Connected Work Zones Implementation Guide and Standard v01.00

Guidance for Setting Up and Operating a Connected Work Zone

December 2024

Previously Work Zone Data Exchange (WZDx)

Developed by: American Association of State Highway and Transportation Officials (AASHTO), ITE—A Community of Transportation Professionals, and National Electrical Manufacturers Association (NEMA)

Supported/Sponsored by: The United States Department of Transportation (USDOT)

Acknowledgement

SAE International served as a partner standards development organization throughout the development of this CWZ Implementation Guide and Standard. SAE International represents the interests of many stakeholders including the automotive industry and was represented by several members on the Connected Work Zones Working Group. The CWZ Implementation Guide and Standard project SDO partners included AASHTO, ITE, NEMA, and SAE International.

Foreword

This Connected Work Zones (CWZ) Implementation Guide and Standard was developed by engaging with stakeholders representing the industry at large including but not limited to infrastructure owners/operators, automobile original equipment manufacturers, work zone equipment manufacturers, and the end users of data and services. The work was supported by the United States Department of Transportation (USDOT) Intelligent Transportation Systems (ITS) Joint Program Office (JPO). Several associations such as the American Association of State Highway Transportation Officials (AASHTO), ITE—A Community of Transportation Professionals, the National Electrical Manufacturers Association (NEMA), and SAE International were involved in ensuring a balanced and effective stakeholder representation and adherence to standards development processes as standards development organizations (SDOs).

This CWZ Implementation Guide and Standard addresses gaps identified by early deployers and provides guidance for organizations seeking to develop interoperable connected work zones across the United States, especially for automated transportation systems. This document focuses on harmonizing the existing Work Zone Data Exchange (WZDx) Specification, CWZ research and pilot deployments, and related standards activities for connected work zones as a starting point.

More information on this effort can be found on the ITE website.

The SDOs supporting this guide include the following:

ITE—A Community of Transportation Professionals

1627 Eye Street, NW, Suite 550
Washington, DC 20006

Siva Narla, snarla@ite.org
Md Ashraf Ahmed, standards@ite.org

AASHTO

555 12th Street, NW, Suite 1000
Washington, DC 20004

Lawrence Dwyer, ldwyer@aashto.org
Ahnaf Morshed, amorshed@aashto.org

NEMA

1300 North 17th Street, Suite 900
Rosslyn, Virginia 22209-380

Steve Griffith, steve.wilson@nema.org
Brian Doherty, brian.doherty@nema.org

SAE International

400 Commonwealth Drive
Warrendale, PA 15096

Christian Thiele, christian.thiele@sae.org

CWZ Working Group Co-chairs

Raj Ponnaluri, Florida DOT
Ross Sheckler, iCone Products

CWZ Working Group Members

Adam Carreon, Arizona DOT
Brandon Patocka, City of Omaha
Benjamin Acimovic, Colorado DOT
Neil Boudreau, Massachusetts DOT
Elise Feldpausch, Michigan DOT
Ahmad Jawad, Road Commission for Oakland County
Shane Zumpf, Trihydro Corporation
David Craig, General Motors
Eric Kolb, Google
Scott Heydt, Horizon Signal
Mike Winters, JTI Traffic
Adam Graham, one.network
Todd Foster, Ver-Mac
Dave Miller, Yunex Traffic

Dallin Starr, Blyncsy (Alternate)
Jacob Larson, City of Omaha (Alternate)
San Lee, Colorado DOT (Alternate)
Marcel Monterie, Google (Alternate)
Adam Kovar, iCone Products (Alternate)
Chris Brookes, Michigan DOT (Alternate)
Rachel Jones, Road Commission for Oakland County (Alternate)
Serge Beaudry, Ver-Mac (Alternate)

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Additional Contributors and Reviewers

In addition to the SDOs, Co-chairs, and Working Group Members, there were many others that contributed to the development of this standard and their input and assistance were critical to the final product. The following list includes those who volunteered their time to help ensure that the resulting guidance and standard met connected work zone community needs, and contributed to the input and review during the development of this guide and standard:

Benjamin Acimovic, Colorado DOT
Jeremy Agulnek, HAAS Alert
Ashraf Ahmed, ITE
Justin Anderson, USDOT
Kingsley Azubike, USDOT
WD Baldwin, FDOT
Serge Beaudry, Ver-Mac
Molly Behan, Volpe Center
Doug Benison, ConSysTec
Alan Benson, Caltrans
Neil E. Boudreau, MassDOT
Brenda Boyce, Booz Allen Hamilton
Jacob Brady, IBI Group
Patrick Chan, ConSysTec
David Craig, General Motors
Deborah Curtis, USDOT
Zorica Cvijovic, Trihydro
Richard Deering, Deering Consulting
Nate Deshmukh-Towery, Volpe Center
Brian Doherty, NEMA
Derald Dudley, USDOT
Bruce Eisenhart, ConSysTec
Tony English, Neaera Consulting
Angela Fessler, Valtech
Todd Foster, Ver-Mac
Craig Franklin, Booz Allen Hamilton
Jacob Frye, Colorado DOT
Michael Gallant, HaulHub Technologies
Viban Gonzales, ConSysTec (Editor)
Adam Graham, one.network
Curtis Hay, General Motors
Devorah Henderson, Qlynx
Brionna Hicks, Noblis
Scott Heydt, Horizon Signal
Manny Insignares, ConSysTec (Editor)
Matt Jasnosz, ITE
Rachel Jones, Road Commission for Oakland County
Eric Kolb, Google
Adam Kovar, iCone Products
AJ Lahiri, ConSysTec
Jacob Larson, City of Omaha
Alexander Lemka, Maricopa County DOT
David Lucas, Maricopa County DOT
Benjamin Mangel, Noblis
Uma Mahesh Madineni, Gurus Infotech
Mike Mercer, Noblis
David McKee, PSS Innovations
Dave Miller, Yunex
Mark Mockett, Volpe Center
Siva Narla, ITE
Sudhakar Nallamothu, USDOT
Spain Niemer, Noblis
Murat Omay, USDOT
Niloo Parvinashtiani, Iteris
Jay Parikh, CAMP

Dagan Packman, Wanco
Brandon Patocka, City of Omaha
Tim Paulino, Wanco
Todd Peterson, USDOT
Christopher Poe, Mixon-Hill
Raj Ponnaluri, Florida DOT
Robert Rausch, Consultant
Faisal Saleem, NOCOE
Erin Schwark, Wisconsin DOT
Kellen Shain, Noblis
Ross Sheckler, iCone Products
Robert Sheehan, USDOT
Eli Sherer, GEWI North America
Nicola Tavares, ITE
Kristin Virshbo, Castle Rock
Adam Wellner, Minnesota DOT
Robert White, AASHTO
Frank Zucco, Wanco
Shane Zumpf, Trihydro
David Fosbroke, CDC

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- The United States Department of Transportation (USDOT)

User Comment Instructions

The term “User Comment” includes any type of written inquiry, comment, question, or proposed revision, from an individual person or organization, about any CWZ Implementation Guide and Standard content. A “Request for Interpretation” is also classified as a User Comment. User Comments are solicited at any time. In preparation of this standards publication, input of users and other interested parties was sought and evaluated. User Comments are generally referred to the Working Group responsible for developing and/or maintaining the CWZ Implementation Guide and Standard. The CWZ Working Group chairpersons, or their designee, may contact the submitter for clarification of the User Comment. When the CWZ Working Group chairpersons or designee reports the CWZ Working Group's consensus opinion related to the User Comment, that opinion is forwarded to the submitter. The CWZ Working Group chairpersons may report that action on the User Comment may be deferred to a future CWZ Working Group meeting and/or a future revision of the standards publication.

A User Comment should be submitted to this address:

ITE—A Community of Transportation Professionals
1627 Eye Street, NW, Suite 550
Washington, DC 20006
email: standards@ite.org

A User Comment should be submitted in the following form:

Standard Publication Number and Version:
Section, Paragraph:
Editorial or Substantive:
Suggested Alternative Language:
Reason:

Please include your name, organization, and email address in your correspondence.

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Executive Summary

Project Objectives and Scope

The purpose of the ITE Connected Work Zones project is to develop and publish a Connected Work Zone (CWZ) Implementation Guide and Standard that focuses on interoperable data exchanges between the various components of a connected work zone.

This CWZ Implementation Guide and Standard addresses gaps identified by early deployers and provides guidance for organizations seeking to develop interoperable connected work zones across the United States, especially for automated transportation systems. This document focuses on harmonizing the existing Work Zone Data Exchange (WZDx) Specification, CWZ research and pilot deployments, and related standards activities addressing connected work zones.

This document identifies key aspects of the interoperability needs of connected work zone systems and provides guidance to enable deployment of consistent CWZ environments across institutional and organizational boundaries. The goal of this document is to identify and document the following:

1. **Interoperable Data Exchanges**. Identify and document the needs for interoperable data exchanges. This includes documenting the data formats, data definitions, data structure, and specifications to enable interoperable data exchanges between CWZ systems and components.
2. **Operational Scenarios**. Identify and document system actors, including end users, data consumers, and data providers, and their interactions, which enable interoperable data exchanges between system components.
3. **Institutional and IOO Guidance Needs**. Identify and document institutional guidance needs, operational policies, constraints, and best practices for using this standard so that deployers can maximize the benefits from their deployments.
4. **Technical Expert Guidance Needs**. Identify and document developer and technical expert guidance needs to enable them to develop project specifications and designs that will result in nationally interoperable data exchanges across CWZ deployments from diverse organizations.

Development of the CWZ Implementation Guide and Standard follows a systems engineering process to be followed by a validation phase to verify the requirements and concepts in this guide. A report summarizing the findings from the validation phase will be developed and accompany this guide.

Background

The USDOT is sponsoring this project to develop, publish, verify, and validate a Connected Work Zone (CWZ) Standard that defines the data elements, capabilities, and interfaces a connected work zone must support to ensure interoperability between components of a connected work zone.

A **connected work zone** is defined as a set of technologies that generates or collects work zone information (whether automatically or manually) and the infrastructure that broadcasts/distributes this information to the public and to vehicles. The CWZ Standard will:

- address ambiguities and gaps identified by early deployers and consolidate multiple independent implementation and standards efforts to lead to the national interoperability of future CWZ deployments across the United States; and
- be published as a Connected Transportation Interoperability (CTI) document.

The CWZ Implementation Guide and Standard employs a systems engineering process, referencing design elements from existing standards and solidifying design content that satisfies multiple SDOs. The result is harmonization of standards activities across centers, vehicles, field devices, and vulnerable road

users/workers. The systems engineering process involves the production of a Concept of Operations (ConOps), System Requirements, System Design Details, and a validation phase.

The draft completion of each of these deliverables is followed by a review period; formal walkthrough process; comment resolution; updates; and, finally, another review period of the updated document. This process allows the document to be fine-tuned and reviewed by all contributors and stakeholders until each detail is deemed technically proficient and approved. This level of detail, combined with reviews by the project team, subject matter experts (SMEs), and other contributors, allows for the production of a CWZ Implementation Guide and Standard that contains both technical depth and clarity.

Purpose of This Document

This document identifies the CWZ deployer needs, sets the requirements, and provides guidance for nationally interoperable connected work zones across the United States. The focus of this document is on system-to-system interfaces to enable interoperable CWZ applications. This document is envisioned as a living document.

Who Should Read This Document?

Stakeholders from multiple industries may benefit from this CWZ Implementation Guide and Standard. These industries include IOOs deploying connected work zones; OEMs; third parties, such as mobile app developers and navigation companies; work zone device manufacturers; multimodal partners; developers of connected work zone applications, and end users of data and services.

Document Overview

In addition to this Executive Summary, this document contains six (6) main sections, as follows:

- **Executive Summary.** This section provides a high-level overview of the entire document and how to use the document.
- **Section 1: General Information.** This section provides introductory and background information about the document, its purpose, and why it is needed. This section discusses the scope of work and references to other documentation.
- **Section 2: Concept of Operations.** This section includes the content of the Concept of Operations, including the Architectural and Data Exchange Needs for a Connected Work Zone as well as Operational Scenarios that illustrate interactions between components of a CWZ.
- **Section 3: System Interface Requirements.** This section includes the System Interface Requirements that satisfy the Architectural and Data Exchange Needs for a Connected Work Zone. A Protocol Requirements List (PRL) is provided, where each need is mapped to all the requirements that satisfy that need.
- **Section 4: System Interface Design Details: Data Exchange Dialogs.** This section includes details on how each data exchange requirement is fulfilled.
- **Section 5: System Interface Design Details: Data Concepts**. This section includes details on how each data content requirement is fulfilled.
- **Section 6: Connected Work Zones Testing.** This section describes the testing required to validate conformance with the normative sections of this CWZ Implementation Guide and Standard and includes example test cases with Requirements to Test Case Traceability Matrix (RTCTM).

The CWZ Implementation Guide and Standard also includes the following Annexes that provide additional background information on various topics:

- **Annex A: Requirements Traceability Matrix.** This normative annex provides a mapping of each requirement to all the design elements that fulfill the requirement.
- **Annex B: Connected Work Zones Guidance Needs.** This informative annex contains a summary of potential guidance needs topics to help organizations plan development and deployment of connected work zones using this standard.
- **Annex C: Guidance for Deployments Involving Multiple Work Zone-related Standards.** This annex provides guidance for CWZ deployers who may need to use multiple standards.
- **Annex D: Recommendations to SDOs.** This annex summarizes comments and recommendations by the CWZ Working Group or its task forces to Standards Development Organizations on existing standards that are referenced by this CWZ Implementation Guide and Standard.
- **Annex E: User Requests.** This informative annex identifies user needs, requirements, and design details considered by the CWZ Working Group but ultimately not included in this version of the CWZ Implementation Guide and Standard. The rationale on why these needs, requirements, and design details were not included is also provided.
- **Annex F: Listing of Differences between the CWZ Standard and the WZDX v4.2 Specification JSON Schemas.** This informative annex lists differences between the JSON Schemas contained in Section 5 of this standard and the WZDX v4.2 Specification JSON Schemas.

Validation Phase

Following the development of the draft final CWZ Implementation Guide and Standard, the CWZ Working Group anticipates releasing a solicitation for Letters of Interest to public agencies to participate in a validation phase to verify the needs, requirements, and design specified in the Guide and Standard. The validation process consists of data collection from each validation site to test for conformance to the CWZ Implementation Guide and Standard. Feedback will also be solicited on the usefulness of the CWZ Implementation Guide and Standard and any further ambiguities. The CWZ Working Group anticipates incorporating some of the analysis results and feedback into the draft final version of the CWZ Implementation Guide and Standard. A separate report summarizing the findings from the analysis and feedback from the validation sites will be released at the end of the validation phase.

Next Steps

This document is intended to be a living document and is an important first step toward developing interoperable connected work zones and supporting connected work zone safety applications. Potential follow-up activities for the ITE Connected Work Zones Working Group will be identified for when additional funding becomes available.

Section 1
General Information [Informative]

1.1 Scope

The purpose of ITE's Connected Work Zones project is to develop and publish a Connected Work Zone (CWZ) Implementation Guide and Standard that provides interoperable data exchanges among the various components of a connected work zone.

