Enabling Connected Work Zones: Needed Activities and Proposed Next Steps

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1. Introduction to Connected Work Zones

1.1 Connected Work Zone Overview

For the purposes of this document, a connected work zone is defined as a work zone equipped with cooperative automated transportation (CAT) technologies that are capable of collecting and disseminating work zone data for consumption by connected and automated vehicles (CAVs) as they approach and move through the work zone. Connected work zones include the provision of location information regarding the geometry of open lanes both approaching and through the work zone, as well as Road Safety Messages (RSMs) / Traveler Information Messages (TIMs) describing lane closures or lane shifts, speed restrictions, worker presence, flaggers directing traffic, and other relevant information.

1.2 Unique Aspects of Work Zones

Work zones are a high-priority focus area for CAT technologies and safety applications given the abnormal travel conditions and safety impacts that occur. Additionally, while connected work zones can benefit from lessons learned and leverage similar technologies being proven as part of connected intersection deployments, work zones have a lot of unique aspects that will change the nature of deployments for connected work zones.

Contractor and Subcontractor Roles. IOOs contract out many work zone activities (i.e., construction and maintenance activities). Additionally, when a contractor performs construction or maintenance work, work zone traffic control is frequently done by subcontractors to those contractors, which can increase the challenge of training and introducing concepts. This structure can benefit IOOs wanting to implement new technologies, which can be achieved relatively easily through the inclusion of new provisions in construction-related requests for proposals (RFPs) thereby requiring contractors and subcontractors to find a way to execute it. On the other hand, IOOs may experience challenges getting what they want through this hierarchy, particularly if provisions are not well defined.

Mobile and Temporary Nature. Work zones frequently move, both in location and time, causing impacts in different places at different times. Even when stationary, work zones are continuously changing (e.g., lanes may be intermittently opened and closed). Further, work zones themselves are temporary and may be relatively short duration activities lasting less than an hour or taking place over many years. As such, the nature of work zones leads to questions of how much effort and time should be spent on data collection and accuracy, the cost-effectiveness of deploying technologies, and the extent to which benefits and efficiencies can be achieved. Finally, there is an interim period for setting up and concluding a work zone (e.g., signage, barriers, barrels, and other traffic control devices) that presents a challenge in providing accurate, real-time information.

Data Latency. Generally, work zone data does not change as often as data from connected intersections. While the work zone data may need to be updated more frequently than at a connected intersection (i.e. work zone lane details versus intersection MAP data), work zone data updates are far less frequent than SPaT data, for example. Therefore, as agencies consider connected work zones, the need for ultra-low latency is less. Therefore, various communications approaches and latency requirements are likely depending on how the information will be used, including dissemination to third-party providers and/or fleet dispatchers that may communicate directly to vehicles through applications using network cellular.

Considering these (and other) unique aspects of work zones, it is imperative that the advancement towards connected work zones not focus solely on the technical hurdles, but also consider established business processes for work zones and identify as early as possible the needed changes to these business processes.

1.3 Context/Purpose and Structure of this Document

To advance connected work zone activities, the Reduced Speed Zone Warning (RSZW) Working Group (WG) has developed resources and promoted a number of technologies. Specifically, the RSZW WG developed the "Infrastructure System to Support the Reduced Speed Zone Warning-Lane Closure Application Model Concept of Operations" to support connected work zone deployments. Related connected work zone activities and resources of interest developed and promoted by the United States Department of Transportation (USDOT) include:

- Federal Highway Administration (FHWA) Work Zone Data Initiative (WZDI);
- USDOT Work Zone Data Exchange (WZDx); and
- USDOT Work Zone Data Collection (WZDC) Toolchain.

This document leverages the experiences and lessons learned from these connected work zone activities, including those at five Departments of Transportation (DOTs) that tested the WZDC Toolchain and were tracked by the RSZW WG (i.e., Arizona DOT, Caltrans, Michigan DOT, Texas DOT, and Virginia DOT). Specifically, this document serves to:

- Describe additional activities that are recommended to advance connected work zones; and
- Summarize next steps the industry should consider when advancing towards connected work zones.

