement of the system;
- Identifying risks and mitigation strategies associated with manual or automated features of the PVSL System.

This plan will proactively address those potential technical challenges by being forward looking to identify the challenges in advance and offer potential solutions to preemptively mitigate prior to system development.

2 EXISTING CONDITIONS

The PVSL system will supplement many of the existing policies, processes and details for executing and managing work zones in Utah. The existing policies, regulations and specifications came from the following documents:

- Utah Code – Statutes and Constitution, May 2014
- UDOT Operating Policies, March 2015
- Utah Manual on Uniform Traffic Control Devices (MUTCD) December 2011
- UDOT Standard & Supplemental Drawings, 2012
- UDOT Standard Specifications and Special Provisions, 2014

2.1 Definition of Terms

There is a set of terms that is used to describe work zones within UDOT. These terms, defined below, must be universally understood and agreed upon within UDOT to make sure that there is consistency within all practices and any new policies and standards related to reducing speed limits in work zones. These are shown in Figure 2-1.

- Work Zone – an area of a highway with construction, maintenance, or utility work activities. A work zone is typically marked by signs, channelizing devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or high-intensity rotating, flashing, oscillating, or strobe lights on a vehicle to the END ROAD WORK sign or the last TTC device. (MUTCD 6C.02 P2);
- Work Area – the area encompassing the Work Zone plus the area starting one mile in advance of the Work Zone;
- Work Space – that portion of the highway closed to road users and set aside for workers, equipment, and material, and a shadow vehicle if one is used upstream. Work spaces are usually delineated for road users by channelizing devices or, to exclude vehicles and pedestrians, by temporary barriers. (MUTCD 6C.06 P2); and
- Active Work Space – the area within the Work Space that has working field personnel present.

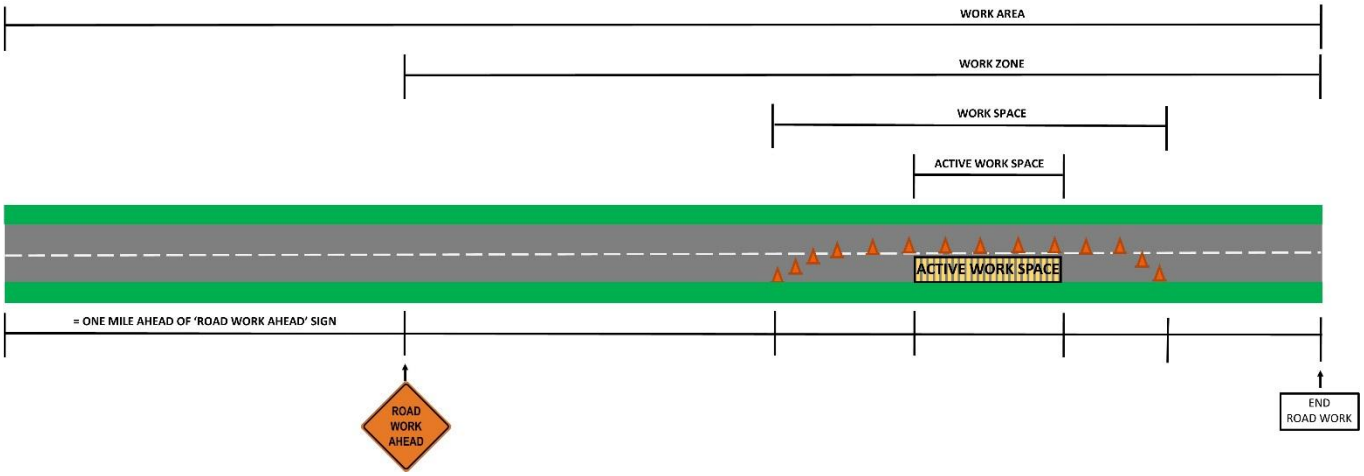


Figure 2-1: Definition of Terms

2.2 Existing Policies and Standards

The following is a non-exclusive set of policies, standards and processes either found in the aforementioned documents and/or discussed during workshops will influence the PVSL system.

Utah Code 41-6a-602

- The maximum posted speed limit in Utah is 80 miles per hour (mph).

- There is a new Utah Code that was added in 2014 that established how government agencies may acceptably use data obtained from cell phones. UDOT's interpretation is that the code prohibits the use of bluetooth for travel time estimation purposes, and prohibits the use of data from cell phones gathered by third parties.

UDOT Operating Policies UDOT 06C-61

- Speed limits may be temporarily reduced by 10 mph; reductions greater than 10 mph must get approval from the Engineer for Traffic Safety in the form of a Traffic Engineering Order (TEO).

Utah MUTCD 2011

- Placement of signs depends on the roadway type and is delegated by the table found in the MUTCD[1] and provided in the Utah Standard Drawing shown in Figure 2-2; if two or more signs are used, the closest sign to the temporary closure should be approximately 1,000 feet away or more.

- The distance between an advanced warning sign and active work zone should not exceed 5 miles; the 'Road Work Next XX Miles' sign may be used instead of the 'Road Work Ahead' sign if the active work zone occurs more than 2 miles away.

Figure 2-2, 2-3, and 2-4 on the following pages depict a standard drawings and a Detail Sheet that have been issued or are under development and are used to implement within work zones when PVSL is being implemented. Figure 2-2 is Traffic Control (TC) 4B1.Figure 2-3 and 2-4 is a new suggested standard for variable speed limit deployment.

[1] *Utah MUTCD, Table 6C-1. Recommended Advance Warning Sign Minimum Spacing*

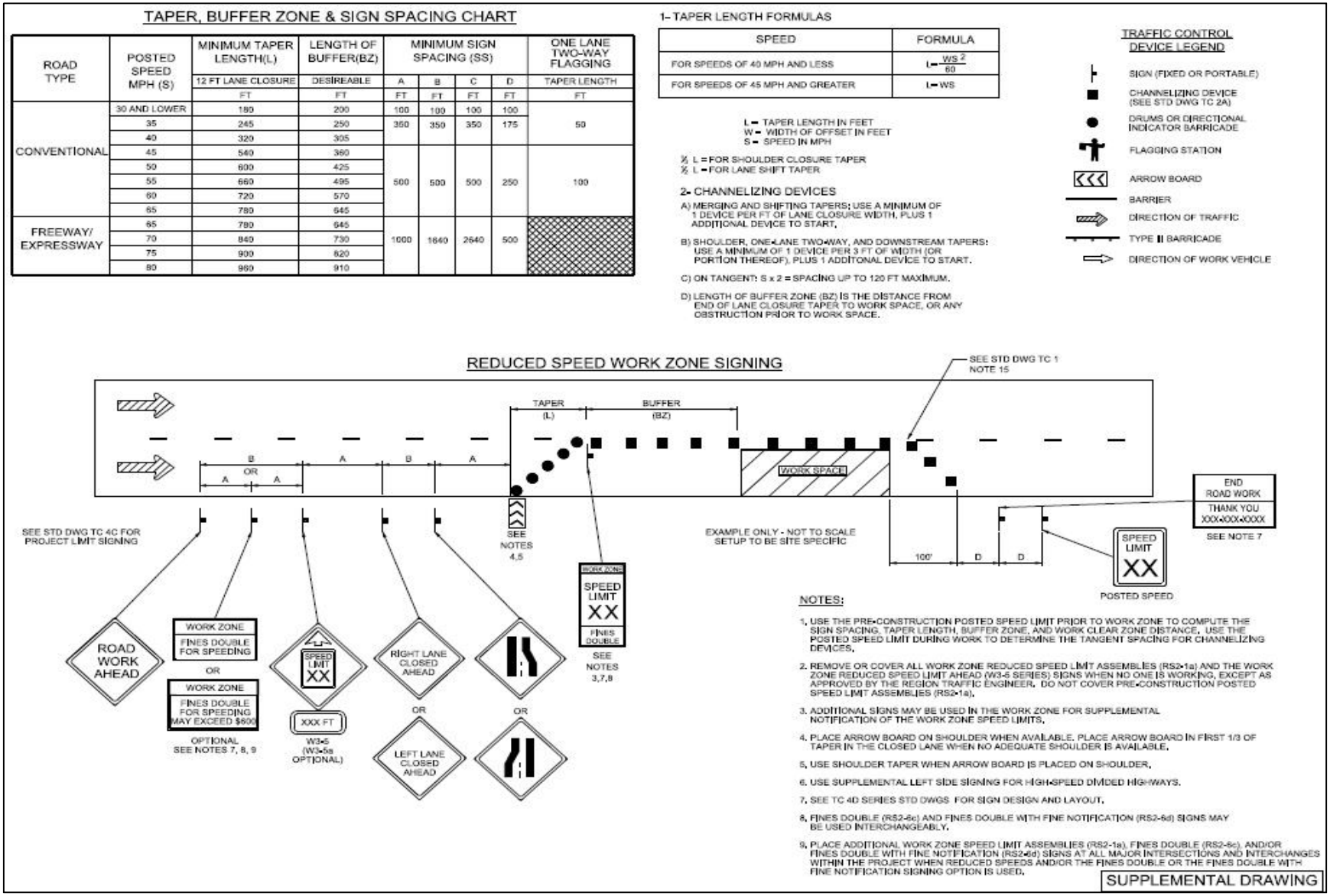


Figure 2-2: Reduced Speed Shoulder Work Zone Signing Supplemental Drawing (TC 4B1)

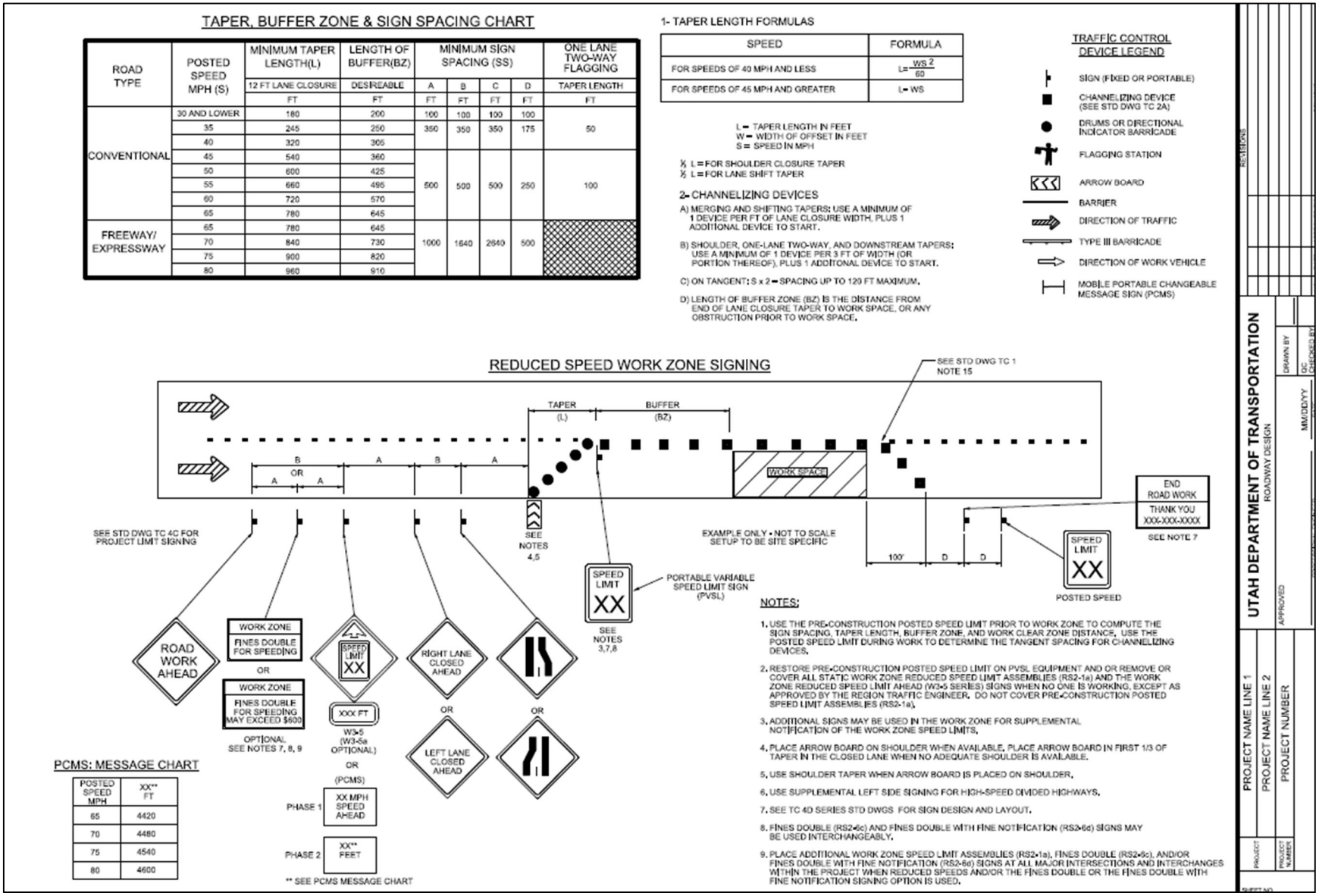


Figure 2-3: Reduced Speed Work Zone Signing Supplemental Drawing

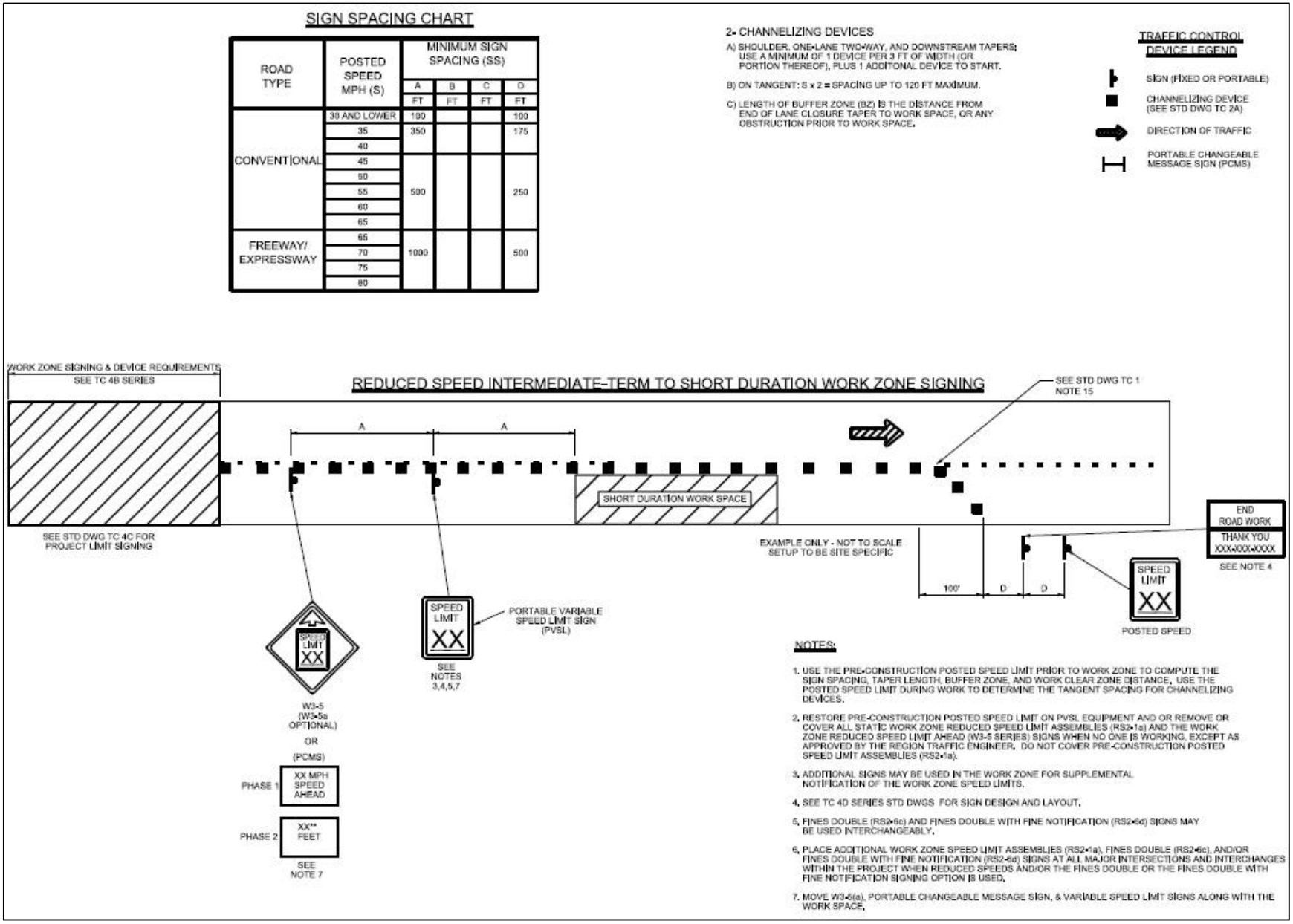


Figure 2-4: Reduced Speed Intermediate-Term to Short Duration Work Zone Signing Supplemental Drawing

2.3 Current Practices at UDOT

In accordance with the policies and standards, UDOT has existing practices and processes for implementing and managing work zones. These practices are important to understanding how UDOT handles reducing speeds in work zones and how work zones are set up, in general.

