



Smart Work Zone Guidelines

Design Guidelines for
Deployment of Work Zone
Intelligent Transportation
Systems (ITS)

October 2018



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Smart Work Zone Guidelines

Executive Summary

Intelligent Transportation Systems (ITS) can be utilized in highway work zones to help improve public safety and mobility. The resulting systems are commonly referred to as “Smart Work Zones” (SWZ) because they leverage the information derived from the ITS equipment to improve operations within and around the work zones.

Texas Department of Transportation’s (TxDOT) use of ITS in work zones is intended to improve safety for motorists as well as the work zone personnel. Other benefits include reducing traffic delay through work zones, providing effective construction-related information to the public, and providing performance metrics for future work zone design improvements.

This document presents the basic guidelines for the consistent and uniform application of SWZs in the State of Texas. It is not intended to supersede the requirements TxDOT and Federal Highway Administration (FHWA) already have in place for designing work zones such as the Texas Manual on Uniform Control Devices (TMUTCD), TxDOT standards, and any other recognized practices commonly used for road and bridge design projects.

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1. Introduction

1.1 Introduction to Smart Work Zones

This guide provides an introduction to six Smart Work Zone (SWZ) systems that have been identified by TxDOT for use in work zones. It includes System Selection Decision Tools, which use project specific criteria for Go/No-Go decisions for each of these systems and Function Selection Decision Tools to meet specific project needs. These tools are intended to streamline the design process and produce a uniform SWZ delivery across the State.

The six SWZ systems include the following:

Temporary Queue Detection: To address the safety issue of slowed or stopped traffic on the approaches of work zones.

Temporary Speed Monitoring: To improve speed zone compliance and encourage more uniform speeds.

Temporary Construction Equipment Alerts: To inform motorists when material handling vehicles enter the traffic stream.

Temporary Travel Time Display: To help approaching motorists make informed decisions about route choices.

Temporary Incident Detection and Surveillance: To provide situational awareness and faster responses to incidents.

Temporary Over-Height Vehicle Warning: To provide advance warning alerts for projects with low structures.

This guide explains the rationale for how to use SWZ system selection criteria, and describes how the SWZ design process parallels the road/bridge project design. It also clarifies how Systems Engineering fits into the SWZ process, and details the effective use of performance metrics.

1.2 Purpose of this Report

This technical report presents TxDOT's recommendations for the basic guidelines for incorporating Intelligent Transportation Systems (ITS) into the TCP for roadway construction projects. These guidelines are intended to clarify what ITS Systems are appropriate for "Smart Work Zones" on TxDOT projects, provide general design and deployment guidance for these systems, and support state-wide work zone ITS standards and specifications.

This report complements existing design practices for work zones, and is not intended to supersede or replace existing standards, Texas MUTCD requirements or other common design practices being used to develop plans and specifications for road or bridge projects in Texas. This is particularly important because the Highway and Bridge Engineers responsible for construction work zones are often unfamiliar with ITS Technologies. These guidelines provide user friendly design tools that help engineers choose and produce consistent and appropriate systems.

1.3 Smart Work Zones Regulation and Guidance

The following excerpt from the February 2016 version of the Massachusetts Department of Transportation's Smart Work Zone Standard Operating Procedures describes the FHWA basis for regulation and guidance of Smart Work Zones.

Federal Highway Administration (FHWA)

In September 2004, FHWA updated the Work Zone Safety and Mobility Rule 23 CFR 630 Subpart J. The Rule applies to all state and local governments that receive Federal-Aid highway funding for road and bridge construction projects. The rule outlined clear and definitive provisions and compliance dates for State and local transportation agencies that using Federal-Aid as follows:

- Define a clear and comprehensive process for evaluating and mitigating the impacts of construction work zones.
- Provide safe work zones for all workers and road users while also providing for the highest level of mobility.
- Define the evaluation techniques to be used during the planning, design, and construction phases of a project.

In 2007, FHWA issued the Work Zone Operations Best Practices Guidebook to provide a compilation of successful work zone operations practices used and recommended by several states and localities for other agencies to determine which of these practices are best suited for their particular situations. Some of those practices deal with the utilization of ITS systems to automatically collect and analyze data, and provide real-time information to motorists and to the construction team.

In addition to the aforementioned publications, FHWA has made available a number of resources developed by the academia, and local and state agencies for implementing various types of ITS in work zones. Such resources can be accessed through FHWA's Work Zone Mobility and Safety Program website¹. The practices described in the guidebook and the website are intended as a descriptive, not prescriptive, depiction of the subject.

¹ <http://www.ops.fhwa.dot.gov/wz/its/indeg.htm>.

Texas Department of Transportation

Vision and Mission

Vision: 'A forward-thinking leader delivering mobility, enabling economic opportunity, and enhancing quality of life for all Texans.'

Mission: 'Through collaboration and leadership, we deliver a safe, reliable, and integrated transportation system that enables the movement of people and goods.'

TxDOT has identified Smart Work Zones as a priority in their response to the FHWA Work Zone Safety and Mobility Guidelines.

1.4 Smart Work Zones: Principles and Applications

Definition

The term “Smart Work Zone” is synonymous with the term “Work Zone ITS”. Both refer to the deployment of ITS technologies and strategies to enhance mobility and safety in and around work zones. They are usually deployed on a temporary basis until the interruptions from roadway construction are over.

These technologies typically produce data and/or images that are processed to become actionable information. In some cases the technology is designed to process the data instantly and then take immediate action without human intervention (e.g. End of Queue detection triggering an upstream Portable Changeable Message Sign to alert approaching motorists). In other cases the data is used by traffic operation dispatchers or others to achieve situational awareness. Once alerted to unfavorable conditions, they quickly follow, or verify pre-planned protocols to respond to these incidents. In both cases, the data can be recorded for use in reports for administrators in decision making. Performance metrics guide decisions that influence the refinement of operational practices for current and future work zones.

Rationale

The intent is to leverage the benefits of Smart Work Zones (SWZs) to improve traffic safety and efficiency ahead of and through highway construction areas. As a strategy to improve safety in our work zones has increased along with the substantial projects programmed by TxDOT in the future, the demand for Smart Work Zones in Texas is imminent. This includes strategies for optimizing the use of these technologies and prioritizing selections to fit into a fiscally constrained program for Traffic Maintenance and Operations. Because SWZs typically involve the production and use of information, feedback from these systems in the form of performance metrics can be used to guide these choices and refine strategies to achieve the goal of improving efficiency and reducing the crash rate in highway construction work zones.

A recent study by Texas Southern University (FHWA/TX-17/0-6915-1) was conducted in cooperation with TxDOT and FHWA to Identify Project Criteria for ITS Deployment in work zones. The conclusions and recommendations of that study closely parallel the strategies recommended in these guidelines.

Systems Engineering for Smart Work Zones

FHWA places an emphasis on using the Systems Engineering process to develop any new ITS solutions. This is typically summarized in a “V” diagram as shown in Figure 1.

Some early applications of SWZs around the country failed to deliver benefits due to poor planning, confusing requirements and a lack of integration. Many of these issues are due to the fact that the SWZ design is introduced into the road design process too late, sometimes even after letting. A Systems Engineering process can address these issues. (More information on the Systems Engineering Process can be found at: https://ops.fhwa.dot.gov/int_its_deployment/sys_eng.htm)

It takes considerable effort to produce an effective Smart Work Zone that integrates properly with the various phases of large road construction projects. This is aggravated by the fact that much of the ITS device placement cannot begin until the changing traffic patterns in the construction project have been identified.

This “V” diagram shows the sequence of Systems Engineering steps that can be used to ensure a final product closely resembles its initial vision. Although Systems Engineering was originally developed by the National Aeronautics and Space Administration (NASA) to effectively manage very large complex projects that typically produce brand new technology solutions, an abbreviated version of this process can be useful for developing SWZs as explain below.

Most of the ITS devices used in SWZs have already been vetted through product acceptance testing and field experience. Therefore, some of the elements on the declining left branch of the “V” Diagram have already been “pre-engineered” into what we are calling “Systems” which, as mentioned earlier, are assembled devices configured to accomplish objectives. Depending on the project’s level of complexity, the left, declining branch of the “V” diagram can be abbreviated to diminish the need for a full Concept of Operations (ConOps) and a High Level Design, leaving the System Requirements and Detailed Design steps remaining. These two steps can then be addressed quickly using two types of Decision Tools that address common work zone issues with simple criteria filters that help the user select appropriate SWZ Systems and sub components for each project.

The rising right side of the “V” Diagram could also be abbreviated somewhat due to the fact that some devices used in SWZs come pre-certified by the manufacturers. Due to the temporary nature of SWZs, this equipment is often re-used by contractors so their investment can be

amortized over several contracts. This makes the delivery of fully tested, reliable systems easier because they “worked the bugs out” the first time they were deployed. To ensure they get paid, these Integrators typically maintain a 10% spare parts inventory to minimize downtime.

The final step in the Systems Engineering process, System Validation, is achieved when the Contractor delivers the performance measures. Folding this validation data from the performance measures back into the Decision Tool criteria can produce a continuous stream of strategy refinements over the years ahead.

The timeline at the top of the ‘V’ Diagram in Figure 2 summarizes the stages of development for a typical new system. Because this timeline also resembles that of a typical highway construction project, we can take advantage of their parallel structures for scheduling the SWZ development steps.

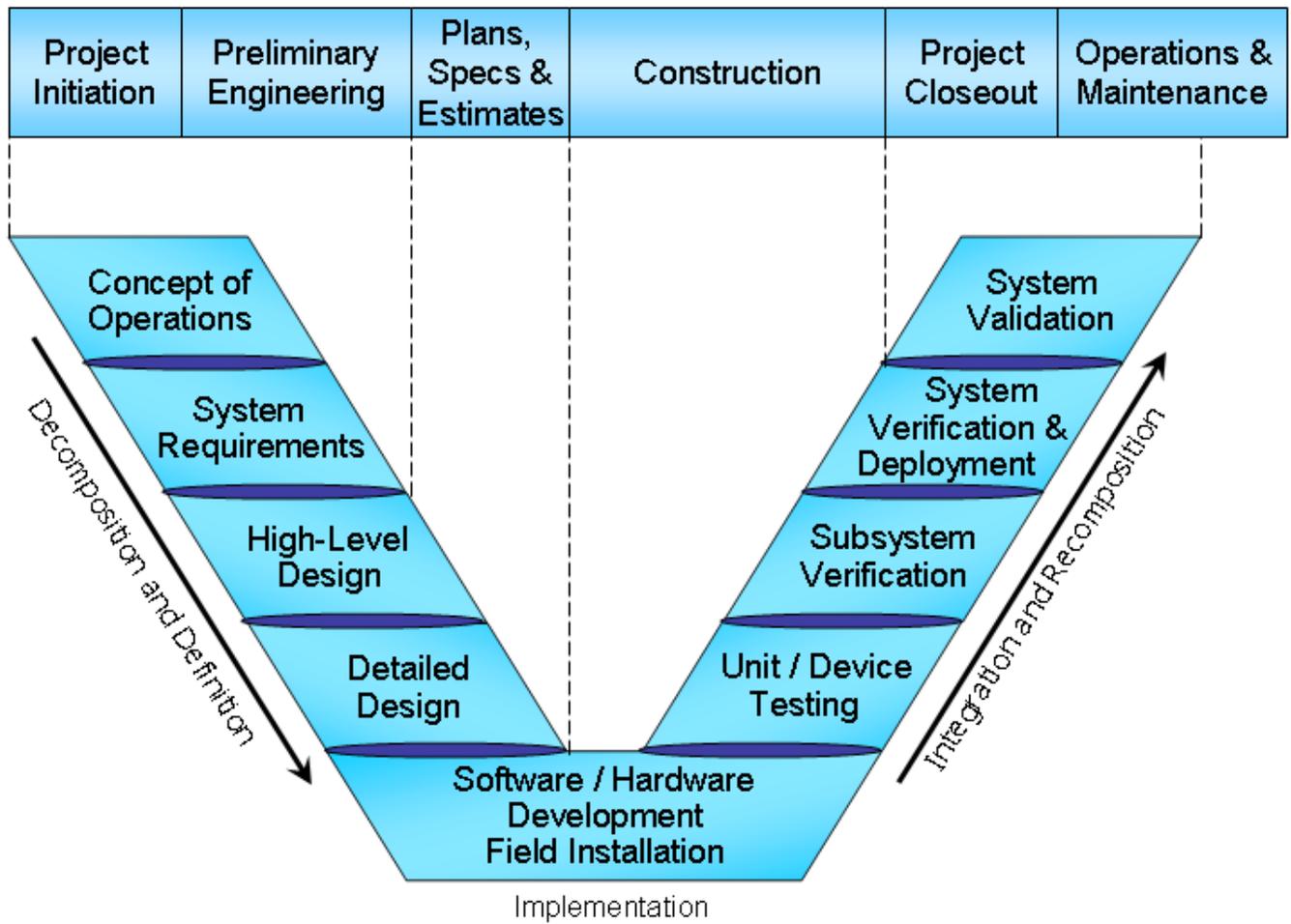


Figure 1: System Engineering 'V' Diagram
 Modified from <https://ops.fhwa.dot.gov/publications/seitsguide/section3.htm>