2. Needs, Goals, and Approach for Advancing Connected Work Zones

The RSZW WG seeks to expand the deployment and operations of connected work zones by more agencies around the country. In order to achieve this, three primary needs have been identified to support further development and ultimately broader deployment of connected work zones, as detailed in the subsections below:

- *Need #1: Broader IOO Experience with RSZW Field Deployments*.
- *Need #2: OEM and Third Party Partner Engagement.*
- *Need #3: Ongoing IOO/OEM Engagement.*

2.1 Need #1: Broader IOO Experience with RSZW Field Deployments

Prior IOO experience deploying connected signalized intersections provides a valuable precedence for implementing other connected infrastructure. These early deployments revealed ambiguities in the standards that caused interoperability challenges, which were not understood until OEM vehicles equipped with applications intended to use the infrastructure data began driving through the connected intersections. While some ambiguities were easily clarified, others required a great deal of collaboration between IOO and OEM stakeholders to successfully address.

Similar issues are expected to be encountered through early deployments of connected work zones and will set the stage for advancing the state of practice for connected work zones with in-vehicle applications.

Connected work zones need to be tested in a greater number of locations for more types of work zone activities to develop better guidance and understand processes for widespread deployment. Additionally, connected work zones need to be tested using different technologies, communications, and information dissemination mechanisms to understand what configurations are most beneficial and cost effective. IOOs need more experience with work zone data and messages, including:

- Assembling data to describe the work zone;
- Generating standardized messages and broadcasting these messages; and
- Receiving their own messages, processing the data in the messages, and comparing that received data against the intended content describing the work zone.

These activities may involve IOOs using portable 'suitcase' testing devices similar to tools currently used in connected intersection verification.

In addition to the issues in this list above, there are additional areas of experience that must be understood, including:

- The role of work zone contractors and subcontractors and understanding elements IOOs should include in a procurement for work zone contractors, both for initial experimentation and long term;
- Determining what information to provide and for what types of work zones that makes the most sense given challenges of mobile work zones; interim periods of setting up, moving, and removing traffic control devices for different phases of work zone activities; balancing the level of effort versus the duration of the work zone; and appropriate use of technologies to most efficiently provide data that is most beneficial to support connected to provide data for work zones;
- Being able to use data to support applications that require lane-level details and also aggregate the data for traveler information and other uses that do not require the same level of detail;
- Specific types of technology and equipment that most efficiently provide the best data and information to support connected work zones; and
- Acceptable data latency thresholds and communication mechanisms that best support connected work zone applications.

While IOOs understand the benefits of sharing work zone data with CAVs, they currently have few resources to understand the business model for achieving connected work zones (e.g., the estimated costs for deployment or communication infrastructure, the estimated costs of generating work zone messages and updating messages as the work zones change activities or locations). As more IOOs deploy connected work zones, all IOOs will gain increased understanding of the associated business model(s).

Increased IOO experience with RSZW field deployments will help to address questions about where connected work zones should be used and how they operate, such as:

- What constitutes a work zone?
- Should industry start with a simple definition of which work zones should be "connected" (e.g., if at least one lane is closed or shifted, or if the duration is greater than a specific amount of time)?
- What elements need to be included in a procurement for a connected work zone?
- How should connected work zone infrastructure systems operate during work zone "set up" and "take down" transition periods?

- Should connected work zones also encompass unplanned incidents, which often become 'work zones' as clean-up or investigations occur? If not, what criteria separate these two types of events?
- Should connected work zone information be disseminated using localized point-to-point media with roadside units (RSUs) or over a network using wide-area and cellular media?