This CWZ Implementation Guide and Standard addresses gaps identified by early deployers and provides guidance for organizations seeking to develop interoperable connected work zones across the United States, especially for automated transportation systems. It focuses on harmonizing the existing Work Zone Data Exchange (WZDx) Specification, CWZ research and pilot deployments, and related standards activities addressing connected work zones.

The development of the CWZ Implementation Guide and Standard follows a systems engineering process, to be followed by a validation phase to verify the requirements and concepts in this guide. A report summarizing the findings will be developed to accompany this Guide.

1.2 References

At the time of publication, the indicated editions were valid. All standards are subject to revision, and parties to agreements based on the CWZ Implementation Guide and Standard are encouraged to consider applying the most recent editions of the standard listed.

1.2.1 Normative References

Normative references contain provisions that, through references in this text, form part of this CWZ Implementation Guide and Standard. Other references in this document may provide a complete understanding or additional information. At the time of publication, the indicated editions were valid. All standards are subject to revision, and parties to agreements based on this CWZ Implementation Guide and Standard are encouraged to consider applying the most recent editions of the standards listed.

Identifier	Title
IETF RFC 7946	The GeoJSON Format, August 2016
IETF RFC 3339	Date and Time on the Internet: Timestamps, July 2002
IETF RFC 4122	A Universally Unique Identifier (UUID) URN Namespace, July 2005
IETF RFC 8259	The JavaScript Object Notation (JSON) Data Interchange Format, December 2017
IETF RFC 9110	HTTP Semantics, June 2022
IETF RFC 3986	Uniform Resource Identifier (URI): Generic Syntax, January 2005
Open Mobility Foundation	Curb Data Specification (CDS), v1.0.0, April 29, 2022
NTCIP 1203 v03	Object Definitions for Dynamic Message Signs (DMS), September 2014 *For the definition of MULTI.

1.2.2 Other References

The following documents and standards may provide the reader with a more complete understanding of connected work zones; however, these documents do not contain direct provisions that are required by the CWZ Implementation Guide and Standard.

Identifier	Title
U.S. Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)	Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), USDOT, http://local.iteris.com/arc-it/
IEEE Std 610.12-1990	IEEE Standard Glossary of Software Engineering Terminology, IEEE, 1990
IEEE Std 829-2008	IEEE Std 829 IEEE Standard for Software and System Test Documentation, IEEE, 2008
IEEE Std 1016-1998	IEEE Recommended Practice for Software Design Descriptions, IEEE, 1998
IEEE Std 1362-1998	IEEE Guide for Information Technology System Definition – Concept of Operations (ConOps) Document, IEEE, 1998
FHWA MUTCD	The Manual on Uniform Traffic Control Devices for Streets and Highways, 2009.
NTCIP 1218 v01	National Transportation Communications for ITS Protocol Object Definitions for Roadside Units (RSUs), v01.38, 2020.
OMG UML-2007, Superstructure	OMG Unified Modeling Language (OMG UML), Superstructure, V2.1.2, 2007.
SAE J2945/4_202305	Road Safety Applications, May 10, 2023
ITE/AASHTO TMDD Standard v3.1	Traffic Management Data Dictionary (TMDD) Standard for the Center to Center Communications, January 13, 2020
USDOT WZDx v4.2	Work Zone Data Exchange Specification, USDOT, February 2023
NEMA TS 10	Connected Vehicle Infrastructure – Roadside Equipment, NEMA, March 2021
FHWA Work Zone ITS Implementation Guide 2014	Work Zone Intelligent Transportation Systems Implementation Guide – Use of Technology and Data for Effective Work Zone Management, January 2014

1.2.3 Contact Information

The following sections provide contact information for publishers of documents referenced in this standard.

1.2.3.1 ARC-IT Documents

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) may be viewed online at:

https://local.iteris.com/arc-it/

1.2.3.2 FHWA Documents

USDOT Federal Highway Administration (FHWA) documents (with designations FHWA-JPO-…) are available at the USDOT National Transportation Library, Repository & Open Science Access Portal (ROSA P):

https://rosap.ntl.bts.gov/

1.2.3.3 IEEE Standards

IEEE standards can be purchased online in electronic format or printed copy from the following:

Techstreet
6300 Interfirst Drive
Ann Arbor, MI 48108

(800) 699-9277
www.techstreet.com/ieee

1.2.3.4 Internet Documents

Obtain Request for Comment (RFC) electronic documents from several repositories on the World Wide Web, or by “anonymous” File Transfer Protocol (FTP) with several hosts. Browse or FTP to the following:

www.rfc-editor.org
https://www.rfc-editor.org/retrieve/

1.2.3.5 ITE Standards

Copies of ITE standards may be obtained from the following:

ITE- A Community of Transportation Professionals
1627 Eye Street, NW, Suite 600
Washington, DC 20006
(202) 785-0060
www.ite.org/technical-resources/

1.2.3.6 NTCIP Standards

Copies of NTCIP standards may be obtained from the following:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 N. 17th Street, Suite 900
Rosslyn, VA 22209-3801
www.ntcip.org
email: ntcip@nema.org
https://www.ntcip.org/document-numbers-and-status/

1.2.3.7 SAE International Documents

Copies of SAE International documents may be obtained from the following:

SAE International
400 Commonwealth Drive
Warrendale, PA 15096
www.sae.org

1.3 Terms

The following terms, definitions, acronyms, and abbreviations are used in this document.

Term	Definition
Actor	An actor specifies a role played by a user or any other system that interacts with the subject. Source: OMG UML-2007, Superstructure.

Term	Definition
Component	One of the parts that make up a system. A component may be hardware or software and may be subdivided into other components. Source: IEEE Std 610.12-1990.
Connected Work Zone (CWZ)	A connected work zone is defined as a set of technologies that generates or collects work zone information (whether automatically or manually) and the infrastructure that broadcasts/distributes this information to the public and to vehicles. Source: USDOT, Intelligent Transportation Systems (ITS) Joint Program Office Performance Work Statement for ITE's Connected Work Zone Implementation Guidance, 2022
CWZ Deployers	A collective term to describe IOOs, contractors, or any organization that deploys a CWZ, with responsibilities for actor components within a CWZ.
External Center	A center, whether virtual, mobile, or stationary, interacting with a Traffic Management Center or Work Zone Center. Typically used to describe a Third-Party Center, such as a back-office or cloud.
Generic Vehicle	A vehicle (passenger vehicle, van, bus, or truck) traveling through a connected work zone, but not associated with any activities within it.
Interface	A shared boundary across which information is passed. Source: *IEEE Std 610.12-1990.*
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. Source: *IEEE Std 610.12-1990.*
Traffic Management Center	Centers, typically managed by IOOs, that tracs (collect) work zone status and conditions, and distribute Work Zone Information.
Universally Unique Identifier (UUID)	A UUID is 128 bits long and can guarantee uniqueness across space and time. Source: *IETF RFC 4122.*
Work Zone Center	Centers that directly collect information from Work Zone Field Devices, Work Zone VRUs, Work Zone Work Vehicles to generate a composite view of the status and conditions of a work zone.
Work Zone Device	Devices and electronic systems that monitor and affect work zone operations on a roadway. Examples include arrow boards, location marker devices, and roadside units (for connected vehicle environments).

Term	Definition
Work Zone Vulnerable Road User (WZVRU)	A term to describe a class of persons at risk of harm within or near an active roadway, such as a work zone, i.e., those unprotected by an outside shield. In the case of a work zone, this may include work zone workers. This standard assumes that WZVRUs wear devices that are able to communicate with a work zone center, work zone equipment and/or vehicles. Sub-categories of WZVRUs may include: • Work Zone Workers • Non-workers passing through the work zone (e.g., individuals casually passing through) • Other Workers, including first responders and incident responders • Persons with disabilities
Work Zone Work Vehicle	A term to describe a class of vehicles within or near an active roadway, such as a work zone. This may include maintenance vehicles, construction vehicles, attenuator vehicles, or in some cases first responder vehicles in a work zone. This standard assumes that work zone vehicles have devices that are able to communicate with a work zone center, work zone equipment, and/or vehicles.

1.4 Abbreviations

The abbreviations and acronyms used in this document are defined below.

AASHTO	American Association of State Highway Transportation Officials
API	Application Programming Interface
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ATMS	Advanced Traffic Management System
CAMP	Collision Avoidance Metrics Partners
CWZ	Connected Work Zone
ConOps	Concept of Operations
C/AV	Connected/Automated Vehicle
C-V2X	Cellular Vehicle to Everything
CV	Connected Vehicle
CVE	Connected Vehicle Environment
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
FHWA	Federal Highway Administration
GeoJSON	Geospatial JSON (see JSON)
GIS	Geographic Information System
GNSS	Global Navigation Satellite System

IEEE	Institute of Electrical and Electronics Engineers
IOO	Infrastructure Owner/Operator
ICD	Interface Control Document
IT	Information Technology
ITE	Institute of Transportation Engineers
JSON	JavaScript Object Notation
LIDAR	Light Detection and Ranging (also LiDAR)
MPH	miles per hour
MUTCD	Manual of Uniform Traffic Control Devices
NEMA	National Electrical Manufacturers Association
ngTMDD	Next Generation Traffic Management Data Dictionary
NOCoE	National Operations Center of Excellence
NTCIP	National Transportation Communications for ITS Protocol
OBU	On-Board Unit
OEM	Automotive Original Equipment Manufacturer
PRL	Protocol Requirements List
RSM	Roadside Safety Message
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services
RTM	Requirements Traceability Matrix
SAE	SAE International
SCMS	Security Credentials Management System
SDO	Standards Development Organization
SEP	Systems Engineering Process
TIM	Traveler Information Message
TIM-PM	Traffic Incident Management Performance Measures
TMDD	Traffic Management Data Dictionary
USDOT	United States Department of Transportation
UUID	Universally Unique Identifier
WZDx	Work Zone Data Exchange Specification
VRU	Vulnerable Road User

Section 2
Concept of Operations (ConOps) [Normative]

Section 2 defines the needs that subsequent sections of this CWZ Implementation Guide and Standard address. Accepted systems engineering processes detail that requirements should only be developed to satisfy well-defined needs. The first stage in this process is to identify the ways in which the CWZ system interface is intended to be used.

This concept of operations provides the reader with the following:

- A detailed description of the scope (or problem statement) covered in this CWZ Implementation Guide and Standard document;
- the key capabilities and interfaces for a connected work zone; and
- the relationship to the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT).

Section 2 is intended for all readers and users of the CWZ Implementation Guide and Standard, including the following:

- **Transportation Managers.** Personnel responsible for making decisions about transportation strategies to implement connected work zones.
- **Transportation Operators.** Personnel responsible for monitoring connected work zones and implementing transportation strategies to address the impacts on travel stemming from work zones.
- **Transportation Engineers.** Personnel responsible for the design and engineering of connected work zones.
- **Maintenance Personnel.** Personnel responsible for ensuring that connected work zones are maintained as intended.
- **Data Consumers.** Personnel at organizations, where the organization consumes connected work zone information and provides additional value based on that information.
- **Data Aggregators, Providers, and Distributors.** Personnel at organizations, where the organization gathers and aggregates connected work zone information, adds value, and distributes the work zone information.
- **System Integrators.** Entities that bring together different components or subsystems into a whole system that functions together.
- **Application Developers.** Developers providing applications that rely on data exchanges between CWZ component actors, whether work zone vulnerable road users, work zone field devices, work zone work vehicles, or work zone centers; and applications that exchange work zone information from a connected work zone and other centers, with a cloud service or back-office location.
- **Temporary Traffic Control Contractor.** A contractor, and possibly the equipment supplier (rental agency), responsible for deploying and maintaining equipment including the connectivity aspects of the equipment, and between the field and vehicle.

2.1 Tutorial [Informative]

A concept of operations describes a proposed system from the users' perspectives. Typically, a concept of operations is used to ensure that system developers understand the users' needs. However, for the purposes of this system interface standard we will use the term “user” to mean one or more system components of a CWZ, with the intent of describing representative examples of benefits that may arise for human end-users.

The terms “Normative” and “Informative” are used to distinguish parts of this ConOps that must be conformed to (Normative) and those that are there for informational purposes (Informative). It is possible

for a section to be identified as Normative but have subsections that are identified as Informative. If a section is Normative then all of its subsections are Normative unless identified otherwise. This entire ConOps section is Normative unless otherwise indicated.

The concept of operations starts with a discussion of the current situation and issues that have led to the need to develop CWZ implementation guidance and a data exchange standard to enable interoperable connected work zones. This discussion is presented in layman's terms such that both the potential users of the system and the system developers can understand and appreciate the situation.

The concept of operations then documents key aspects about the proposed system, including the following:

- **Reference Physical Architecture.** The reference physical architecture (view) defines the overall context of a connected work zone system and defines what component actors and interfaces are addressed by this CWZ Standard & Implementation Guide.
- **Needs.** The needs identify and describe the interfaces and data exchanges that users may require to achieve some benefit. These needs address a specific aspect of the problem statement (Section 2.2). The needs are structured and organized into a more manageable format that forms the basis of the traceability table that relates needs to the functional requirements contained in Section 3.
- **Operational Scenarios.** The operational scenarios allow a reader to understand the different parts and functions of a CWZ. An operational scenario explains how the component actors of a CWZ interact to enable the benefits of deploying connected work zones using this standard. The operational scenarios are representative examples illustrating interactions between component actors of a CWZ.
- **Operational Policies and Constraints.** A narrative description of specific policies or constraints relative to the operational environment that have a direct impact on the deployment of connected work zones using this CWZ Implementation Guide.
- **Relationship to the National ITS Architecture Reference.** This section describes how the elements of a CWZ are described by the National ITS Architecture Reference (ARC-IT).

Section 3 applies the needs identified in the ConOps to define the interface requirements for a CWZ. Each need traces to one or more requirements, and each requirement is derived from at least one need. This traceability is documented in a Protocol Requirements List (PRL) in Section 3.10, where each need is mapped to all the corresponding requirements.

Like the needs, the requirements are identified by broad stakeholder collaboration. Each requirement is captured in Section 3 as a formal “shall” statement. Each requirement is then presented in the Requirements Traceability Matrix (RTM) in Annex A, which defines how the requirement is fulfilled by a design element.

2.2 Current Situation and Problem Statement [Informative]

Work zone safety is of utmost concern to transportation agencies. According to the National Highway Traffic Safety Administration, in 2020 there were 857 fatalities and an estimated 102,000 work zone crashes in the United States. There have been numerous research projects, deployments, and standards development to support work zone safety, but there have been inconsistencies with the interpretations and implementation of the existing standards and in the use and expectations of data exchanges. There are also inconsistencies between deployments, such as usage of different data and data formats across interfaces, and security requirements. Another discovery was that most infrastructure owner operators (IOOs) do not have the manpower or technical knowledge to properly deploy and operate connected work zones. These deployment issues highlight a need for an industry standard that enables national interoperability and provides guidance for how to deploy, operate, and maintain connected work zones.

2.3 Reference Physical Architecture [Informative]

2.3.1 Connected Work Zone Physical Architecture

This section presents an overview of the actor components that make up the CWZ Architecture as defined for this document. Two figures are presented to accommodate various deployment needs. While the two diagrams may be combined, we provide them separately for clarity. Please note that the two diagrams are consistent and can be mixed and matched depending on the deployment's needs.