2.3.1 Reducing Speeds in Work Zones

In accordance with the UDOT Operating Policy on speed reductions, a 10 mph reduction to the speed limit within a work zone for a duration of 20 days is allowed and does not require a TEO. Any speed reduction that is greater than 10 mph or a reduction that occurs for more than 20 days requires submittal of a TEO for approval by the Engineer for Traffic Safety. While 10 mph is the only increment that is discussed in the Policy, reductions in excess of 10mph have occurred in association with a work zone when conditions have justified their use.

When a speed limit is reduced by 15 mph or less, the reduction can be accomplished in two signs; by a speed limit sign and a warning sign. A warning sign must be provided to alert drivers of the reduced speeds. Currently, a static warning sign (W3-5 in the MUTCD as shown in Figure 2-5; or RS2-14a as an alternate option shown in Figure 2-6) is used for this purpose. Speed limit reductions that are 15 mph or less only require a single W3-5 sign per Supplemental Drawing SN-6.

Figure 2-5: Example of W3-5 Warning Sign

Figure 2-6: Example of RS2-14a Warning Sign

A speed limit reduction of 20 mph or more typically requires a minimum of two, successive speed limit reductions in order to reach the target speed. Each of these reductions require a speed limit sign and two W3-5 signs. However, it was discussed that UDOT plans to implement a 20 mph reduction with only one W3-5 or RS2-14a sign and a PVSL LED sign (as opposed to a static speed limit sign) for cases where there is good visibility and lower average traffic volumes on the roadway. Speed limit reductions of 20 mph are only allowed while the contractor is working; at other times, such as during lunch or during the night, the speed limit must be returned to the normal operating speed limit.

A speed limit reduction of 25 mph or more requires a speed reduction to be completed in two steps using two W3-5 or RS2-14a signs and is only implemented in the active work space where there are field personnel working (see Figure 2-7). To achieve 25+ mph reductions, two successive speed limit reductions are advised, and the general practice is to have the first speed reduction be a lower reduction increment than the second. For example, to reduce the speed limit from 80 mph to 45 mph, the first reduction should be from 80 mph to 65 mph (15 mph

reduction) and the second reduction should be 65 mph to 45 mph (20 mph reduction). An example of the signage sequence for this type of reduction can be seen in Figure 2-7.

UDOT Detail sheets depict the usage of the XX MPH SPEED ZONE AHEAD sign in permanent speed limit reductions which is being slightly modified to say VARIABLE SPEED ZONE AHEAD in this PVSL pilot deployment.

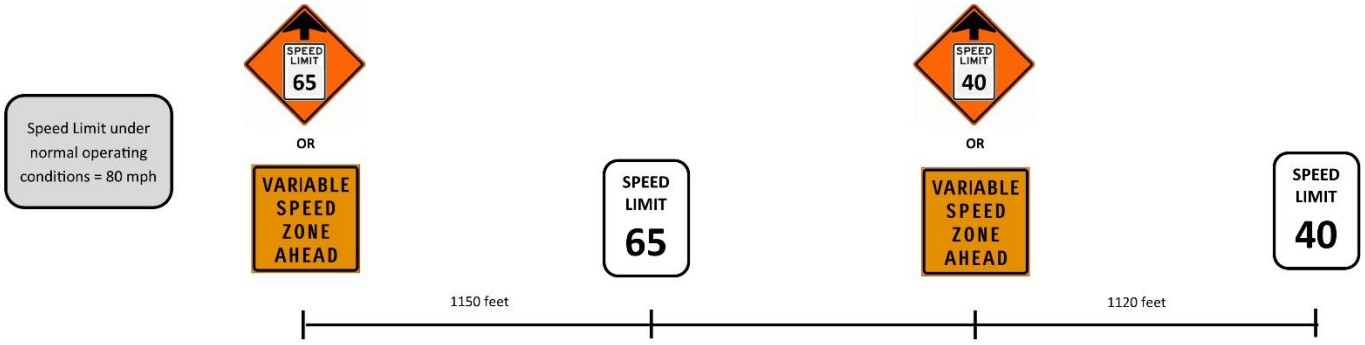


Figure 2-7: Signage for Speed Reductions of 25 mph or More

Reductions of 40 mph or more is considered unreasonable and is not implemented in work zones.

In current practices, one of the most important considerations when implementing work zone-related speed limit reductions is to minimize the length of roadway that is impacted by the reduced speeds to help improve public trust for reduced speed limits. According to policy UDOT 06C-61, "When temporary conditions occur, regulatory speed changes shall only be used? during impacted times and in impacted areas…", which in most cases indicates, reduced speed limits will only be granted during times when there are workers present in an active work space or when there are other, unavoidable hazards that require slower speeds to ensure safety of drivers and workers.

2.3.2 VSL in Utah

There are Special Provisions and Detail Sheets to UDOT Standard provisions and TC Series Standard Drawings in development to provide better guidance on the use of VSL in work zones in Utah. Figures similar to 2-1 and 2-2 may provide high-level guidance on the use and location of VSL signs as they relate to a work zone for operational scenarios as depicted in the various Figures within Section 9 of this report. UDOT is developing a 2017 standard that may include any new drawings or specifications/standard provisions pertaining to PVSL usage that have arisen since the 2012 version. Currently, UDOT prepares a Special Provision 01554S to provide initial guidance on the use of variable speeds based on current UDOT processes. While these special provisions are currently in place, it is understood that these provisions may be updated and refined based on the outcomes of this project.

UDOT has a permanent variable speed zone installed in Parley's Canyon, which is a mountainous portion of Interstate 80 (I-80) east of Salt Lake City. The stretch of highway frequently experiences moderate to heavy traffic and significant elevation differences, which is compounded by frequent poor weather and low visibility. A total of fifteen permanent VSL signs are in place in both the eastbound and westbound directions within Parley's Canyon.

The speed limits that are displayed are divided into four zones based on varying elevations and geography and may range from 35 mph to 65 mph. At the beginning of the variable speed limit zone, drivers are warned about the possibility of variable speed limits by a RS2-14a static sign. The posted speed limit for the roadway can differ by zone, although all speeds within a single zone are the same. Speed limits for a zone are adjusted by the Traffic Operation Center (TOC) when it is determined to be necessary by a Traffic Engineer based on traffic and weather input from the TOC as well as input from UHP. The posted speed limits on all signs are regulatory and can be enforced by the Utah Highway Patrol (UHP).

3 JUSTIFICATION FOR AND NATURE OF CHANGES

3.1 Limitations of the Current System or Situation

Portable variable speed limits currently deployed consist of LED speed trailers deployed at specific points in the work zone where speed limits are manually entered based on an approved TEO.

There are distinct variations in work zone activity from project to project. Many of the VSL specifications that are currently in use are based on the limited operations (00555S) that were project-specific and consistent with rural projects and extended work zones in high speed situations.

Existing Special Provisions do not account for the variability of impact caused by work zones on traffic nor the ability for the system to automatically adjust speeds or messages based on conditions. Contractors already see benefit in deploying VSL at the beginning and end interim points of their work zones because they see better speed compliance on the part of the motorists.

There is a concern that an extensive amount of devices and static signage requirements for work zones may not be desired for deployment as it may result in a significant amount of work required to set up and move the system that may result in the system not being utilized. Work zones may be set on a time schedule (a work day) that is based on pre-work traffic counts or set up and moved along with specific operations when they are active if only active for a portion of the day.

UDOT has identified a need to create a PVSL system that is beneficial and easy to use when deployed in work zones. Benefits to using a strategically constructed intelligent PVSL system include the ability to provide a safer work environment for the workers and the travelling public and potentially extend the work day windows.

3.2 Strategic and Overarching Objectives

The goal of the PVSL system is to prudently reduce speeds within active work zones along Utah highways to make construction zones safer for field personnel and the traveling public while minimizing the effects of the work zones on the traveling public. This will be accomplished through smart work zone traffic management that will impact safety through increased public compliance and smooth flow of travel speeds.

Even though the primary goal for the UDOT PVSL system is to improve work zone safety, dynamic VSL (DVSL) systems are also used for congestion management. With the duel functionality of the intended systems, there is also a possibility of including both functionalities within the UDOT PVSL System and achieving additional benefits.

3.3 Desired Changes

3.3.1 Functionality Prioritization

A fully developed and capable PVSL system potentially supports a number of PVSL functionalities, including those listed below:

- Provide real-time detection for traffic speed and traffic lane occupancy (queue detection)
- Adjust upstream speed limits based on field activities and based on detected traffic speeds/queue
- Provide dynamic advanced notification to drivers about variable speed limits
- Provide travel time or traffic delay information through the work zone
- Provide surveillance/monitoring capability at the work zone
- Provide real-time weather detection

Cost, time, ease of use, could limit UDOT's ability to perform each potential PVSL functionality. This ConOps prioritizes the functionalities that will achieve the direct goals and objectives of a pilot PVSL system that creates

the basis for PVSL use on future projects. The following list offers prioritization of potential PVSL functionalities that could be supported by this pilot PVSL system:

Required for Pilot Project:

- Recommended variable speeds display; and
- Median and 85th percentile speed.

High Priority for Pilot Project:

- Advanced queue warning message in front of taper;
- Travel times through active work space;
- Advanced queue detection in advance of taper; and
- Travel delay through active work space.

Low Priority for Pilot Project:

- Aggregate data to calculate performance metrics;
- Queue warning message within restricted work space;
- Travel times through work zone;
- Queue detection within work space;
- Travel delay through work zone;
- Weather data collection to inform for safe speeds;
- Graphical interface for displaying performance metrics;
- Surveillance within active work space; and
- Surveillance through work zone.

3.3.2 Technologies

Technologies were specifically chosen to not overwhelm the basic functionalities are needed to achieve the purpose of the PVSL pilot deployment. It is anticipated that this project will include the following primary infrastructure to support PVSL functionality as described in this ConOps:

- Portable VSL (PVSL) – this is anticipated to be similar to the currently deployed DVSL in UDOT work zones.
- Mainline detection by lane – this device will support data collection and processing to inform VSL speed limit recommendations and real-time monitoring of queuing and speed conditions in the work zone.
- Wireless communication – this device will support the cellular communications to all intelligent devices in the work zone so they can be managed from one centralized platform (to be referred to as the 'Site Control System').
- Portable variable message sign (PVMS) – this device will support additional communication to the traveling public in relation to conditions in the work zone, speeds being displayed, or travel time (as warranted).
- Site control system – this is a centralized platform that will be able to manage all devices from one location for the most efficient deployment and operations of the PVSL. It is anticipated that this will be off site and connected via cellular data.

The following technologies were considered but were determined not to be priorities in initial deployment because they cannot inform an intelligent detection system for speed recommendations:

- Camera surveillance technology; and
- RWIS technology.

3.3.3 Operational Integration

There are many requirements on the RE, the Contractor, and UDOT Region Offices in relation to existing deployment of VSL in work zones. While this PVSL pilot deployment is not recommending changing existing static signing required as part of work zone deployment, it is recommending additional and supplemental infrastructure in order to impact the safety and mobility in the work zone. This project will require a modification of current practices in work zones.

Special provisions, standard drawings, and TEO requirements specifically for PVSL implementation will be required that identify how this system will be deployed and integrated into a work zone. .

Considerations for operational integration have been identified in the Roles and Responsibilities in Section 5 of this document. This section discusses the individual requirements of the personnel responsible for operations and management of the system.

The Operational Scenarios identified in Section 9 will support the development of standard drawings and special provisions required to implement a basic PVSL system, including the initial pilot system deployments.

3.3.4 Work Zone Project Deployment Priorities

The intent of this ConOps is to focus on developing this pilot construction projects with specific parameters. The types of construction projects/work zones that will be considered as candidates for testing the PVSL system have the following characteristics:

- Both rural locations and urban;
- Multilane project (more than three undivided lanes [two lanes in one direction and one lane in the other direction] would be ideal or more than four divided lanes [two lanes in each direction]). Three lane sections are acceptable but may have challenges finding a case to test; preference is a focus on four lane divided or undivided roads with single in one or both directions;
- Roadway resurfacing and slab replacement-type construction;
- Work zone with long buffer zone;
- Work duration of at least 30 days;
- Project area with enough traffic volume to measure, but not an area that is known to be an challenge (I-15, I-80);
- Project roadway with higher speeds (45 mph or greater) – 50 mph is a break point for MUTCD “high” speed;
- Project roadway that is relatively flat and straight (simple geometries with minimal curves and elevation changes);
- Situations where work zones could be compared with other work zones easily by project type; and
- “Non-emergency” projects so that the level and type of advanced notification to the public of the work zone is consistent (and thus comparable) between projects.

The following list identifies types of projects that will avoided when testing the PVSL system due to the complexities involved in implementation, placement, and monitoring of conditions at the work site.

- Avoid projects that are “moving operations” like striping, sweeping, grinding rumble strips, etc.;
- Avoid projects with just shoulder work (i.e., projects that have too small of a traffic impact to worry about);
- Avoid projects that use flagger control, pilot cars, and temporary signals;
- Avoid projects where lane closures will require positive protection;
- Avoid work zones that are too close (minimum one mile) to a traffic signal or other access control to eliminate external influences on the system being tested; and
- Avoid weeks/weekends that may have special events or holidays.

There are many types of projects that will not fall under the categories that will be included for testing under this PVSL pilot deployment that may benefit from PVSL deployment in the future. The concepts developed for this project incorporate anticipated broadening of the types of projects for which PVSL could support such as work zones that include curvature, speed changes, shoulder closures.

4 CONCEPTS FOR THE PROPOSED SYSTEM

4.1 Operational Concept

Figure 4-1 shows the relationships of system components and inputs/outputs that are expected to occur as part of the PVSL system.