Five goals have been identified to address this need:

1. **Integrate Connected Work Zones into Established Work Zone Activities of Associations** at the national, state, and local levels to address the 'business process' aspects that go beyond the technical aspects. Associations such as AASHTO, ITE, American Traffic Safety Services Association (ATSSA), and ITS America have established programs that collectively contribute to advancing work zone safety and mobility. In particular, these activities understand and support the unique aspects of the business processes around work zones. Establishing connections to these networks and ongoing activities early can help to define best practices and standardize approaches sooner than if connected work zones are advanced and introduced to these associations later. Earlier interaction with the OEMs interested in connected work zone applications will accomplish an open exchange and dialog.
2. **Establish and Operate Connected Work Zones** by different IOOs in different settings that build on available resources like the WZDC Toolchain and WZDx specification to better understand needs and ambiguities.
3. **Establish a Nationally Consistent Approach for Managing and Communicating Work Zone Data** by coordinating existing work zone data efforts (e.g., the WZDx and SAE efforts) to generate an agreed-upon, nationally consistent approach for generating and disseminating work zone data for CAVs.
4. **Understand Tradeoffs for Local Versus Network Broadcasts of Work Zone Information** by testing the relative effectiveness of using each communications approach to disseminate information to drivers, and also examine the relative cost for each approach.
5. **Validate Message Exchange** by testing and analyzing work zone data in CAV messages to understand how to accurately convey actual work zone conditions.
6. **Understand the IOO Business Case** by leveraging experiences from test deployments to better understand relative costs, benefits, and level of effort that will inform how feasibility for deploying connected work zones.

2.2 Need #2: OEM and Third-Party Partner Engagement.

There is a need to understand OEM and third-party interests in utilizing connected work zone data, as well as understanding how each may cooperate, provide their own inputs, and what they may need from a connected work zone from an IOO versus what they may be able to contribute. More specifically:

- OEMs that have been engaged to-date in developing RSZW/connected work zone applications are likely interested in developing safety applications to warn drivers of needed lane changes or speed reductions to improve safety as the vehicle travelers through the work zone; and

- Third-party application developers and providers like Waze, Google, and Apple, as well as freight dispatch or pre-clearance providers like Drivewyze, may focus on in-vehicle messaging capabilities to advise drivers of delays, detours in advance of the work zone as well as warning drivers as they approach the work zone.

As IOOs begin to conduct the tests and connected work zone deployments described above, OEM and third-party engagement and collaboration will be needed to better understand the utility of connected work zone data via in-vehicle and application mechanisms. Engagement may lead to assembling a group of OEMs and third parties around connected work zones and employing a structured systems engineering approach to identify specific in-vehicle and application data needs. Past experiences with this process have always revealed details of implementation and operation needs, identified specific requirements that must be met that were not thought of before the process, and included a Functional Safety Assessment to identify hazards present in the combined infrastructure / vehicle connected work zone system.

Specifically, OEM and third party engagement and collaboration with IOOs may identify issues requiring additional discussions with partners, such that OEMs and third parties are able to meaningfully offer input regarding:

- Completeness of data, including the preferred and minimum required accuracy, precision, and latency for in-vehicle and mobile application(s).
- Data that can be provided from OEMs and third parties to support IOOs.
- Testing and verification needs for data to be considered ready for production deployment.
- Additional perspectives that are critical to in-vehicle and mobile application development.

Four additional goals have been identified to address this need:

7. **Understand needs and operational concepts for RSZW vehicle application(s) for connected work zones** through development of a ConOps that reflects the vehicle system perspective.
8. **Understand requirements for RSZW vehicle application(s) for connected work zones**, which will result in a requirements document that reflects the vehicle system perspective.
9. **Understand hazards and functional safety requirements of RSZW vehicle application(s) for connected work zones** by conducting a functional safety analysis.

2.3 Need #3: IOO/OEM/Third-Party Engagement

To support the other two needs and enhance all of the resulting systems engineering, development, and testing activities, there is an underlying need to have ongoing engagement and collaboration between IOOs, OEMs, and third parties. This engagement helps IOOs, OEMs, and third parties understand each other's needs, available contributions, perspectives, constraints, and lessons learned.