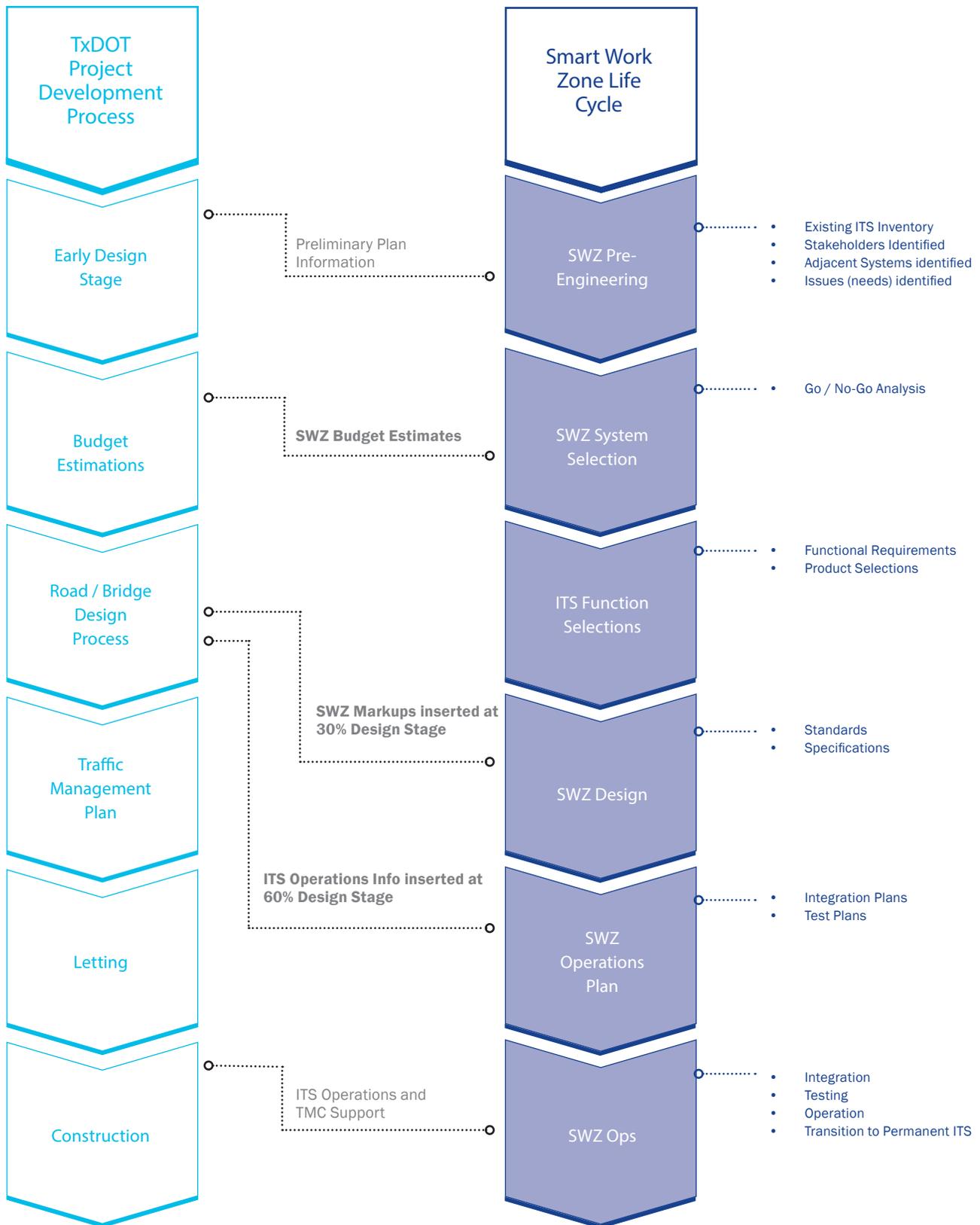


Figure 2: Timelines showing TxDOT Construction Process and Smart Work Zone Life Cycle

Figure 2 illustrates several key strategies that facilitate the SWZ design process:

- The Smart Work Zone Life Cycle on the right is the key to reducing the SWZ development time. Note that some of the steps actually occur before the physical road design even starts. This enables the SWZ Designers to identify project specific issues such as how to handle adjacent projects with overlapping boundaries, addressing concerns from emergency response agencies, and the concerns of local stakeholders who will be impacted by the project. Also note that the Systems selection occurs early relative to the road design. These Systems can be selected after the basic construction traffic pattern shifts have been determined. Getting this jump start on the SWZ Design process enables the remaining steps in the Smart Work Zone Life Cycle on the right to be sequenced in parallel with the remaining steps of the Construction Process on the top of Figure 2.
- Identifying the stakeholders early is a way of avoiding changes later in the process. Emergency response agencies and Traffic Management Centers (TMC) in particular have unique concerns that should be considered during the early design stage of a road, bridge or tunnel project. These organizations are already equipped to respond to highway incidents. SWZs can help them be more aware of traffic conditions within the construction zone areas by equipping them with video, incident detection and dashboards. For example, a vehicle speed gauge on a SWZ Dashboard can help identify when speed enforcement is truly necessary. This conserves their limited resources and addresses the fact that police presence can actually reduce throughput capacity in some cases. Giving these two groups real time situational awareness and performance progress reports enables them to quickly respond to incidents and to help apply countermeasures that prevent incidents from occurring in the first place.
- The ITS Design Stage in the SWZ Timeline in Figure 2 also includes provisions for addressing permanent ITS equipment issues. These may be new, replacement, or relocations of existing ITS technologies such as vehicle detectors or permanent dynamic message signs. If these are scheduled for delivery early in the construction sequence, they can be leveraged as useful components of the SWZ, minimizing the need to add temporary ITS equipment. Temporary wireless communication systems can even be installed to support operations until fiber can be installed which frequently must wait until grading and bridge structures are in place.
- Several of the SWZ Systems are designed for portable operation. These assembled products are pre-engineered to work as systems or to be linked together and operate globally across one or more work zones. Their portable design also enables easy relocation as traffic patterns change. These systems offer flexibility for re-use during subsequent projects, minimizing the development time and costs for those projects.

2. TxDOT Smart Work Zone Systems

A literature review was conducted on applicable Smart Work Zone documentation from federal agencies, other state departments of transportation (DOT), universities and research institutions to identify the most effective strategies for building Smart Work Zones. The work also included a search for available ITS technologies used to make work zones safer and more efficient.

Based on this literature review and SWZ project experience in Texas, TxDOT has identified six configurations of ITS applications for Smart Work Zone systems as options for the districts for project implementation. Table 1 summarizes the six priority System categories being emphasized by TxDOT.

Illustrations for each of the six Systems are presented on the following pages. Please note that the actual quantity, locations and spacing of the devices shown in each graphic may vary and are project specific. These conceptual drawings are only intended to suggest what equipment is typically included or considered as optional for each System.

The messages in the illustrations are displayed as examples. During construction these initial examples may be modified at the Engineer's discretion. It is also possible that some of these devices (eg. the PCMS) may be relocated as traffic patterns change, or if traffic conditions are different from what is expected during the design process. If that is likely

to happen, provisions should be made to pay for relocation costs.

Standard clear zone requirements will be necessary for all portable devices located on the shoulder. Standard construction signage (not shown on these illustrations) must also be included in the plans.

All of these systems have the capability of producing raw data that can be collected, communicated and archived for generating performance measures. These metrics can be presented in real time or in the form of reports for historical analysis. If these are desired, then provisions should be made in the specifications and bidding documents to cover the costs of producing these reports.

Whenever possible, the SWZ systems should be integrated into the existing ITS infrastructure. For example, existing Dynamic Message Signs upstream can be used as advance notification systems for Queue Detection or Travel Time Systems. In some cases, existing ITS devices may need to be modified or relocated as part of the project line items. When this occurs, it is important to make these changes to the existing infrastructure early in the construction process so they can be used during the remainder of the road/bridge project.

System	Description
Temporary Queue Detection System	System that continuously monitors traffic on the approaches to and within construction work zones to detect slowed or stopped traffic. This information is then presented to approaching motorists so they can make informed decisions.
Temporary Speed Monitoring System	System that uses sensors to measure vehicle speeds approaching work zone. Speed data is then immediately presented to the motorist.
Temporary Construction Equipment Alert System	System that delivers immediate information to motorists about construction vehicles and equipment that are entering the highway from a work zone.
Temporary Travel Time System	System that continuously monitors travel times through a work zone, and then presents this information to approaching motorists so they can make informed decisions.
Temporary Incident Detection and Surveillance System	System that uses sensors and/or video to detect crashes and other incident conditions within a work zone and then communicates that information to a local TMC and/or to emergency response agencies. The alerts are then confirmed remotely using live streaming video, snapshots or on-site personnel. This System can be used to provide critical information to responders who help them decide exactly what equipment to bring, how best to approach the incident, and any additional precautions that might be needed to protect themselves and the public.
Temporary Over-Height Vehicle Warning System	System detects vehicles or loads that are too tall to clear physical limitations such as low bridges in a work zone, and then conveys a warning message to approaching vehicles.

Table 1: Smart Work Zone Systems

2.1 Temporary Queue Detection System

Problem Statement

This System addresses the problem of approaching vehicles suddenly being confronted with slowed or stopped traffic. This situation exists at the back end of any queue. It is particularly troublesome because that is a point of high risk that typically moves as the queue grows or shrinks. That movement makes it unpredictable for approaching motorists. This risk can increase with high traffic volumes, blind curves (vertical or horizontal), on/off ramps that

cause additional navigation burden for motorists, distracting urban environments, or rural environments where motorists may become inattentive.

Countermeasures

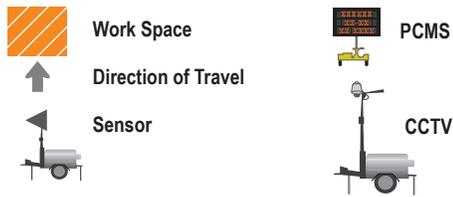
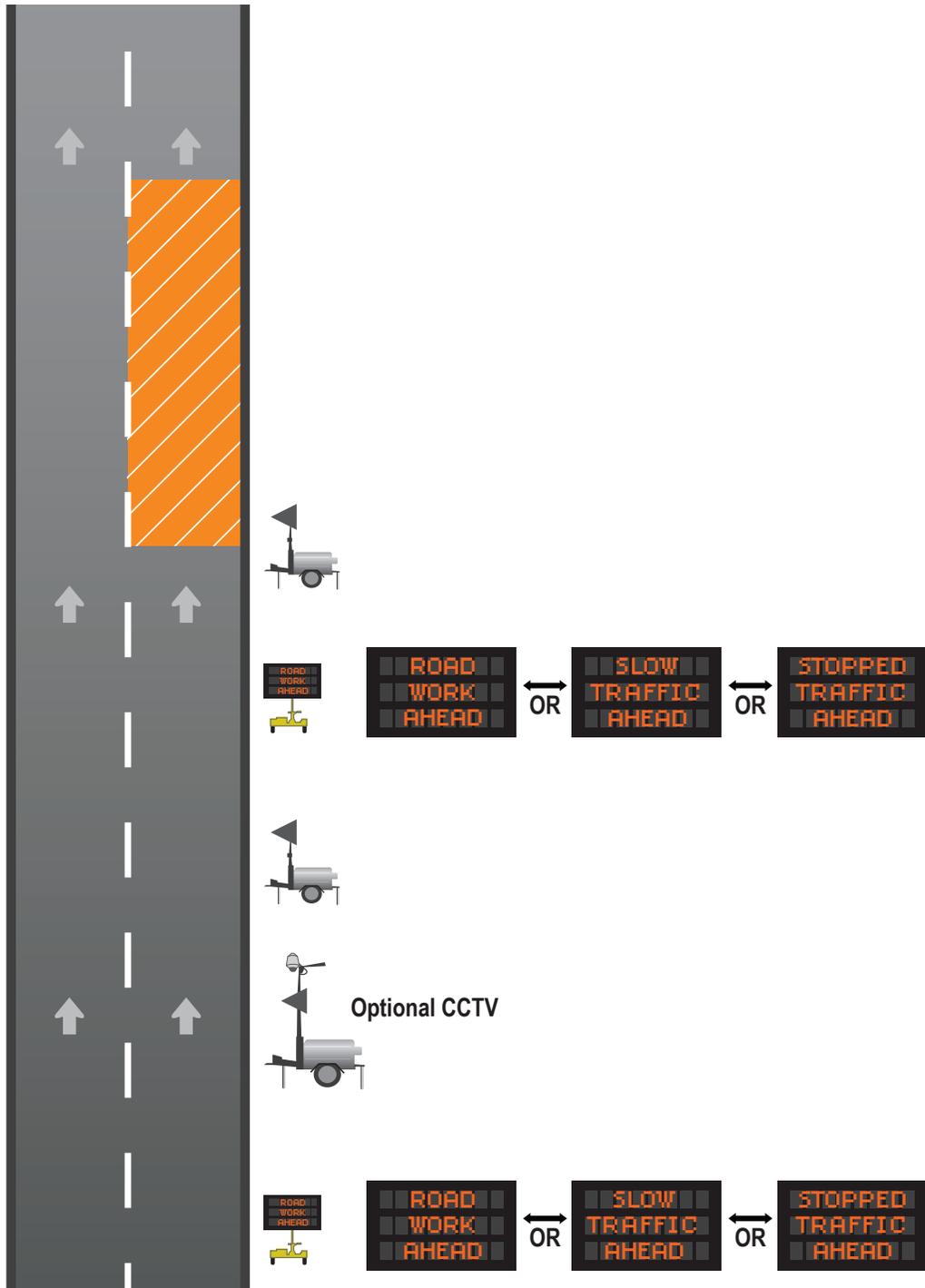
Any strategy that increases an approaching motorist's attention to the driving task and awareness of the circumstances can serve as a countermeasure to minimize crash potential. Some transportation agencies conspicuously deploy motorist assistance vehicles or police officers at the moving edge of the queue with their vehicle warning lights flashing when conditions warrant. This works well, but is an expensive, labor intensive solution.

Queues typically form at lane closures and decision points. An ITS Queue Detection System is a strategy that can improve motorists' awareness of the situation, and increase their attention levels. The System includes a queue detector, a messaging system, a network to connect the two, and a connection to a TMC to make them aware of changing conditions. A data archiving system can be included as well to produce performance metrics that are useful for scheduling lane restrictions that minimize exposure, cost effective enforcement officer presence and effective planning for future construction zones. Figure 3 shows how the system is typically configured.

	Free Flow Condition	Travel Delays Or Slow Traffic	Long Travel Delays or Stopped Traffic
	Downstream Sensor Speed >45 mph	Downstream Sensor Speed <45 mph	Downstream Sensor Speed <25 mph
Display 1 (7.5 miles from WZ)	Road Work Ahead	SLOW TRAFFIC X MILES	STOPPED TRAFFIC X MILES
Display 2 (3.5 mile from WZ)	Road Work Ahead	SLOW TRAFFIC X MILES	STOPPED TRAFFIC X MILES

(See Standard Sheets for Temporary Queue Detection System for additional details)

Table 2: Typical messages to be displayed on PCMS



Notes:
Layout is not drawn to scale
number and location of devices will vary

Figure 3: Temporary Queue Detection System

The CCTV camera is optional for this application. If situational awareness of the work zone conditions is needed by a TMC, local enforcement authorities or the Contractor, then a trailer mounted CCTV can be included. (See Temporary Incident Detection and Surveillance System Graphic notes for dual purposing the CCTV cameras.) Table 2 shows typical messages to be displayed on PCMS for each situation.

2.2 Temporary Speed Monitoring System

Problem Statement

This System addresses the problem of high crash risk caused by unsafe vehicle speeds in construction areas. There are several key factors related to the Speed Monitoring System.

- The most obvious is excessive speed above what is considered safe for conditions. Typically this will be the posted or advisory speed limit, but can be lower during inclement weather, heavy traffic or other abnormal conditions. Both real time and archived speed data can be useful for enforcement to schedule speed compliance efforts, and for a TMC to invoke messages to motorists as a means for encouraging voluntary compliance. This metric is fairly easy to produce using radar or other forms of speed detection.
- A second, less obvious factor is non-uniformity of speed. When motorists are all traveling at the same speed they have fewer decisions to make in regard to navigating through work zone traffic. When a few motorists choose to travel at speeds significantly above or below the average, they increase the risk for themselves and for other motorists in their immediate environment who are forced to react to these unexpected conditions. This metric can also be produced with vehicle speed detection systems, but requires some additional processing to calculate the difference between individual vehicle speeds and the mean speed of the traffic stream – vehicle speed variability.