Figure 1 illustrates the sharing of WorkZoneFeed and DeviceFeed information without the use of a Work Zone Data Exchange Intermediary.

Note: The term "actor component," as used in this context and shown as a rectangle in the diagram, is a computing device and does not represent a person or stakeholder. An actor component is the end-point of a data interface between computing devices with the purpose of work zone data exchange. Our intent is to specify an architecture for data exchanges that communicate information between computing devices, whether in centers, in vehicles, in field devices, or on people.

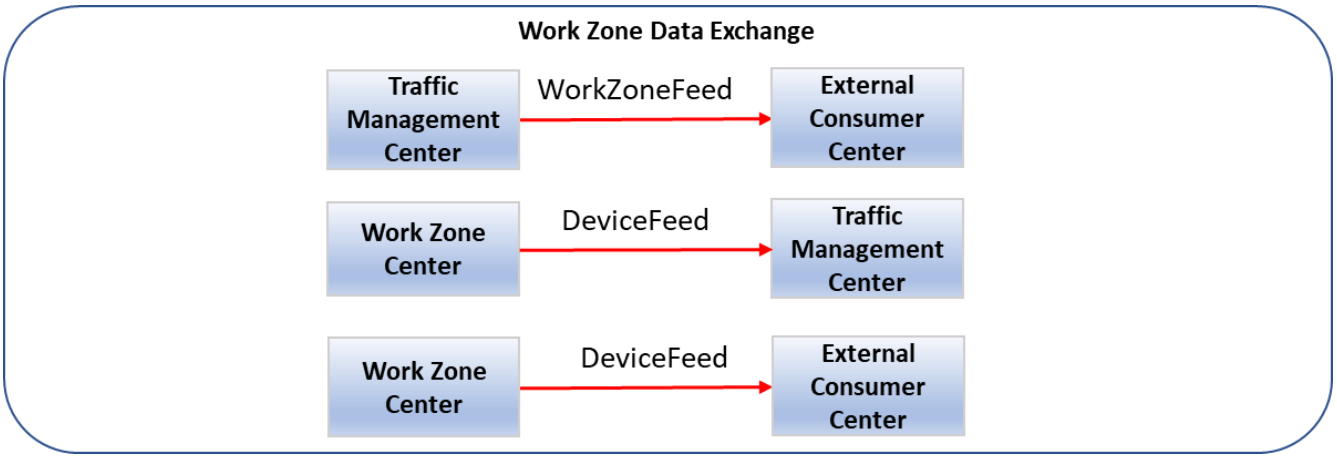


Figure 1. Physical Architecture: Work Zone Data Collection and Distribution

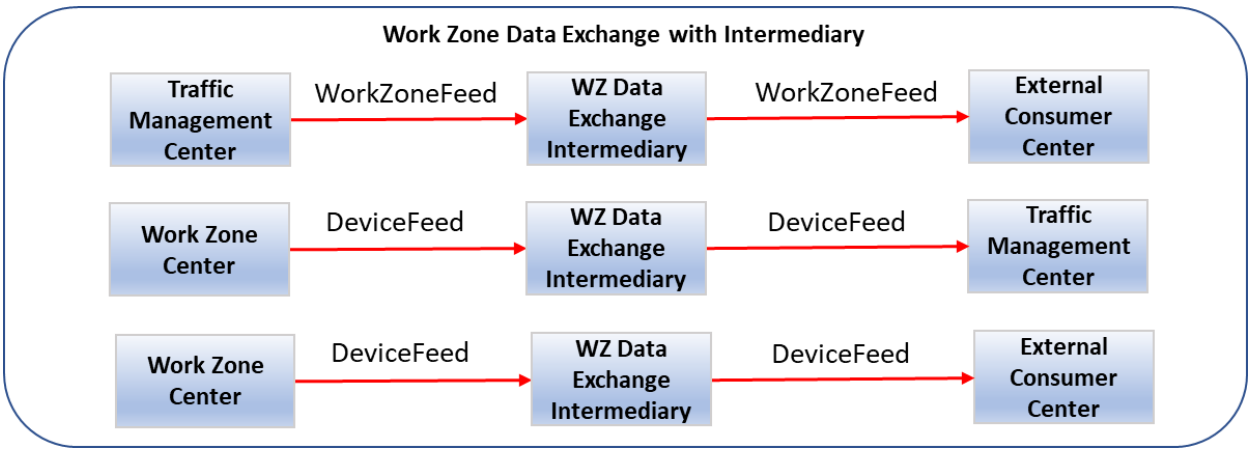


Figure 2. Physical Architecture: Work Zone Data Collection and Distribution with Intermediary

Figures 1 and 2 above are not intended to identify every combination of information exchanges between actor components involving WorkZoneFeeds and DeviceFeeds. There are potentially many other reasonable combinations; for example, Traffic Management Centers may blend the device feed information with other work zone information resulting in a work zone feed. This is illustrated in Operational Scenario 2.6.3 later in this document.

Definitions for WorkZoneFeed and DeviceFeed are presented below:

- **WorkZoneFeed**. Provides high-level information about events on roadways related to work zones that impact the characteristics of the roadway and involve a change from the default state (e.g., a lane closure).
- **DeviceFeed**. Provides information (location, status, dynamic data) about field devices deployed on the roadway in work zones.

The following sections describe the actor components that interact to provide the benefits of a CWZ:

Primary Actors. Communications with these actors as defined in this standard is generally in-scope.

- **Traffic Management Center.** A center, typically managed by an IOO, that tracks (collects) status and conditions, and distributes Work Zone Information.
- **Work Zone Center.** A center that directly collects information from Work Zone Field Devices, Work Zone VRUs, and Work Zone Work Vehicles to generate a composite view of the status and conditions of a work zone. Data may be collected from equipment in the work zone or entered manually by a person.
- **External Center.** A center, whether virtual, mobile, or stationary, interacting with a Traffic Management Center or Work Zone Center. Typically used to describe a Third-Party Center, such as a back-office or cloud.
- **Work Zone Data Exchange Intermediary.** A center that collects, aggregates, stores, and distributes work zone information on behalf of other centers.

Peripheral Actors. Communication with these actors is generally outside the scope of this standard.

- **Work Zone Devices.**
  - **Work Zone Field Device.** Devices and electronic systems that monitor and affect work zone operations on a roadway. Examples include arrow boards, location marker devices, and roadside units (for connected vehicle environments), among others. This may include a hub field device master that communicates with other equipment in the work zone.
  - **Work Zone Vulnerable Road User Device.** Devices worn by persons at risk of harm within or near an active roadway, such as a work zone.
  - **Work Zone Work Vehicle Device.** Devices in work vehicles within or near an active roadway, such as a work zone. Examples may include maintenance vehicles, construction vehicles, attenuator vehicles, or in some cases, first responder vehicles in a work zone.
- **Generic Vehicle.** A vehicle (e.g., passenger vehicle, van, bus, or truck) traveling through a connected work zone but not responsible for any activities within it.

2.4 Tutorial – Data Exchange Roles and Mechanisms [Informative],

2.4.1 Data Exchange Roles

CWZs have multiple actors as described in the prior section. For any particular set of data exchanges there are actor roles that need to be defined to accomplish data exchanges.

- Data Provider Role. A data provider is an actor component that has data and is able to provide that data through a defined communications interaction with another actor component that needs and is able to consume that data.
- Data Consumer Role. A data consumer is an actor component that needs data and can acquire and consume it through a defined communication interaction with another actor component that provides the necessary data.

- Data Exchange Intermediary Role. An actor component that serves as both a data provider and a data consumer. For example, an actor that collects data (consumer), aggregates it, and then distributes it (provides).

2.4.2 Data Exchange Mechanism

For the purposes of this CWZ ConOps, we will define a polling data exchange mechanism as follows:

- Polling is a communications interaction between system actors where a data consumer system initiates the data exchange with a request for information. Upon request, the data provider system sends information to the data consumer system.

2.4.3 Communications Interactions in Lay Terms

Polling is a way for a data consumer to request data from a data provider.

The following scenario describes this human interaction, with Chris as the data consumer, and Paula as the data provider.

Chris walks up to a counter where Paula is standing behind the counter. Chris presents Paula with a slip of paper (let's call this an authentication) with Chris's name on it. Paula looks at the piece of paper, nods in approval, and then retrieves a three-ring binder with 500 pages of information (one for each work zone, representing all work zone activities within the state of Florida. The binder serves as a metaphor for a complete set of work zone data at a specific point in time.

Chris asks how often Paula can provide updates, and let's say Paula states she is able to do so every five minutes. With polling, this exchange—where Chris presents a slip of paper and receives a three-ring binder (a single poll)— repeats continuously. Within a 24-hour period, Chris polled 288 times, and Paula provided 288 binders.

One example use of the polling method is the General Transit Feed Specification (GTFS).

2.5 Needs

The needs for a connected work zone are organized as follows:

- **Architectural Needs.** These needs identify and describe the various interactions between component actors in a CWZ system, as well as higher-level needs that apply to all actors and most, if not all, interactions.
- **Data Exchange Needs.** These needs describe data exchanged between actors, where one or more actors serve as data provider or consumer. Please note that the roles of data provider and data consumer may change depending on the specific need. These data exchange needs also reflect data content needs.

2.5.1 Architectural Needs

This section, outlining the architectural needs of CWZs, is organized into sub-sections as follows:

- Backward Compatibility
- GeoJSON Data Exchange [Constraint]
- GeoJSON Data Format [Constraint]
- GeoJSON Data Validation
- Frequency of Data Updates
- UTC Date-Time Format [Constraint]

Note: The term “CWZ Deployer” is used sparingly throughout Section 2.5 (Needs) when neither a data provider nor data consumer can be identified as an actor. This happens, for example, in the description of the architectural needs below.

2.5.1.1 Architectural Need – Compatibility with the WZDx Specification

CWZ deployers need to describe and implement a mechanism to support compatibility with the design elements specified in WZDx v4.2.

2.5.1.2 Architectural Need – GeoJSON Data Exchange [Constraint]

2.5.1.2.1 GeoJSON Data Exchange – Poll for Data [Constraint]

CWZ deployers need to share the current status of work zone information in the GeoJSON data format. Poll for Data is a synchronous method of data communications.

2.5.1.3 Architectural Need – GeoJSON Data Format [Constraint]

CWZ deployers must continue using the GeoJSON data format (as applied in the WZDx specification). A JSON schema is used to describe the GeoJSON format and can also validate the conformance of work zone data to the specification described in the JSON schema

Feedback from CWZ deployers indicates that the JSON schema and GeoJSON data format work well, as follows:

- The GeoJSON data format provides a framework to support the geospatial information value chain.
- The GeoJSON data format works well for high-bandwidth communications (e.g., internet connections).
- The GeoJSON data format provides outputs that support data visualization. For example, the data can be used with off-the-shelf GIS tools directly “out of the box.

2.5.1.4 Architectural Need – GeoJSON Data Validation [Constraint]

CWZ deployers need to verify conformance of work zone data against the design. Currently, the verification of work zone data (e.g., a WZDx WorkZoneFeed) is accomplished using off-the-shelf software that verifies the work zone data against the specification's JSON Schema.

2.5.1.5 Architectural Need – Frequency of Data Updates

CWZ data providers use the frequency of updates time to reflect how often real-time work zone condition information is made available.

CWZ data consumers need to know the frequency of work zone data updates when new information is available.

2.5.1.6 Architectural Need – UTC Date-Time Format Specification [Constraint]

CWZ deployers need to exchange date-time data in a standardized format.

CWZ deployers need to continue using the UTC Date-Time format specification.

2.5.2 Data Exchange Needs

This section introduces the terms “zone” and “project.” A zone describes a section of roadway where VRUs, vehicles, and devices are present. A zone will generally have consistent characteristics throughout the section of roadway. A project may include one or more zones to represent varying roadway characteristics that change across space and/or time.

This section states the data exchange needs between CWZ actor components and is organized into the following sub-sections:

- Zone Metadata
- Zone Location

- Zone Schedule
- Zone Status
- Zone Lanes
- Zone Speed Limit
- Zone Traffic Data
- Zone Device
- Zone Vulnerable Road User (VRU) Device
- Zone Work Vehicle Device

The diagram below provides a high-level visual interpretation of these sections, which together represent the data exchange needs of connected work zones. The diagram is not intended as a schematic representation for software, application, or database design.

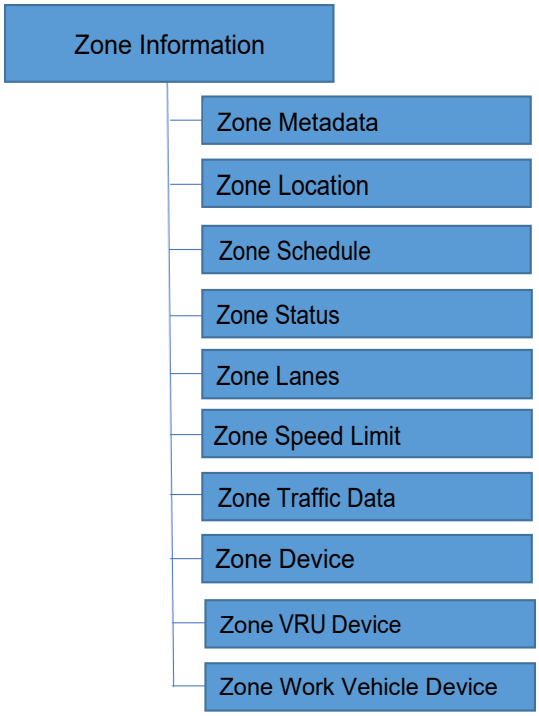


Figure 3. Data Exchange Needs – Zone Information Organization

2.5.2.1 Zone Metadata

CWZ data providers need to provide metadata about work zone information to data consumers. Metadata may support the need for data discovery and may provide information about the data's provenance, trustworthiness, and chain of custody.

2.5.2.1.1 Zone Metadata – Zone Data Standard Version

CWZ data providers need to provide the version of the standard so that data consumers can identify and support multiple versions.

2.5.2.1.2 Zone Metadata – Zone Identifier

2.5.2.1.2.1 Support Zone Identifier for Zones

CWZ data providers need to include the zone identifier when providing work zone information to data consumers.

2.5.2.1.2.2 Support Unique Zone Identifiers

CWZ deployers need zone identifiers that uniquely identify each zone.

2.5.2.1.2.3 Support Unique Zone Group Identifiers

CWZ deployers need unique zones group identifiers to group zones within the same project.

2.5.2.1.2.4 Support Zone Identifiers for VRUs, Devices, Work Zone Vehicles, Lanes, and Speed Limit Zones

CWZ deployers need to associate VRUs, devices, work vehicles, lane configurations, speed limit zones, etc., with a uniquely identifiable zone or group of zones comprising a project.

2.5.2.1.3 Zone Metadata – Zone Activity Type

CWZ data providers need to specify the activity type present within a zone when providing work zone information to data consumers. Activity types may include: repair of spring cracks, pothole repairs, striping, mowing, guard rail repairs, repaving, construction, etc.

2.5.2.1.4 Zone Metadata – Zone Data Timestamp

CWZ data providers need to include a timestamp reflecting the creation time of the zone data when providing work zone information. Data consumers need this timestamp to assess the age, accuracy, and reliability of the data.