Two goals have been identified to address this need:

10. **Engage with OEMs and Third Parties that have prototype or operational applications that rely on connected work zone data** to demonstrate one or more applications with connected work zone data with one or more IOOs in various settings.
11. **Support forums for ongoing IOO/OEM/Third-Party collaboration**, which may leverage or build on existing working groups or result in new initiatives.

3. Work Plan to Address the Needs

This section describes next steps identified by the RSZW WG as it relates to the three primary needs to better understand connected work zones, support further development, and ultimately achieve broader deployment. The RSZW WG envisions following the same approach that was taken to advance the state practice for Connected Intersections, as depicted in Figure 1. While the RSZW Infrastructure System ConOps was completed in 2019, the subsequent steps summarized in Figure 1 and detailed in Table 1 are needed to:

- Understand what the eventual OEM vehicle systems' functions will be and the need for IOO provided data (i.e., what data is needed, how will it be used) that typically is defined during use cases and scenario development actions when creating a Concept of Operations, and the best mechanisms for collecting and broadcasting that data.
- Understand the system hazards and functional safety concept associated with the vehicle systems' planned use of infrastructure data.
- Define minimum requirements for the infrastructure and vehicle systems.
- Understand how the WZDI, WZDx, SAE J2945 Road Safety Message (RSM), and the WZDC Toolchain can assist IOOs and OEMs in accomplishing the minimum requirements and what gaps still remain, including what enhancements, tools, or technologies are still needed.
- Understand what ambiguities exist in the use of existing standards.
- Understand critical differences between what IOOs can output today, what OEMs need, and a roadmap to implementation of the infrastructure to support connected work zones.