Countermeasures

Any strategy that improves overall compliance with posted speed limits will effectively address this problem because it produces more uniform vehicle speeds that minimize the drivers' need to apply their brakes or change lanes. Police presence is highly effective, but is expensive, plus it also has a short "shelf life". Dynamic Messages or Speed Feedback Trailers can also be effective, especially if they are presented discriminatingly when conditions warrant so motorists maintain respect for the messages.

A Speed Monitoring System can be used in a Smart Work Zone to systematically address this problem. This ITS tool can improve motorists' awareness of the situation, and increase their attention levels. There are several ways this can be accomplished. The system can include one or more speed detectors, a messaging system, a network to connect the two, and a connection to a TMC and/or enforcement agency to make them aware of changing conditions. A data archiving system can be included to produce performance metrics that are useful for scheduling enforcement officer presence.

Stand-alone Speed Feedback systems are available to promote speed compliance. Figure 4 below shows an example. These systems are typically trailer mounted radar devices with signs that continuously produce brief messages or a simple two digit LED message. These portable units can also be configured with data archiving capability and remote communications to provide alerts for extreme speeds, hourly data archives or system status notifications.



-  Work Space
-  Direction of Travel
-  Sensor



Notes:
Layout is not drawn to scale
number and location of devices will vary

Figure 4: Temporary Speed Monitoring System

Either the Feedback trailers or the Speed Detectors can be optional depending on need and project budget. The Detectors can also be dual purposed for use in the Travel Time System. Either of these devices can be configured to produce real time alerts to nearby enforcement officers regarding excessively high or low speeds. Historical (hour of the week) reports can also be generated to help enforcement optimize their officer assignments so they maximize their effectiveness. Periods of moderate traffic volume that have large variances in speed across adjacent lanes upstream of the taper are also cause for concern as they indicate a higher potential for crashes to occur. That set of circumstances places a heavy burden on motorist skills as they merge into a single file.

2.3 Temporary Construction Equipment Alert System

Problem Statement

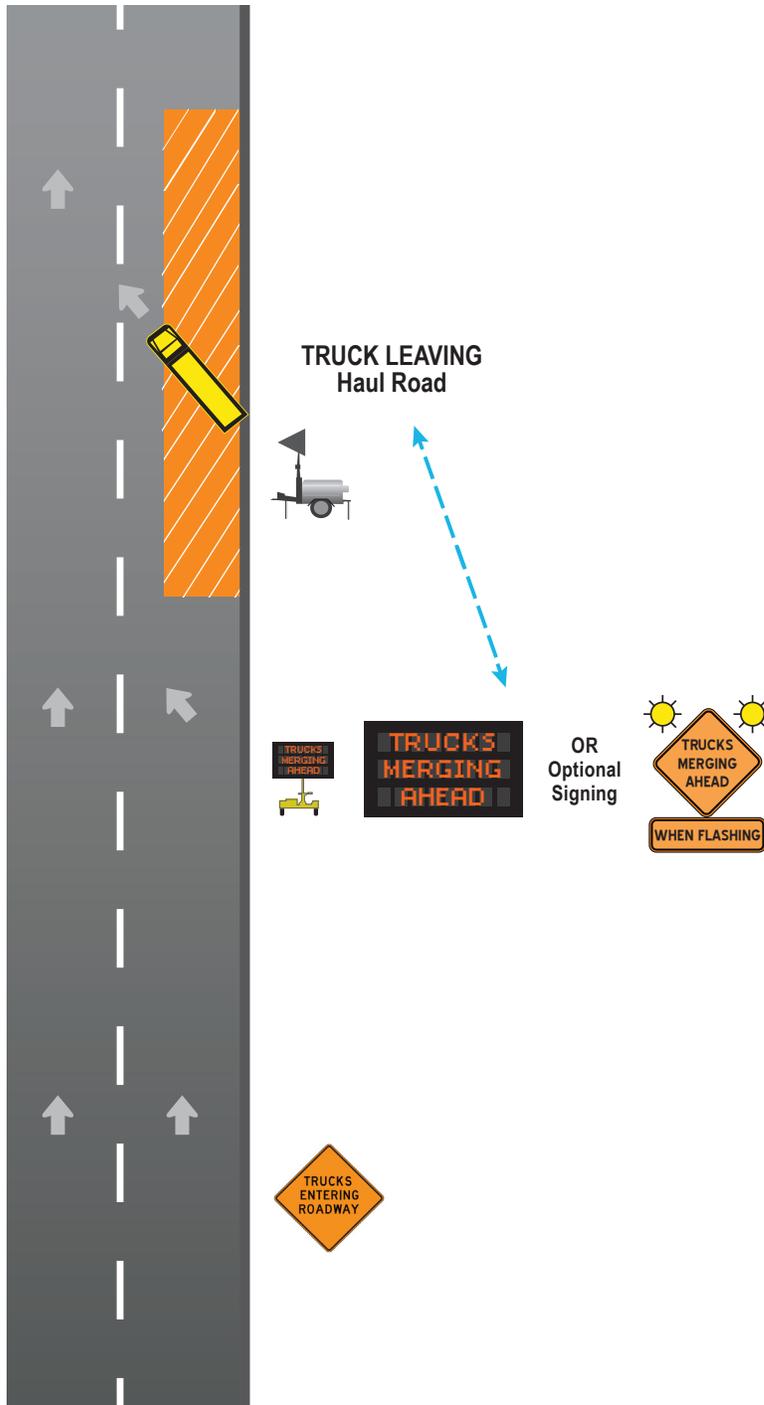
This System addresses the problem of construction vehicles entering into the traffic stream. This causes motorists to react, which increases risk for them and for other motorists behind them who have to react to sudden stops or slowdowns. A project's Traffic Control Plans typically try to avoid this problem, but there are some conditions when there is no other choice but to have material handling trucks use the mainline as their path to and from the work areas.

Countermeasures

If conditions are such that these trucks must blend with traffic, one strategy is to have the barricaded area extend past the actual work area. This gives the material handling trucks a longer distance to match their speed with that of through traffic, making the merging maneuver safer and more obvious to the motorists.

A Construction Equipment Alert System, illustrated in Figure 5, can also address this issue. It consists of a truck detector, a message sign (or warning sign with flashers), and a wireless communication link to trigger the sign. These systems are typically stand-alone, so they do not usually have a link to a TMC.

One issue that must be handled is a means for distinguishing between these trucks and all other equipment that moves within the work zone so that false triggers do not occur. This can be handled by carefully limiting the detection zone, or by having a vehicle-to-infrastructure (V2I) communication device in each construction vehicle that will be leaving the work area and entering the traffic stream.



	Work Space		PCMS
	Direction of Travel		Wireless Communication
	Sensor		Static Signs (CW27-1T)

Notes:
Layout is not drawn to scale
number and location of devices will vary

Figure 5: Temporary Construction Equipment Alert System
The communication system that links the sensor to the Warning Sign must be a point to point wireless device because the sign must respond immediately and reliably to the detection call. Cellular communications should not be allowed.

2.4 Temporary Travel Time System

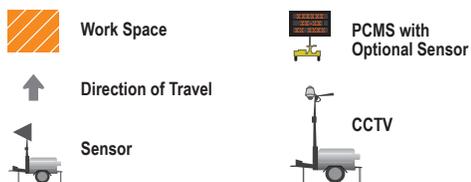
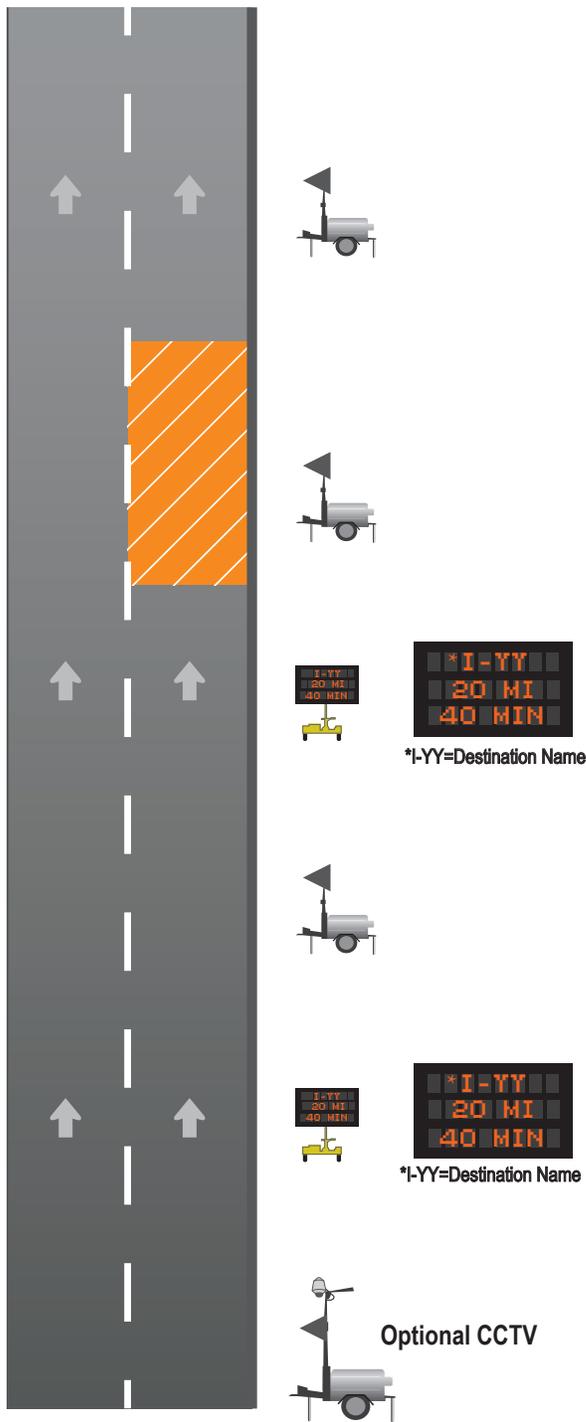
Problem Statement

This System addresses the problem of motorist delay frequently caused by work zones. When motorists experience delay, they tend to overestimate their additional travel time experience, causing aggravation that can lead to reckless and dangerous driver behavior. Travel Time information can be provided in advance of the work zone so motorists can make informed decisions and set realistic expectations.

Countermeasures

Giving motorists the current travel time to a reference point beyond the work zone can alleviate some of the frustration that motorists experience.

The equipment consists of a detection system that measures the travel time through the work zone, and a communication system to one or more message boards or travel time signs, see Figure 6. During the system design, the Engineer should identify project specific destination names for each PCMS. Typical destinations will be shown in Chapter 5. The System provides information that clarifies motorists' expectations if they choose to travel through the work zone, or encourages diversions along alternate routes if that is a better choice.



Notes:
 Layout is not drawn to scale
 number and location of devices will vary

Figure 6: Temporary Travel Time System

Several different forms of detection are available to provide the raw speed data needed by the system to calculate the travel time or delay values that are displayed. These can include devices such as radar, video analytics, or Bluetooth. An alternative to physical detection equipment is crowd sourced data that uses vehicle GPS navigation system data samples to calculate link travel times. Besides the non-invasive nature of probe data, it can also be used to monitor traffic flow on alternate routes, enabling upstream messages to motorists advising them of their best route choice options.

2.5 Temporary Incident Detection and Surveillance System

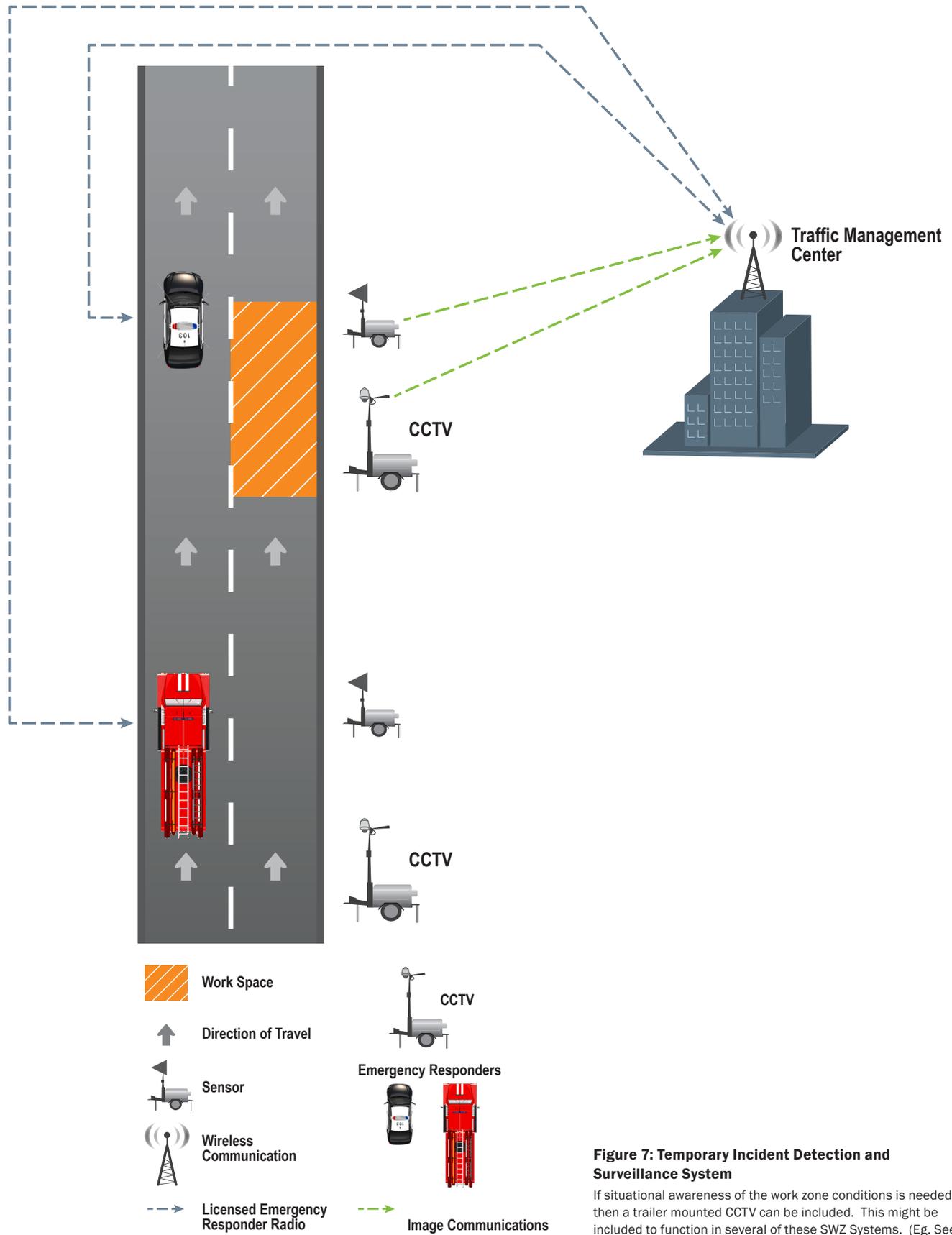
Problem Statement

This System addresses the problem of higher than normal crash risk in most work zones and also includes the approaches to work zones where traffic is affected. This problem may always exist simply because work zones increase demand on motorist skills. When safety service patrols are included in work zones, the personnel operating those programs need details about each disabled vehicle or crash site (eg. Size of vehicle, orientation of vehicle, fuel/cargo spills, etc.) so the appropriate response vehicles/equipment can be deployed effectively.