2.5.2.1.5 Zone Metadata – Zone Data Source

CWZ data providers need to provide data consumers with a data source identifier that indicates the original source of the data and most recent source of updates.

2.5.2.2 Zone Location

2.5.2.2.1 Zone Location – Geometry

CWZ deployers want to notify/alert distracted drivers ahead of their arrival at the work zone so that they can travel safely through the zone.

CWZ data providers need to provide zone location geometry when providing work zone information to data consumers.

2.5.2.3 Zone Schedule

2.5.2.3.1 Zone Schedule – Date-Times

CWZ data providers need to provide data consumers with the date and times when a work zone is scheduled to be active.

2.5.2.4 Zone Segmentation

2.5.2.4.1 Zone Segmentation – Geometry

CWZ data providers need to provide zone geometries that correspond to a roadway segment with consistent zone characteristics (including, but not limited to road name, direction, lanes closed, start or end location). If characteristics vary along a section of roadway, CWZ data providers need to represent the area as multiple related zones.

2.5.2.4.2 Zone Segmentation – Date-Times

CWZ data providers need to provide zone schedules that correspond to roadway segments with consistent zone characteristics, such as road name, direction, lanes closed, and start or end time. If characteristics vary during the work period. CWZ data providers need to represent the work as multiple related zones with distinct schedules.

2.5.2.5 Zone Status

2.5.2.5.1 Zone Status – Is Active

One of the biggest challenges for CWZ data providers is determining when the active work is actually occurring. Knowledge of planned activity is generally unreliable and insufficient to satisfy the timeliness requirements of safety applications.

CWZ data providers need to indicate when a work zone is active when providing work zone information to data consumers.

2.5.2.5.2 Zone Status – Length

CWZ deployers manage work zone activities that can stretch across long distances, sometimes up to 60 miles.

CWZ data providers need to specify the zone length when providing work zone information to work zone data consumers.

2.5.2.5.3 Zone Status – Number of Lanes Open

CWZ data providers need to indicate the number of lanes open (available for traffic) when providing work zone information to work zone data consumers.

2.5.2.5.4 Zone Status – Ad-hoc (Unscheduled/Unplanned)

Some work zones are dynamic, arising without prior notice and lasting for short durations.

CWZ data providers need to provide information for ad-hoc work zones when providing work zone information to work zone data consumers.

2.5.2.5.5 Zone Status – Is Rolling/Moving

Many work zones are dynamic, without a fixed location, and move continuously over time. Examples include work zones for mowing, striping operations, and repaving.

CWZ data providers need to provide information for rolling/moving work zones when providing work zone information to work zone data consumers.

2.5.2.6 Zone Lanes

2.5.2.6.1 Zone Lanes – Numbering and Identification

2.5.2.6.1.1 Lane Information

CWZ deployers have identified the need to report information for every lane affected by construction or maintenance in a work zone.

2.5.2.6.1.2 Lane Numbering Is Left-to-Right or Right-to-Left

CWZ deployers have identified the need for a nationally consistent method of lane numbering.

CWZ data providers must specify the lane numbering method, including whether lanes are numbered left-to-right or right-to-left, as well as the starting number for the first lane, when providing work zone information to work zone data consumers.

2.5.2.6.2 Zone Lanes – Lane Type

CWZ data providers must use standardized titles for lane types when providing work zone information to work zone data consumers. For example, they must specify if a lane is a shoulder, drivable, or a special-use lane.

2.5.2.6.2.1 Zone Lanes – Lane is Drivable

CWZ data providers need to indicate whether a lane is drivable when providing work zone information to work zone data consumers.

2.5.2.6.2.2 Zone Lanes – Special Use

CWZ data providers need to indicate whether a lane is designated for special use when providing work zone information to work zone data consumers.

2.5.2.6.2.3 Zone Lanes – Reversible Lane

CWZ data providers need to identify whether a lane is reversible, including its status, and direction, when providing work zone information to work zone data consumers. When a lane is reversible, lane numbering that is normally left-to-right becomes right-to-left.

2.5.2.6.3 Zone Lanes – Connected Vehicle Environment Roadside Safety Applications

CWZ deployers developing applications for the connected vehicle environment may require detailed geometry attributes assigned to each node per lane in a work zone to account for road curvature. This need specifically supports the generation of MAP messages for CV applications. Example of deployers with this need include connected vehicle applications, CV pilots, and CV research projects.

CWZ data providers need to provide zone lane-level geometry when providing work zone information to work zone data consumers.

2.5.2.6.4 Zone Lanes – Lane Tapers

CWZ deployers need to identify lane tapers. CWZ deployers have referenced the MUTCD and determined that tapers should be developed based on roadway speed.

CWZ deployers using vehicles with driver assist functionality must navigate a work zone taper and need to know the taper start/end points, the direction of lane change left/right, and the number of lanes to change.

2.5.2.6.4.1 Taper Start and End Positions, Direction of Taper, and Number of Lanes to Taper

CWZ data providers need to provide lane taper information, including start location, end location, direction (left-to-right or right-to-left), and the number of lanes to taper when providing work zone information to work zone data consumers.

2.5.2.6.5 Zone Lanes – Lane Closure Status

CWZ data providers need to indicate whether a lane is open or closed when providing work zone information to work zone data consumers.

2.5.2.7 Zone Speed Limit

CWZ deployers need real-time updates about speed limits in work zones, including the start and end points, and speed limit reductions in effect.

2.5.2.7.1 Zone Speed Limit – Positions/Geometry

CWZ data providers need to provide speed limit zone geometry, including start and end points of speed limit changes, when providing work zone information to work zone data consumers.

2.5.2.7.2 Zone Speed Limit – Speed Limit Change

CWZ data providers need to provide speed limit changes when providing work zone information to work zone data consumers.

2.5.2.8 Zone Traffic Data

CWZ deployers need to develop and maintain historical work zone traffic data for later data analysis about work zones.

2.5.2.8.1 Zone Traffic – Speed, Volume, and Occupancy

CWZ deployers may deploy devices to capture information about traffic speed, volume, and occupancy.

CWZ data providers need to provide information on traffic speed, volume, and occupancy for vehicles traveling through the work zone to work zone data consumers.

2.5.2.8.2 Zone Traffic – Queue Warning

CWZ data providers need to issue queue warnings for work zone data consumers entering a work zone when providing work zone information to work zone data consumers.

2.5.2.9 Zone Device

2.5.2.9.1 Zone Device – Inventory and Status

CWZ deployers send alerts to devices such as flashing beacons to work zone VRUs and drivers traveling through work zones.

CWZ data providers need to provide information about device inventory, availability, and status when providing work zone information to data consumers.

CWZ deployers need information about devices deployed in work zones, including:

- Device type
- Device location
- Device status

2.5.2.9.2 Zone Device – Location Marker Type

CWZ deployers use location marker devices to identify and broadcast various work zone attribute locations, such as start and end points of work zone approaches, VRUs, taper zones. and speed limit reduction zones.

CWZ data providers need to provide location marker type and position when providing work zone information to data consumers.

2.5.2.9.3 Zone Device – Device Type

CWZ data providers need to specify the device type when providing work zone information to work zone data consumers.

Representative examples of zone device types include the following:

- Arrow Boards
- Cameras
- Portable Message Signs
- Speed Limit Signs
- Speed Feedback Signs
- Location Markers
- Roadside Units

2.5.2.9.4 Zone Device – Position/Geometry

CWZ data providers need to provide the location or geometry of each device when providing work zone information to work zone data consumers.

2.5.2.9.5 Zone Device – Device Status

CWZ data providers need to provide the status of each device when providing work zone information to work zone data consumers.

2.5.2.9.6 Zone Device – Zone Identifier

CWZ data providers need to provide the zone identifier and/or project identifier associated with each work zone device when providing work zone information to work zone data consumers.

2.5.2.10 Zone Vulnerable Road Users (VRU) Device

2.5.2.10.1 Zone VRU Device – Worker Presence Status/Activity

The requirements contained in this section may be generalized to apply to VRUs, a superset of work zone workers.

CWZ deployers have identified a mission-critical need to absolutely identify in real-time whether workers are present in a work zone. For example, an OEM may allow the autodrive feature on a vehicle to stay active if no workers are present, but if workers are detected, the OEM may return control of the vehicle to the driver.

CWZ data providers need to provide real-time indications of workers presence in the work zone when providing work zone information to work zone data consumers.

2.5.2.10.2 Zone VRU Device – Position/Geometry

The requirements in this section include work zone workers, a subset of VRUs.

CWZ deployers need to address real-time VRU presence identification. This includes:

- Providing a geographic description of an area within a work zone where VRUs are present.
- Providing a point location to describe where workers are present, such as when a worker is wearing a vest with electronics that determine the VRU's position/location.

CWZ deployers need VRU location information.

CWZ data providers need to provide real time indication of areas within the work zone where VRUs are present when providing work zone information to work zone data consumers.

CWZ data providers need to provide real time indication of VRU position/location where VRUs are present when providing work zone information to work zone data consumers.

2.5.2.11 Zone Work Vehicle Device

CWZ deployers need to know the real-time position and location of work vehicles in the work zone. CWZ deployers state that vehicles in a work zone present a hazardous condition. Generally, vehicle types for which location is needed to be shared include:

- Attenuator vehicles
- Construction vehicles
- Maintenance vehicles
- Emergency vehicles
- Stalled or disabled vehicles

2.5.2.11.1 Zone Work Vehicle Device – Vehicle Type

CWZ data providers need to provide the work vehicle type when providing work zone information to work zone data consumers. Work vehicle types include: attenuator vehicles, construction vehicles, maintenance vehicles, emergency vehicles, and stalled or disabled vehicles.

2.5.2.11.2 Zone Work Vehicle Device – Vehicle Position

CWZ data providers need to provide the location or position of work vehicles when providing work zone information to work zone data consumers. Work vehicles parked or stalled near travel lanes present a hazard.

2.6 Operational Scenarios [Informative]

A scenario is a step-by-step description of how the proposed set of system interfaces should operate under specific conditions. Operational Scenarios help readers understand how all the components of a system interact to provide operational capabilities. [Adapted from IEEE 1362-1998]

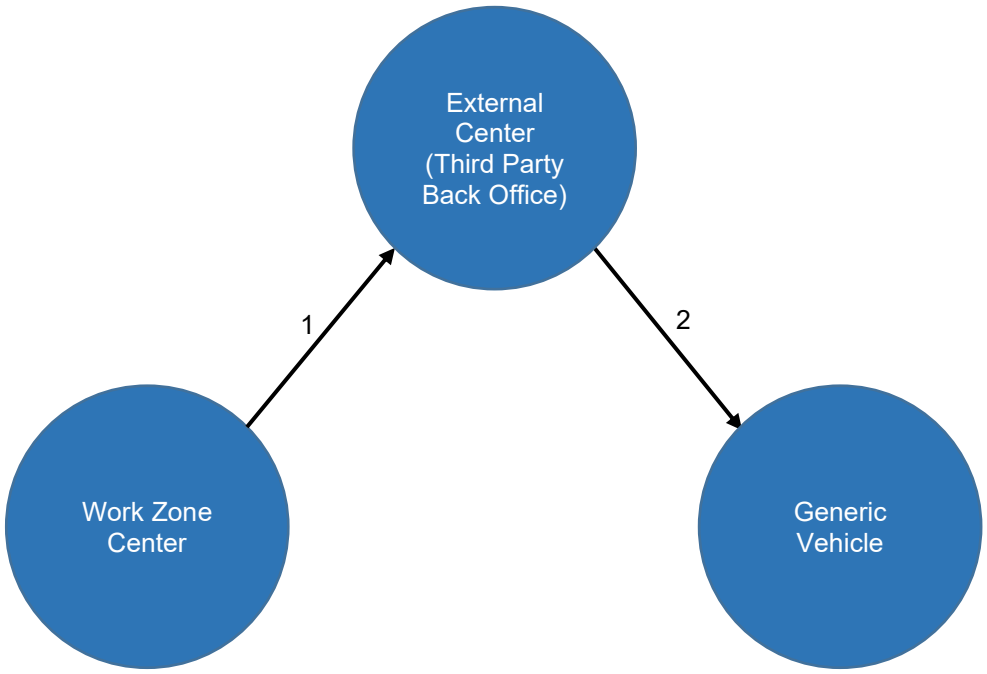
For the purposes of this project, the proposed system is a connected work zone. The operational scenarios allow a reader to understand the different component actors of a CWZ, proposed functions, and data exchanges under a given set of conditions. Pre-conditions are outlined, and a narrative guides the reader through the sequence of events and data exchanges, concluding with a desired end state or condition.

These are intended to illustrate representative examples of interactions between component actors. They are not intended to be all-encompassing.

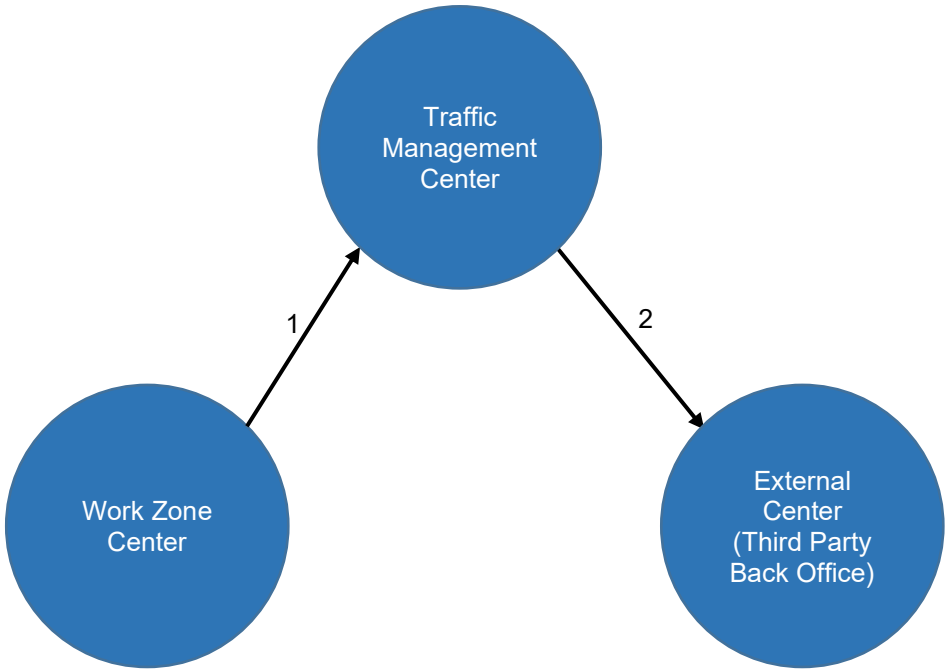
Table 1. Operational Scenario Template

Title	Operational Scenario Title. Shortest possible problem statement, and usually stating the desired end-condition.
Problem Aspect	Some situation of concern, for example Work Zone Vulnerable Road User and Driver Safety.
Description	A description of the scenario. For example, the purpose of this scenario is to provide advisories, warnings, or alerts to drivers.
Pre-Conditions	A listing of factors, attributes, or measures about the environment/conditions describing the beginning state of the operational scenario.
Optional Diagram	A sequence diagram showing actors and a numbered sequence of interactions and events to demonstrate how to transition from pre-condition to end-condition states.
Narrative and Sequence of Steps	1) A numbered narrative that usually describes the steps shown in the sequence diagram.
End Conditions or State	Everyone safe! A listing of factors, attributes, or measures describing the final state of the environment or conditions for the operational scenario.