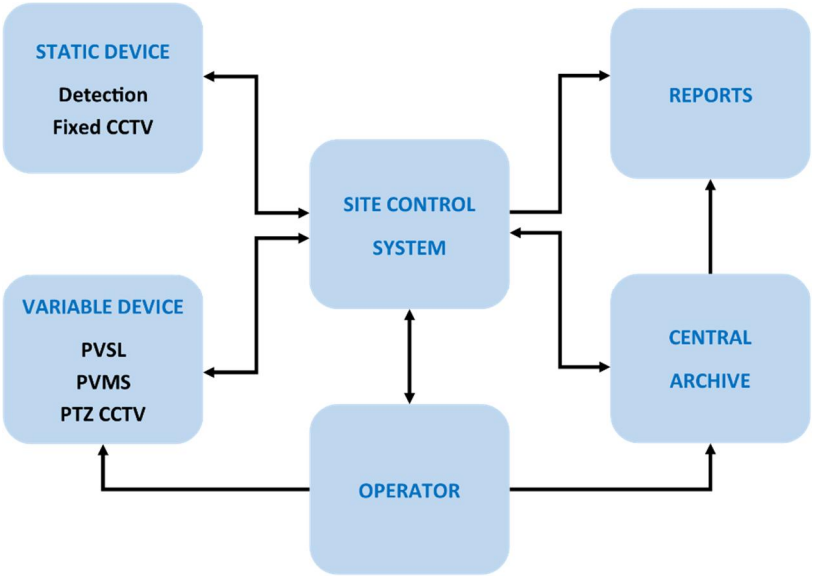


Figure 4-1: PVSL System Architecture Diagram

4.2 Operational Parameters and Limits

Documentation from other states that have deployed VSL for their work zones (that are similar, but not exact in nature, to this pilot PVSL system) were reviewed to identify known limits that UDOT may want to impose upon the system, how it is deployed, or how it is operated. The best practice review of other states included VSL deployments in Colorado, Iowa, Ohio, Oregon, Michigan, Minnesota, Texas, Virginia and Washington.

A workshop was held in September 2015 to review UDOT's current construction area Traffic Control (TC) standards/processes and brainstorm ideas for how this new system could be deployed (which devices, where these devices would be located, and what are the practical limits for using this technology). The goal of the workshop was to develop a basic understanding of the potential operational scenarios that this technology would be applied to and identify potential limits/safeguards for how this technology will be used. The following operational parameters and limits were defined for this PVSL pilot system development and implementation:

General requirements for speed limit controls:

1. A TEO needs to be approved prior to work starting and will need to give details as to speed limits (upper and lower thresholds) of work in that TEO request.
2. Flexible speed increments of five (5) mph, as warranted by work zone conditions and RE judgment.
3. When speeds are lowered over two consecutive PVSL signs, the larger increment of reduction should be on the second PVSL sign, if they cannot be the same increment.
4. Regarding the upper and lower speed limit in an active work zone:
   - Max configurable speed is posted speed limit for the roadway.
   - Minimum speed is project specific.

- Target Speed: According to UDOT, it is around 49mph where the max capacity through a work zone (around 1600vph) is achieved.

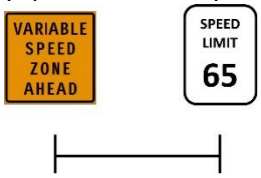
5. There may be a safe traveling speed displayed through the work zone, but in the event that the displayed speed is causing any queuing, detection could inform an updated variable speed limit that gets set above the original work zone speed, up to 10mph higher than the lowest set work zone speed.
6. Minimum frequency for changing speeds is 5 to 10 minutes. Five minutes should be set as the minimum, but the project may want to consider collecting data using the 10 minute minimum to see if there are any notable differences between the 5 and 10 minute thresholds.
7. Speed limits should not be reduced in advance of taper.
8. Performance based traffic control would involve a predictive algorithm based on how detection has collected data on work zone traffic performance. A performance based traffic control system could be set up as a test period for the first for two weeks of the PVSL pilot deployment at a construction site and then analyze data to determine if the performance based traffic control algorithm is correctly anticipating work zone traffic performance.
9. The return to speed sign at the end of the work space should be a static sign.

System Response to Queuing:

1. If prevailing speed is lower than the posted speed (i.e., 85th percentile speed is 35mph but posted speed is 45mph), then do not change the speed limit to the 85th percentile speed.
2. If prevailing speed is higher than posted speed, then the system/RE should determine if it is safe to adjust speed limits higher to match prevailing speeds.
3. If queuing occurs in advance of the taper (i.e., lane closure taper), then the system could have additional detection and PVSL equipment upstream of taper).
4. If queuing is detected within the work space (i.e., beyond the end of the taper) there was some debate about whether or not the system could recommend a change in speed to help alleviate the work space queuing.

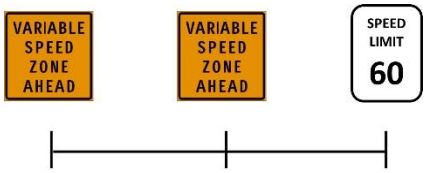
Variable Speed Limit Ahead signage and PVSL usage for various Speed Reduction Increments[2]:

1. System Setup (One Variable Speed Limit Ahead sign in advance of One PVSL sign)



- Upper threshold is 20mph in one step.
- Standard threshold is 15mph in one step.
- Lower threshold is 10mph in one step.

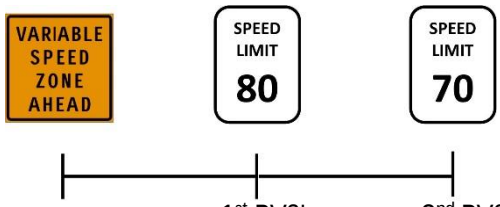
2. System Setup (Two Variable Speed Limit Ahead signs in advance of One PVSL sign)



- Upper threshold is 25mph in one step.
- Standard threshold is 20mph in one step.
- Standard threshold is 15mph in one step.
- Lower threshold is 10mph in one step.

[2] The graphics and table below provide examples of sign configurations and speed limits for a roadway with a normal operating speed of 80 mph being reduced to various, lower speed limits

3. System Setup (One Variable Speed Limit Ahead sign in advance of Two PVSL signs)



Total Speed Reduction	1st PVSL Encountered	2nd PVSL Encountered
10 mph	80 mph	70 mph
15 mph	80 mph	65 mph
20 mph	80 mph	60 mph
20 mph	70 mph	60 mph
25 mph	70 mph	55 mph
30 mph	65 mph	50 mph
30 mph	70 mph	50 mph
35 mph	65 mph	45 mph
40 mph	60 mph	40 mph

Increments for Increasing Speeds:

1. The PVSL system needs to have a maximum speed limit set for each project and that maximum speed is the posted speed of the roadway prior to construction.
2. For stepping up speeds based on prevailing conditions identified by the system (i.e., speed detectors, queue detectors, weather conditions, etc.), the system should incrementally raise the speed limits.
   - For raising speeds, the system should support increments as low as 5mph up to 10mph over the lowest set work zone speed, provided that the maximum allowed speed for the roadway is not exceeded.
3. As warranted by work zone conditions and RE judgment, the system should be capable of returning to the maximum speed (i.e., the RE has the option of overriding the system at any time to return all speed to the normal condition posted speed of the roadway without incrementally stepping up the speeds).

Variable speed changes and the location of the variable speed limits will be captured and archived for enforcement verification if a citation is given in a work zone. Enforcement will be a critical factor for compliance in the ultimate adoption of this system into Utah standard application in work zones. For the purposes of this pilot project, law enforcement will not be strategically placed during the pilot testing in the work zone because that will skew the data of normal traffic compliance.

Each of these operational parameters and limits were used in the development of the needs and requirements as part of this ConOps and will be incorporated into special provisions and drawings, as necessary, to depict how this PVSL system will be implemented and used in a work zone.

4.3 Modes of Operation

4.3.1 Lane Configurations for Pilot Testing

There are three types of lane configurations where the pilot PVSL system will be tested and validated. Section 3.3.4 outlines the types of projects that this pilot PVSL system will and will not be tested, and the lane configurations shown in Figure 4-2 are consistent with those that will potentially be tested. The first kind of work zone involves a four-lane, divided roadway, where one direction is restricted to a single lane due to the work zone. The second

lane configuration is a four-lane, undivided roadway where one direction is restriction to one lane due to the work zone. The final configuration involves a six-lane, divided roadway, where one direction of travel is restricted from three lanes to two lanes or three lanes to one lane. These lane configurations were chosen based on the predefined criteria for the types of work zone conditions that will be included for pilot testing of the PVSL system.

In each of these configurations, it is possible that both directions of travel is restricted which warrants a single PVSL deployment with two directions of configurations for PVSL equipment managed independently.

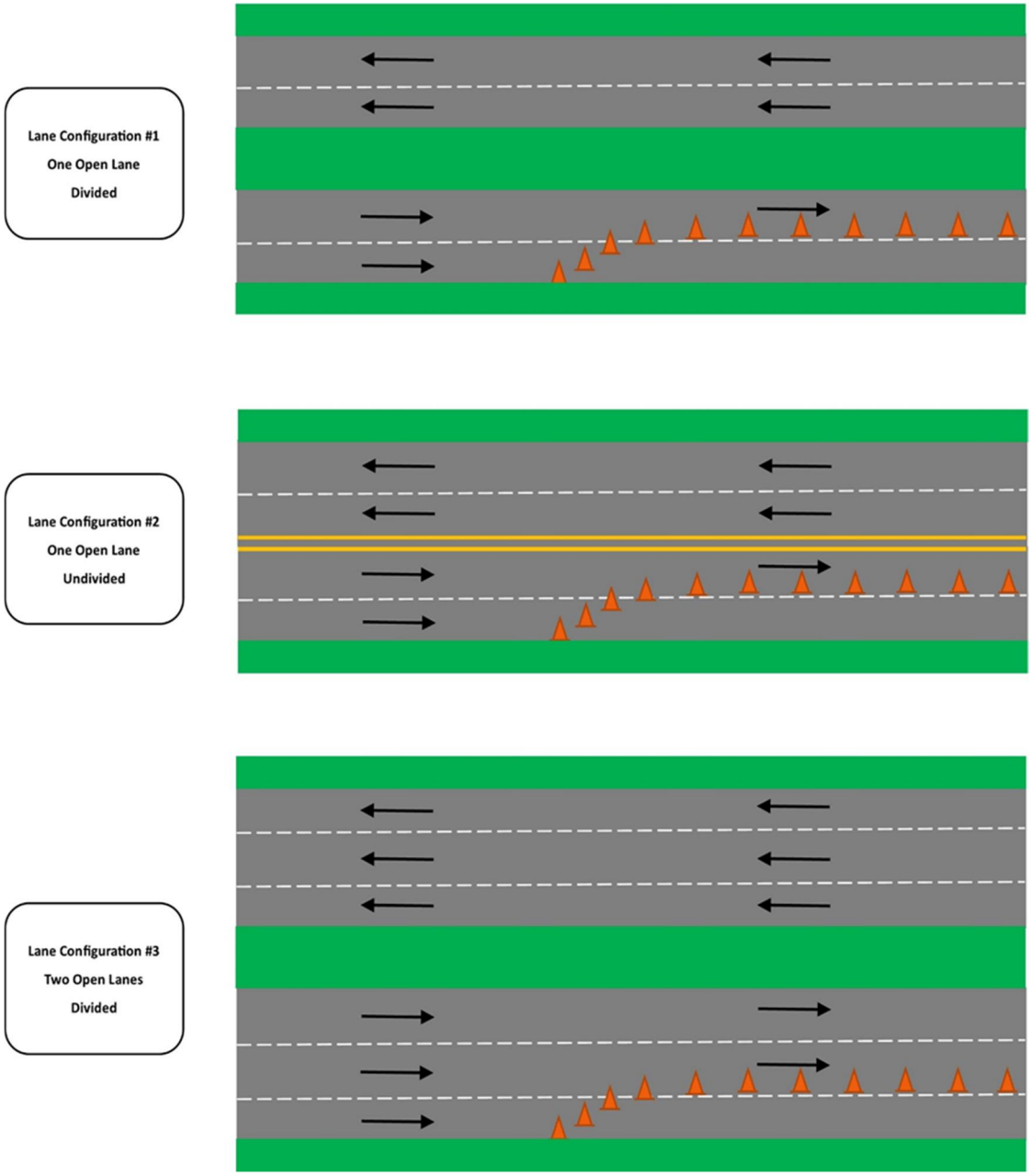


Figure 4-2: Project Lane Configurations for Use of Pilot PVSL System

4.3.2 Level of Automation

Changing of the speed limits will be a manually approved process that can be implemented automatically. The dynamic algorithm within the system will need to suggest/recommend a change in speed limit to be approved by

the RE prior to implementation. The RE could approve the recommended speed limit and automatically implement it within the system, and then the system would implement the recommended changes. The RE may delegate someone in the field to approve/make the system changes and may need to communicate to the field personnel what the speeds are changing to.

4.3.3 Queue Warning Component

A queue warning system has been identified as a 'highly desirable' functionality, but not a required functionality. Queue warning may be an optional component of the system because if it is too complicated to deploy, it may not be used.

A queue warning system is typically used for congestion management and the primary goal for the UDOT PVSL (portable VSL) is safety for workers and travelers. Two different systems, each with different purposes, especially if the queue warning system is intended to warn the traveling public of a queue that is being caused by the lane reduction taper.

For the purposes of this pilot PVSL system, a queue warning system has been depicted in operational scenarios (Figures 9-1, 9-2 and 9-8) in order to show relationship of static signage of a work zone with queue warning signage. A queue warning sign could be a VMS and the message on the VMS could be a PVSL system generated travel delay time posted on the sign. Providing travel time messages on the VMS signs could also be used to support the public information and perception component of deploying the system. The system would need to detect speeds to get travel times and could do counts related to speeds and travel times to get delay. If the system is providing queue warning in advance of the work zone (not work space) additional system detectors will need to be added to the system that are specifically just for queue warning functionality.

Queue warning can also be used for public information and to get speed compliance. Queue warning can be used for events and incident management scenarios in combination with a work zone deployment of the PVSL system. Although these combination scenarios may not be tested in the pilot PVSL system deployment, they could happen in the future and will be incorporated into ultimate conditions for the deployment of a PVSL system

5 ROLES AND RESPONSIBILITIES WITH PROPOSED SYSTEM

UDOT has already established many agency, personnel, and Contractor roles within the existing deployment of VSL in work zones as well as responsibilities associated with those roles. Table 5-1 outlines all stakeholder roles and responsibilities in this PVSL system deployment using two primary sources: existing policies, guidelines, and standards in relation to how UDOT has deployed VSL for work zones currently; and documentation from other states that have deployed VSL for their work zones.

Securing the PVSL system will be the responsibility of both the PVSL vendor providing the equipment and the Contractor deploying the equipment within the Construction work zone. The security requirements identified within the PVSL System Requirements Report (see Appendix B) include both physical security requirements and system security requirements. In general PVSL equipment provider will be responsible for providing equipment that supports these security requirements and the Contractor deploying the equipment will be responsible for ensuring these security provisions are maintained while the equipment is being deployed.

The responsibilities defined for the PVSL system are categorized by DAILY OPERATIONS, LONG TERM OPERATIONS, QUALITY CONTROL OPERATIONS, and THIRD PARTY RELATIONSHIPS. Roles are segmented by OPERATIONS and MANAGEMENT. Primary/secondary responsibilities as well as Initial/Ultimate roles are identified where a stakeholder role and responsibility is determined. 'TBD' identifies areas that are dependent on the system used and the home of the database for the system and therefore cannot be defined as of yet.