Countermeasures

Any means for improving the situational awareness of emergency responders will reduce the time to detect, respond and clear incidents. Incident Detection and Surveillance Systems typically include incident detection and video surveillance equipment, see Figure 7. These tools are most often connected a TMC that contacts the appropriate agencies to respond to incidents and notify the public. Timely response to clear an incident reduces the probability of a secondary incident which may have severe consequences.

This information can also be used by enforcement agencies to incorporate countermeasures that reduce the occurrences of incidents in the first place. When conditions that increase crash risk exist such as road maintenance, severe weather, debris on the roadway or certain traffic flow conditions, the conspicuous presence of a police officer can usually smooth the flow rate and increase motorists' attentiveness.



Notes:
 Layout is not drawn to scale
 number and location of devices will vary

Figure 7: Temporary Incident Detection and Surveillance System

If situational awareness of the work zone conditions is needed, then a trailer mounted CCTV can be included. This might be included to function in several of these SWZ Systems. (Eg. See Queue Detection System Graphic notes for dual purposing the CCTV cameras.)

2.6 Temporary Over-Height Vehicle Warning System

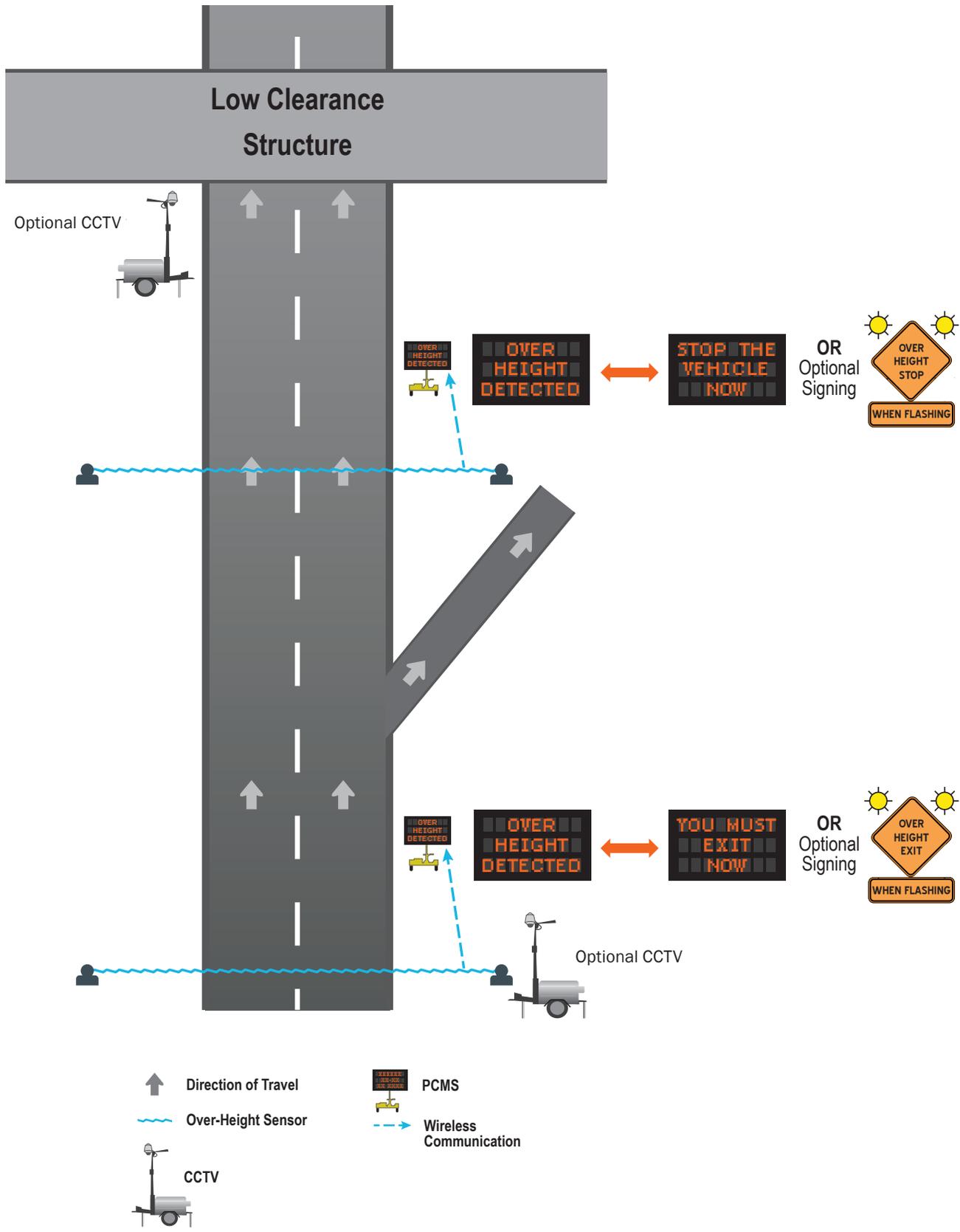
Problem Statement

This System addresses the problem of vehicles striking low structures. Although most Interstate facilities meet minimum height standards, there sometimes are low structures on other State Highways and issues with arch bridges when shoulders are used as temporary travel lanes. While these incidents are rare, they tend to be catastrophic when they occur. Real time vehicle height detection and driver notifications can be used to address this problem.

Countermeasures

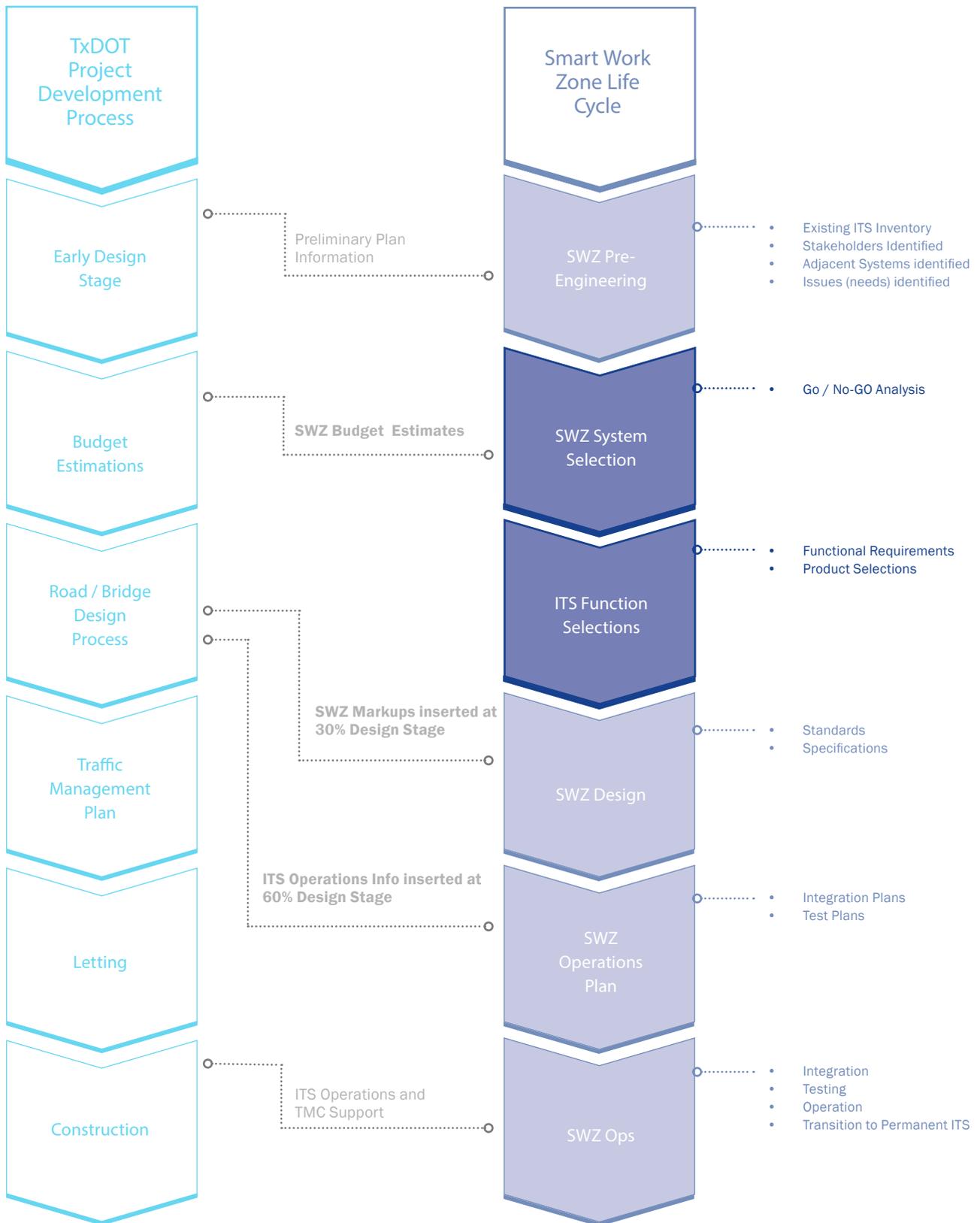
In a few cases where traffic is traveling at very low speeds, simple, low-tech horizontal height bars or dangling chains can be used to alert a driver that their vehicle is too tall to navigate under the low structure ahead.

For most other cases, an electronic detection system is required to identify vehicle height problems. Twin light beam technology has been used successfully by a number of states as an effective application for detecting these tall vehicles or Over-Height cargo. Dynamic Message Boards or fixed signs with flashing beacons are triggered instantly when any Over-Height detection occurs, see Figure 8.



Notes:
 Layout is not drawn to scale
 number and location of devices will vary

Figure 8: Temporary Over-Height Vehicle Warning System



3. Selection Procedure for Smart Work Zones

3.1 Identification of Work Zone Data Needs

To select proper SWZ Systems requires full understanding of the project characteristics. Several key elements are presented below that need to be taken into consideration in decision making and designs. This data is needed before completing the decision tool workbook scoring criteria shown in Appendix A.

Duration of the Work Zone

Statistically, the longer a work zone exists, the higher the impact on traffic conditions and crash risks. Very short term projects such as lane closures for only a few hours or days may not justify the expense of a SWZ System unless there are extenuating circumstances.

Highway function class and traffic volumes

Traffic volumes and road capacity directly affect travel time, headways and uniformity of speeds in a traffic stream.

Impact from local traffic generators

Local traffic generators such as sports arenas, industrial centers with a large population of employees or material movements, or other attractions can produce sudden traffic at the entry/exit points to the highways that feed these facilities. If a work zone is operating near capacity, traffic generated by those facilities can produce severe delay and longer queues than expected during normal operating hours.

Estimated queue length

This is the most important factor for determining the need for a Queue Detection System. The extent to which a work zone produces queues can be used as a gauge for a Go/NoGo decision on this System. The lengths and durations of the queues can be used to compare different projects to prioritize when budgets are tight. Queue lengths can also be a factor for determining which hours of the week a lane can be closed if the nature of the work allows for short term lane closures.

Sight distance at back of queue

Limited sight distance at the back of queues reduces motorists reaction time to the presence of stopped traffic ahead.

Existing traffic issues

The mainline roadway itself may have unusual characteristics such as a higher than normal incident rate, gridlock or exit ramp backups due to connecting arterial spill overs during peak hours, rail crossings interrupting exit ramp flow immediately after the ramp leaves the mainline, or a tendency to flood during high water circumstances.

Availability of alternate routes

Traffic can be distributed across alternate routes when available and feasible, which reduces the demand and, therefore, the queue potential. The feasibility of any proposed alternate should be evaluated first. Is the proposed alternate comparable in terms of roadway functional class? For example, can the alternate route handle heavy truck traffic? When alternate routes are not available, ITS systems become more important to maintain safe speeds and maximum capacity.

Merging conflict or hazards on the approach to work zone

Conflicts can cause sudden changes in speed, creating a hazard for trailing and merging motorists.

Complex traffic control layouts

Situations like multiple crossovers, sharp curves, lane splits, etc. challenge motorists' skills, leading to higher crash rates.

Constraints for emergency responders

The construction process may limit fire, police, ambulance or other emergency response agencies' ability to reach an incident site. This can include very narrow or no shoulders, long stretches of roadway with no crossovers, International borders making turn arounds difficult, narrow lanes, or any other factor that limits their access during the construction process.

Chronic speeding issues

Some roadways have a chronic history of extremely high (eg. aggressive motorists) or extremely low (eg. non-motorized vehicles) speeds. These situations can increase the risk potential for crashes to occur.

Large speed variations

Uniform traffic flow is the goal for a work zone, which occurs when motorists are traveling at approximately the same speed and their headways are adequate to enable them to react successfully for sudden changes such as a stopped vehicle ahead.

Adjacent/consecutive project

When multiple construction projects are strung together effectively creating one large work zone, the combination of projects should be considered as one project in determining the need for SWZ System.

Scattered, short term projects

Projects like bridge painting can surprise motorists.

Extreme weather condition

Safety can be a big concern where the work zone is operating in an area with a known history of sudden extreme weather conditions such as ice, flooding, windstorms, sandstorms, or a project duration that covers several harsh weather seasons.

Connected Vehicle

It is anticipated that when a few percent of the population of vehicles are connected vehicles, they will effectively influence the overall behavior of the traffic stream. Examples include more uniform speeds, fewer incidents and improved navigational guidance for trailing vehicles that are not equipped with vehicle to roadside communication systems.

Existing ITS Systems

Existing ITS systems can be leveraged when the work zone falls within the jurisdiction of a Traffic Management Center (TMC). SWZ equipment can be brought in and connected to the TMC as if they were an extension of the normal TMC operations. It is a cost-efficient strategy that takes advantage of the TMC's ability to notify emergency responders, publish traveler information to an extensive list of media, and process any performance metric data that is being produced by the SWZ devices. This strategy expands the TMC staff's situational awareness.

Heavy vehicles

The percentage of heavy vehicles can be a significant factor for degrading speed uniformity due to the tendency for trucks to travel at lower speeds than smaller vehicles, causing a frequent speed differential. Their physical size also occludes other motorists' view of the approaching traffic conditions.

Construction vehicle entering the highway

Construction vehicles entering mainline traffic disrupt traffic flow. Motorists need to be aware of this conflict ahead of time.

Over-Height Vehicle / Low Clearance Structure

Although most interstate structures meet minimum design standards for vertical clearance, circumstances such as temporary false work, shoulders being used as driving lanes under arch bridges, or temporary detours that use local roads with low structures can cause temporary vertical clearance hazards.