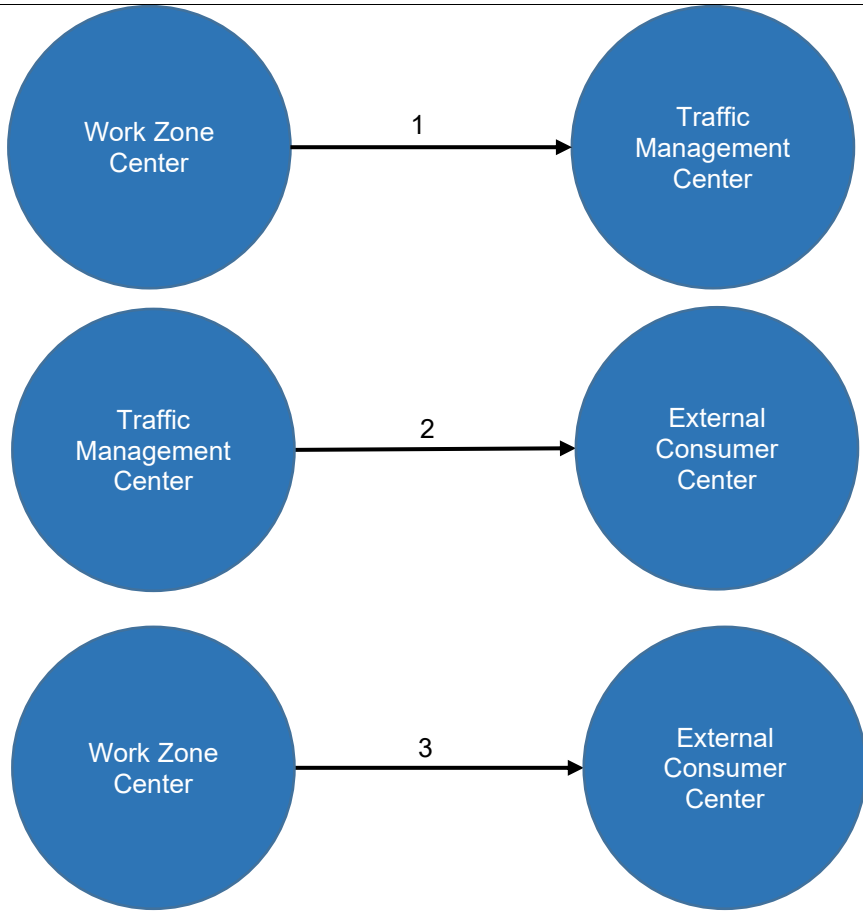
2.6.1 Ad-hoc Notification of Work Zone Ahead

Title	Ad-hoc Notification of Work Zone Ahead
Problem Aspect	Work zones may want to provide advanced notification of their presence to vehicles.
Description	The work zone may want to provide advanced notification to vehicles of its presence. This can be achieved with the cooperation of a third party, such as an OEM or a smartphone navigation application. Some deployers refer to this as ad-hoc.
Pre-Conditions	• The work zone location is known by the Work Zone Center. • The Work Zone Center is connected to an External Center with vehicle notification capabilities. • In this scenario, a Traffic Management Center (TMC) does not know about this work zone (ad-hoc).
Optional Diagram	
Narrative and Sequence of Steps	1) The Work Zone Center sends work zone information (DeviceFeed) to an External Center. 2) The External Center provides the work zone ahead notification to a Generic Vehicle (proprietary).
End Conditions or State	The driver of the Generic Vehicle is notified of the work zone ahead through their smartphone navigation app or vehicle notification system.

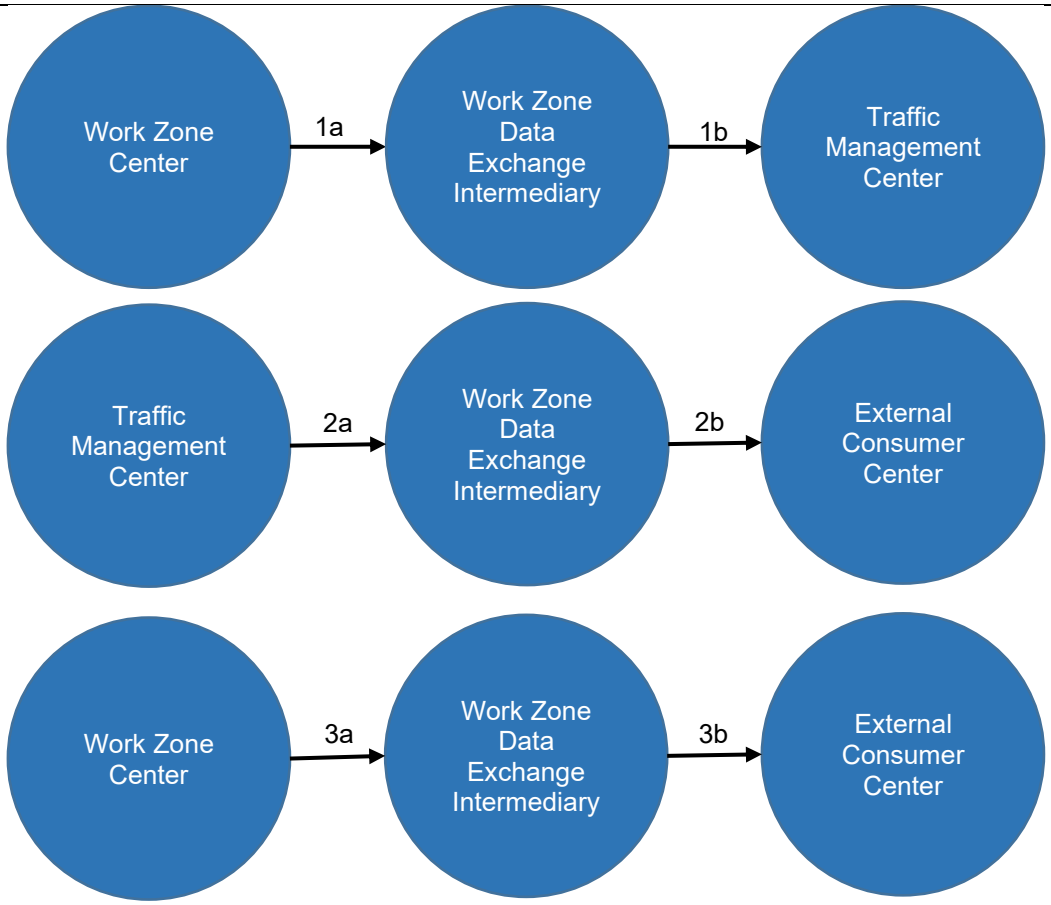
2.6.2 IOO Notification of Work Zone Information

Title	IOO Notification – Work Zone Information
Problem Aspect	Work zones may want to share advanced notification of their presence to external centers.
Description	The IOO may want to provide advanced notification to External Centers of the presence of a work zone.
Pre-Conditions	• The work zone location is known by the Work Zone Center. • The work zone center is connected to a Traffic Management enter, which assigns an IOO work zone identifier.
Optional Diagram	
Narrative and Sequence of Steps	1) The Work Zone Center sends work zone information (DeviceFeed) to a Traffic Management Center. 2) The Traffic Management Center forwards the work zone information to an External Center.
End Conditions or State	The External Center has recived notification of work zone information.

2.6.3 Work Zone Data Collection and Distribution

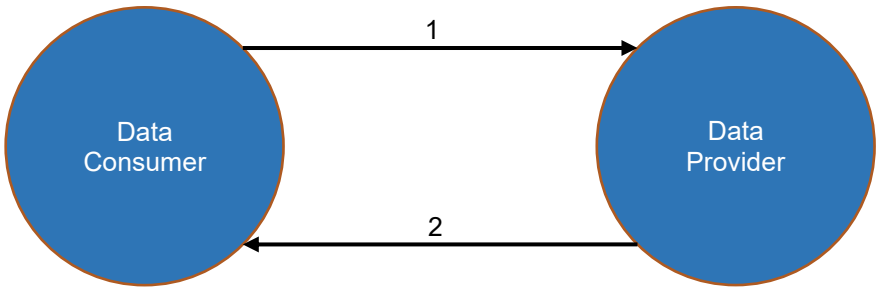
Title	Work Zone Data Collection and Distribution
Problem Aspect	Work zone actors may wish to communicate data with each other.
Description	Collection and distribution of work zone and device information.
Pre-Conditions	• The Work Zone Center, Traffic Management Center, and External Consumer Center are connected for communication of data.
Optional Diagram	
Narrative and Sequence of Steps	1) The Work Zone Center sends the DeviceFeed for all devices managed by the Work Zone Center. Each device ID is assigned a UUID by the Work Zone Center. 2) The Traffic Management Center assigns a unique work zone ID in the WorkZoneFeed. The Traffic Management Center matches the device IDs to their work zone IDs to determine device status, i.e., an arrow board is active, and therefore the work zone is active. The Traffic Management Center forwards the WorkZoneFeed information to an External Consumer Center. 3) Work Zone Center sends the DeviceFeed to the External Consumer Center.
End Conditions or State	The Traffic Management Center and External Consumer Center have up-to-date information about work zones and their conditions.

2.6.4 Work Zone Data Collection and Distribution (Data Exchange Intermediary)

Title	Work Zone Data Collection and Distribution (Intermediary)
Problem Aspect	Work zone actors may wish to communicate through an intermediary.
Description	Collection and distribution of work zone and device information via an intermediary system.
Pre-Conditions	• The Work Zone Center, Traffic Management Center, and External Consumer Center are connected to the Work Zone Data Exchange Intermediary for communication of data.
Optional Diagram	
Narrative and Sequence of Steps	1a) The Work Zone Center sends device information for all devices it manages (DeviceFeed) to a Work Zone Data Exchange Intermediary. Each device ID has a UUID, assigned by the Work Zone Center. 1b) The Work Zone Data Exchange Intermediary sends information (DeviceFeed) to the TMC. 2a) A work zone ID is unique, assigned by the Traffic Management Center in the WorkZoneFeed. The Traffic Management Center matches the device status, i.e., an arrow board is active, and therefore the work zone is active. The Traffic Management Center sends information to the Work Zone Data Exchange Intermediary (WorkZoneFeed). 2b) The Work Zone Data Exchange Intermediary sends information to an External Consumer Center (WorkZoneFeed). 3a) The Work Zone Center sends all device data (DeviceFeed) to the Work Zone Data Exchange Intermediary.

	3b) The Work Zone Data Exchange Intermediary forwards the DeviceFeed to the External Consumer Center.
End Conditions or State	The Traffic Management Center and External Consumer Center have up-to-date information about work zones and their conditions.

2.6.5 Generic Work Zone Information Data Exchange (Poll for Data)

Title	Generic Work Zone Information Data Exchange (Poll for Data)
Problem Aspect	A Data Consumer (a CWZ component actor) requires current up-to-date information from a Data Provider (another CWZ component actor).
Description	When a Data Consumer requires current information from a Data Provider, whether as an update or to establish a baseline of information, the Data Consumer polls the data provider to ensure the data is current.
Pre-Conditions	• The Data Consumer has an authorized connection to the Data Provider.
Optional Diagram	
Narrative and Sequence of Steps	1) The Data Consumer sends a request for information to the Data Provider. 2) The Data Provider responds with the requested information.
End Conditions or State	The Data Consumer has current and accurate information about work zones and conditions.

2.7 Operational Policies and Constraints

The following operational policies and constraints apply to the use of this CWZ Implementation Guide and Standard document.

2.7.1 Operational Policies and Constraints – Manual of Uniform Control Devices (MUTCD)

The operation and maintenance of connected work zones are governed by the regulatory guidelines or policies established by the operating agency (IOO). These may include the USDOT's and relevant states' Manual of Uniform Traffic Control Devices (MUTCD), as well as state and local ordinances, policies, and procedures.

2.7.2 Operational Policies and Constraints – Security

The operation and maintenance of connected work zone information and system security are governed by the regulatory guidelines and policies of the data provider.

2.7.3 Operational Policies and Constraints – Uniform Resource Identifiers

The operation and maintenance of connected work zone information and websites, including the determination of uniform resource identifiers, are governed by the regulatory guidelines and policies of the data provider.

2.7.4 Operational Policies and Constraints – Universally Unique Identifiers (UUIDs)

The assignment of UUIDs is governed by the regulatory guidelines and policies of the data provider. For example, policies to guarantee privacy may dictate the assignment of uniform resource identifiers may necessitate changes to UUIDs over time. Likewise, data consumers may need to specify the need for UUIDs to remain consistent across time.

2.8 Relationship to the Architecture Reference for Cooperative and Intelligent Transportation [Informative]

This section describes how portions of the Architecture Reference for Cooperative and Intelligent Transportation, known as ARC-IT, are addressed by this CWZ Implementation Guide and Standard.

At the highest level of abstraction, the physical architecture consists of center components, field components, vehicle components, and personal components. ARC-IT defines these components as follows:

- **Center.** An entity that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms "back office" and "center" are used interchangeably. “Center” is traditionally a transportation-focused term, evoking management centers to support transportation needs, while “back office” generally refers to commercial applications.
- **Field.** These are intelligent infrastructure elements distributed near or along the transportation network which perform surveillance (e.g., traffic detectors, cameras), traffic control (e.g., traffic signal controllers), information provision (e.g., dynamic message signs) and local transaction (e.g., tolling, parking) functions. Typically, their operation is governed by transportation management functions running in back offices. Field components also include RSU, LTE-CV2X, and other non-Dedicated Short Range Communication (DSRC) wireless communications infrastructure that provides communications between mobile elements and fixed infrastructure.
- **Personal.** Equipment used by travelers to access transportation services both pre-trip and enroute. This includes mobile/handheld devices as well as desktop equipment owned and operated by the traveler.
- **Vehicle.** Vehicles, including driver information and safety systems applicable to each vehicle type.

Service Packages and associated diagrams show the key interfaces and flow of information exchanged between components. The service package in ARC-IT that best identifies the scope of Connected Work Zones is MC06: Work Zone Management.

2.8.1 ARC-IT Work Zone Management Service Package

MC06: Work Zone Management. This service package manages work zones by controlling traffic in areas of the roadway where maintenance, construction, or utility work activities are underway. Traffic conditions are monitored using CCTV cameras and controlled using dynamic message signs (DMS), Highway Advisory Radio (HAR), gates, and barriers. Work zone information is coordinated with other groups (e.g., traveler information, traffic management, other maintenance and construction centers). Work zone speeds and delays are provided to the motorist prior to the work zones. This service package provides control of field equipment in all maintenance and construction areas, including fixed, portable, and truck-mounted devices for both stationary and mobile work zones.