Table 5-1: Roles and Responsibilities Matrix

LEGEND			
P	Initial Role During Pilot PVSL System		Primary Responsibility
U	Ultimate Role		Secondary Responsibility
X	Role Not Dependent on Owner of System		Primary Always Involved
			Secondary Always Involved

Responsibilities	OPERATIONS ROLES					MANAGEMENT ROLES				
	UDOT Resident Engineer	Region Safety Manager	Incident Management Team	Primary Contractor	Utah Highway Patrol	Region Traffic Division	Engineer of Traffic and Safety	Public Information Manager	UDOT Project Development	UDOT TOC
DAILY OPERATIONS										
Provide the PVSL system				U					P	
Prepare recommendation for and supporting documentation for temporary regulatory speed limits (TEO may be required)	X			U		X				
Initiate, Process, and Approve TEO	X			U		X	X			
Determine impacted areas and impacted times and make necessary signing changes, including removing signs not consistent with construction impact.	X			U						
Review the construction activities within the region as applicable to ensure compliance with approved TCP and MOT plans	X			U		X				
Set up, calibrate and maintain equipment as part of PVSL system				X					P	
Accept contractor-provided equipment for use in deployment of PVSL system	X								P	X

Responsibilities	OPERATIONS ROLES					MANAGEMENT ROLES				
	UDOT Resident Engineer	Region Safety Manager	Incident Management Team	Primary Contractor	Utah Highway Patrol	Region Traffic Division	Engineer of Traffic and Safety	Public Information Manager	UDOT Project Development	UDOT TOC
DAILY OPERATIONS										
Change of speed limit based on preapproved conditions	X			X		X				
Move VSL signs and sensors as needed during work zone phasing				X						
Upload/download data logger that archives PVSLS deployment data in an easily searchable database documenting speed limit changes, the reason for the change, and the duration of the change	X	X		X			X			X
Tag data and information in the searchable database to provide to others	TBD					TBD				
LONG TERM OPERATIONS										
Review recommendations and provide direction to the staff regarding proposed corrective action to be taken or authorize changes to the Traffic control plan (TCP), Maintenance of Traffic (MOT) according to applicable Department Policies, Procedures, specifications, or special provisions	X									
Provide training for Region Traffic Engineers, Safety Mangers, construction, maintenance and design personnel							X			
Assign a member of the crew to be responsible for the management of traffic through the work zone	X			X						
Assign a member of the crew to be responsible for the management and operations of the PVSL system	P			U						
Control and handle all other changes in cooperation with the Regional Director, District Engineer, or Regional Resident Engineer as appropriate	X									
QUALITY CONTROL OPERATIONS										
Randomly inspect traffic control work zones				X			X			
Notify applicable Region of any deficiencies	P			U						
Refer non-corrected deficiencies to the Operations Engineer for consideration	X					X				
Take appropriate action to remedy deficiencies in control				X						
Use emergency hazards to immediately correct hazardous situations	X									
Conduct on-going inspection of work site to ensure compliance with approved TCP/MOT	X									
Request assistance from appropriate Region Staff for problems requiring engineering evaluation	X									
Document all traffic incidents in traveled lanes and status occurring in the work site	X	X		X						
Report all traffic incidents in traveled lanes and status occurring in the work site to the searchable database and to traveler information outlets as warranted for public distribution	TBD					TBD				
Perform traffic control review per 01554 specification.	X			X						

Responsibilities	OPERATIONS ROLES					MANAGEMENT ROLES				
	UDOT Resident Engineer	Region Safety Manager	Incident Management Team	Primary Contractor	Utah Highway Patrol	Region Traffic Division	Engineer of Traffic and Safety	Public Information Manager	UDOT Project Development	UDOT TOC
THIRD PARTY RELATIONSHIPS										
Enforce variable speed limits					X					
Establish Communication with Utah Highway Patrol or local law enforcement agency with jurisdiction over work site location to ensure notification of any accidents associated with the work site. Investigate all of the above type accidents	X	X	X							
Review accident history for each project site and recommends strategies for work zone safety improvement	X				X		X			
Utilize pagers to know current speed limits					X					
Coordinate with local media to inform motorists of the system's purpose and the drivers legal responsibility								X		X

6 NEEDS IDENTIFICATION

PVSL system needs have been outlined based on inputs and outputs from each system component. Additional needs have been identified based upon technology functionality options. These needs have been carried forward to high-level functional requirements in order to support the procurement, design, and implementation of the PVSL system.

Although specific technologies are not being identified in this ConOps, the purpose of the device and the functionality that it needs to support toward the ultimate goals and objectives of this pilot system will help to specify what type of technology will most meet the needs of the system.

Needs of the system are captured in Appendix A showing priority of additional needs that are beyond the 'must have features' that this pilot system will be incorporating in initial development. The overall objective for establishing priorities for each need is to mitigate the risk of initial deployment problems in terms of system costs, complexity, and schedule.

7 SYSTEM REQUIREMENTS

Using the needs identified in Section 6 as well as analyzing the performance measures, a preliminary set of high-level system and functional requirements were developed into the following categories:

- PVSL Functional Requirements – system inputs, system operational processes/algorithms, system outputs
- PVSL System Policies/Procedures Requirements – where there are policies/procedures that need to be updated, these have been defined for UDOT to develop an action plan as required

Functional requirements linked to each individual need of the system are captured in Appendix B – PVSL System Requirements Report. In some cases, multiple requirements were identified for one specific need and there has been a preliminary priority assigned to requirements based on the priority level of the need. Some requirements may have a higher priority than others within one need category and it will be important for UDOT to review requirements for their individual priority. Priorities defined include:

- Required – Initial Deployment Requirements
- High Priority – System Enhancement Requirements
- Medium-Low – Future Enhancement Options

The requirements report enables the traceability of operational needs (as identified in the ConOps) to functional requirements to verification methods. All requirements are to be written in the form of "shall" statements. Determination of the requirements is critical for system interface design. The use of the requirements is consistent with the systems engineering approach, where only user needs drive the requirements.

For the purpose of this document and Appendix A, only Required and High Priority categories of requirements have been provided for review. The high-level functional requirements will be used as the basis of design of the PVSL system.

8 OPERATIONAL SCENARIOS

This section describes the operational scenarios for how the PVSL system is envisioned to be deployed. This section does not encompass all of the potential scenarios for the system, but rather provides graphical representation of where the traffic control devices (including VSL and VMS) will be located for each different type of construction work zone restriction. By clarifying specific scenarios, functional requirements of the system and impacts on the partner agencies can be fine-tuned to mitigate uncertainty in how the system will function.

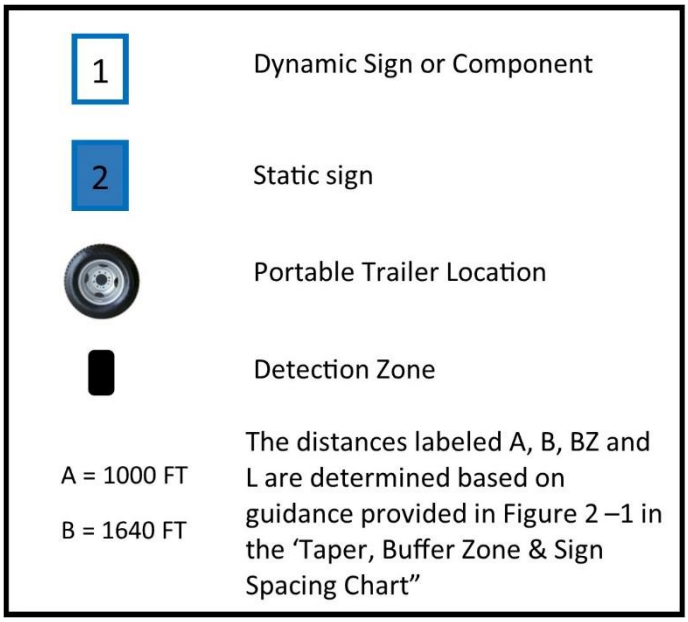
8.1 Standard Signage in Advance of Work Space Taper

For all work zones, there is a procession of standard signage that precedes any work space. Much of this signage are static signs placed at standard distances between each other with respect to the work space limits. There is some standard guidance for the location and spacing of dynamic signs, such as VMS (signs labeled 1) and PVSL (signs labeled 8), within this series of signs in advance of the work space. The VMS that appear in the graphics are shown to support queue warning, which is one potential functionality of the ultimate PVSL system. While queue warning is not considered a foundational application for this system, it has been identified as an application that could be used in association with work zones, and thus is included as an option in this concept of operations (refer to Section 4.3.3). The inclusion of queue warning requires the deployment of additional detection (represented by the small, black ovals in each lane) as well as a VMS sign.

Figure 8-1 below provides a graphical representation of the signage guidance that is placed in advance of a work space taper for instances where two travel lanes in the same direction are reduced to one. Figure 8-2 shows the configuration of signage that is needed prior to a work space where three lanes are reduced to two; for this scenario, signage is needed on both sides of the road in areas where there are three travel lanes across. This is done to make sure that the signage and speed limits are visible to drivers in all lanes.

The legend below is relevant to all subsequent figures that are included in this section.

LEGEND



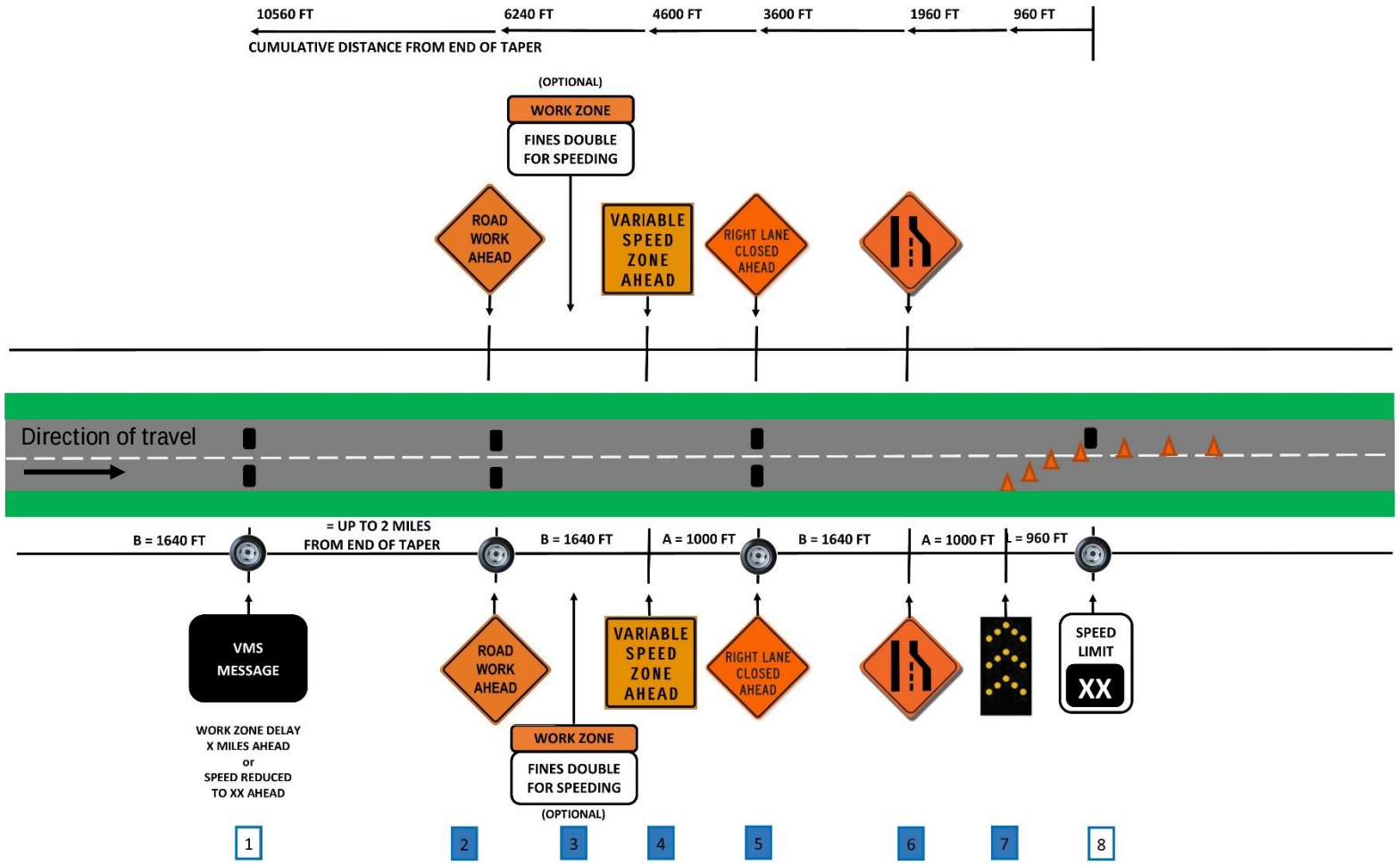


Figure 8-1: Signage in Advance of a Work Space – Reducing Two Lanes to One Lane

(Assuming 80 mph design speed)

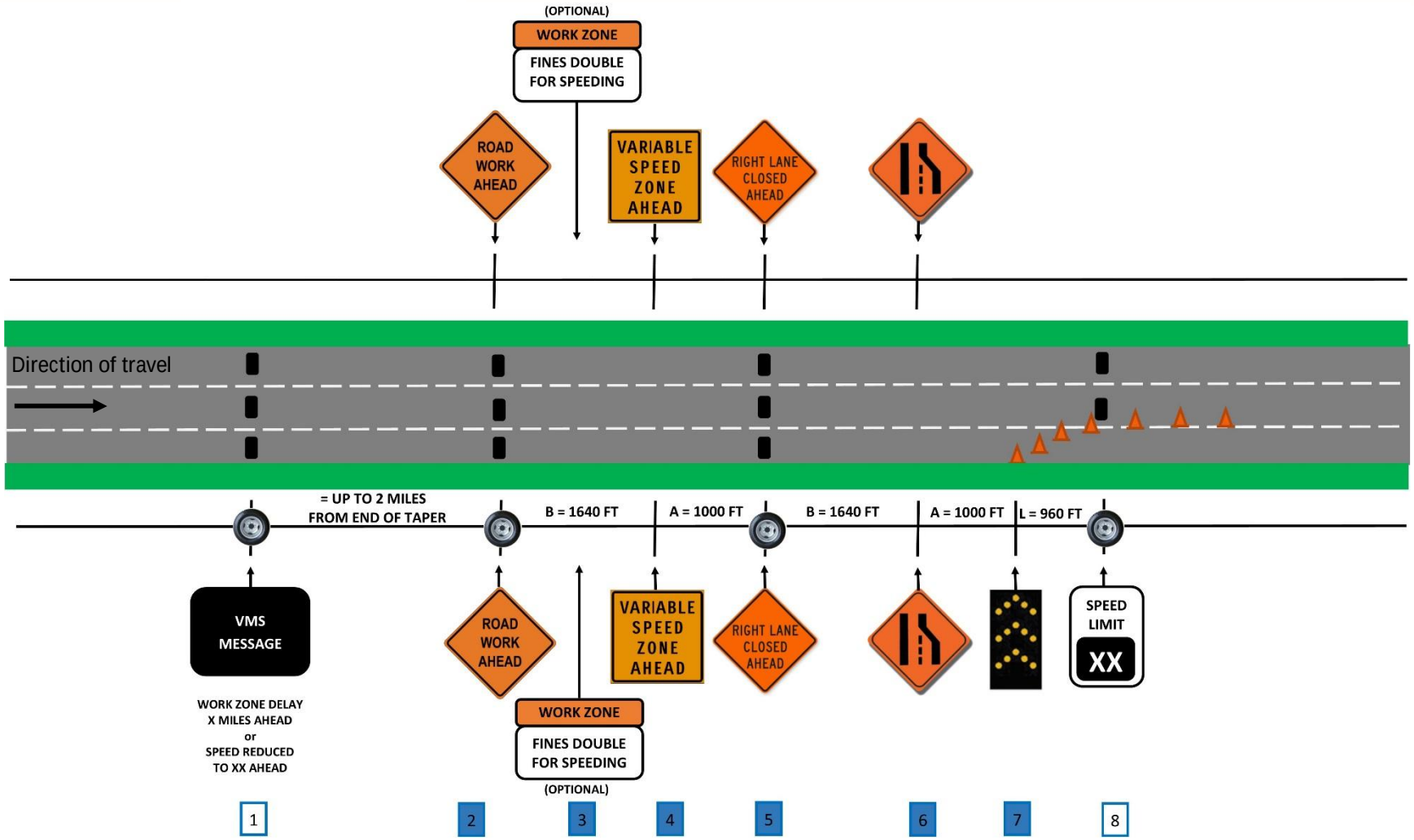


Figure 8-2: Signage in Advance of a Work Space – Reducing Three Lanes to Two Lanes

(Assuming 80 mph design speed)

8.2 Work Zone Type 1: Two Lanes Restricted to One Lane on a Divided Road

Figures 8-3 through 8-7 provide various scenarios for a work zone that involves a divided roadway that is experiencing a lane reduction from two lanes to one lane. For each of these scenarios, signage is only required on one side of the roadway, because the road is a maximum of two lanes wide. Additionally, it should be noted that the signage seen in each figure below is proceeded by the procession of signage (labeled 1-8) described previously in Figures 9-1 and 9-2.