3.2 Selection Process & Criteria

Table 3 shows the key elements to be considered when determining if a specific SWZ System is needed or not. ITS devices can be assembled into groups called Systems that accomplish specific objectives. Because the criteria for system selections are unique to each project, a SWZ Decision Tool has been developed to streamline the SWZ selection process. These can be found in the Excel Decision Tool Workbook included in Appendix A. The Decision Tool enables an overall Smart Work Zone Go/NoGo decision to be made by scoring the extent to which each criterion in Section 3.1 above is satisfied. The Go/NoGo Decision Tool automatically assigns those values to each of the six SWZ Systems to produce a total score for each system and presents a summary in the Summary Tab. This produces a logical basis for including any combination of SWZ Systems into the project design, which effectively defines the SWZ Scope.

Because the queue area in front of a work zone is typically the area of highest risk for crashes to occur, the estimated queue length is an important factor in the decision process. The metric recommended for this is queue length. This is a factor in several of the SWZ systems, particularly the Queue Detection System. To produce a realistic estimate of the queue, three options are recommended:

1. If a traffic modeling program is available, it will produce the most realistic estimate of the queue.
2. TxDOT also has an internally available tool called Q-DAT which can estimate queue length. For access to this tool, please contact Traffic Operations Division, Traffic Engineering Section, Policy and Standards Branch.
3. A third option is a lookup table in Appendix B. The Average Annual Daily Traffic (AADT) value for the project is located among the threshold values for different queue lengths to determine the scoring for the Queue factor in the Go/No-Go Decision Tool. These two tables were developed based on a single case study and a single day traffic count. The look-up tables are intended to only provide an approximate queue length.

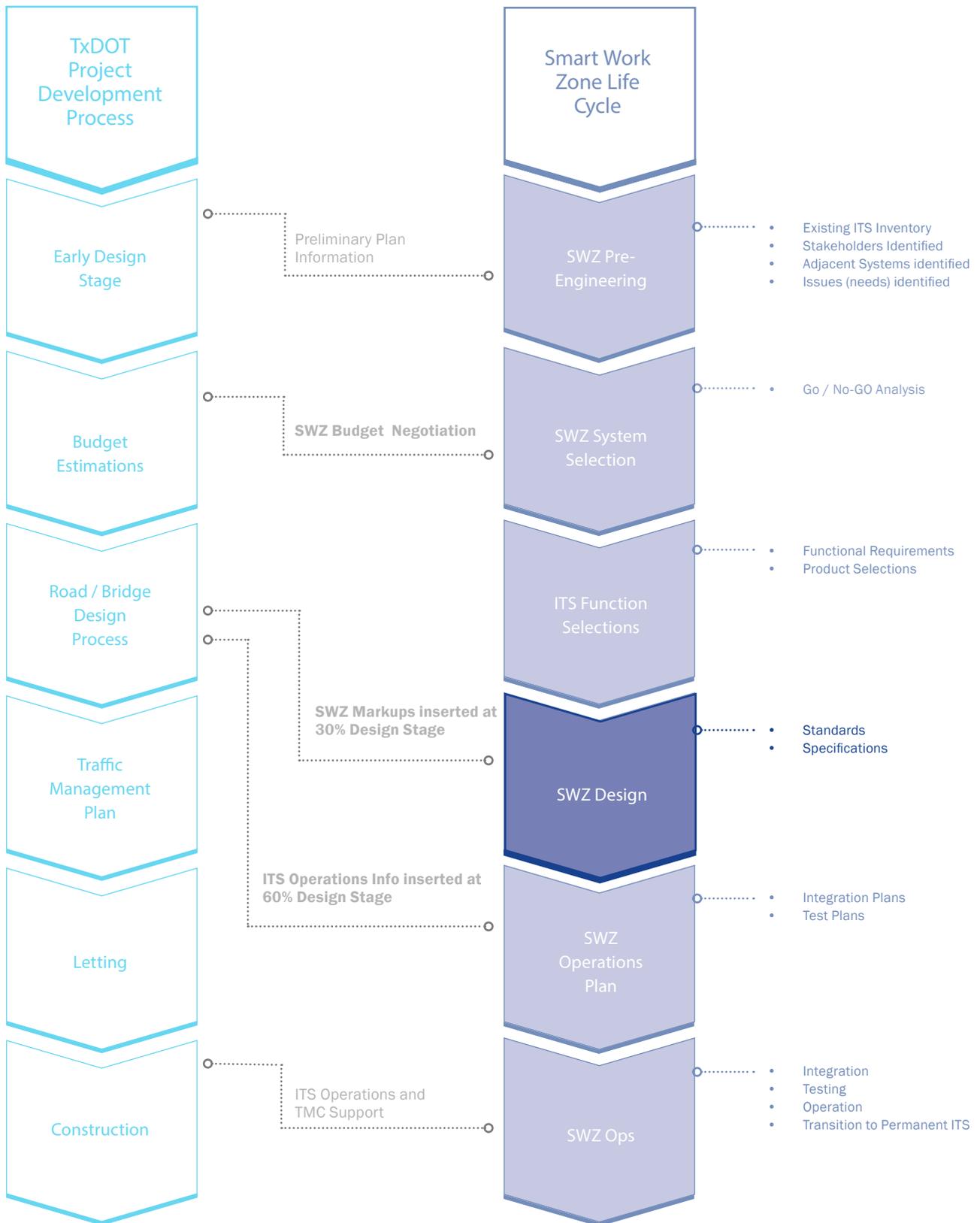
With the Go/NoGo tool, the designer should use engineering judgement to determine if smart work zones systems are needed. Once the Systems have been selected, an approximate cost estimate can be produced.

Appendix C includes some sample cost data from projects that included various SWZ elements.

Scoring Factors	Systems					
	Temporary Queue Detection	Temporary Speed Monitoring	Temporary Construction Vehicle Alert	Temporary Travel Time System	Temporary Incident Detection & Surveillance	Temporary Over-Height Warning
Duration of the Work Zone	X	X	X	X	X	
Highway Function Class and ADT	X	X	X	X	X	
Impact from local traffic generators	X	X		X	X	
Estimated Queue Length	X	X		X		
Sight Distance at back of Queue	X	X			X	
Existing traffic issues	X	X	X	X	X	
Availability of Alternate routes	X			X		
Merging conflict or hazards on the approach to work zone	X	X			X	
Complex traffic control layout	X	X	X		X	
Constraints for emergency responder					X	
Chronic speeding issues		X	X		X	
Large speed variations		X	X		X	
Adjacent/consecutive project	X	X		X	X	
Scattered/short term project	X	X			X	
Extreme weather condition	X			X	X	
Connected vehicle	X	X	X	X	X	
Existing ITS Systems	X			X		
Heavy vehicles	X	X	X	X	X	
Construction vehicle entering		X	X			
Over-Height vehicle/Low Clearance Structure						X

Table 3: Selection Process and Criteria

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4. Smart Work Zone Design

Design process

Before a SWZ design begins, certain project specific information needs to be identified. This research occurs at an early stage when the schematic design is being performed, and should include input from the appropriate district staff who are familiar with the nature of the roadwork being planned, along with any concerns that will affect the work. A detailed view of this process was introduced in Section 4. At this early stage, the specific SWZ systems are selected based on project needs. The Go/No-Go Decision Tool can assist with this initial process. After determining the specific SWZ systems to be used, the functional requirements for each system need to be determined along with cost estimates. High level SWZ design details should be inserted into the road/bridge design process beginning around the 30% design phase.

The SWZ operations plan should be developed at the 60% design stage, including the integration and test plans. Introducing the integration and testing aspects of the SWZ at the 60% stage enables the designers, the TMCs and any other stakeholders such as the emergency response agencies to prepare for their involvement with the SWZ well in advance of the letting. This also gives them an opportunity to suggest refinements in the plans while there is still time to get changes made.

It should be noted that the SWZ design is different from the permanent and temporary ITS designs. Design of permanent ITS is for equipment that will remain in place after construction is completed. This can include new or upgraded ITS equipment that will be part of the permanent ITS infrastructure. Temporary ITS design refers to temporary modifications to permanent ITS equipment intended to keep them operational during the construction. For example, this could include temporary power or communications while those utility services are being rerouted. It could also include relocation of the existing, permanent devices. SWZ design is intended to provide temporary (often portable) systems that address traffic and safety concerns only during construction periods. However, if applicable, SWZ equipment can be used to temporarily support the permanent ITS operations. Permanent ITS equipment can also be incorporated into a SWZ system if it makes sense to use it. The goal is to coordinate all of the ITS systems that can be useful in a work zone.

Design Plans

The designer should at a minimum include the following details in the design plans:

- Specified locations for system components to be installed (and relocated if applicable).
- Time frame and duration of the system being implemented. If system is to be relocated, specify the duration of all locations before removal.
- Frequency of performance report . If it is not specified, it will be reported monthly.
- Details on integration of the system if the system need to be integrated with a TMC, emergency responders or any other platform. It includes what data to be integrated, frequency, format, and who to integrate the data with among other things.
- Specifications, standard sheets, and any supporting drawings.
- Bid quantities

4.1 Temporary Queue Detection System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 1 sensor/per mile, 1 Portable Changeable Message Sign (PCMS) per sensor and an operating system
- Sensor coverage in terms of roadway approach width, and length of anticipated maximum queues
- Automated continuous data acquisition if performance measures are needed or if a TMC desires situational awareness is desired
- Message Delivery latency time
- Battery recharge rates on solar powered systems
- Real time data transfer connectivity to various agencies or a TMC
- Requirements for any archived data transmission to a TMC
- System operation hours - typically 24/7
- Clearly define if there will be concurrent deployment of systems during the project.
- Identify relocation of the system during project phases.
- Error detection-correction mechanisms and clearly defined consequences when failure rates are excessive

PCMS Operations

PCMS should be dedicated exclusively to the temporary queue detection system and not display other messages. PCMS are recommended to display ROAD/WORK/AHEAD message when the system is not activated or there is a system failure.

Optional Functions

Project specific circumstances may warrant some optional features for Queue Detection Systems. These can include the following.

Lane Merge Systems come in two categories: Early Lane Merge and Late Lane Merge. The Early version works well in situations where there is an abundance of roadway upstream such as in rural applications. The Late version addresses the issue of ramps interrupting the lane merging operations. These two systems should only be used when queues are going to exist. The primary advantage is that they smooth the merging process which can increase capacity, reduce crash rates due to erratic merging, and improve headway compliance-an additional safety measure. They also provide enforcement officers with a clear means for defining merging violation. The data generated by these lane merge systems can also produce some useful information that might lead to the potential for crash risk prediction.

CCTV can be useful in a Queue Detection System because they can be used by a TMC, the Contractor, or enforcement personnel to confirm the system is operating properly, to identify incidents, or to spot disabled vehicles. Because the queuing area is one of the most frequent areas for crashes to occur, having a CCTV pointed at the queue can be very useful to incident response operations as they acquire information about the nature of the incidents such as, truck involvement, orientation of the vehicles after the incident, fires or spills, number of vehicles involved, etc.

Video analytics can be used to count vehicles, detect speeding, assess lane changing frequencies, and detect errant vehicles leaving the roadway. To a limited extent, it can also detect wrong way vehicles.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day (required).	TxDOT use to evaluate overall performance of the system.
2. Speed sampling (typically use the highest speed detected in an approaching group of vehicles during a sampling period)	Speed sampling periods	TMC use to trigger queue warning message changes
	Speed bins and distribution curves per hour, and/or per day	TMC use to increase motorist awareness of potential queue crashes;
3. Time and duration of each active queue alert message		Contractor use to make changes to traffic pattern changes or scheduling road work,
		TxDOT Public Relations use for website updates and news media pushes.
		TxDOT use to assess impacts of the roadwork for current and future contracts,
		Enforcement use to optimize their scheduling of police presence.
	Number of times of queue alert message type was active and its duration per week. (required)	TxDOT use of message dwell time for determining the impact of a work zone (or of a contractor’s work procedures). This can also be used as a means for determining what hours a lane can be closed if serious congestion issues routinely arise for specific hours of the week.
	Headway variance (if individual vehicle speeds are detected)	TMC or possible research analysis use of headway distributions to predict current crash risk. (Non-uniform headways place more of a burden on the motorists’ skills.)
	Mobile source emission assessment (if individual speeds are detected)	Traffic Air Quality modeling of mobile source emissions in real time using only vehicle detector data.

Table 4: Temporary Queue Detection System Performance Measures

4.2 Temporary Speed Monitoring System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 1 Display Panel and sensor
- Sensors need to be located to provide situational awareness of the critical areas within the work zone and its approach
- Automated continuous data acquisition if performance measures are needed
- Battery recharge rates on solar powered systems
- Real time data transfer connectivity to various agencies or a TMC
- Format and frequency requirements for archive data transmission to a TMC
- System operation hours - typically 24/7
- Error detection-correction mechanisms
- Speed sampling rates
- Clearly define if there will be concurrent deployment of systems during the project

Optional Functions

Project specific circumstances may justify some features for Speed Monitoring Systems. These can include the following.

Combination Radar/CCTV systems are also becoming available. These systems enable an enforcement officer downstream (typically at the outlet of a work zone) to view a live video of approaching traffic with individual vehicle speed tags superimposed on violating vehicles. This gives the officer probable cause for enforcement action and is not considered automated enforcement, so it is legal in every state. The officer can then re-measure the vehicle's speed using hand held radar as it arrives at the officer's location near the outlet of the work zone, which is a safe haven for issuing tickets.

GPS Navigation System Data can be purchased by the agency as an alternative to physical speed detectors. This provides a low cost means for assessing overall speed at a frequency of 5 to 15 minute intervals. This may be enough to support enforcement scheduling, identify incidents, and assess overall work zone performance. This can also be an effective means for assessing speed issues at work zones that are of short duration and scattered across the state, such as bridge painting operations. An additional benefit of this approach is that it can provide comparative speed assessments across the work zone vs. alternate routes.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day. (required)	TxDOT use to evaluate overall performance of the system.
2. Timestamp of each new speed reading collected (regardless of detection type)	Speed bins and distribution curves per hour, and/or per day. Frequency of total speed violations per month. Calculated 85th percentile speed per hour of each day. (required)	TMC and researchers may possibly use speed variance to predict crash potential (The greater the variance, the greater the risk of motorists making bad choices for lane changes and tailgating).
3. Radar feedback trailer detection with speed display	Radar Feedback to motorists (and archived speed/timestamp records)	<p>Motorists use to be reminded of the reduced speed limit and their current speeds.</p> <p>TMC use to assess effectiveness of speed and warning signs.</p> <p>Enforcement use to determine optimal times to be present and encourage uniform speeds through the work zone.</p>

Table 5: Temporary Speed Monitoring System Performance Measures

4.3 Temporary Construction Equipment Alert System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 1 sensor and at least 1 Warning Device
- Sensor coverage areas to ensure that only vehicles entering the traffic stream trigger the messages
- Communication between the construction vehicle detector and the message board must be point to point wireless because the transmission time must occur in milliseconds. Cellular communications will not be fast enough
- Battery recharge rates on solar powered systems
- The system will typically be a stand-alone system with no connectivity to a TMC
- Format and frequency requirements for archive data if desired by TxDOT
- System operation hours - typically 24/7
- Error detection-correction mechanisms
- Removal/Relocation of the system if/when the access roadway is eliminated or relocated
- Clearly define if there will be concurrent deployment of systems during the project

PCMS Operations

If PCMS is used, it should be dedicated exclusively to the construction equipment alert system and not display other messages. PCMS is recommended to display WATCH/YOUR/SPEED message when the system is not activated. PCMS is recommended to display a blank message, when there is a power failure or communication problem.