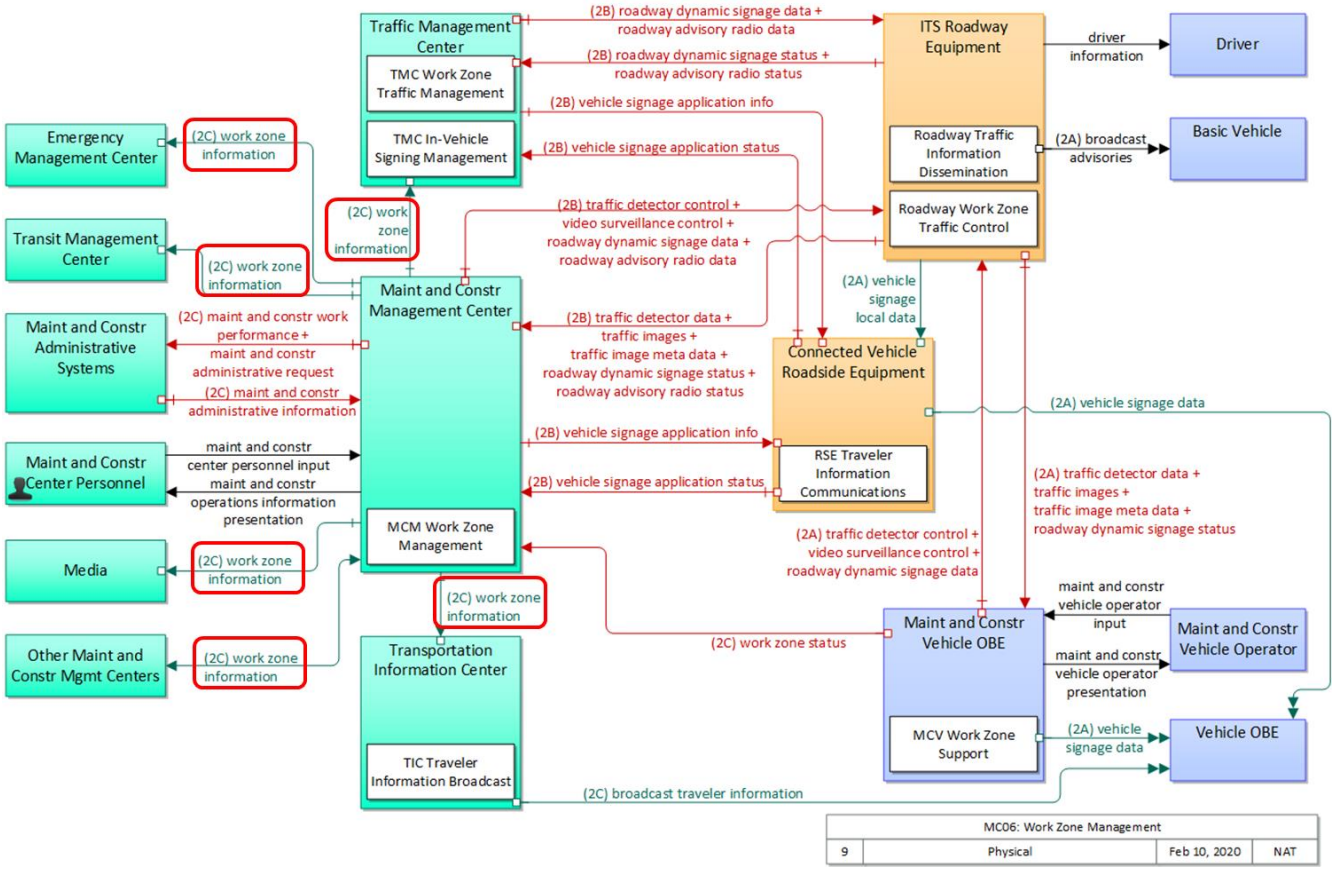


Figure 4. ARC-IT – Work Zone Management Service Package Diagram.

This standard covers definition of the work zone information flows (encapsulated in red).

Section 3
System Requirements [Normative]

3.1 Introduction [Informative]

The requirements for the CWZ Standard and Implementation Guide follow.

3.2 Architectural Requirements

The architectural requirements for the CWZ Standard and Implementation Guide follow.

3.2.1 Compatibility with the WZDx Specification

The CWZ WG believes that the approach described here supports the objective to preserve the investment of deployers in prior versions of WZDx, minimizing the burden of updating legacy deployments to this standard. The general approach below states that where applicable, a WZDx specification design element shall be reused, rather than developing new data requirements and design elements.

3.2.1.1 Exceptions

During development of this standard, the CWZ WG asserted that full backward compatibility was not required, and that the following exceptions superseded the need for full backward compatibility with the WZDx v4.2 specification:

a) Elements described as DEPRECATED have been removed in this standard.
b) Some elements described as OPTIONAL have been made MANDATORY in this standard.
c) Some elements were renamed to generalize unit choices, for example the choice of miles or kilometers for reference post. Metric units were left as-is.
d) Certain enumerations elements were renamed for clarity in this standard.

3.2.1.2 Requirement

Where applicable, data requirements described in this standard shall be reused, based on WZDx 4.2 specification to maintain compatibility with the WZDx specification and numerous current deployments, with exceptions as defined in Section 3.2.1.1.

3.2.2 GeoJSON Data Format

Work zone information shall be provided in the GeoJSON data format.

3.2.3 GeoJSON Data Validation

Work zone information in the GeoJSON data format shall be validated (verified) using the JSON Schema contained in this standard.

3.2.4 Business Rules

The following business rules help ensure standardized and interpretable use of the requirements in this standard. While this standard describes the required structure and data fields, business rules are additional requirements that promote consistent national level. Note that business rules are distinct from best practices in that the latter are suggestions and business rules are requirements that cannot be validated by the JSON schema.

3.2.4.1 Event Segments Follow Attribute Changes

A work zone or detour must be segmented into separate WorkZoneRoadEvents or DetourRoadEvents if certain characteristics vary **within the overall location and/or time frame of the work zone or detour**. This rule exclusively applies to characteristics represented by the properties: road_name, direction, start_date, end_date**,** vehicle_impact, lanes, and worker_presence**.**

The following guidelines are provided:

- A road event should identify any related WorkZoneRoadEvents and DetourRoadEvents using the related_road_events and project_id properties on the RoadEventCoreDetails object.
- A series of sequential or recurring road events comprising a complex work zone or detour should use the first- and next-in-sequence or first- and next-occurrence enumerations of the RelatedRoadEventType. A work zone or detour represented by multiple road events should also use the project_id property to identify the project that the events correspond to.
- A WorkZoneRoadEvent should identify any prescribed detour using the related-detour enumeration; a DetourRoadEvent should identify the work zone necessitating the detour using the related-work-zone enumeration; both may refer to the same project identifier as other work zones and detours in the project area.

3.2.4.2 WorkZoneRoadEvent Lanes

If the lanes property on the WorkZoneRoadEvent is provided, it must include one entry for every lane in the road event. Providing lane information for only some of the lanes in a road event is not allowed.

3.2.4.3 Lane Order

A Lane order or TrafficSensorLaneData lane_order value of 1 must represent the left-most lane when facing downstream traffic and an increase in 1 must represent moving a single lane to the right.

3.2.4.4 Data Source ID Referential Integrity

The data_source_id value must match to the data_source_id property of a FeedDataSource included within the same GeoJSON document on the WorkZoneRoadEvents and DetourRoadEvents.

3.2.4.5 UTC Date-Time Format Specification

All dates and times must be expressed in UTC.

3.2.4.6 UUID Format Specification

All universally unique identifiers (UUID) must comply with the UUID standard (RFC 4122) reference. There may be cases (e.g., cases of privacy) where the UUID may need to change over time.

3.3 Data Exchange Requirements

Requirements for data exchange follow.

3.3.1 Exchange WorkZoneFeed Information

Requirements for the exchange of WorkZoneFeed information follow.

3.3.1.1 Send WorkZoneFeed Upon Request

A data provider shall send WorkZoneFeed information upon request from a data consumer.

3.3.2 Exchange DeviceFeed Information

Requirements for the exchange of DeviceFeed information follow.

3.3.2.1 Send DeviceFeed Upon Request

A data provider shall send DeviceFeed information upon request from a data consumer.

3.4 WorkZoneFeed Requirements

The WorkZoneFeed includes the following data definitions, some of which are defined as optional.

3.4.1 Contents of WorkZoneFeed

The WorkZoneFeed shall consist of the following mandatory and optional requirements:

a) **feed_info.** Information about the Work Zone Feed. See 3.5 FeedInfo Requirements. **Required**.
b) **type.** The GeoJSON object type. For a WorkZoneFeed, this must be the string 'FeatureCollection'. **Required.**
c) **features.** An array of GeoJSON Feature objects (RFC 7946 Section 3.2) representing a WorkZoneFeed's road events. The array consists of one or more instances of the RoadEventFeature. See 3.6 RoadEventFeature Requirements. **Required.**
d) **bbox.** Information on the coordinate range for all RoadEventFeatures in the feed. Must be an array of length '2n' where 'n' is the number of dimensions represented in the contained geometries, with all axes of the most southwesterly point followed by all axes of the more northeasterly point. The axes order of a bbox follows the axes order of geometries. See 3.9 BoundingBox Requirements. **Optional.**

3.5 FeedInfo Requirements

The FeedInfo includes the following data definitions, some of which are defined as optional.

3.5.1 Contents of FeedInfo

The FeedInfo shall consist of the following mandatory and optional requirements:

a) **publisher.** The organization responsible for publishing the feed. Example: 'State DOT'. **Required.**
b) **contact_name.** The name of the individual or group responsible for the data feed. Example: 'Jo Help'. **Optional.**
c) **contact_email.** The email address of the individual or group responsible for the data feed. Example: 'abc@testcity1.gov'. **Optional.**
d) **update_frequency.** The frequency in seconds at which the data feed is updated. Example: '60'. A value of '-1' indicates that the data feed is not being updated. A value of '0' indicates update on change. **Required.**
e) **update_date.** The UTC date and time when the GeoJSON file (representing the instance of the feed) was generated. The recency of the value of this property depends on if the feed producer is generating a new feed GeoJSON file for each request or generating the file in advance and making it available for download (this standard does not mandate a particular distribution method). Note all date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. Business Rule #5. **Required.**
f) **version.** The specification version used to create the data feed in 'major.minor' format. Note this mandates that all data in a feed complies to a single version of WorkZoneFeed. Examples: '1.1', '2.0'. **Required.**
g) **license.** The URL of the license that applies to the data in the feed. The recommended string is "https://creativecommons.org/publicdomain/zero/1.0/". **Required.**
h) **data_sources.** A list of specific data sources for the road event data in the feed. Length of array must be at least one. See 3.5.2 FeedDataSource. **Required.**

3.5.2 Contents of FeedDataSource

The FeedDataSource shall consist of the following mandatory and optional requirements:

a) **data_source_id.** A unique identifier for the data source organization providing work zone data. This identifier is a Universally Unique Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds and over time. Linked to a road event by the 'data_source_id' property on the road event's core details or a field device by the 'data_source_id' property on the device's core details. See Business Rule #4. **Required.**
b) **organization_name.** The name of the organization for the authoritative source of the work zone data. Example: County DOT. **Required.**
c) **contact_name.** The name of the individual or group responsible for the data source. Example: 'Jo Help'. **Optional.**
d) **contact_email.** The email address of the individual or group responsible for the data source. **Optional.**
e) **update_frequency.** The frequency in seconds at which the data source is updated. A value of '-1' indicates that the data source is not being updated. A value of '0' indicates update on change. **Required.**
f) **update_date.** The UTC date and time when the data source was last updated. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**

3.6 RoadEventFeature Requirements

The RoadEventFeature includes the following data definitions, some of which are defined as optional.

3.6.1 Contents of RoadEventFeature

The RoadEventFeature shall consist of the following mandatory and optional requirements:

a) **id**. A unique identifier issued by the data feed provider to identify the road event. This identifier is a Universally Unique Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds and over time. This is a GeoJSON property. **Required.**
b) **type.** The GeoJSON object type. This MUST be the string 'Feature'. This is a GeoJSON property. **Required.**
c) **properties.** The specific details of the road event. This is a GeoJSON property. The road event consists of either a WorkZoneRoadEvent or a DetourRoadEvent. See 3.6.2 Contents of WorkZoneRoadEvent or 3.6.3 Contents of DetourRoadEvent. **Required.**
d) **geometry.** The geometry of the road event. The Geometry object's 'type' property MUST be LineString (RFC 7946 Section 3.1.4) or Point (RFC 7946 Section 3.1.2). 'LineString' allows specifying the entire road event path and should be preferred. ‘LineString’ should be used when at least the start and end coordinates are known. The order of coordinates is meaningful: the first coordinate is the first (furthest upstream) point a road user encounters when traveling through the road event. ‘Point' should be used when only one coordinate is known. Where both start and end data are required (e.g., is_start_position_verified and is_end_position_verified), the ‘Point’ type is allowed. **Required.**
e) **bbox.** Information on the coordinate range for this RoadEventFeature. Must be an array of length '2n' where 'n' is the number of dimensions represented in the 'geometry' property, with all axes of the most southwesterly point followed by all axes of the more northeasterly point. The axes order of a bbox follows the axes order of the 'geometry'. This is a GeoJSON property. See 3.9 BoundingBox Requirements. **Optional.**

3.6.2 Contents of WorkZoneRoadEvent

The WorkZoneRoadEvent shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all types of road events, not specific to work zones. See Business Rule #1. See 3.6.4 Contents of RoadEventCoreDetails. **Required.**
b) **beginning_cross_street.** Name or number of the nearest cross street along the roadway where the event begins. **Optional.**
c) **ending_cross_street.** Name or number of the nearest cross street along the roadway where the event ends. **Optional.**

d) **beginning_reference_post.** The linear distance measured against a reference post marker along a roadway where the event begins. A reference post may be a milepost or mile marker, a surveyed distance posted along a roadway measuring the length (in miles or tenth of a mile) from the south west to the north east. These markers are typically notated on State and local government digital road networks. **Optional.**
e) **ending_reference_post.** The linear distance measured against a reference post marker along a roadway where the event ends. A reference post may be a milepost or mile marker, a surveyed distance posted along a roadway measuring the length (in miles or tenth of a mile) from the south west to the north east. These markers are typically notated on State and local government digital road networks. **Optional.**
f) **reference_post_unit.** Unit of measurement for the WorkZoneRoadEvent 'beginning_reference_post' and 'ending_reference_post', if applicable. See 3.6.19 Enumeration of UnitOfMeasurement. **Conditional;** required if either 'beginning_reference_post' or ending_reference_post' is not null.
g) **is_start_position_verified.** Indicates if the start position (first geometric coordinate pair) is based on actual reported data from a GPS-equipped device that measured the location of the start of the work zone. **Required.**
h) **is_end_position_verified.** Indicates if the end position (last geometric coordinate pair) is based on actual reported data from a GPS-equipped device that measured the location of the end of the work zone. **Required.**
i) **start_date.** The UTC time and date when the event begins. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
j) **end_date.** The UTC time and date when the event ends. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
k) **is_start_date_verified.** Indicates if work has been confirmed to have started, such as from a person or field device. **Required.**
l) **is_end_date_verified.** Indicates if work has been confirmed to have ended, such as from a person or field device. **Required.**
m) **work_zone_type.** The type of work zone road event, such as if the road event is static or actively moving as part of a moving operation. See 3.6.13 Enumeration of WorkZoneType. **Optional.**
n) **vehicle_impact.** The impact to vehicular lanes along a single road in a single direction. See 3.6.14 Enumeration of VehicleImpact. **Required.**
o) **location_method.** The typical method used to locate the beginning and end of a work zone impact area. See 3.6.5 Enumeration of LocationMethod. **Required.**
p) **worker_presence.** Indicates whether workers are present in the road event area. See 3.6.11 Contents of WorkerPresence. **Optional.**
q) **reduced_speed_limit_kph.** The reduced speed limit posted within the road event, in kilometers per hour. This property only needs to be supplied if the speed limit within the road event is lower than the posted speed limit of the roadway. **Optional.**
r) **restrictions.** A list of zero or more road restrictions that apply to the roadway segment described by this road event. Restrictions can also be provided on an individual lane. See 3.6.9 Contents of Restriction. **Optional.**
s) **types_of_work.** A list of the types of work being performed in a road event and whether each type results in an architectural change to the roadway. See 3.6.7 Contents of TypeOfWork. **Optional.**
t) **lanes.** A list of individual lanes within a road event (roadway segment). See Business Rules #1 and #2. See 3.6.8 Contents of Lane. **Optional.**
u) **impacted_cds_curb_zones.** A list of references to external CDS Curb Zones impacted by the work zone. See 3.6.10 Contents of CdsCurbZonesReference. **Optional.**