8.2.1 Active Work Space is Close to the Taper

Figure 8-3 depicts a scenario where there is a short work space and the active work space, where there are workers present, is close to the taper. For this scenario, the PVSL sign is located at the end of the taper and the posted speed is influenced by data provided by the detectors within the work space that include prevailing speeds and traffic congestion. At the end of the work space, the speed limit is returned to normal conditions, which in this scenario is 80 mph, using a static speed limit sign. In this scenario as it is depicted, any changes to the position or size of the active work space will require the contractor to move the PVSL sign, detectors, and static speed limit accordingly.

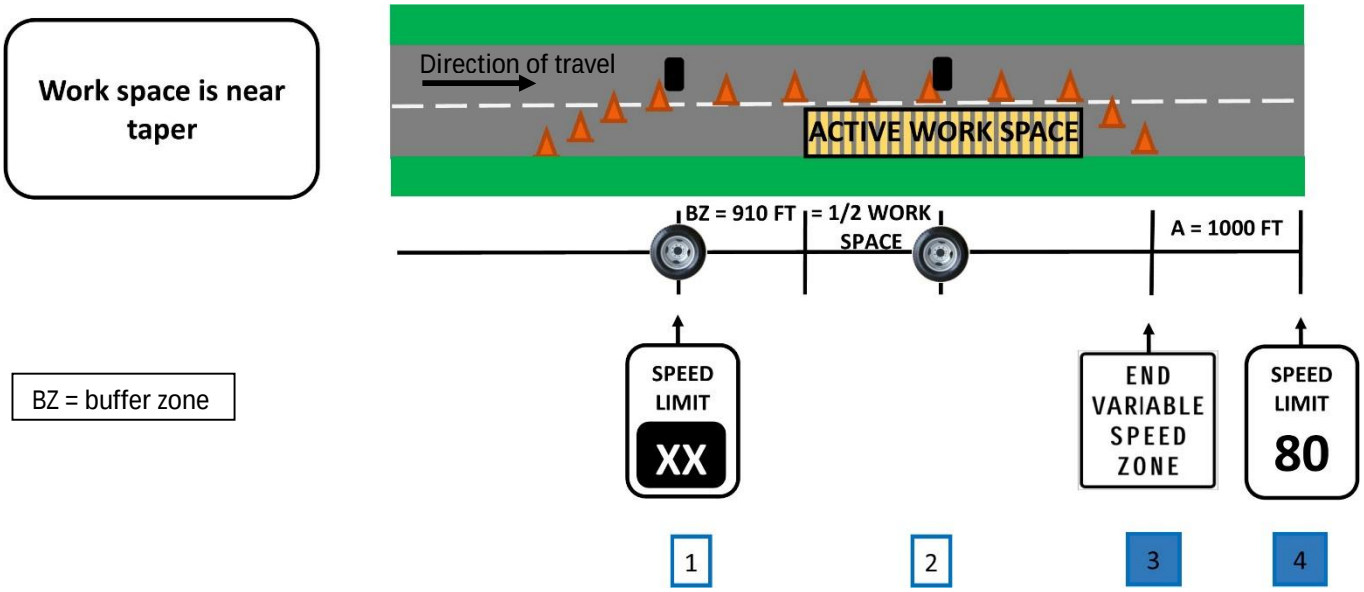


Figure 8-3: Work Zone 1: Two Lanes Reduced to One Lane and Active Work Space is Close to Taper

8.2.2 Work Space is Far from the Taper

In contrast to the previous scenario where the active work space is close to the taper, this next scenario (Figure 8-4) depicts a situation where the active work space is far from the end of the work space taper. In this scenario, it may not be necessary to have the same level of speed reduction throughout the entire work zone, and thus there will likely need to be multiple PVSL signs that provide appropriate speed limits. The PVSL at the beginning of the taper will post an initial speed reduction that results from worker presence or work zone hazard, and the second PVSL might provide a further reduced speed limit in advance of the active work space. Because the speed reduction is being undertaken in two increments, advanced warning, in the form of a VSL or static sign (labeled as sign 3), is needed prior to the second speed limit reduction. If the location of the active work space within the designated work space changes, the contractor will be required to move the equipment (PVSL signs, static signs, detectors, wireless radios, etc.) relative to the location of the new active work zone.

Additionally, for this scenario, an additional wireless radio and additional detection may be required if the distance between the first PVSL and the second PVSL is ½ mile or more. At the end of the work space, the speed limit is brought back up to the normal speed limit of the roadway.

8.2.3 Multiple Active Work Spaces

Figure 8-5 depicts a scenario where there are two, active work spaces within a single work space. Each active work space will require a speed reduction that is greater than that of a normal work zone, however, based on current UDOT policies, the speed limit cannot be reduced to that level for the entirety of the work space. Instead, a minimum of three (3) PVSL signs will be needed in order to reduce the speed in advance of active work space #1, increase the speed limit back to that of the work zone at the conclusion of active work space #1, and reduce the speed limit again in advance of active work space #2.

As in other scenarios, additional wireless radios for communication connectivity will be needed and additional detectors will be required in order to advise the posted speed limits on the PVSL signs. For example, if there is minimum traffic and free flowing speeds between active work space #1 and active work space #2 in this scenario, then the speed limit posted on the second PVSL (labeled as sign 3) may be posted at a higher speed limit than it would if there was congestion and slow traffic speeds detected between the two active work spaces. The dynamic nature of this PVSL system is based on data provided by upstream detectors, and thus as the work space gets larger, more detection will be necessary to inform each speed limit sign. Also, if the location of either active work space changes, the contractor will have to move the signs and other devices accordingly so that the speed limit signs and detectors/wireless radios are positioned correctly within the work space to provide drivers with advanced speed limit information.

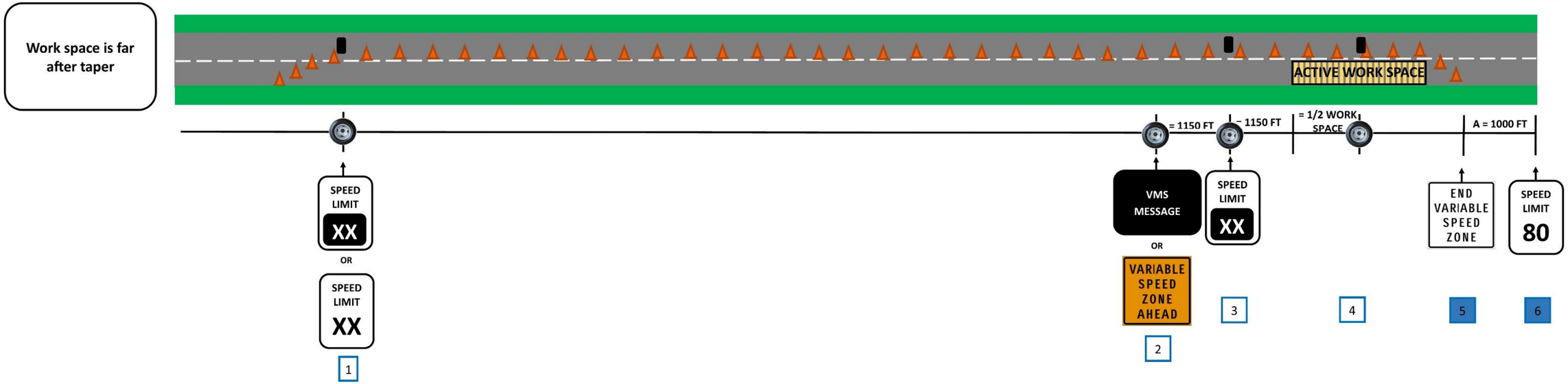


Figure 8-4: Work Zone 1: Two Lanes Reduced to One Lane and Active Work Space is Far from Taper

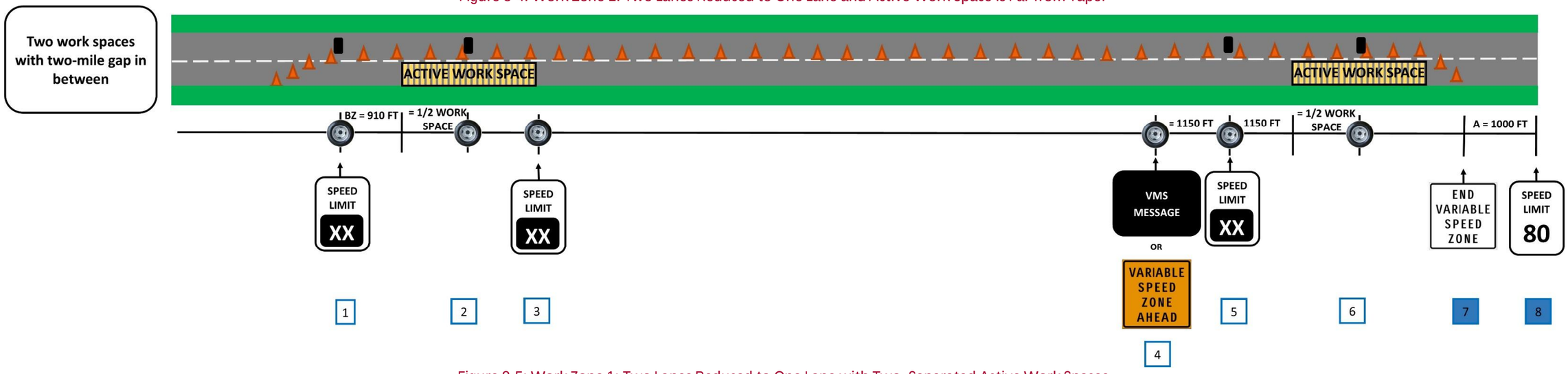


Figure 8-5: Work Zone 1: Two Lanes Reduced to One Lane with Two, Separated Active Work Spaces

8.2.4 Extended Work Space that Begins Near the Taper

This next scenario depicts work zones that are set up for work such as re-paving of a travel lane or the shoulder, where the active work space starts just after the taper and extended through the whole work space. This scenario occurs for work that covers large areas. Unlike the previous scenario where the active work spaces were separated by two miles of non-active space, this work zone effectively has field personnel through its entire length.

Figure 8-6 depicts this scenario. As can be seen, this scenario could require many PVSL signs, placed every one to one and a half miles apart, based on the length of the work space. With the extended work space, the multiple PVSL sign configuration allows for the most accurate and dynamic control of traffic speed through the work zone. Without multiple PVSL signs, one of two situations would occur: 1. A single speed limit would have to be set for the whole work space, regardless of real-time traffic conditions; or 2. The contractor would have to continually move the PVSL signs within the work space to make sure to cover the active work space at that time. By providing a series of PVSL signs along the work space, the system can provide real-time speed limits based on prevailing traffic conditions to help optimize the flow of traffic through the work space and it prevents a situation where the contractor would have to constantly move the PVSL system components to reflect the changing location of the active work space over time.

This scenario has detectors placed every half mile (or every one third of a mile) to provide traffic speed and lane occupancy data into the PVSL system and allow the system to display a speed limit based on real-time traffic conditions. If speeds at the beginning of the active work space are detected to be slower than the posted speed limit, then speeds near the taper can be adjusted accordingly. However, if the detectors detect increased speeds in the second half of the active work space, then the speed limit for that portion of the active work space could be adjusted (at the discretion of the RE) to reflect the improved traffic flow and allow vehicles to move quicker through the end portion of the active work space and return to normal operating conditions sooner. It may require positioning of law enforcement within the active work space to enforce for speed limits, although that mechanism for support is not a PVSL system pilot deployment controlled function and would need the RE to request such assistance.

8.2.5 Extended Work Space that is Far from the Taper

Figure 8-7 depicts a work zone scenario that provides the system functionality intended by the PVSL system but limits the number of times that the system would have to be moved or rearranged within a work space. In the previously discussed scenarios, it was noted that any time that the active work space moves within the set work space, the contractor would have to move the PVSL signs and other associated equipment accordingly. With the scenario shown in Figure 9-7, the entire work space is equipped with PVSL signs and equipment and only the appropriate equipment would be activated based on the location of the active work space; the other signs could show the same speed limit until the point where the speed limit changes.

While this scenario requires the contractor to rent or procure more signs and devices, it will save time and effort by avoiding the requirement of constantly moving the signs based on the location of the active work space. This scenario could be especially effective for work zones that have a highly dynamic active work space that move around frequently.