Optional Functions

Project specific circumstances may warrant some optional features for the Construction Equipment Alert Systems. These can include the following:

Short range transponder or bluetooth based detection devices may be needed if other construction equipment is likely to be in close proximity to the vehicles leaving the work area, making it difficult for a detector such as radar to discriminate between vehicles. This would minimize false positive detections.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day. (required)	TxDOT use to evaluate overall performance of the system.
2. Construction vehicle entry/exit gate system triggers	Total number of times warning devices were activated per week. (required)	TxDOT use to track the frequency of material handling truck activity. Researchers' use to correlate material handling truck activity with crash statistics.
	Total number of reported crashes that occurred involving construction equipment vehicles. (required)	TxDOT use to assess work zone crash risks.

Table 6: Temporary Construction Equipment System Performance Measures

4.4 Temporary Travel Time System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 2 sensors at either end of the segment if using Bluetooth, 2 PCMS and an operating system
- Sensor locations to ensure comprehensive coverage of the work zone and the approach
- Automated continuous data acquisition if performance measures are needed or TMC desires situational awareness
- Battery recharge rates on solar powered systems.
- Real time data transfer connectivity to various agencies or a TMC
- Format and frequency requirements for archive data transmission to a TMC
- System operation hours - typically 24/7
- Error detection-correction mechanisms
- Travel Time/Delay sampling rates

The destination message to be displayed on the Portable Changeable Message Sign is specific to each Smart Work Zone. The message should be identified by the designer and included in the plans for the Contractor’s knowledge. Options for destinations to be displayed are:

- City Limits
- Crossing roadway

Optional Functions

Project specific circumstances may warrant some optional features for Travel Time Systems. These can include the following.

Regional Travel Time Extensions can be used to encourage motorists 10 – 50 miles upstream that a regional alternate route is available. The detection would be the same, but the messages and the delivery systems would be designed to accommodate traveler information at these diversion points.

Probe Vehicle Travel Time Data can be utilized by the agency as an alternative or supplement to physical speed detectors. This provides a low cost means for assessing overall speed at a frequency of 5 to 15 minute intervals. This may be enough to support enforcement scheduling, identify incidents, and assess overall work zone performance. This can also be an effective means for assessing comparative speed assessments across the work zone vs. alternate routes so that motorists are presented with their best option at the local diversion points. If a regional Travel Time System is used, the Probe Vehicle Travel Time data can also be used to calculate travel times from the diversion point to the beginning of the work zone. This parameter can then be used to determine when the distant alternate advisories should be initiated and lifted.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day. (required)	TxDOT use to evaluate overall performance of the system.
2. Speed sampling at multiple points along the work zone (including the queue area)	Travel and Delay times estimate bin histograms per hour of each day. (required)	Motorists use to make informed decisions about alternate routes, arrival expectancies and congestion ahead.
3. Bluetooth MAC address/ timestamp sampling at various points along the work zone (including the queue area)		TxDOT use to assess impact of work zone configurations to possibly make changes to construction traffic patterns TMC use to produce alternate route advisories.
4. Crowd sourced GPS subscription segment speed data	Standard deviation of travel time estimates per month. (required)	TxDOT use to assess impact of work zone configurations to possibly make changes to construction traffic patterns. TMC use to produce alternate route advisories.

Table 7: Temporary Travel Time System Performance Measures

4.5 Temporary Incident Detection and Surveillance System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 1 sensor every mile, at least 1 video imaging system, and a Data streaming System
- CCTV camera locations to ensure comprehensive coverage of the work zone and the approaches. This will typically be areas of high risk such as the approach to a taper or crossover. This can include any areas where the designer anticipates motorist taking evasive or aggressive action
- Automated continuous data acquisition if performance measures are needed or TMCs need situational awareness is desired
- Battery recharge rates on solar powered systems
- Real time data transfer connectivity to various agencies or a TMC
- Format and frequency requirements for archive data transmission to a TMC
- System operation hours - typically 24/7
- Error detection-correction mechanisms
- Video image delivery rates

Optional Functions

Project specific circumstances may warrant some optional features for Incident Detection and Surveillance Systems. These can include the following:

- Mobile CCTV cameras mounted on emergency or motorist assistance vehicles can provide on-site images where large incidents are occurring. They should be equipped with live data feeds to a TMC to be effective.
- Wrong Way Detection devices may be warranted for unusual intersections where motorist have been known to travel in the opposite direction of traffic by mistake. Sometimes the construction environment can be confusing to motorists who have sight limitations, are impaired or distracted, or during the night time hours.
- 360 degree radar combined with CCTV images can be useful for enforcement to maintain speed and headway compliance. These systems tag individual vehicles on the images with speed violation values so downstream enforcement personnel can isolate those aggressive drivers as they exit the work zone. This rather costly system would be justified in high volume, high speed work zone applications.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day. (required)	TxDOT use to evaluate overall performance of the system.

Table 8: Temporary Incident Detection and Surveillance System Performance Measures

4.6 Temporary Over-Height Vehicle Warning System

Design Requirements

The following requirements need to be addressed in the design documentation and specifications:

- A basic system should include at least 1 sensor and 1 warning device before an exit ramp, at least 1 sensor and 1 warning device before the low clearance structure, and an operating system.
- Sensor locations and coverage areas to ensure capturing over-height vehicles.
- Incident archiving is useful for assessing the need to raise the structure or apply some other sort of re-engineering strategy.
- Battery recharge rates on solar powered systems if they are portable.
- Real time data transfer connectivity to various agencies or a TMC.
- Format and frequency requirements for archive data transmission to a TMC.
- System operation hours - typically 24/7.
- Error detection-correction mechanisms.
- Clearly define if there is concurrent deployment of systems during the project.
- Identify any needed relocation of the system during project phases.
- Ensure standard static clearance warning signing is in place, properly located, and in good condition.

PCMS Operations

PCMS should be dedicated exclusively to the over-height vehicle warning system and not display other messages. It is recommended to display the height of the hazard when system is not activated. A sample message can be LOW/BRIDGE/12'-0".

Optional Functions

Project specific circumstances may warrant some optional features for Over-Height Warning Systems. This can include the following:

Traffic Management Center Integration can be used by linking the detection devices to the TMC to alert them when the system is triggered.

Data collected	Metrics	Use
1. Equipment stoppages and resumptions	Time stamps of equipment stoppages and resumptions per day. (required)	TxDOT use to evaluate overall performance of the system.
2. Frequency of Over-Height vehicle.	Total number of Over-Height alerts triggered per month.	TxDOT use to assess Over-Height vehicle frequency.
3. Number of Over-Height vehicle/cargo hitting low clearance structures.	Total number of times the structure was struck by Over-Height vehicles or cargo per week.	TxDOT use to evaluation effectiveness of the system.

Table 9: Temporary Over-Height Vehicle Warning System Performance Measures

4.7 Procurement

Smart Work Zone Systems shall be procured as contract bid items. TxDOT has developed the bid item specifications for work zone ITS systems, which may be found on the Department's website.

SWZ systems are typically included in conventional road/bridge contracts as traffic management line items. An alternative approach is to let an independent Smart Work Zone Contract that produces SWZs that cover a series of roadwork projects. This alternate contracting mechanism would enable "bridging" of SWZs across multiple contracts in terms of roadwork locations and construction time frames. Independent SWZ contracts have been successfully implemented in the State of Iowa. "Iowa DOT's statewide approach to intelligent work zones is unique. Many states deploy various types of intelligent work zone technologies on a project-by-project basis, but their systems may not be compatible across projects and their traffic management centers may not be able to monitor them. In our case, the Traffic Management Center receives alerts when queues are detected and uses the cameras and dynamic message signs just like our permanent cameras and signs. And they are also able to let us know whenever equipment or a work zone may need attention. This approach makes it easier to integrate, operate and update the SWZs as conditions change and also produces more consistent, reliable systems with a single point of contact for TxDOT TMC operations".

4.8 Typical costs

Typical SWZ costs can be expected to range between 1% and 5% of total project cost. The cost can vary significantly due to project specific characteristics and needs.

Some sample cost information from various DOTs and vendors are given below:

State of Illinois District 8 presentation "ITS Smart Work Zones" shows that based on six projects during 2014/2015 construction season, the average cost of SWZ deployment is about 3% of total project cost.

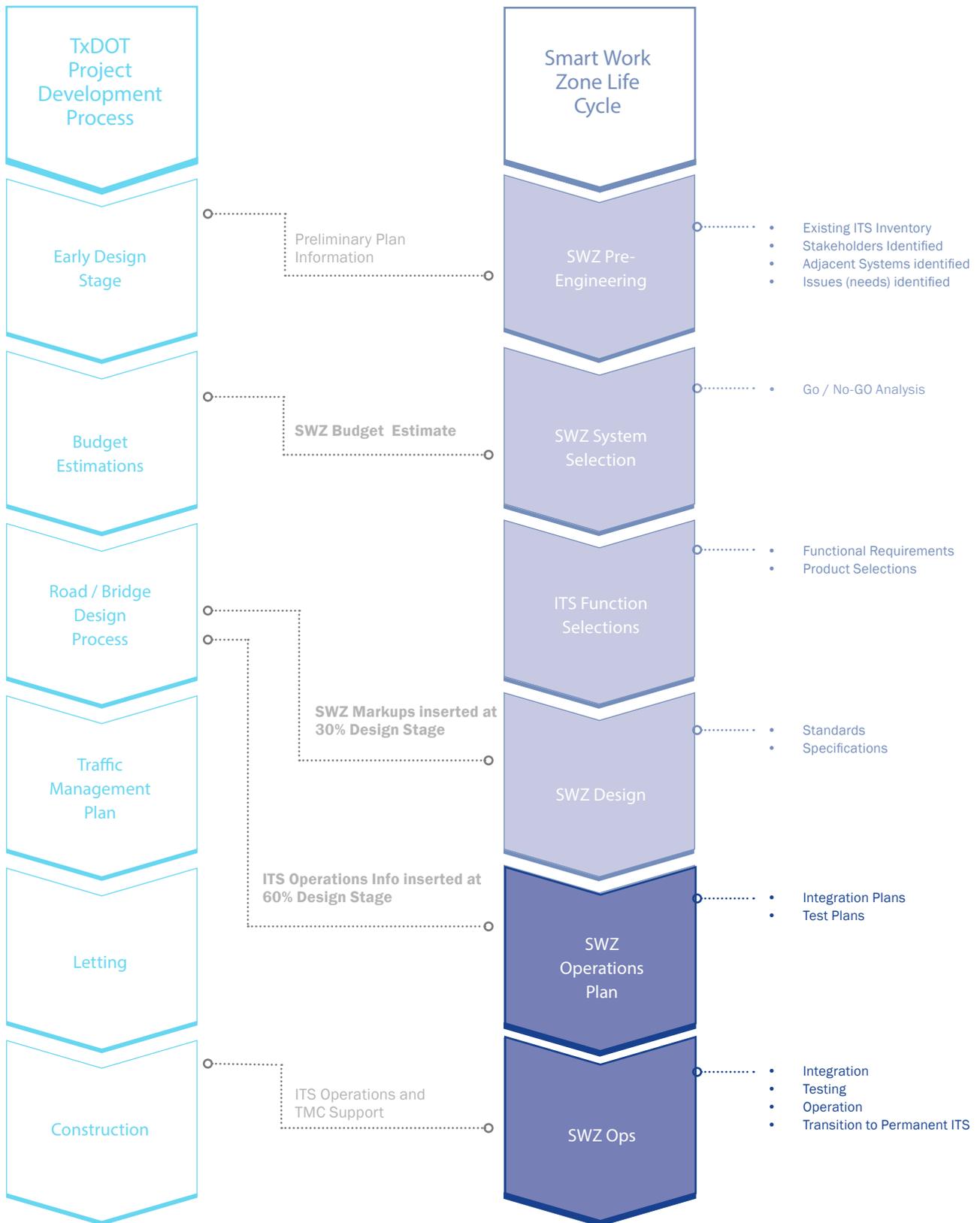
Source: State of Illinois District 8 presentation "ITS Smart Work Zones" at THE Conference 2015

In the case study "Massachusetts Department of Transportation Technology Applications on the Callahan Tunnel Project", construction Dec 2013 to Mar 2014, MassDOT procured equipment as a lump sum bid item and it accounted for 5% of total project cost. Project duration was about 4 months and deployment occurred during winter requiring maintenance.

Source: Case study: Massachusetts Department of Transportation Technology Applications on the Callahan Tunnel Project.

More cost examples are presented in Appendix C.

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5. Smart Work Zone Deployment

5.1 Operations and Maintenance

The Contractor shall be responsible for the setup, calibration and maintenance of the ITS equipment through the life of the project. Initial dates for activating the system should be specified in the design documents along with consequences for failure to meet the schedule. Adhering to the schedule for operating a system is important because the first few days of a new work zone or a major change in traffic patterns typically cause motorists some confusion as they navigate through unfamiliar traffic patterns.

The “Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges”, adopted November 2014 also addresses operations.

Section 2.6 of the above mentioned Standard Specifications addresses how to deal with discrepancies between the TMUTCD, the Compliant Work Zone Traffic Control Device List (CWZTCDL) and the Plan. It also addresses how unexpected changes should be handled.

Section 2.6.1 in the TMUTCD mandates that the Contractor provide a “...Contractor’s Responsible Person (CRP) and an alternate to be the representative of the Contractor who is responsible for taking or directing corrective measures regarding the traffic control.” This section also addresses how this person must be accessible and responsive 24 hour per day.

This topic of Operations and Maintenance also includes the production and delivery of data and performance reports to the various agencies as specified in the contract. The content, format, and quality of data production shall also be specified in the contract documents. Again, consequences for failure to deliver within appropriate time frames need to be included in the specifications.

Security

The Contractor shall be responsible to meet minimum security requirements for the equipment and the data as specified in the contract documents. This shall include protected procedures for agency personnel to access the data as needed, or to override a malfunctioning system to terminate traveler information that is discovered to be in error. This can include periodic performance reports and direct feeds to TMC dashboards as required.

5.2 SWZ Data

Intelligent Transportation Systems produce and act upon information which is derived from various sources of data. Examples include vehicle speeds, counts, classifications and detection time stamps. CCTV images are another form of data that becomes useful for various applications such as confirming incidents, identifying roadway damage or cargo spills. Effective use of this information can significantly reduce delay, improve safety and reduce air pollution.

5.3 Evaluation

The Contractor shall be responsible for all maintenance of the SWZ system during the entire project as specified in the contract documents. This includes repair, replacement, calibration, recalibration, and relocation as needed. Consequences for failure to deliver or maintain this equipment should be clearly stated in the contract documents to ensure a reliable SWZ system.