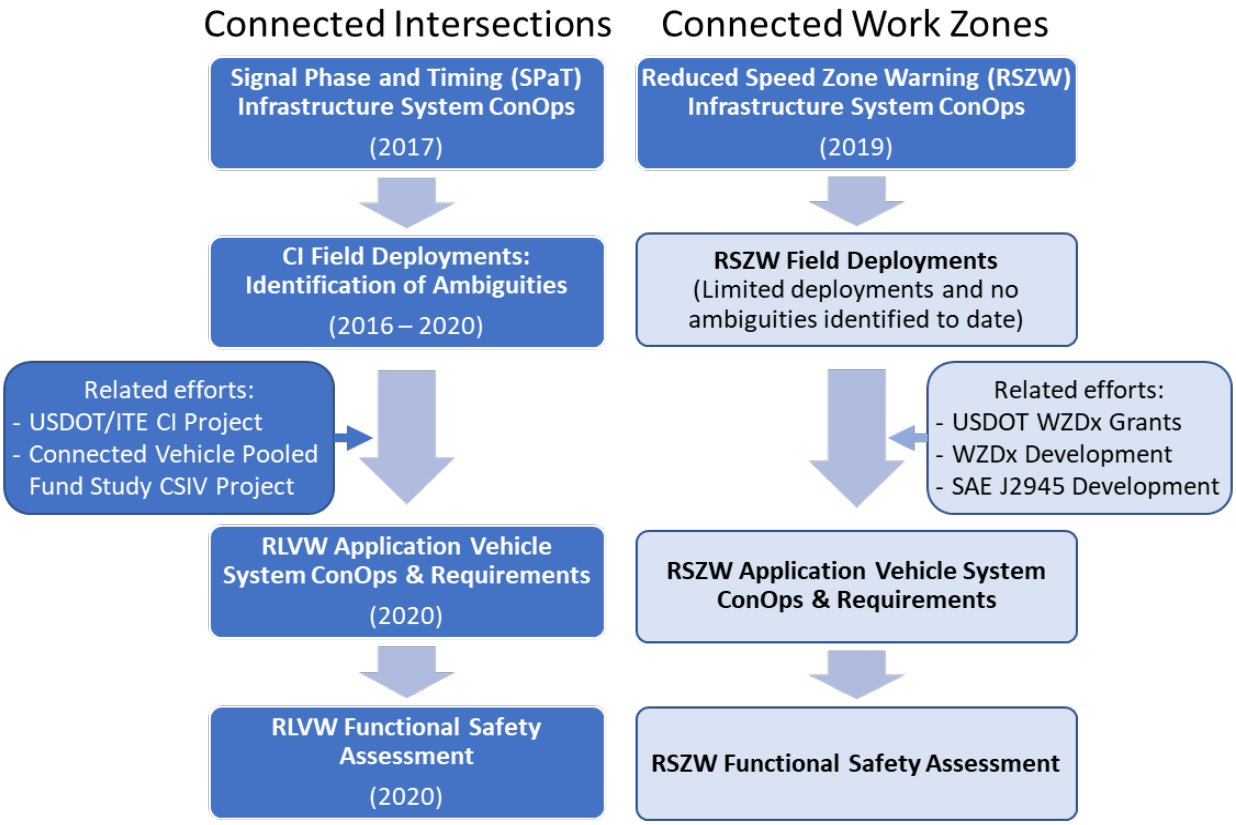

Figure 1. Parallel Approach of Connected Intersections and Connected Work Zones Activities, showing activities that have been completed in dark blue (and the year of completion).

Table 1. Identified Goals, Actions, and Associated Outcomes to Advance Connected Work Zones.

Goals	Actions	Outcomes
Need: Broader IOO Experience with RSZW Field Deployments		
1. **Integrate Connected Work Zones into Established Work Zone Activities of Associations.** This will be done at the national, state, and local levels to address outstanding challenges and issues to standardize practices for deployment sooner than later.	1.1 Introduce the current status of connected work zones to associations such as AASHTO, ITS America, ITE, and ATSSA and engage with each to understand how connected work zones could be incorporated into their work zone activities with IOOs. 1.2 Establish a two-way exchange of information between the other actions (defined below) and these associations, with the intent that one or more associations eventually takes leadership in aspects of connected work zones.	Focus existing activities on connected work zone challenges to initiate standardization activities sooner.
2. **Establish and Operate Connected Work Zones.** Build on available resources like the WZDC Toolchain and WZDx specification to better understand needs and ambiguities.	2.1 Develop general guidance about what elements to include in a connected work zone procurement to support IOO deployment. 2.2 Use the WZDC Toolchain or another tool to collect or assemble data and generate messages containing work zone information. 2.3 Broadcast the messages with roadside units and/or network communications. 2.4 Update the messages with new information as work zones change, including updated location, lane impacts, and closures.	Better understand connected work zones from the infrastructure perspective, identify ambiguities and inconsistencies, and address questions about where connected work zones are used and how they operate.
3. **Establish a Nationally Consistent Approach for Managing and Communicating Work Zone Data.** Coordinate existing work zone data efforts to generate an agreed-upon, nationally consistent approach for generating and disseminating work zone data for CAVs.	3.1 Coordinate related work zone data activities being conducted by USDOT, CAT Coalition, and SAE, including the Work Zone Data Initiative (WZDI), Work Zone Data Exchange (WZDx) Specification, RSZW Working Group Connected Work Zones, and SAE J2945. 3.2 Develop a common approach for leveraging the WZDI data dictionary, WZDx specification, and SAE J2945 to manage data in a nationally consistent data format. 3.3 Identify any gaps in these data formats to support CAVs and/or the generation of associated messages (e.g. Road Safety Messages [RSMs] and Traveler Information Messages [TIMs]). 3.4 Develop guidance for creation of work zone MAP messages.	Consistent and interoperable standard(s) for work zone event data and procedures for creating messages.