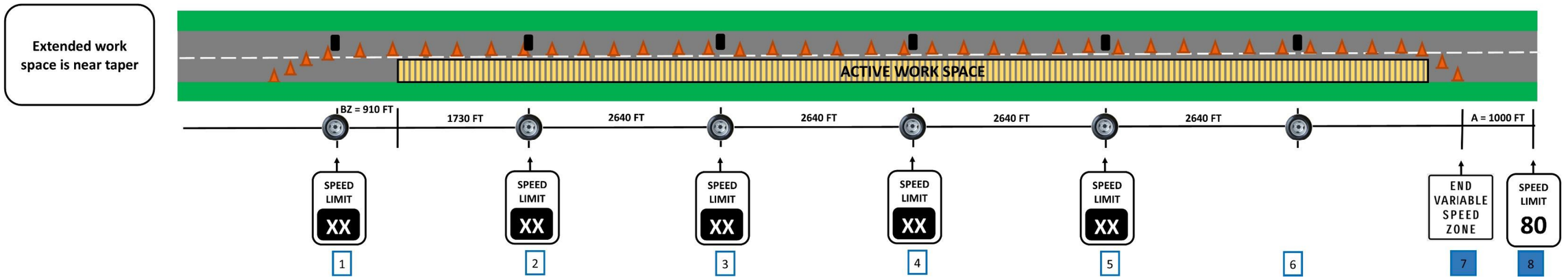


Figure 8-6: Work Zone 1: Two Lanes Reduced to One Lane with an Extended Work Space that Begins Near the Taper

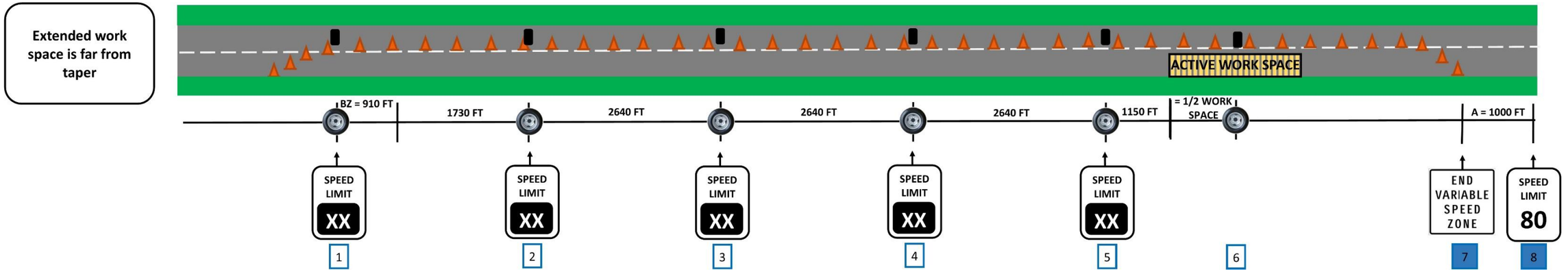


Figure 8-7: Work Zone 1: Two Lanes Reduced to One Lane with an Extended Work Space that Begins Far from the Taper

8.3 Work Zone Type 2: Three Lanes Restricted to Two Lane on a Divided Road

For roadways that are three lanes that get reduced to two lanes during construction, the possible work zone scenarios are very similar to those shown in the previous figures for Work Zone Type 1: Two Lanes Restricted to One Lane. The only difference in the scenario between these two lane configurations is that an additional set of detectors will be required at each detection location because there is an additional lane to cover. The detection in this proposed system is lane-by-lane detection, meaning that detectors will be deployed on every travel lane to provide a complete set of data for the roadway.

Figure 8-8 shows the scenario where the active work space is close to the taper (similar to Figure 9-3 on a previous page). Figure 9-8 also shows the configuration of signs prior to the work space, which is consistent with the graphic provided in Figure 9-2). As you can see in Figure 9-8, the configuration of signage near the active work space is the same as in the scenario for two lane road except that there is another set of detectors to accommodate the additional travel lane through the work zone.

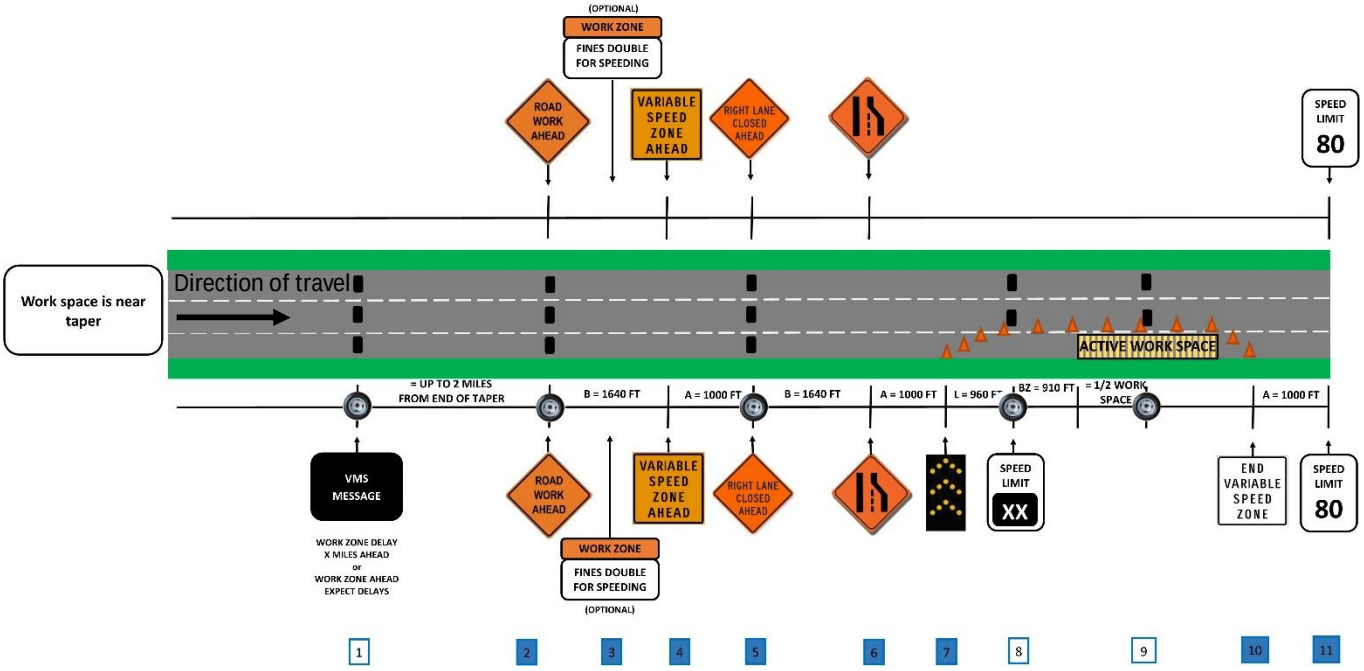


Figure 8-8: Work Zone 2: Three Lanes Reduced to Two Lanes and Active Work Space is Close to Taper

9 PERFORMANCE MANAGEMENT

As part of the PVSL system development process, performance measures were discussed with the Technical Advisory Committee (TAC) in the context of overall goals and objectives for the project. Table 9-1 provides a summary matrix that categorizes the derived performance measures relating to the expectations of the audience being served, namely into FIELD and PUBLIC. Measures related to the FIELD category are those that are directly influenced by the physical system and its functions. The measures identified in the PUBLIC category are those whose performance is dependent on factors external to the PVSL system, such as opinions or reactions to the system by the public.

Table 9-1: PVSL Performance Measurement Plan

Category	Goal	Objective	Measure
FIELD	Safety	Safer for field personnel	• Limits exposure to workers for making VSL adjustments (i.e., limits need to go to each VSL) • Speed in work space • Speed compliance within the work space when field personnel are present • Worker satisfaction
	Ease of use	Ease of deployment and operation	• Time it takes to set up, adjust or shift the system in a work zone • Time it takes to learn how to operate the PVSL • Cost of the system (labor hours and renting devices).
PUBLIC	Safety	Safer for public	• Number of crashes
	Public trust	Posted speeds comply with worker activity	All measurers below are measured within the work space: • Speed compliance when workers are present. • % of drivers that encounter reduced speed limits • The length (distance) for which the speed is reduced • Delay (time it takes to transverse the work space) for when a driver encounters reduced speed limits.
		Increased and reliable information	• Travel time through the work space • Uptime of system • Customer satisfaction
	Easy to use	Easy for public to understand	• Speed variation

It is understood that no metrics can be taken while UHP is present, because driving habits tend to change when law enforcement is visible on the construction site. Surveys can also be helpful to both categories to gauge customer satisfaction.

UDOT will need to establish a baseline of "before" data for which to compare the "after" data once the system has been implemented. UDOT should potentially consider phasing the implementation of the system on a given project, in order to test the "active" versus "not active" PVSL system. An example would be to establish three different data points such as: 1) lay down detection with no other signs placed, 2) then to place signs without turning them on, and 3) then to activate signs, all while the normal construction activities remain consistent from one phrase to another.

10 INTEGRATION OF THE SYSTEM

10.1 System Test Plan

Acceptance testing consists of testing the system against the requirements and making sure that the system performs in a way that it was intended to do. The developer in charge of establishing the Site Control System platform will be responsible for developing a System Test Plan, which describes the environment in which the delivered system will be tested. The System Test Plan will include detailed written procedures which will provide detailed steps for testing the system to determine if the system works in a manner that meets functional and performance requirements. System validation should include positive and negative test cases to identify bugs or issues. The developer will provide a testing platform and test requirements that will query the interface to get expected results.

The acceptance testing will be carried out independently with the developer project manager and the UDOT project manager to observe the testing for test failures, deviations or anomalies. Both negative and positive test cases will be used. The System Test Plan will test each of the requirements to determine the final system performs in accordance with the written requirements.

The System Test Plan should include further detail of the following sections:

Test Item#	Requirement	Test Procedure	Expected Results	PASS/FAIL	Comments

10.2 Systems Acceptance

The systems acceptance process is critical because this is where the UDOT becomes responsible for the continued maintenance and management of the systems, products, and processes delivered. The developer in charge of establishing the Site Control System platform will create the test cases for each of the system requirements which will detail the test procedure to verify that the requirement is satisfied. The result of the test cases will be documented as PASS or FAIL during the final acceptance test which will be performed with an UDOT representative present during the testing.

10.3 Impacts of PVSL System

The following impacts have been identified that UDOT and partner agencies will experience upon implementation of the PVSL System. These will be important in considering the ultimate operations and maintenance of the PVSL System within the context of existing agency processes.

10.3.1Organizational Impacts

As a result of implementing the PVSL System and infrastructure, there will be agency processes and procedures that will need to adjust to accommodate the new functionality provided. The following organizational impacts have been identified that will need to be addressed by UDOT and the Contractors:

- New network usage and reliability requirements that to minimize or eliminate downtime in the system;
- Additional performance management requirements on the UDOT and Contractor's systems;
- Enhanced exposure of organizational activities to the traveling public which may result in new input provided by the traveling public and new attention to how UDOT and the Contractors manage a work zone;
- Hours of operation of the Contractors may be adjusted for longer work days if the PVSL System is effective in producing a safer and more efficient work environment at the work site;
- A new policy to define the parameters for which the PVSL System user defined thresholds can be adjusted from default values; and

- A periodic Technical Advisory Committee meeting will be needed in order to verify that the PVSL System is operating as originally designed and to identify updates/adjustments to user defined thresholds if warranted.

10.3.2Operational and Developmental Impacts

There are operational and developmental impacts during the development of the system related to UDOT and the Contractors, including:

- The PVSL System introduces immediate safety risks if the PVSL functions are used incorrectly; therefore, a revised priority of the monitoring and management of the PVSL Site Control System may be required;
- Operator responsibility for managing the PVSL System aligned with UDOT's current practices which require daily, periodic Traffic Control inspection and documentation;
- Effective response to alerts that are created by the PVSL System;
- Adjusted/updated hierarchy of message types priority levels will be needed to incorporate new PVSL applications;
- Operational procedures during incident management in the work zone will be expanded based on the new functionality and involvement the PVSL System will provide; and
- Thorough training will be required with any new operator or RE that may be responsible for managing the PVSL System and any new updates to the PVSL System in the future for all operators or Resident Engineers.

APPENDIX A – PVSL SYSTEM AND USER NEEDS MATRIX

	MUST HAVE FEATURES	PRIORITIZATION OF ADDITIONAL NEEDS		
	Required for Pilot	HIGH	MEDIUM	LOW
DEVICE - SITE CONTROL SYSTEM				
Static Device Input to Site Control System				
Detection to collect volume (counting vehicles)				
Detection to collect speed (can be used to determine queue also)	YES	N/A	N/A	N/A
Detection to collect occupancy (measure used for queue/congestion detection)				
Detection to collect anonymous vehicle tracking (not Bluetooth)				
Detection for vehicle classification				
Detector communications status	YES	N/A	N/A	N/A
Wireless communications device status				
RWIS device status				
RWIS device communications status				
Power system alarms (low on power, power remaining, power loss, etc.)				
Power system communications status				
GPS coordinate of device location				
Field device communication protocols must be based on open standards				
Field device communication protocols must be willing to share protocol documentation	YES	N/A	N/A	N/A
Variable Device Input to Site Control System				
PVSL message being displayed	YES	N/A	N/A	N/A
PVSL communication status	YES	N/A	N/A	N/A
PVMS message being displayed				
PVMS communication status				
CCTV image				
CCTV communications status				
GPS coordinate of PVSL device location	YES	N/A	N/A	N/A
GPS coordinate of PVMS device location				
Field device communication protocols must be based on open standards				
Field device communication protocols must be willing to share protocol documentation	YES	N/A	N/A	N/A
Site Control System Output to Static Device				
Detector data request	YES	N/A	N/A	N/A
Detector communications status request	YES	N/A	N/A	N/A
Anonymous vehicle tracking data request (i.e., travel times)				
Wireless communications status request				
Power system alarms/status request				
Power system communications status request				
Other device location GPS coordinates request				
RWIS data request				

Site Control System Output to Variable Device				
RWIS device communications status request				
PVSL message to display	YES	N/A	N/A	N/A
PVSL communications status request	YES	N/A	N/A	N/A
PVMS message to display				
PVMS communications status request				
PVSL device location GPS coordinates request	YES	N/A	N/A	N/A
Other device location GPS coordinates request				
CCTV communications status request				
OPERATOR - SITE CONTROL SYSTEM				
Operator Input to Site Control System				
Selection of work zone phasing and configuration	YES	N/A	N/A	N/A
Entry of work zone phasing and configuration that does not match preset selection options	YES	N/A	N/A	N/A
Manual entry of layout of devices within work zone	YES	N/A	N/A	N/A
Entry of TEO work zone operational parameters	YES	N/A	N/A	N/A
System can be defined to set a minimum frequency for changing displays (i.e., timer that waits a period of time before changing the display)				
RE approval of site control system recommendation	YES	N/A	N/A	N/A
User settable time for site control system to wait for RE to take action (i.e., if RE does not respond in this time the system will do the next definable action)				
User settable (other threshold) for site control system to wait for RE to take action				
RE entry of speed limit for individual PVSL device to be implemented (with confirmation message)	YES	N/A	N/A	N/A
RE entry of speed limits for group of PVSL devices to be implemented (with confirmation message)	YES	N/A	N/A	N/A
RE entry of message for individual PVMS device to be implemented (with confirmation message)	YES	N/A	N/A	N/A
RE entry of messages for group of PVMS devices to be implemented (with confirmation message)				
Entry and storage of library of pre-approved PVMS messages that can be selected for implementation (with confirmation message)				
RE entry of pre-set configurations (speeds and messages) for group of PVSL and PVMS devices that could be selected/implemented later (with confirmation message)				
Devices accessible/controllable from project site (site server located off project site)	YES	N/A	N/A	N/A
Devices accessible/controllable from site control client workstation that links to site control system (i.e., laptop WiFi link to Local Area Network)				
Devices accessible/controllable from mobile device on the LAN (i.e., notebook/cell phone WiFi link to local area network)				
Secure access to system during access through mobile device on WiFi (i.e. VPN, packet encryption, etc.)				
Remote access to site control system (i.e., phone company network)	YES	N/A	N/A	N/A
Secure access to system during access through phone company network (i.e. VPN, packet encryption, etc.)				