3.6.3 Contents of DetourRoadEvent

The DetourRoadEvent shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details of the road event that are shared by all types of road events, not specific to detours. See Business Rule #1. See 3.6.4 Contents of RoadEventCoreDetails. **Required.**

b) **beginning_cross_street.** Name or number of the nearest cross street where the event begins. **Optional.**
c) **ending_cross_street.** Name or number of the nearest cross street where the event ends. **Optional.**
d) **beginning_reference_post.** The linear distance measured against a reference post marker along a roadway where the event begins. A reference post may be a milepost or mile marker, a surveyed distance posted along a roadway measuring the length (in miles or tenth of a mile) from the southwest to the northeast. These markers are typically notated on state and local government digital road networks. **Optional.**
e) **ending_reference_post.** The linear distance measured against a reference post marker along a roadway where the event ends. A reference post may be a milepost or mile marker, a surveyed distance posted along a roadway measuring the length (in miles or tenth of a mile) from the south west to the north east. These markers are typically notated on State and local government digital road networks. **Optional**.
f) **reference_post_unit.** Unit of measurement for the DetourRoadEvent 'beginning_reference_post' and 'ending_reference_post', if applicable. See 3.6.19 Enumeration of UnitOfMeasurement. **Conditional;** required if either 'beginning_reference_post' or ending_reference_post' is not null.
g) **start_date.** The UTC time and date when the event begins. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
h) **end_date.** The UTC time and date when the event ends. All date-time formats shall follow RFC 3339 Section 5.6 Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
i) **is_start_date_verified.** Indicates whether the detour start has been confirmed by a person, field device, or traffic management center. **Required.**
j) **is_end_date_verified.** Indicates whether the detour end has been confirmed by a person, field device, or traffic management center. **Required.**

3.6.4 Contents of RoadEventCoreDetails

The RoadEventCoreDetails shall consist of the following mandatory and optional requirements:

a) **data_source_id.** Identifies the data source from which the road event originates. See Business Rule #4. **Required.**
b) **event_type.** The type/classification of road event. See 3.6.12 Enumeration of EventType. **Required.**
c) **related_road_events.** A list of related road events. Examples include but are not limited to the sequence along the roadway, recurring work zones, related detours, or other associated road events in a similar work area. See 3.6.6 Contents of RelatedRoadEvent. **Optional.**
d) **project_id.** An identifier for the project that the event is part of. A project is the highest-level representation of an area where road work takes place and may span multiple adjacent or intersecting roadways. A project will contain one or more RoadEventFeatures. This project ID does not correspond to an object in a WorkZoneFeed. It is used to group events (and devices, see FieldDeviceCoreDetails) and is a Universally Unique Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds and over time. **Optional.**
e) **road_names.** A list of publicly known names of the road on which the event occurs. This may include the road number designated by a jurisdiction such as a county, state, or interstate (e.g., I-5, VT 133). **Required.**
f) **direction.** The digitization direction of the road that is impacted by the event. This value is based on the standard naming for U.S. roadways and indicates the direction of the traffic flow regardless of the real heading angle. Example 'northbound' (for I-5 North). See 3.8 Direction Requirements. **Required.**
g) **name.** A human-readable name for the road event. **Optional.**
h) **description.** Short free text description of road event. **Optional.**
i) **creation_date.** The UTC time and date when the activity or event was created. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Optional.**
j) **update_date.** The UTC date and time when the RoadEventFeature (including child objects) that the RoadEventCoreDetails applies to was most recently updated or confirmed as up to date. All

date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Optional.**

3.6.5 Enumeration of LocationMethod

The LocationMethod Enumerated Type describes the typical method used to locate the beginning and end of a work zone impact area.
The following identifies the enumerations for LocationMethod:

- **channel-device-method.** Location of first and last channeling device (e.g., cone or barrier) that is part of a “travel impact effect” (taper) or designates a work zone transition area. *This is the preferred location method.*
- **sign-method.** Location of first and last work zone-related signs.
- **junction-method.** Location of a junction (e.g., a cross street or exit/entrance ramp) before and after a work zone.
- **other.** Location method does not match any of the other options.
- **unknown.** Location method is not known.

Additional Information
The following sections detail the usage of each location method.

- **channel-device-method** (Preferred Method)
  Location of first and last channeling device (e.g., cone or barrier) that is part of a “travel impact effect” (taper) or designates a work zone transition area. For complex work zones with multiple activities, beginning and end locations are the first channeling device for first activity up to the last channeling device of the last activity.

  - **Simple Scenario**
    This example shows one work zone area within a single work zone project. See Figure 5.

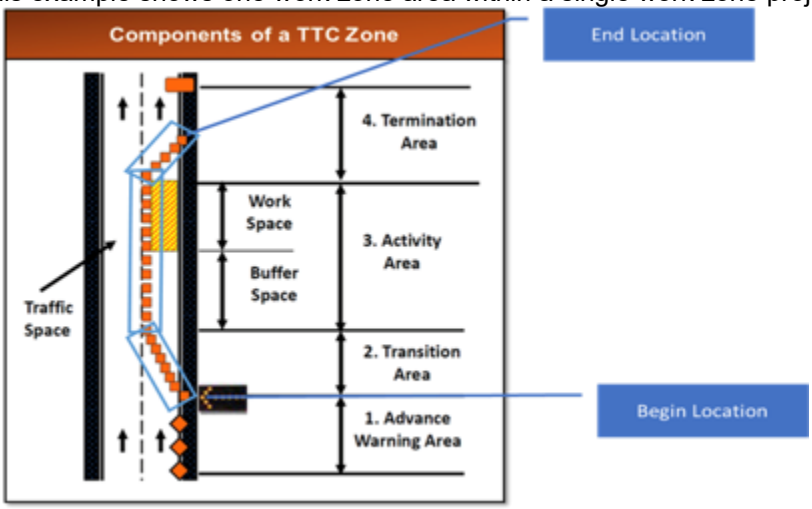


Figure 5. Simple Scenario

  - **Complex Scenario**
    This example shows three work zone activity areas within a single work zone project. Each activity area is treated as an independent work zone activity record, with its own beginning and end locations corresponding to where each lane taper begins and ends. See Figure 6.

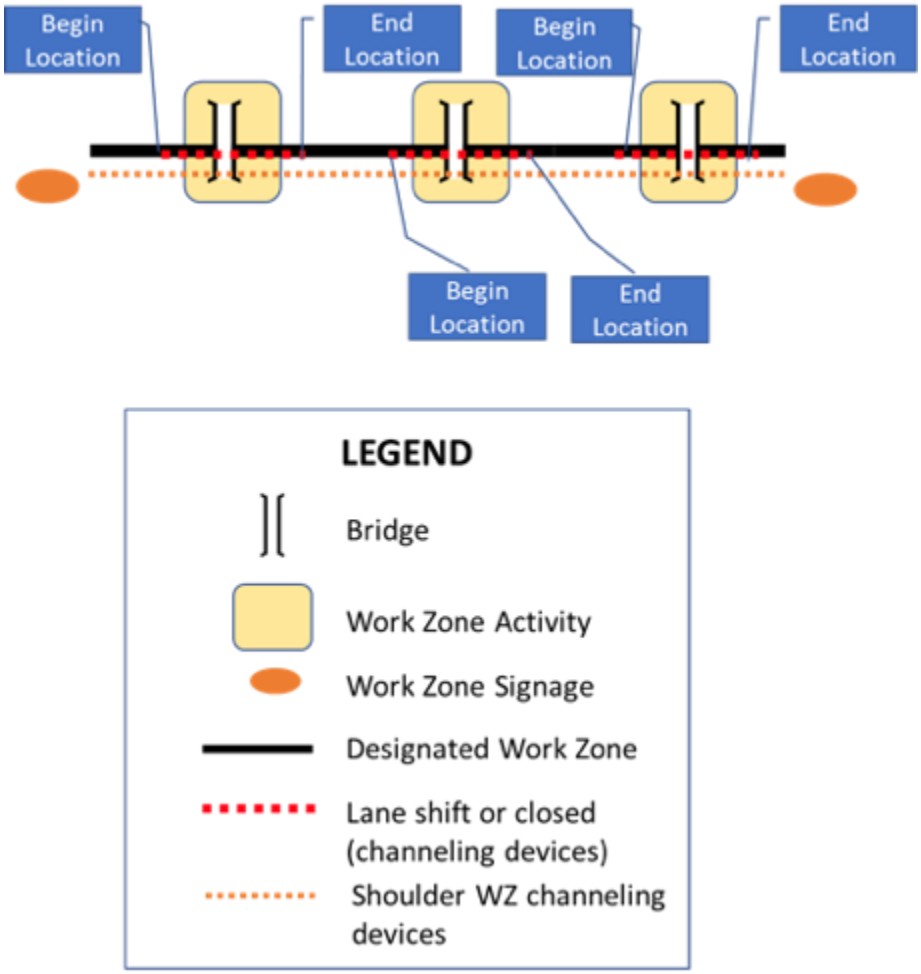


Figure 6. Complex Scenario

- **sign-method**
  Location of first and last work zone-related signs, which may differ from the channelization location. For complex work zones, the beginning location would be the first sign before the first activity, and the end would be the last sign following the last activity. See Figure 7.

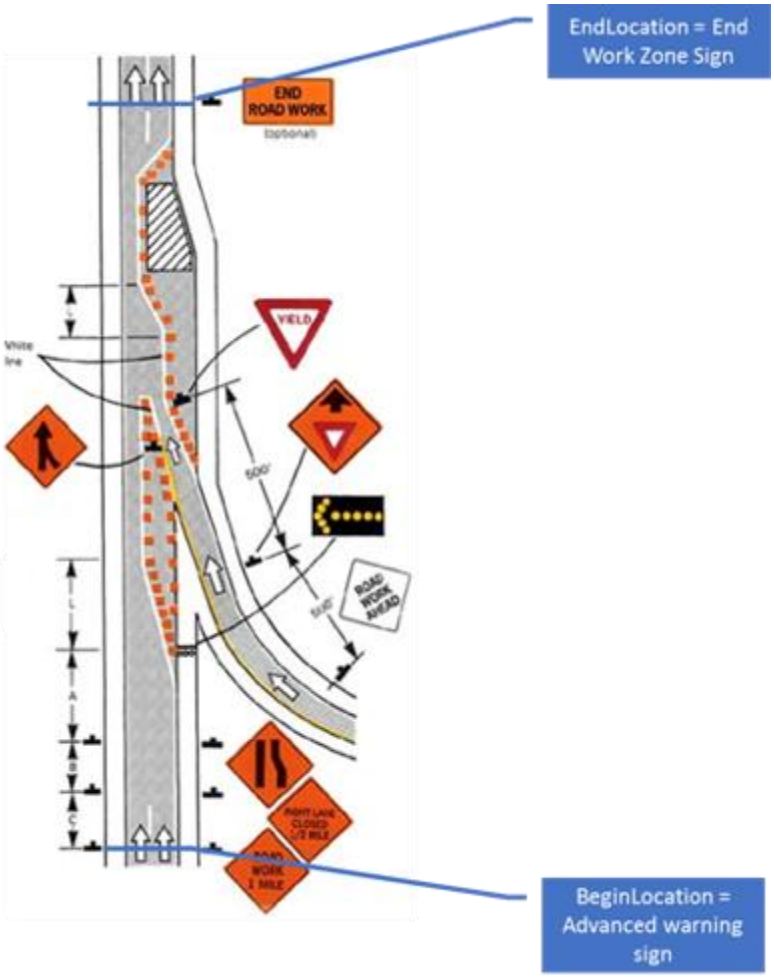


Figure 7. Sign Method

- **junction-method**
  Location of a Junction (e.g., a cross street or exit/entrance ramp) before and after a work zone. Note that this is similar to the approach used by Waze to designate a road closure event.

    - **Arterial Scenario**
      See Figure 8.

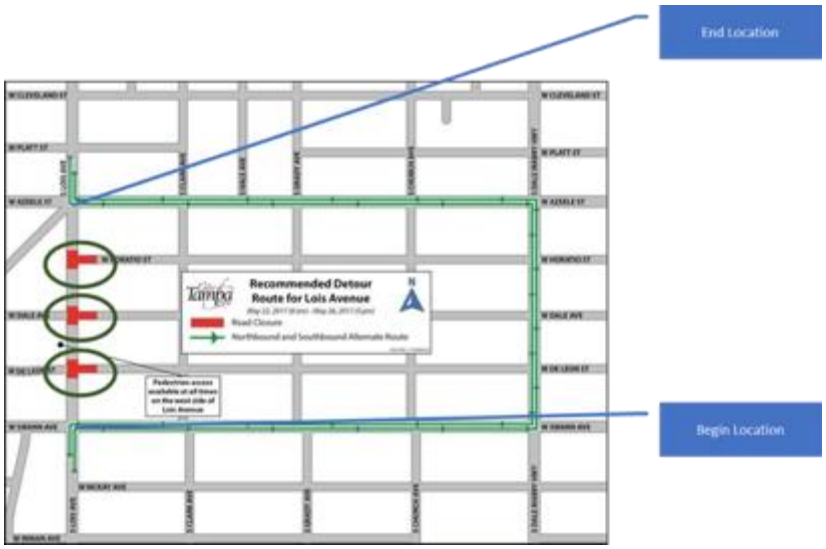


Figure 8. Arterial Scenario

- **Highway Scenario**
  See Figure 9.