5.4 Decommission/Removal

The Contractor is responsible for the removal of all SWZ systems as specified in the contract documents. This will typically occur at the point in the project when it is no longer needed and often occurs prior to acceptance. In some cases the equipment may be required to be left operational to gather additional post-project data for research purposes.

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References

1. Work Zone Intelligent Transportation Systems Implementation Guide. FHWA-HOP-014-008. Washington D.C.: Federal Highway Administration. January 2014.
2. Federal Highways Administration, U.S. Department of Transportation. Manual on Uniform Traffic Control Devices. 2009 Edition with Revisions 1 and 2, May 2012.
3. Texas Manual on Uniform Traffic Control Devices, 2011 Version, Revision 2, TxDOT, 2014
4. Federal Highways Administration, U.S. Department of Transportation. Portable Changeable Message Sign Handbook. FHWA-RD-03-066. 2003.
5. New Hampshire Work Zone ITS Toolbox, Work Zone ITS Guideline for Smart Work Zone System Selection, 2011 Edition. https://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/swzman_05102011.pdf
6. Iowa DOT, Traffic Critical Projects Program 2015 Final Report. http://www.itsheartland.org/events/2016/2016HeartlandPresentations/Session1_Kramer.pdf
7. CTDOT Smart Work Zone Guideline 2017, http://www.ct.gov/dot/lib/dot/documents/dconstruction/wzs_reviews/str_swz_guide_final_2017-04-06_with_cover.pdf
8. State of Illinois District 8 presentation “ITS Smart Work Zones” at THE Conference 2015. <http://www.theconf.com/presentations/2015/Experiences%20with%20Smart%20Work%20Zones%20in%20Southern%20Illinois.pdf>
9. Case study: Massachusetts Department of Transportation Technology Applications on the Callahan Tunnel Project. 2014. https://www.workzonesafety.org/files/documents/SWZ/MA_TA_case_study.pdf
10. Portable Work Zone Management Systems (ITS in Work Zones) Technology Review and Workshop Presentation: Background Material, IBI Group Memorandum dated August 22, 2016.
11. TxDOT Traffic Engineering Standard Sheet. <http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/toc.htm>
12. Iowa Statewide Smart Work Zone <http://www.transportationmatters.iowadot.gov/2017/04/new-technologies-make-iowa-work-zones-safer.html>

Appendices

- A. SWZ Selection Go-No-Go Decision Tool
- B. Maximum Queue Length Estimator
- C. SWZ System Cost Examples

Appendix A. SWZ System Go/No-Go Decision Tool

Smart Work Zone

This Workbook is a Decision Tree for Smart Work Zone system selection.

TxDOT currently promotes the use of six SWZ systems that are addressed individually in the next six workbook tabs.

These Go/NoGo Decision trees produce planning level scores for each of those six SWZ systems. That score can be helpful for prioritizing and budgeting purposes.

Instructions :

For Go/NoGo Decision Tree

- 1- Insert the appropriate values for each criteria in the "Score" column.
- 2- On "Estimate Queue Length" use the "Max Queue Length" tab if a rigorous calculation is not available.
- 3- Once the scores are completed, the "Normalized Total" can be used to decide the Systems to use.
- 4- When the system selection is completed move on to the "System Cost Samples" to estimate if the projects can be funded.
- 5- All of the six systems scores are summarized in the "4 - Summary" tab.

For System Cost Examples

- 1- Examples of past projects costs are listed here.
- 2- Each system has a different example.
- 3- Select the Project Description that best fits the characteristics of the scored project.

Smart Work Zone Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems Temporary Queue Detection System		
Project Number:		
County:		
CSI:		
Letting:		
Date Form Completed:		
Completed by:		
Scoring Factors	Scoring Range	Score
Impact from local traffic generators	Significant-local facilities are large enough to have official destination signs on the Interstate highway such as conference centers, sports arenas etc., so they produce large surges in traffic before/after large events (20 points) Moderate-Local businesses or public facilities generate traffic volumes that routinely backup the on/off ramps such as morning and evening rush hours (10 points) Minimal-Any circumstance that causes occasional backups on the on/off ramps such as congested local arterials or rail crossings (5 points) None (0 points)	
Estimated Queue Length (Calculated, or see Max Queue Length tab for rough estimate)	> 7 miles (130 points) 3.5 to 7 miles (110 points) 0 to 3.5 miles (85 points) None (0 points)	
Sight Distance at back of Queue	Sight distance issues exist where the back of queue will likely occur. (30 points)	
Existing traffic issues	Higher than normal crash rates, gridlock or frequent exit ramp backups (30 points) Not applicable (0 points)	
Availability of Alternate routes	Convenient alternate routes with capacity are available. (3 points) No alternate routes available (0 points)	
Merging conflict or hazards on the approach to work zone	External merging conflicts or hazards on the approach to or within the work zone. (15 points) Not applicable (0 points)	
Complex traffic control layout	Multiple crossovers, sharp curves or lane splits (3 points) Not applicable (0 points)	
Adjacent/consecutive project	There are adjacent active projects effectively creating a mega-project that totals... longer than 10 miles or longer than 2 years (3 points) between 5 to 10 miles or between 1 and 2 years (2 points) between 2 to 5 miles or between 6 months to 1 year (1 point) less than 2 miles or less than 6 months (0 points)	
Scattered/short term project	The project includes multiple short term lane restricting activities that are scattered across the state. (ex. bridge painting) (3 points) Not applicable (0 points)	
Extreme weather condition	Work zone has a known history of sudden extreme weather condition, sandstorm, etc. Or project duration covers several harsh weather season. (3 points) Not applicable (0 points)	
Connected vehicle	>5% (3 points) <5% (0 points)	
Existing ITS Systems	Project falls inside an existing Advanced Traffic Management System? The TMC has the intent to incorporate the travel time and delay estimating system into the TMC operations? The TMC can remotely control their existing advance traveler information systems? (Each question worth 1 point)	
Heavy vehicles	>12% (3 points) >9% (2 points) >6% (1 point) <=6% (0 points)	
Raw Scores		0
Max Possible score		249
Normalized Scores (0 to 100)*		0

* Normalized Score is calculated by Raw Scores*100/Max Possible Score

Smart Work Zone																														
Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems																														
Temporary Speed Monitoring System																														
Project Number:																														
County:																														
CSJ:																														
Letting:																														
Date Form Completed:																														
Completed by:																														
Scoring Factors	Scoring Range																													
Duration of the Work Zone	For projects with multiple work zones (ex. bridge painting or patching), score the duration of the longest work zone only. > 1 year (10 points) 1 - 10 months (5 points) < 1 months (0 points)																													
Highway Function Class and ADT	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th rowspan="2">Functional Class</th> <th colspan="4">ADT</th> </tr> <tr> <th>200,000+</th> <th>100,000+</th> <th>50,000+</th> <th>20,000+</th> </tr> </thead> <tbody> <tr> <td>Interstate</td> <td style="background-color: red;">50</td> <td style="background-color: red;">50</td> <td style="background-color: red;">50</td> <td style="background-color: red;">30</td> </tr> <tr> <td>Freeway/expressway</td> <td style="background-color: red;">50</td> <td style="background-color: red;">50</td> <td style="background-color: yellow;">30</td> <td style="background-color: yellow;">30</td> </tr> <tr> <td>Major Arterial</td> <td></td> <td style="background-color: yellow;">30</td> <td style="background-color: green;">30</td> <td style="background-color: green;">10</td> </tr> <tr> <td>Other</td> <td></td> <td></td> <td style="background-color: green;">10</td> <td style="background-color: green;">10</td> </tr> </tbody> </table>	Functional Class	ADT				200,000+	100,000+	50,000+	20,000+	Interstate	50	50	50	30	Freeway/expressway	50	50	30	30	Major Arterial		30	30	10	Other			10	10
Functional Class	ADT																													
	200,000+	100,000+	50,000+	20,000+																										
Interstate	50	50	50	30																										
Freeway/expressway	50	50	30	30																										
Major Arterial		30	30	10																										
Other			10	10																										
Impact from local traffic generators	Significant-local facilities are large enough to have official destination signs on the Interstate highway such as conference centers, sports arenas etc., so they produce large surges in traffic before/after large events (10 points) Moderate-Local businesses or public facilities generate traffic volumes that routinely backup the on/off ramps such as morning and evening rush hours (6 points) Minimal-Any circumstance that causes occasional backups on the on/off ramps such as congested local arterials or rail crossings (3 points) None (0 points)																													
Estimated Queue Length (Calculated, or see Max Queue Length tab for rough estimate)	> 7 miles (10 points) 3.5 to 7 miles (7 points) 0 to 3.5 miles (3 points) None (0 points)																													
Sight Distance at back of Queue	Sight distance issues exist where the back of queue will likely occur. (3 points) Not applicable (0 points)																													
Existing traffic issues	Higher than normal crash rates gridlock or frequent exit ramp backups (30 points) Not applicable (0 points)																													
Merging conflict or hazards on the approach to work zone	External merging conflicts or hazards on the approach to or within the work zone. (3 points)																													
Complex traffic control layout	Multiple crossovers, sharp curves or lane splits (3 points) Not applicable (0 points)																													
Chronic speeding issues	Work zones in the area have a history of chronic speeders >20 mph over speed limit. (50 points) Not applicable (0 points)																													
Large speed variations	Work zone area has a history of unusually high average traffic speed variability. This is common on Interstate by-pass and outer rings. (50 points) Not applicable (0 points)																													
Adjacent/consecutive project	There are adjacent active projects effectively creating a mega-project that totals... longer than 10 miles or longer than 2 years (3 points) between 5 to 10 miles or between 1 and 2 years (2 points) between 2 to 5 miles or between 6 months to 1 year (1 point) less than 2 miles or less than 6 months (0 points)																													
Scattered/short term project	The project includes multiple short term lane restricting activities that are scattered across the state. (ex. bridge painting) (3 points) Not applicable (0 points)																													
Heavy vehicles	>12% (3 points) >9% (2 points) >6% (1 point) <6% (0 points)																													
Construction vehicle entering	Construction vehicles (material handling trucks) will enter/exit the main lanes traffic stream (3 points) Vehicles will be entering/exiting from outside the work zone (0 points)																													
Raw Scores																														
Max Possible score																														
Normalized Scores (0 to 100)																														
* Normalized Score is calculated by Raw Scores*100/Max Possible Score																														
0	231																													
0	0																													

Smart Work Zone																															
Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems																															
Temporary Construction Equipment Alert System																															
Project Number:																															
County:																															
CSJ:																															
Letting:																															
Date Form Completed:																															
Completed by:																															
Scoring Factors	Scoring Range	Score																													
Duration of the Work Zone	For projects with multiple work zones (ex. bridge painting or patching), score the duration of the longest work zone only. > 1 year (10 points) 1 - 10 months (5 points) < 1 months (0 points)																														
Highway Function Class and ADT	<table border="1" style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <thead> <tr> <th rowspan="2">Functional Class</th> <th colspan="4">ADT</th> </tr> <tr> <th>200,000+</th> <th>100,000+</th> <th>50,000+</th> <th>20,000+</th> </tr> </thead> <tbody> <tr> <td>Interstate</td> <td style="background-color: #ff0000; color: white;">20</td> <td style="background-color: #ff0000; color: white;">20</td> <td style="background-color: #ff0000; color: white;">20</td> <td style="background-color: #ff0000; color: white;">10</td> </tr> <tr> <td>Freeway/expressway</td> <td style="background-color: #ffcc00;">20</td> <td style="background-color: #ffcc00;">20</td> <td style="background-color: #ffcc00;">10</td> <td style="background-color: #ffcc00;">10</td> </tr> <tr> <td>Major Aterial</td> <td></td> <td style="background-color: #ffff00;">10</td> <td style="background-color: #ffff00;">10</td> <td style="background-color: #ffff00;">5</td> </tr> <tr> <td>Other</td> <td></td> <td></td> <td style="background-color: #00ff00;">5</td> <td style="background-color: #00ff00;">5</td> </tr> </tbody> </table>	Functional Class	ADT				200,000+	100,000+	50,000+	20,000+	Interstate	20	20	20	10	Freeway/expressway	20	20	10	10	Major Aterial		10	10	5	Other			5	5	
Functional Class	ADT																														
	200,000+	100,000+	50,000+	20,000+																											
Interstate	20	20	20	10																											
Freeway/expressway	20	20	10	10																											
Major Aterial		10	10	5																											
Other			5	5																											
Existing traffic issues	Higher than normal crash rates, gridlock or frequent exit ramp backups (30 points) Not applicable (0 points)																														
Complex traffic control layout	Multiple crossovers, sharp curves or lane splits (3 points)																														
Chronic speeding issues	Work zones in the area have a history of chronic speeders >20 mph over speed limit. (3 points)																														
Large speed variations	Work zone area has a history of unusually high average traffic speed variability. This is common on Interstate by-pass and outer rings. (3 points) Not applicable (0 points)																														
Connected vehicle	>5% (3 points) <5% (0 points)																														
Heavy vehicles	>12% (3 points) >9% (2 points) >6% (1 point) <6% (0 points)																														
Construction vehicle entering	Construction vehicles (material handling trucks) will enter/exit the main lanes traffic stream (120 points) vehicles will be entering/exiting from outside the work zone (0 points)																														
Raw Scores		0																													
Max Possible score		195																													
Normalized Scores (0 to 100)		0																													
* Normalized Score is calculated by Raw Scores*100/Max Possible Score																															