Site Control System Output to Operator				
RE entry of non-recurring congestion condition warranting documentation				
Streaming surveillance viewable by RE				
Provide message (speed or PVMS message) being displayed in real-time	YES	N/A	N/A	N/A
Provide one screen that provides status of all devices	YES	N/A	N/A	N/A
Provide one screen that provides status of one direction of devices	YES	N/A	N/A	N/A
Auto-detect field PVSL device location and automatically display the order of PVSL devices based on their GPS coordinates	YES	N/A	N/A	N/A
Auto-detect other field device locations and automatically display the order of devices based on their GPS coordinates				
Auto-detect field device location in order to automatically suggest a construction zone configuration				
Strobe light or other visual alarm that the RE needs to log onto the site control system				
Send alerts to multiple users	YES	N/A	N/A	N/A
Configurable alerts	YES	N/A	N/A	N/A
Sends alerts for PVSL device failures (GUI alarm, email-based, or text message)	YES	N/A	N/A	N/A
Sends alerts for other device failures (GUI alarm, email-based, or text message)				
Sends alerts for PVSL speeds that are being recommended to change (GUI alarm, email-based, or text message)	YES	N/A	N/A	N/A
Sends alerts for PVMS messages that are being recommended to change (GUI alarm, email-based, or text message)				
Sends alerts for PVSL signs that have changed speed (GUI alarm, email-based, or text message)				
Sends alerts for PVMS that have changed message (GUI alarm, email-based, or text message)				
Send alert for low power (GUI alarm or email-based)				
Status data (queue detection and crash) sent to UDOT TOC for situational awareness				
Data sent to public information person for external parties				
Surveillance in work zone				
Surveillance in advance of work zone				
Surveillance of all PVSL system components to verify display				
Streaming surveillance sent to Region Office				
Streaming surveillance sent to UDOT TOC				
View graphical interface for monitoring performance				
OPERATOR - VARIABLE DEVICE				
Operator Input to Variable Device				
Manual PVSL control/status panel (not using site control system)				
Manual PVSL control direct connect laptop (not using site control system)				
Manual PVMS control panel/status (not using site control system)				
Concealable kill switch on PVSL and PVMS	YES	N/A	N/A	N/A
Wireless communications status request				

CENTRAL ARCHIVE - SITE CONTROL SYSTEM				
Site Control System Input to Central Archive				
Archive PVSL speeds with day and timestamp (speed, location, status, etc.) polled	YES	N/A	N/A	N/A
Archive device status with day and timestamp				
Tracks errors in system				
Historical tracking of all functions and data (speed, location, status, etc.) collected by site control system				
Historical tracking of all user activity by site control system	YES	N/A	N/A	N/A
Historical tracking of hours of operation				
Central Archive Output to Site Control System				
Request to connect to site control system for download				
Request to download new data				
OPERATOR - CENTRAL ARCHIVE				
Operator Input to Central Archive				
Query specific data sets within central archive	YES	N/A	N/A	N/A
SITE CONTROL SYSTEM - REPORTS				
Site Control System Output to Reports				
Performance measures defined for PVSL system in specific report formats				
System activity log	YES	N/A	N/A	N/A
User activity log	YES	N/A	N/A	N/A
CENTRAL ARCHIVE - REPORTS				
Central Archive Output to Reports				
Performance measures defined for PVSL system in specific report formats based on frequency set				
OTHER ITEMS				
Overarching System Guidelines				
System components must be portable	YES	N/A	N/A	N/A
System must be rated for outdoor use	YES	N/A	N/A	N/A
Devices are IP addressable	YES	N/A	N/A	N/A
Physical security method for PVSL and PDMS devices	YES	N/A	N/A	N/A
Trailers for portable devices able to connect to one another for hauling	YES	N/A	N/A	N/A
Grounding for PVSL and PDMS devices	YES	N/A	N/A	N/A
Site Control System Response Automation				
Manual system with option to go automated if desired	YES	N/A	N/A	N/A
Automated to recommend messages for display on PVMS				
Scheduler for function recommendations				
On/off for function recommendations	YES	N/A	N/A	N/A
Variable Device Response Automation				
Loss of communications to site control system saves last display or go blank				
Device errors cause system to save last display or go blank				
Delay timer for loss of communications response				

Future Capabilities				
Detection for anonymous vehicle tracking (Bluetooth, WiFi or other)				
Variable speeds in advance of work zone				
Additional PVSL devices on hand in case of failure	YES	N/A	N/A	N/A
System Security				
User name and password for access to system (via site control system)	YES	N/A	N/A	N/A
User name and password for access to system (via client workstation/mobile access)				
Permission controls for different user types (i.e., system admin, RE, etc.)				
Device username/password change from factory default settings	YES	N/A	N/A	N/A
Assign user names and passwords on a per project basis and delete after each project	YES	N/A	N/A	N/A

APPENDIX B – PVSL SYSTEM REQUIREMENTS REPORT

User Need ID	Requirement Description	Required Or High Priority
DEVICE - SITE CONTROL SYSTEM		
Static Device Input to Site Control System		
1		High Priority
	Detection devices, or field device masters, shall be IP addressable and provide vehicle volume data in the communication messages.	High Priority
2		Required
	Detection devices, or field device masters, shall provide vehicle speed data in the communication messages.	Required
6		Required
	Detector device, or field device master, shall be IP addressable and respond to a communications status request.	Required
	Field device masters, connecting detection devices, shall provide loss of detector communications alarms.	High Priority
10		High Priority
	Power system devices shall provide system alarms.	High Priority
	Power system device alarms shall include a power loss alarm.	High Priority
	Power system device alarms shall include a "critically low on power" alarm	High Priority
	Power system device alarms shall include a message identifying how much power is remaining	High Priority
11		High Priority
	Power system devices, or field device masters, shall be IP addressable and respond to a communications status request.	High Priority
	Field device masters, connecting power system devices, shall provide loss of power system communications alarm.	High Priority
12		High Priority
	Field device masters, connecting multiple system devices, shall provide GPS coordinate of their location directly or through a separate GPS locating device.	High Priority
	Detection devices shall provide GPS coordinate of their location directly, through a field master, or through a separate GPS locating device.	High Priority
	Power system devices shall provide GPS coordinate of their location directly, through a field master, or through a separate GPS locating device.	High Priority
	Wireless network devices shall provide GPS coordinate of their location directly, through a field master, or through a separate GPS locating device.	High Priority
14		Required
	The vendor shall provide detection device communications protocol documentation.	Required
	The vendor shall provide communication protocol documentation for the detector field device masters.	Required
	The vendor shall provide power system device communication protocol documentation.	Required
	The vendor shall provide communication protocol documentation for the power system field device masters.	Required
Variable Device Input to Site Control System		
15		Required
	VSL devices, or field device master, shall be IP addressable and provide VSL display message state in the communication messages.	Required
16		Required
	VSL device, or field device master, shall be IP addressable and respond to a communications status request.	Required
	Field device masters, connecting VSL devices, shall provide loss of VSL communications alarm.	High Priority
17		Required
	VMS devices, or field device master, shall be IP addressable and provide VMS display message state in the communication messages.	Required
18		Required
	VMS device, or field device master, shall be IP addressable and respond to a communications status request.	Required
	Field device masters, connecting VMS devices, shall provide loss of VMS communications alarm.	High Priority
21		Required
	VSL devices shall provide GPS coordinate of their location directly, through a field master, or through a separate GPS locating device.	Required
22		High Priority
	VMS devices shall provide GPS coordinate of their location directly, through a field master, or through a separate GPS locating device.	High Priority
26		Required
	The vendor shall provide VSL device communication protocol documentation.	Required

User Need ID	Requirement Description	Required Or High Priority
	The vendor shall provide communication protocol documentation for the VSL field device masters.	Required
	The vendor shall provide VMS device communication protocol documentation.	Required
	The vendor shall provide communication protocol documentation for the VMS field device masters.	Required
Site Control System Output to Static Device		
27		Required
	The Site Control System shall request detector volume data from detector device, or field device masters.	Required
	The Site Control System shall request detector speed data from detector device, or field device masters.	Required
	The Site Control System shall log historical detector volume data received.	Required
	The Site Control System shall log historical detector speed data received.	Required
28		Required
	The Site Control System shall request communications status of detection devices.	Required
	The Site Control System shall determine communications status of detection devices.	Required
	The Site Control System shall log historical communications status of detection devices.	Required
	The Site Control System shall request communication status of detection field device masters.	Required
	The Site Control System shall determine communication status of detection field device masters.	Required
	The Site Control System shall log historical communications status of detection field device masters.	Required
31		High Priority
	The Site Control System shall request power system alarms.	High Priority
	The Site Control System shall log historical power system alarms in a relational database.	High Priority
32		High Priority
	The Site Control System shall determine communication status of power system devices.	High Priority
	The Site Control System shall log historical communication status of power system devices.	High Priority
33		High Priority
	The Site Control System shall request the GPS location of detection devices.	High Priority
	The Site Control System shall display GPS location of detection devices.	High Priority
	The Site Control System shall log historical GPS location of detection devices.	High Priority
	The Site Control System shall request the GPS location of power system devices.	High Priority
	The Site Control System shall display GPS location of power system devices.	High Priority
	The Site Control System shall log historical GPS location of power system devices.	High Priority
	The Site Control System shall request the GPS location of wireless network devices.	High Priority
	The Site Control System shall display GPS location of wireless network devices.	High Priority
	The Site Control System shall log historical GPS location of wireless network devices.	High Priority
Site Control System Output to Variable Device		
36		Required
	The Site Control System shall send a request to post a speed on a VSL display.	Required
	The Site Control System shall send a request for the current VSL display state.	Required
	The Site Control System shall display VSL state reported by the VSL devices.	Required
	The Site Control System shall log historical VSL display state data.	Required
37		Required
	The Site Control System shall send a request for the current communications status of VSL devices.	Required
	The Site Control System shall display communications status of VSL devices.	Required
	The Site Control System shall log historical communications status of VSL devices.	Required
38		High Priority
	The Site Control System shall send a request to post a speed on a VMS display.	High Priority
	The Site Control System shall send a request for the current VMS display state.	High Priority
	The Site Control System shall display VSL state reported by the VMS devices.	High Priority
	The Site Control System shall log historical VMS display state data.	High Priority
39		High Priority
	The Site Control System shall send a request for the current communications status of VMS devices.	High Priority
	The Site Control System shall display communication status of VMS devices.	High Priority
	The Site Control System shall log historical communication status of VMS devices.	High Priority
40		Required
	The Site Control System shall request the GPS location of VSL devices.	Required
	The Site Control System shall display GPS location reported by the VSL devices.	Required
	The Site Control System shall log historical GPS location of VSL devices.	Required
41		High Priority
	The Site Control System shall request the GPS location of VMS devices.	High Priority

User Need ID	Requirement Description	Required Or High Priority
	The Site Control System shall display GPS location reported by the VMS devices.	High Priority
	The Site Control System shall log historical GPS location of VMS devices.	High Priority
	OPERATOR - SITE CONTROL SYSTEM	
	Operator Input to Site Control System	
43		Required
	The Site Control System shall support work zone configuration and phasing.	Required
	The Site Control System shall support entry of work zone roadway geometry (i.e., number of lanes, width of lanes, width of median & shoulders, length of work zone, etc.).	Required
	The Site Control System shall support entry of work zone roadway restrictions (i.e., tapers lengths, buffer zones, etc.) workspace area, and active work space area.	Required
	The Site Control System shall support identifying multiple directions of traffic (i.e., two separate work zone, one for each direction of traffic)	Required
	The Site Control System shall support displaying each work zone (i.e., one direction of traffic) on a separate display screen/window.	Required
	The Site Control System shall support displaying work zones on the same screen/window (one large display of the true roadway geometry for both directions of traffic.)	Required
	The Site Control System shall support moving/resizing the active workspace within a work zone.	Required
44		Required
	The Site Control System shall support saving a work zone configuration into a library of preconfigured work zone layouts .	Required
	The Site Control System shall provide definition of projects that contain similar work zone configurations and phasing.	Required
	The Site Control System shall support selection of preconfigured work zone layouts by an operator per project.	Required
	The Site Control System shall support manual override/changes of pre-selected work zone layout configuration and phasing.	Required
45		Required
	The Site Control System shall support manual and ad-hoc operator device configuration of work zone layout.	Required
	The Site Control System shall support entry of static speed limit sign locations and associated posted speeds within the work zone.	Required
	The Site Control System shall support entry of VSL device locations.	Required
	The Site Control System shall support entry of VMS device locations.	Required
	The Site Control System shall support entry of detector device locations.	Required
	The Site Control System shall support entry of multiple detection areas for each detector device location.	Required
	The Site Control System shall support entry of power supply system locations.	Required
46		Required
	The Site Control System shall support configuration of TEO operational parameters for each work zone.	Required
47		High Priority
		High Priority
	The Site Control System shall support a user settable time minimum threshold between VMS message display limit changes (recommendations and automatic commands).	High Priority
	The Site Control System shall support a user settable threshold to wait for operator approval when making automatic changes to a VSL devices.	High Priority
	The Site Control System shall support a user settable threshold to wait for operator approval when making automatic changes to a VMS devices.	High Priority
48		Required
	The Site Control System shall provide a administrator level setting to turn the required approval process on and off.	Required
	The Site Control System recommendations shall be able to recommend speed limit changes, for each VSL device location, and require an authorized operator to approve the change before the Site Control System sends a command to the device to implement the recommendation.	Required
	The Site Control System shall be able to ask for the operator to confirm that they want to make a recommended speed limit change, after they chose to implement the recommendation and before the Site Control System send a command to the VSL device to make the change.	Required
	The Site Control System shall log the operators credentials into the system historical database each time an operator accepts and confirms the implementation of a recommended speed limit change.	Required
51		Required

User Need ID	Requirement Description	Required Or High Priority
	The Site Control System shall support manual entry of a single VSL device speed limit message and request operator confirmation of the change before the Site Control System send a command to the VSL device to implement the change.	Required
	The Site Control System shall log the operators credentials into the system historical database each time an operator implements a speed limit change.	Required
52		Required
	The Site Control System shall support manual entry of groups of VSL devices to change speeds and then select to implement the group of speed limit changes.	Required
	The Site Control System shall allow a different speed limits for each VSL device in a VSL group.	Required
	The Site Control System shall request confirmation from the operator prior to implementing the VSL devices group change.	Required
	The Site Control System shall log the operators credentials into the system historical database each time an operator implements a change to a group of VSL devices.	Required
53		Required
	The Site Control System shall support manual entry of a single VMS device display message and request operator confirmation of the change before the Site Control System send a command to the VMS device to implement the change.	Required
	The Site Control System shall log the operators credentials into the system historical database each time an operator implements a VMS display message change.	Required
54		High Priority
	The Site Control System shall support manual entry of groups of VMS devices to change display messages and then select to implement the group of VMS display message changes.	High Priority
	The Site Control System shall allow a different message for each device in a VMS group message.	High Priority
	The Site Control System shall request confirmation from the operator prior to sending the group VMS device messages.	High Priority
55		High Priority
	The Site Control System shall support selecting library messages for a single VMS device.	High Priority
	The Site Control System shall request confirmation from the operator prior to implementing a library message for a VMS.	High Priority
	The Site Control System shall support selecting different library messages for each VMS in a group VMS devices.	High Priority
	The Site Control System shall request confirmation from the operator prior to implementing library messages for a group of VMS devices.	High Priority
	The Site Control System shall support saving library messages for VMS devices.	High Priority
	The Site Control System shall request confirmation from the operator prior to saving library messages for VMS devices.	High Priority
56		High Priority
	The Site Control System shall support saving work zone configurations, including speeds and messages for VSL and VMS in a work zone layout.	High Priority
	The Site Control System shall request confirmation from the operator prior to saving work zone configurations.	High Priority
	The Site Control System shall support operator implementation of saved work zone configurations.	High Priority
	The Site Control System shall request confirmation from the operator prior to implementing a saved work zone configuration.	High Priority
57		Required
	The Site Control System shall be located off the project work site.	Required
	The Site Control System shall support one or more operator interfaces on the project work site.	Required
61		Required
	The Site Control System shall communicate from a UDOT facility or a cloud hosting environment, to the remote project work zone.	Required
	The vendor shall supply the equipment for remote access to the remote project work zone from the Site Control System facility.	Required
Site Control System Output to Operator		