Goals	Actions	Outcomes
4. **Understand Tradeoffs for Local Versus Network Broadcasts of Work Zone Information.** Expand testing efforts to examine the comparative advantages of different communications approaches.	4.1 Conduct tests of broadcasting messages (e.g. RSMs and TIMs) containing work zone information via both local and network broadcasts. 4.2 Compare relative functionality and effectiveness of the messages received by vehicles and identify tradeoffs, including timeliness. 4.3 Identify relative cost for each approach examined.	Better understand what technology and communications solutions are most cost-effective at providing needed work zone information.
5. **Validate Message Exchange.** Test and analyze work zone data in CAV messages to understand how to accurately convey actual work zone conditions.	5.1 Conduct tests of receiving and processing messages (e.g., RSMs and TIMs) containing work zone information. 5.2 Compare interpretations of these messages to the actual work zone activities and conditions in the field. 5.3 Identify how to better incorporate work zone information into messages for improved accuracy.	Better understand message exchange, interoperability issues, and how to describe work zone conditions in work zone messages.
6. **Understand the IOO Business Case.** Leverage experiences from test deployments to better understand relative costs, benefits, and level of effort that will inform how feasibility for deploying connected work zones.	6.1 Examine potential IOO business models for percentage of work zones that might be 'connected' in the near-, mid-, and long-term future under various conditions (i.e. CAV releases and penetration rates). 6.2 Examine both technical aspects and business processes involved in operating connected work zones. 6.3 Examine possible benefits and challenges of connectivity.	Business case and understanding of where and how to deploy connected work zones.
Need: OEM and Third Party Engagement		
7. **Understand needs and operational concepts for RSZW vehicle application for connected work zones.** Develop ConOps that reflects the vehicle system perspective.	7.1 Engage OEMS to assemble a consortium around connected work zones to collaborate in a systems engineering application development process. 7.2 Identify user needs, system needs, and operational concepts for how and where an RSZW Application operates.	Connected Work Zone RSZW Application Vehicle System Concept of Operations

Goals	Actions	Outcomes
8. **Understand requirements for RSZW vehicle application for connected work zones.** Generate requirements document that reflects the vehicle system perspective.	8.1 Continue OEM connected work zone consortium collaboration and build on ConOps to generate RSZW application vehicle system requirements. 8.2 Facilitate IOO and OEM coordination to understand data needs for the application.	Connected Work Zone RSZW Application Vehicle System Requirements
9. **Understand risks and safety hazards of RSZW vehicle application for connected work zones.** Conduct functional safety analysis.	9.1 Continue OEM connected work zone consortium collaboration to support a functional safety analysis for the proposed RSZW application vehicle system that also incorporates associated infrastructure and data.	Connected Work Zone RSZW Application Vehicle System Functional Safety Analysis that identifies hazards not previously considered and advances the safety of the concept.
Need: IOO/OEM/Third-Party Engagement		
10. **Engage with OEMs and Third Parties that have prototype or operational applications that rely on connected work zone data.** Demonstrate one or more applications with connected work zone data with one or more IOOs in various settings.	10.1 Identify one or more OEM or third-party applications that are either a prototype or operational, which are available for testing. 10.2 Facilitate IOO, OEM, and third-party coordination to understand testing and verification needs for the application. 10.3 Identify one or more IOOs that will support testing activities for the prototype RSZW vehicle application(s) for connected work zones in various settings and configurations. 10.4 Identify and document challenges and lessons learned regarding IOO connected work zone data needs and application performance in various work zone types and locations.	Demonstrate Prototype Connected Work Zone RSZW Application(s)
11. **Support forums for ongoing IOO/OEM/Third-Party collaboration**, which may leverage or build on existing working groups or result in new initiatives.	11.1 Determine whether an existing working group like the RSZW Working Group in the CAT Coalition IOO/OEM Forum would be appropriate for ongoing discussions. 11.2 Determine whether one or more new initiatives sponsored by USDOT, the Connected Vehicle Pooled Fund Study, standards development organizations (SDOs) like SAE, professional associations like ITE, or other entities are needed to complete various actions.	Ongoing IOO/OEM collaboration to support all other actions to support deployment and development of connected work zones.