Smart Work Zone Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems Temporary Travel Time System																															
Project Number:																															
County:																															
CSJ:																															
Letting:																															
Date Form Completed:																															
Completed by:																															
Scoring Factors	Scoring Range	Score																													
Duration of the Work Zone	For projects with multiple work zones (ex. bridge painting or patching), score the duration of the longest work zone only. > 1 year (10 points) 1 - 10 months (5 points) < 1 months (0 points)																														
Highway Function Class and ADT	<table border="1"> <thead> <tr> <th rowspan="2">Functional Class</th> <th colspan="4">ADT</th> </tr> <tr> <th>200,000+</th> <th>100,000+</th> <th>50,000+</th> <th>20,000+</th> </tr> </thead> <tbody> <tr> <td>Interstate</td> <td>50</td> <td>50</td> <td>50</td> <td>30</td> </tr> <tr> <td>Freeway/expressway</td> <td>50</td> <td>50</td> <td>30</td> <td>30</td> </tr> <tr> <td>Major Aterial</td> <td></td> <td>30</td> <td>30</td> <td>10</td> </tr> <tr> <td>Other</td> <td></td> <td></td> <td>10</td> <td>10</td> </tr> </tbody> </table>	Functional Class	ADT				200,000+	100,000+	50,000+	20,000+	Interstate	50	50	50	30	Freeway/expressway	50	50	30	30	Major Aterial		30	30	10	Other			10	10	
Functional Class	ADT																														
	200,000+	100,000+	50,000+	20,000+																											
Interstate	50	50	50	30																											
Freeway/expressway	50	50	30	30																											
Major Aterial		30	30	10																											
Other			10	10																											
Impact from local traffic generators	Significant-local facilities are large enough to have official destination signs on the Interstate highway such as conference centers, sports arenas etc., so they produce large surges in traffic before/after large events (20 points) Moderate-Local businesses or public facilities generate traffic volumes that routinely backup the on/off ramps such as morning and evening rush hours (10 points) Minimal-Any circumstance that causes occasional backups on the on/off ramps such as congested local arterials or rail crossings (5 points) None (0 points)																														
Estimated Queue Length (Calculated, or see Max Queue Length tab for rough estimate)	> 7 miles (80 points) 3.5 to 7 miles (70 points) 0 to 3.5 miles (60 points) None (0 points)																														
Existing traffic issues	higher than normal crash rates, gridlock or frequent exit ramp backups (3 points) Not applicable (0 points)																														
Availability of Alternate routes	Convenient alternate routes with capacity are available. (3 points)																														
Adjacent/consecutive project	There are adjacent active projects effectively creating a mega-project that totals... longer than 10 miles or longer than 2 years (3 points) between 5 to 10 miles or between 1 and 2 years (2 points) between 2 to 5 miles or between 6 months to 1 year (1 point) less than 2 miles or less than 6 months (0 points)																														
Extreme weather condition	Work zone has a known history of sudden extreme weather condition, sandstorm, etc. Project duration covers several harsh weather season. (3 points)																														
Connected vehicle	>5% (3 points) <5% (0 points)																														
Existing ITS Systems	Project falls inside an existing Advanced Traffic Management System? The TMC has the intent to incorporate the travel time and delay estimating system into the TMC operations? The TMC can remotely control their existing advance traveler information systems? (Each question worth 10 point)																														
Heavy vehicles	>12% (3 points) >9% (2 points) >6% (1 point) <6% (0 points)																														
Raw Scores		0																													
Max Possible score		208																													
Normalized Scores (0 to 100)		0																													

* Normalized Score is calculated by Raw Scores*100/Max Possible Score

Smart Work Zone Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems Temporary Incident Detection & Surveillance System																															
Project Number:																															
County:																															
CSJ:																															
Letting:																															
Date Form Completed:																															
Completed by:																															
Scoring Factors	Scoring Range	Score																													
Duration of the Work Zone	For projects with multiple work zones (ex. bridge painting or patching), score the duration of the longest work zone only. > 1 year (10 points) 1 - 10 months (5 points) < 1 months (0 points)																														
Highway Function Class and ADT	<table border="1"> <thead> <tr> <th rowspan="2">Functional Class</th> <th colspan="4">ADT</th> </tr> <tr> <th>200,000+</th> <th>100,000+</th> <th>50,000+</th> <th>20,000+</th> </tr> </thead> <tbody> <tr> <td>Interstate</td> <td>80</td> <td>80</td> <td>80</td> <td>50</td> </tr> <tr> <td>Freeway/expressway</td> <td>80</td> <td>80</td> <td>50</td> <td>50</td> </tr> <tr> <td>Major Arterial</td> <td></td> <td>50</td> <td>50</td> <td>20</td> </tr> <tr> <td>Other</td> <td></td> <td></td> <td>20</td> <td>20</td> </tr> </tbody> </table>	Functional Class	ADT				200,000+	100,000+	50,000+	20,000+	Interstate	80	80	80	50	Freeway/expressway	80	80	50	50	Major Arterial		50	50	20	Other			20	20	
Functional Class	ADT																														
	200,000+	100,000+	50,000+	20,000+																											
Interstate	80	80	80	50																											
Freeway/expressway	80	80	50	50																											
Major Arterial		50	50	20																											
Other			20	20																											
Impact from local traffic generators	Significant-local facilities are large enough to have official destination signs on the Interstate highway such as conference centers, sports arenas etc., so they produce large surges in traffic before/after large events (10 points) Moderate-Local businesses or public facilities generate traffic volumes that routinely backup the on/off ramps such as morning and evening rush hours (6 points) Minimal-Any circumstance that causes occasional backups on the on/off ramps such as congested local arterials or rail crossings (3 points) None (0 points)																														
Sight Distance at back of Queue	Sight distance issues exist where the back of queue will likely occur. (50 points)																														
Existing traffic issues	higher than normal crash rates, gridlock or frequent exit ramp backups (50 points) Not applicable (0 points)																														
Merging conflict or hazards on the approach to work zone	External merging conflicts or hazards on the approach to or within the work zone. (3 points) Not applicable (0 points)																														
Complex traffic control layout	multiple crossovers, sharp curves or lane splits (3 points) Not applicable (0 points)																														
Navigating constraints for emergency responders	Construction activity will impose significant constraints for emergency responders to access incidents. (ex. narrow lanes or no shoulders) (50 points) Not applicable (0 points)																														
Chronic speeding issues	Work zones in the area have a history of chronic speeders >20 mph over speed limit. (3 points) Not applicable (0 points)																														
Large speed variations	Work zone area has a history of unusually high average traffic speed variability. This is common on Interstate by-pass and outer rings. (50 points) Not applicable (0 points)																														
Adjacent/consecutive project	There are adjacent active projects effectively creating a mega-project that totals... longer than 10 miles or longer than 2 years (3 points) between 5 to 10 miles or between 1 and 2 years (2 points) between 2 to 5 miles or between 6 months to 1 year (1 point) less than 2 miles or less than 6 months (0 points)																														
Scattered/short term project	The project includes multiple short term lane restricting activities that are scattered across the state. (ex. bridge painting) (3 points) Not applicable (0 points)																														
Extreme weather condition	Work zone has a known history of sudden extreme weather condition, sandstorm, etc. Project duration covers several harsh weather season. (3 points) Not applicable (0 points)																														
Connected vehicle	>5% (3 points) <5% (0 points)																														
Heavy vehicles	>12% (60 points) >9% (40 points) >6% (20 point) <6% (0 points)																														
Raw Scores		0																													
Max Possible score		381																													
Normalized Scores (0 to 100)		0																													

*Normalized Score is calculated by Raw Scores*100/Max Possible Score

Smart Work Zone Go/No-Go Decision Tree - A criteria based tool for selecting Smart Work Zone Systems Temporary Over-height Vehicle Warning System		
Project Number:		
County:		
CSJ:		
Letting:		
Date Form Completed:		
Completed by:		
Scoring Factors	Scoring Range	Score
Over-height vehicle/Low Clearance Structure	Low structures are over mainline traffic (100 points)	
	Low structures are located on adjoining roadways such as ramps (75 points)	
	Low structures are located on nearby alternate routes (local or state owned) (45 points)	
	There are no low structures (0 points)	
	Raw Scores	0
Max Possible score		100
Normalized Scores (0 to 100)		0
* Normalized Score is calculated by Raw Scores*100/Max Possible Score		

Decisions:

Is strongly recommended if the score is greater than 65
Should be given consideration if score is between 33 and 65
Is probably not recommended if the score is below 33

System	Total Score
Temporary Queue Detection System	
Temporary Speed Monitoring System	
Temporary Construction Equipment Alert System	
Temporary Travel Time System	
Temporary Incident Detection & Surveillance System	
Temporary Over-height Vehicle Warning System	

Appendix B. Maximum Queue Length Estimator

Estimated Queue Factor Scoring (based on AADT)(24-hour lane closure)									
AADT values are 2 directional counts. Queue length values represent one direction only.									
Queue Length Categories >>>		Approx. maximum AADT values per queue length category							
# Lanes Pre-Work Zone	# Lanes during Work Zone	No significant queuing	AADT	Mild Queuing < 3.5 miles	AADT	Moderate Queuing 3.5 to 7.5 miles	AADT	Heavy Queuing > 7.5 miles	AADT
2	1	Score 0	40,000	Score 3	46,000	Score 7	52,000	Score 10	> 52,000
3	2		82,000		92,000		102,000		> 102,000
3	1		40,000		50,000		56,000		>56,000

Estimated Queue Factor Scoring (based on AADT)(9PM to 5AM lane closure)									
AADT values are 2 directional counts. Queue length values represent one direction only.									
Queue Length Categories >>>		Approx. maximum AADT values per queue length category							
# Lanes Pre-Work Zone	# Lanes during Work Zone	No significant queuing	AADT	Mild Queuing < 3.5 miles	AADT	Moderate Queuing 3.5 to 7.5 miles	AADT	Heavy Queuing > 7.5 miles	AADT
2	1	Score 0	52,000	Score 3	84,000	Score 7	108,000	Score 10	> 108,000
3	2		100,000		138,000		200,000		> 200,000
3	1		54,000		98,000		132,000		> 132,000

How to use this Table: Identify lane closure hours during a day (24 hour or 9PM to 5 AM) to determine which table to use.
 Find an approximate 2 directional AADT for your Work Zone from TxDOT's Traffic Count Website or some other source.
 On the table above, enter the row that describes your project's lane usage (one directional). (ex. 3 lanes to 2)
 Proceed to the right on that row until you locate the first AADT value higher than your project's AADT
 If your project's AADT is greater than the value in the last column to the right, use a score of 10
 The Estimated Queue Factor score is then found in the yellow box immediately to the left of that AADT.
 The queuing range for your project is in the cell immediately above the yellow box with the score.

Limitations of this Table: These two tables were developed based on a single case study and a single day traffic count.
 The look-up tables are intended to only provide an approximate queue length.

Appendix C. SWZ System Cost Examples

System Cost Examples			
ITS System Go/No Go	Project Description		
<p>Temporary Queue Detection System</p> <p>System that continuously monitors traffic on the approaches and within construction work zones to detect slowed or stopped traffic. This information is then presented to approaching motorists so they can make informed decisions. [A Basic System should include at least 1 sensor every 1 mile, 1 PCMS every sensor, and an Operating System]</p>	<p>Texas 70 days Letting Year: 2017 Cost Includes: 2017</p> <p>Installation/Removal 1 PCMS 4 Doppler Radar</p> <p>24/7 Maintenance Staff Wireless communication</p> <p>Operation Central Software Solar Power Operated</p> <p>Equipment leased \$104,160 each setup (0.07% of total construction cost) CSJ: 0271-04-071</p>	<p>Texas 110 days Letting Year: On 2016 Cost Includes:</p> <p>Installation/Removal 1 PCMS 4 Doppler Radar</p> <p>24/7 Maintenance Staff Wireless communication</p> <p>Operation Central Software Solar Power Operated</p> <p>Equipment leased \$586.20 each setup (0.39% of total construction cost) CSJ: 0015-15-380</p>	<p>Texas 192 days Letting Year: 2017 Cost Includes:</p> <p>Installation/Removal 1 PCMS 4 Doppler Radar</p> <p>24/7 Maintenance Staff Wireless communication</p> <p>Operation Central Software Solar Power Operated</p> <p>Equipment leased \$560 each setup(0.25% of total construction cost) CSJ: 0015-13-378</p>
<p>Temporary Travel Time System</p> <p>System that continuously monitors travel times through a work zone, and then presents this information to approaching motorists so they can make informed decisions. [A Basic System should include at least 2 sensors at either end of the segment if using Bluetooth, 2 PCMS and an Operating System]</p>	<p>Wisconsin 5 months Letting Year: On 2017 Cost Includes:</p> <p>Installation/Removal 14 PCMS 2 Camera Trailers</p> <p>24/7 Maintenance Staff Wireless communication 16 Sensors</p> <p>Operation Solar Power Operated Central Software</p> <p>Equipment leased \$113,000 Source: Vendor (Street Smart Rental)</p>	<p>Texas 24 months Letting Year: On 2016 Cost Includes:</p> <p>Installation/Removal 4 PCMS 4 CCTV cameras</p> <p>24/7 Maintenance Staff 8 Lane Sidefire Radar 4 Trailers Wireless communication Equipment leased</p> <p>Operation Solar Power Operated Central Software</p> <p>\$410,000 (1% of total construction cost) CSJ: 0015-13-378</p>	<p>Texas 34 months Letting Year: 2015 Cost Includes:</p> <p>Installation/Removal 8 PCMS 8 CCTV cameras</p> <p>24/7 Maintenance Staff 8 Lane Sidefire Radar 8 Trailers Wireless communication Equipment leased</p> <p>Operation Solar Power Operated Central Software</p> <p>\$835,690 (1% of total construction cost) CSJ: 0015-13-379</p>
<p>Temporary Incident Detection and Surveillance System</p> <p>System that uses sensors and/or video to detect crashes and other incident conditions within a work zone and then communicates that information to a local TMC and/or to emergency response agencies. The alerts are then confirmed remotely using live streaming video, snapshots or on-site personnel. This System can be used to provide critical information to responders who help them decide exactly what equipment to bring, how best to approach the incident, and any additional precautions that might be needed to protect themselves and the public. [A Basic System should include at least 1 sensor every 1 mile, at least 1 Video Imaging System, and a Data Streaming System]</p>	<p>Texas 20 months Letting Year: 2016 Cost Includes:</p> <p>Installation/Removal 3 Trailers 1 Doppler Radar 8 Lane Sidefire Radar</p> <p>24/7 Maintenance Staff Wireless communication 3 CCTV camera 1 PCMS with modem</p> <p>Operation Solar Power Operated Central Software 3 PCMS</p> <p>Equipment leased \$306,616.75(2% of total construction cost) CSJ: 0015-13-380</p>	<p>Texas 46 months Letting Year: 2017 Cost Includes:</p> <p>Installation/Removal 9 Trailers 8 Lane Sidefire Radar</p> <p>24/7 Maintenance Staff Wireless communication 9 CCTV cameras 9 PCMS</p> <p>Operation Solar Power Operated Central Software</p> <p>Equipment leased \$1,574,058 (1% of total construction cost) CSJ: 10 0271-04-071</p>	<p>Texas 76 months Letting Year: 2017 Cost Includes:</p> <p>Installation/Removal 8 Trailers 8 Lane Sidefire Radar 6 Doppler Radar Units</p> <p>24/7 Maintenance Staff Wireless communication 8 CCTV cameras 8 PCMS</p> <p>Operation Solar Power Operated Central Software</p> <p>Equipment leased \$2,395,816 (1% of total construction cost) CSJ: 0271-17-161</p>
<p>Temporary Construction Equipment Alert System</p> <p>System that delivers immediate information to motorists about construction vehicles and equipment that are entering the highway from a work zone. [A Basic System should include at least 1 sensor and at least 1 Warning Device]</p>	<p>Willow River, MN 6 months</p> <p>Mobilization 6 Doppler Radar Software</p> <p>Cost Includes: 16 Advance Warning Flashers Cellphone Communication Installation/Removal E-mail reporting Equipment leased</p> <p>Removal 24/7 Maintenance Staff Post mounted</p> <p>\$44,000 (0.37% of total construction cost)</p>	<p>Honolulu, HI 45 months</p> <p>Mobilization 8 PCMS software E-mail reporting</p> <p>Cost Includes: Cellphone Communication License Plate Reader System Installation/Removal 15 Bluetooth Sensors Equipment leased</p> <p>Removal 24/7 Maintenance Staff Post/Trailer mounted</p> <p>\$400,000 (0.05% of total construction cost)</p>	