User Need ID	Requirement Description	Required Or High Priority
65		Required
	The Site Control System shall display real-time messages being displayed on each VSL within each work zone.	Required
	The Site Control System shall display real-time messages being displayed on each VMS within each work zone.	Required
66		Required
	The Site Control System shall support displaying both project work zones layouts (roadway geometry and devices for both directions of traffic.) with real-time messages (i.e., VSL speeds and VMS messages posted) and device status information in one screen.	Required
67		Required
	The Site Control System shall support displaying a work zone layout (i.e., one direction of traffic) with real-time messages (i.e., VSL speeds and VMS messages posted) and device status information in one screen.	Required
	The Site Control System shall allow selection of which work zone (i.e., which direction of traffic) to open in the real-time display screen.	Required
68		Required
	The Site Control System real-time screen shall detect the VSL device location and display the VSL in order based on their GPS coordinates.	Required
	The Site Control System real-time screen shall indicate to the operator if a VSL device is out of order (both chronologically and direction of travel) in the work zone roadway geometry configuration, based on the GPS coordinate data from the VSL device.	Required
69		High Priority
	The Site Control System work zone configuration and phasing input screen shall automatically populate system devices in chronological order, based on the GPS coordinate data from the field device.	High Priority
	The Site Control System work zone configuration and phasing input screen shall provide a means for the operator to identify which work zones each devices is assigned to (i.e., which direction of traffic) and shall sort each device (both chronological order and direction of travel), based on the GPS coordinate data from the field device and the direction of travel assigned by the operator.	High Priority
	The Site Control System work zone configuration and phasing input screen shall provide a means for the operator to drag the device (from the respective chronological order field) to the position it will reside within the work zone roadway geometry display.	High Priority
	The Site Control System real-time screen shall indicate to the operator if a device is out of order (both chronologically and direction of travel) in the work zone roadway geometry configuration, based on the GPS coordinate data from the field device.	High Priority
72		Required
	The Site Control System shall support sending alarms to multiple users.	Required
	The Site Control System shall support sending alarms to text or email.	Required
	The Site Control System shall include a graphical user interface to view system alarms.	Required
73		Required
	The Site Control System shall support configuration of system alarms.	Required
74		Required
	The Site Control System alarms shall include VSL device failures.	Required
75		High Priority
	The Site Control System alarms shall include VMS device failures.	High Priority
	The Site Control System alarms shall include Detector device failures.	High Priority
	The Site Control System alarms shall include Power System device failures.	High Priority
	The Site Control System alarms shall include Communications failures.	High Priority
76		Required
	The Site Control System alarms shall include VSL speed limit change recommendations.	Required
78		High Priority
	The Site Control System alarms shall include VSL speed limit change messages sent to devices.	High Priority
79		High Priority

User Need ID	Requirement Description	Required Or High Priority
	The Site Control System alarms shall include PVMS messages sent to devices.	High Priority
80		High Priority
	The Site Control System alarms shall include low power events.	High Priority
	OPERATOR - VARIABLE DEVICE	
	Operator Input to Variable Device	
89		High Priority
	VSL devices shall support manual control and status through the front panel on the device.	High Priority
91		High Priority
	VMS devices shall support manual control and status through the front panel on the device.	High Priority
92		Required
	Each VSL device shall have a power or display kill switch that is concealed but readily accessible.	Required
	Each VMS device shall have a power or display kill switch that is concealed but readily accessible.	Required
	Each Power System shall have a power kill switch that is concealed but readily accessible.	Required
	SITE CONTROL SYSTEM - CENTRAL ARCHIVE	
	Site Control System Input to Central Archive	
94		Required
	The Site Control System shall log historical VSL speed data, to include speed, location, date/time stamp.	Required
95		High Priority
	The Site Control System shall log historical device status and include a date/time stamp.	High Priority
96		High Priority
	The Site Control System shall store error log information and include a date/time stamp.	High Priority
97		High Priority
	The Site Control System shall support an administrator level user to set the period of time to keep historical system data.	High Priority
	The Site Control System shall maintain a historical log of all data received from the VSL devices and include a date/time stamp.	High Priority
	The Site Control System shall maintain a historical log of all data received from the VMS devices and include a date/time stamp.	High Priority
	The Site Control System shall maintain a historical log of all data received from the Detector devices and include a date/time stamp.	High Priority
	The Site Control System shall maintain a historical log of all data received from the Power System devices and include a date/time stamp.	High Priority
	The Site Control System shall maintain a historical log of all data received from the GPS location sensor devices and include a date/time stamp.	High Priority
	The Site Control System shall maintain a historical log of all data received from any field master devices and include a date/time stamp.	High Priority
98		Required
	The Site Control System shall track user activity for all Save, Edit, and Delete for configuration.	Required
	The Site Control System shall track user activity for all user initiated commands to field devices.	Required
99		High Priority
	The Site Control System shall log historical hours of operation that the system was performing work zone operations manually and automatically.	High Priority
	Central Archive Output to Site Control System	
	OPERATOR - CENTRAL ARCHIVE	
	Operator Input to Central Archive	
102		Required
	The Site Control System shall provide operators the ability to query specific data sets from its historical archive	Required
	The Site Control System shall provide operators the ability to select groups of data fields and to query and select that data field that the query will sort (based on the value within the field) the information received.	Required
	SITE CONTROL SYSTEM - REPORTS	
	Site Control System Output to Reports	
104		Required

User Need ID	Requirement Description	Required Or High Priority
	The Site Control System shall provide a report for speed limits that were displayed on each VSL device, with time duration (start and stop time) that each speed limit was displayed and the corresponding GPS location of the associated VSL device.	Required
	The Site Control System shall provide a report to retrieve historical system activity to include date, time, and message for commands sent to the field.	High Priority
	The Site Control System shall provide a report to retrieve historical system activity to include date, time, and decision criteria for making automatic commands.	High Priority
	The Site Control System shall provide a report for travel time, computed queue, and travel delay.	High Priority
105		Required
	The Site Control System shall provide a report to retrieve historical user activity to include date, time, and all user actions for Saving, Editing, and Deleting data in the system.	Required
	The Site Control System shall provide a report to retrieve historical user activity to include date, time, and user commands to field devices.	Required
CENTRAL ARCHIVE - REPORTS		
Central Archive Output to Reports		
OTHER ITEMS		
Overarching System Guidelines		
107		Required
	System Device Components (Detectors, VSL, VMS, GPS Locator, Cell Modem, and PDA) must be easily mountable to / removable from the device trailer	Required
	System Device Components must be easily interchangeable (i.e., swappable with a spare device and easy to connect / configure)	Required
	System Device Components must weigh less then 30lbs and mountable by a single person	High Priority
	Communications equipment enclosures used for housing electronic components must provide a standoff mounting board for equipment. Equipment mounted to the mounting board must be easily removable and re-mountable.	High Priority
	Communications equipment enclosures must use screw down terminal blocks and/or cable couplers for connecting all wires between individual device components within the enclosure, so each device can be individually removed and replaced without impacting the other device components within the enclosure.	High Priority
	Cables used to interconnect separate device enclosures (i.e., VSL to PDA, VSL to communications Enclosure, Detector to communications enclosure, etc.) must be outdoor rated (sun resistant and water resistant) use rugged/water-tight couplers at each end; and each device enclosure must have the necessary corresponding cable coupler(s) accessible from the exterior side of the device enclosure, so all cables between device enclosures can be quickly disconnected and reconnected.	High Priority
	Cable mounting provisions must be provided within the trailer for securing cables during system operation and during transport to a different location. Cable mounting provisions must secure the cable at a minimum of 2' intervals and at both ends of every bend point.	Required
	Cable mounting provisions must support easy access to add, remove, and replace cables without fishing the cable through a trailer support frame. The use of Velcro cable straps attached to the trailer structure are acceptable.	High Priority
	The device trailer must have an easily accessible enclosure to house the batteries, charger, and other power distribution assemble (PDA) components.	Required
	The device trailer must be provided with mounting provisions to haul all required trailer components from one location to the next without needing a separate vehicle to transport any of the components.	Required
	The device trailer must be provided with an enclosure to house all necessary spare parts, cables, tools, and consumable preventative maintenance equipment for maintaining the devices mounted on the trailer plus 25% extra space to facilitate quick packing/unpacking of equipment.	High Priority
	The device trailer must be street legal (i.e., break lights connected to towing vehicle), support driving speeds of 80mph when being towed, and provided with a standard size trailer hitch.	Required
	The device trailer must have a minimum of two level gages (length and width positions) to indicate when the trailer is level.	Required
	The device trailer must have adjustable leveling legs that can completely support the weight of a fully loaded trailer. The adjustable height of the legs shall be able to raise the trailer wheels a minimum of 6" between the bottom of the wheels and a flat/level surface that the trailer is standing on.	Required
	The device trailer must have adjustable outriggers that the leveling legs are mounted to for preventing the trailer from tipping over in high winds.	Required

User Need ID	Requirement Description	Required Or High Priority
	Each outrigger mounting bracket shall be adjustable to extend the leveling leg up to a minimum 4' feet away from the trailer base frame.	Required
	The device trailer must have a minimum of eight adjustable outriggers (two on each side of the trailer base frame) .	High Priority
	The device trailer must have a full-size spare tire (rim, fully inflated tire, and lug nuts) mounted to the trailer frame.	Required
108		Required
	System Device Component enclosures must be NEMA-3R (Rainproof and sleet resistant) or IP22 (Protection against solid objects over 12mm and against direct spray up to 15° from vertical) rated for outdoor use	Required
	Communications equipment enclosures used for housing electronic components that don't meet NEMA-3R/IP22 requirements shall be a minimum of NEMA-3R rated and shall provide a ventilation system (i.e., temperature sensor, ventilation fan, and dust filters)	Required
	System Device Component enclosures must meet NEMA TS1/TS2 Environmental requirements for temperature.	Required
	System Device Component enclosures must meet NEMA TS1/TS2 Environmental requirements for shock and vibration for traffic control equipment.	High Priority
	The enclosure housing the batteries, charger, and other power distribution assemble (PDA) components shall meet NEMA-3R requirements.	Required
	The enclosure housing spare parts, tools, and consumable preventative maintenance equipment shall meet NEMA-3R requirements.	High Priority
109		Required
	The field devices shall be IP addressable for communication with the Site Control System.	Required
110		Required
	Manual controls (i.e., controls at the device location) for the VSL and VMS must be protected behind a lockable access door with hinges that hold the door when in the opened position.	Required
	Communications equipment enclosures used for housing electronic components must provide a lockable enclosure access door with hinges to hold the door when in the open position.	Required
	The enclosure housing the batteries, charger, and other power distribution assemble (PDA) components shall have a lockable access door.	Required
	The enclosure housing spare parts, tools, and consumable preventative maintenance equipment shall have a lockable access door.	High Priority
111		Required
	Each device trailer must be capable of being hauled by a vehicle in any of the following conditions: 1) directly connected to the hauling vehicle via a standard trailer hitch; 2) connected to a separate trailer that is connected to the hauling vehicle; 3) directly connected to the hauling vehicle with a 2nd trailer connected behind it; and 4) connected between two trailers (one connected to the hauling vehicle and the other connected behind the trailer)	Required
112		Required
	Each device trailer shall have an equipment ground bus with screw down lug provisions with an approved electrical connection to the main support frame of the trailer.	Required
	Each device trailer shall have a minimum of three ground rods (one to be driven into the ground during operation and two spare).	High Priority
	Each device trailer shall have a copper #4 AWG grounding electrode conductor (10' minimum length) connected between the equipment ground bus bar and the ground rod, when trailer is not being solely by the trailer wheels and hauling vehicle wheels. (i.e., when a metal part of the trailer is touching the ground or another vehicle that is touching the ground, then the trailer should be grounded)	Required
	Each metallic device enclosure mounted to the trailer shall have a ground lug on the external side of the enclosure and a bonding jumper between the enclosure and the equipment ground bus on the trailer. All bonding jumpers must be connected at each end via a screw down lug.	Required
		Required
Site Control System Computations		
114		Required
	The Site Control System shall command a VSL to a user-specified speed display when a user-specified speed threshold is reached at a detection device.	Required
	Automatic commands from the Site Control System shall be configurable per project.	Required
115		High Priority
	The Site Control System shall command a queue warning message to a VMS when a user-specified queue threshold is detected.	High Priority
117		High Priority
	The Site Control System shall determine travel times through a work space.	High Priority

User Need ID	Requirement Description	Required Or High Priority
	The Site Control System shall command travel times to VMS if a user-specified travel time threshold is exceeded.	High Priority
119		High Priority
	The Site Control System shall determine queue detection in advance or a taper.	High Priority
	The Site Control System shall log queue with a date and time stamp.	High Priority
121		High Priority
	The Site Control System shall determine travel delay through active work space.	High Priority
	The Site Control System shall log travel delay with a date and time stamp.	High Priority
123		Required
	Detector devices or Site Control System shall support collecting data to calculate median and 85th percentile speeds.	Required
Site Control System Response Automation		
126		Required
	The Site Control System shall allow manual device override during both Automated On and Automated Off work zone conditions.	Required
128		High Priority
	The Site Control System shall support scheduling the user settable automated mode.	High Priority
	The Site Control System schedule shall include a fixed date and time schedule, and a recurring schedule.	High Priority
129		Required
	The Site Control System shall support a user settable mode of operation per work zone, and include Automated On, and Automated Off.	Required
Variable Device Response Automation		
130		High Priority
	The VSL Device shall be configurable to blank VSL display if the VSL loses communication.	High Priority
131		High Priority
	The Site Control System shall blank messages to online PVMS and online PVSL if a command fails for one field device in a group of linked devices during Automation.	High Priority
	The VSL Device shall be configurable to blank VSL display if the VSL loses communication.	High Priority
132		High Priority
	Each VSL shall include a delay timer (i.e., wait a period of time) before the VSL goes blank for losing communications with the Site Control System.	High Priority
	Each VMS shall include a delay timer (i.e., wait a period of time) before the VMS goes blank for losing communications with the Site Control System.	High Priority
Future Capabilities		
135		Required
	The Contractor shall maintain a minimum of two workable spare devices on hand at the project site, for every type of device/component being deployed on the project.	Required
System Security		
136		Required
	The Site Control System shall support authentication for operator access.	Required
137		High Priority
	The Site Control System shall support authentication prior to an operator gaining remote access.	High Priority
139		Required
	The vendor shall change field device user name and passwords, such that the devices are not set with the factory default settings.	Required
140		Required
	The Site Control System shall support configuring temporary and permanent users.	Required
	The Site Control System shall support temporary users on a per project basis.	Required
	The Site Control System shall remove temporary user names and passwords at the end of each project.	Required