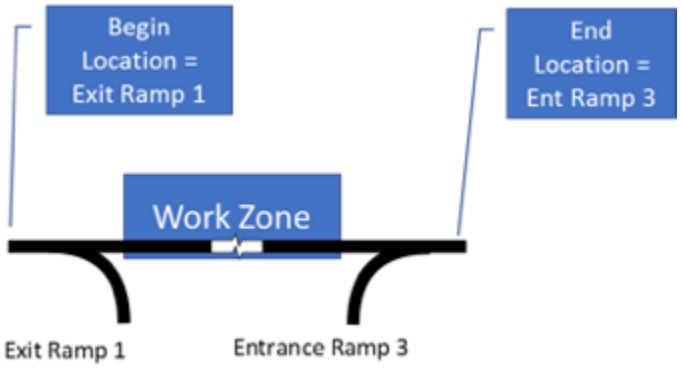


Figure 9. Highway Scenario

3.6.6 Contents of RelatedRoadEvent

The RelatedRoadEvent shall consist of the following requirements:

a) **type.** The type of relationship with the road event being identified, such as another sequence of related work zones, a detour, or the next road event in sequence. See 3.6.23 Enumeration of RelatedRoadEventType. **Required.**

b) **id.** An identifier for the related road event. The value must correspond to the 'id' of a RoadEventFeature within the same feed. **Required.**

3.6.7 Contents of TypeOfWork

The TypeOfWork shall consist of the following mandatory and optional requirements:

a) **type_name.** A high-level text description of the type of work being done. See 3.6.16 Enumeration of WorkTypeName. **Required.**

b) **is_architectural_change.** A flag indicating whether the type of work will result in an architectural change to the roadway. **Optional.**

3.6.8 Contents of Lane

The Lane shall consist of the following mandatory and optional requirements:

a) **order.** The position of a lane in sequence on the roadway. This value is an index indicating the order of all the lanes for a road event, starting with 1 for the left-most lane. See Business Rule #3. **Required.**
b) **status.** Status of the lane for the traveling public. See 3.6.17 Enumeration of LaneStatus. **Required.**
c) **type.** An indication of the type of lane or shoulder. See 3.6.18 Enumeration of LaneType. **Required.**
d) **restrictions.** A list of zero or more restrictions specific to the lane. See 3.6.9 Contents of Restriction. **Optional.**

3.6.9 Contents of Restriction

The Restriction shall consist of the following mandatory and optional requirements:

a) **type.** The type of restriction being enforced. See 3.6.15 Enumeration of RestrictionType. **Required.**
b) **value.** A value associated with the restriction, if applicable. For example, if 'type' is 'reduced-height', 'value' and 'unit' together would allow indicating what value the height was reduced to. **Optional.**
c) **unit.** Unit of measurement for the restriction 'value', if applicable. See 3.6.19 Enumeration of UnitOfMeasurement. **Conditional:** required if 'value' is not null.

3.6.10 Contents of CdsCurbZonesReference

The CdsCurbZonesReference shall consist of the following requirements. See OpenMobilityFoundation's Curb Data Specification at https://github.com/openmobilityfoundation/curb-data-specification.

a) **cds_curb_zone_ids.** A list of CDS Curb Zone 'ids'. **Required.**
b) **cds_curbs_api_url.** An identifier for the source of the requested CDS Curbs API. This MUST be a full HTTPS URL pointing to the main Curbs API that contains detailed information about each curb zone identified in 'cds_curb_zone_ids'. **Required.**

3.6.11 Contents of WorkerPresence

The WorkerPresence shall consist of the following mandatory and optional requirements:

a) **are_workers_present.** Indicates whether workers are present in the work zone event area. This value align with the definition provided in the 'definition' property if it is provided. **Required.**
b) **method.** how worker presence in a work zone event area is determined. See 3.6.20 Enumeration of WorkerPresenceMethod. **Optional.**
c) **worker_presence_last_confirmed_date.** The UTC date and time at which the presence of workers was last confirmed. All date-time formats shall follow RFC 3339 Section 5.6. See Business Rule #5. **Optional.**
d) **confidence.** The data producer's confidence in the value of 'are_workers_present'. See 3.6.22 Enumeration of WorkerPresenceConfidence. **Optional.**
e) **definition.** A list of situations in which workers are considered to be present in the jurisdiction of the data provider. See 3.6.21 Enumeration of WorkerPresenceDefinition. **Optional.**
f) **other_method.** Details the method used to determine worker presence in a work zone event area if the enumeration method is 'other'.. **Conditional;** required if 'method' enumeration is 'other'.

3.6.12 Enumeration of EventType

The EventType Enumerated Type describes the type of a WorkZoneFeed road event.
The following identifies the enumerations for EventType:

- **work-zone.** An area of a trafficway with highway construction, maintenance, or utility-work activities. A work zone is typically marked by signs, channeling devices, barriers, pavement markings, and/or work vehicles. It extends from the first warning sign or flashing lights on a vehicle to the "End of Road Work" sign or the last traffic control device. A work zone may vary in durations and may include stationary or moving activities.
  Inclusions:
  1. Long-term stationary highway construction such as building a new bridge, adding travel lanes to the roadway, and extending an existing trafficway.
  2. Mobile highway maintenance, such as striping the roadway median, roadside grass mowing/landscaping, and pothole repair.
  3. Short-term stationary utility work such as repairing electric, gas, or water lines within the trafficway.

  Exclusions:
  1. Private construction, maintenance, or utility work outside the trafficway.

  *The AASHTO term equivalent to “roadway” is “traveled way.”
  *The AASHTO term equivalent to “trafficway” is “highway, street, or road.”
  Source: https://www.fhwa.dot.gov/publications/publicroads/99mayjun/workzone.cfm
- **detour.** A temporary rerouting of road users onto an existing trafficway to avoid a work zone or other impedance
  Source: https://mutcd.fhwa.dot.gov/htm/2009/part6/part6c.htm

3.6.13 Enumeration of WorkZoneType

The WorkZoneType Enumerated Type describes the type of work zone road event.
The following identifies the enumerations for WorkZoneType:

- **static.** The road event statically placed - not moving.
- **moving.** The road event is actively moving on the roadway. As opposed to 'planned-moving-area', the road event geometry changes as the operation moves.
- **planned-moving-area.** The planned extent of a moving operation. The active work area will be somewhere within this road event. As opposed to 'moving', the road event geometry typically does not actively change.

3.6.14 Enumeration of VehicleImpact

The VehicleImpact Enumerated Type describes the impact to vehicular lanes along a single road in a single direction.
The following identifies the enumerations for VehicleImpact:

- **all-lanes-closed.** All lanes are closed
- **some-lanes-closed.** Some lanes are closed
- **all-lanes-open.** All lanes are open
- **alternating-one-way.** The roadway is alternating one way
- **some-lanes-closed-merge-left.** Some lanes merge to the left
- **some-lanes-closed-merge-right.** Some lanes merge to the right
- **all-lanes-open-shift-left.** All lanes are open, shift to the left
- **all-lanes-open-shift-right.** All lanes are open, shift to the right
- **some-lanes-closed-split.** Some lanes end and split and merge to the right and left
- **flagging.** A flagging operation is in effect
- **temporary-traffic-signal.** A temporary traffic signal is in operation
- **unknown.** The vehicle impact is unknown

3.6.15 Enumeration of RestrictionType

The RestrictionType Enumerated Type describes the type of vehicle restriction on a roadway.
The following identifies the enumerations for RestrictionType:

- **local-access-only.** Access is restricted to local addresses, emergency services, deliveries, and direct property access.
- **no-trucks.** Trucks are prohibited from traveling this part of the network.
- **travel-peak-hours-only.** Travel restricted to travel peak hours only.
- **hov-3.** Travel restricted to high occupancy vehicles of three or more.
- **hov-2.** Travel restricted to high occupancy vehicles of two or more.
- **no-parking.** No parking along the segment being described.
- **reduced-width.** Lane width is reduced along the segment being described.
- **reduced-height.** Height restrictions are reduced along the segment being described.
- **reduced-length.** Vehicle length restrictions are reduced along the segment being described.
- **reduced-weight.** Vehicle weight restrictions are reduced along the segment being described.
- **axle-load-limit.** Vehicle axle-load-limit restrictions are reduced along the segment being described.
- **gross-weight-limit.** Vehicle gross-weight-limit restrictions are reduced along the segment being described.
- **towing-prohibited.** Towing is prohibited along the segment being described.
- **permitted-oversize-loads-prohibited.** “Permitted oversize loads” prohibited along the segment being described; this applies to annual oversize load permits.
- **no-passing.** Crossing the center line markings for passing is prohibited.

3.6.16 Enumeration of WorkTypeName

The WorkTypeName Enumerated Type is a high-level text description of the type of work being done in a road event.
The following identifies the enumerations for WorkTypeName:

- **non-encroachment.** Work with no impact on the roadway, such as trash pickup, mowing, or landscaping.
- **minor-road-defect-repair.** Pothole repair, road crack repair and sealing, and other small road defect repairs.
- **roadside-work.** Work that is isolated to the side of the road and not in the main travel way, such as repair, replacement, or addition of streetlights, VMS, signs (guide, warning, regulatory, and information signs) in the ground.
- **overhead-work.** Work that occurs above the road, such as repair/replacement of overpasses, overhead VMS, wires, overhead signs, signals, etc. This type of work requires a bucket truck or similar setup rather than being isolated to the side of the road.
- **below-road-work.** Work occurring below the road such as boring or bridge repair.
- **barrier-work.** Repair, replacement, addition, or change of barriers, guardrails, retaining walls, K-barriers, or similar.
- **surface-work.** New resurfacing, such as adding new lanes, moving lanes, or adding or changing connectivity (turn lanes), as well as creation or repair of non-drivable surfaces such as the shoulder or median.
- **painting.** Repainting, re-striping, adding new lanes, moving lanes, adding stop bars/lines, etc. *Note: 'is_architectural_change' (See 3.6.7 b)) field should be false when new paint is expected to be within 1 meter of the old paint.*
- **roadway-relocation.** Physically relocating the road, such as adding a bridge or removing a sharp curve.

- **roadway-creation.** Adding a new road.

3.6.17 Enumeration of LaneStatus

The LaneStatus Enumerated Type describes the status of a lane for the traveling public.
The following identifies the enumerations for LaneStatus:

- **open.** The lane is open for normal usage
- **closed.** The lane is closed to normal usage
- **shift-left.** The lane shifts left from its current bearing and continues
- **shift-right.** The lane shifts right from its current bearing and continues
- **merge-left.** The lane gradually tapers while merging into the lane directly to the left
- **merge-right.** The lane gradually tapers while merging into the lane directly to the right
- **alternating-flow.** Traffic may travel in either direction, depending on certain conditions. Example conditions include time of day (e.g., reversible lanes), automated controls, or on-site personnel

3.6.18 Enumeration of LaneType

The LaneType Enumerated Type provides a description of the static properties of a section of the roadway, intended to reflect information about its function that is not covered by its status (see LaneStatus).
The following identifies the enumerations for LaneType:

- **general.** A generic lane type, intended to be used for general purpose travel lanes.
- **exit-lane.** A lane leading towards an egress from the current roadway. An 'exit-lane' usually becomes an 'exit-ramp' after a gore point.
- **exit-ramp.** A lane at an interchange leading away from the current roadway to another roadway.
- **entrance-lane.** A lane leading away from an ingress to the current roadway. An 'entrance-ramp' usually becomes an 'entrance-lane' after a gore point.
- **entrance-ramp.** A lane at an interchange for traffic to ingress from another roadway to the mainline.
- **sidewalk.** A path for pedestrians, usually on the side of the roadway.
- **bike-lane.** A lane on the roadway for use by cyclists only.
- **shoulder.** A portion of the roadway that is outside (either right or left) of the main travel lanes. A shoulder can have many uses but is not intended for general traffic.
- **parking.** A lane designated for parking that prohibits travel.
- **median.** An often unpaved, non-drivable area that separates sections of the roadway. In most cases a median should only be described if it separates lanes in a single direction of travel. As per Business Rule #1 each direction of travel must be represented by a separate road event.
- **two-way-center-turn-lane.** A lane in the center of a bidirectional roadway that traffic from both directions uses to make a turn that crosses the opposite direction of traffic (i.e., left in right-side driving countries, and right in left-side driving countries).

Additional Information
The LaneType enumerated type was originally based on the TMDD LaneRoadway Enumeration, which was imported into TMDD from SAE 2540 (ITIS Standard). In later release, other standards were examined for inspiration. These include SAE J2735 and the ISO 20524-1 Geographic Data Files (GDF) standard.

3.6.19 Enumeration of UnitOfMeasurement

The UnitOfMeasurement Enumerated Type indicates the unit of measurement. This enumerated type is intended for use across the specification and more values can be added in the future if needed.
The following identifies the enumerations for UnitOfMeasurement:

- **feet.** Imperial system 'feet'
- **inches.** Imperial system 'inches'
- **centimeters.** Metric system 'centimeters'

- **pounds.** Imperial system 'pounds'
- **tons.** Imperial system 'tons'
- **kilograms.** Metric system 'kilograms'
- **miles.** Imperial system 'miles'
- **kilometers.** Metric system 'kilometers'

3.6.20 Enumeration of WorkerPresenceMethod

The WorkerPresenceMethod Enumerated Type describes methods for determining worker presence in a work zone event area.

The following identifies the enumerations for WorkerPresenceMethod:

- **camera-monitoring.** Presence of workers is confirmed through cameras in the work zone event area.
- **maintenance-vehicle-present.** A GPS-enabled maintenance vehicle is located in the road event area.
- **wearables-present.** Workers wearing wearable detection equipment are present in the work zone.
- **mobile-device-present.** Workers with a GPS-enabled mobile device on their person are present in the work zone.
- **check-in-app.** Workers have checked into the work zone via a mobile app.
- **check-in-verbal.** Workers have checked into the work zone via phone or radio to a remote operations center.
- **other.** Worker presence determined through another method. Details in text field for WorkerPresence other_method.

3.6.21 Enumeration of WorkerPresenceDefinition

The WorkerPresenceDefinition Enumerated Type describes situations in which workers may be considered present in a work zone.
The following identifies the enumerations for WorkerPresenceDefinition:

- **workers-in-work-zone-working.** Humans are physically in the work zone event area, doing road work.
- **workers-in-work-zone-not-working.** Humans are physically in the work zone event area but not performing work.
- **mobile-equipment-in-work-zone-moving.** Mobile equipment is moving within the work zone event area, implying the presence of a worker.
- **mobile-equipment-in-work-zone-not-moving.** Mobile equipment is in the work zone event area but is not moving.
- **fixed-equipment-in-work-zone.** Fixed equipment is in the work zone event area.
- **humans-behind-barrier.** Humans are present in the work zone event area but separated from traffic by a barrier.
- **humans-in-right-of-way.** Humans are present on the drivable surface.

3.6.22 Enumeration of WorkerPresenceConfidence

The WorkerPresenceConfidence Enumerated Type is a high-level description of a feed publisher's confidence in the reported value of 'are_workers_present' on the WorkerPresence object.
The following identifies the enumerations for WorkerPresenceConfidence:

- **low.** Feed publisher is not confident in the reported value, such as when data is manually reported or not updated frequently.

- **medium.** Feed publisher is somewhat confident in the reported value, such as when the value is manually reported but is being updated in a timely manner, or when worker presence is indirectly inferred from other equipment like a smart arrow board.
- **high.** Feed publisher is very confident in the reported value, such as when automated systems with GPS locations are used to generate the value.

3.6.23 Enumeration of RelatedRoadEventType

The RelatedRoadEventType Enumerated Type describes the relationship between road events, and the road event that the RelatedRoadEvent object references. For example, it may indicate the first road event in a sequence of events along the roadway, an instance of a recurrent work zone, a nearby work zone-type road event, or a nearby detour-type road event.
In many cases, the related road event type only refers to the first road event, as the corresponding "work zone" may encompass multiple road events. In these situations, end users must identify the "first" road event and iterate through all linked road events to find all related road events.
The following identifies the enumerations for RelatedRoadEventType:

- **first-in-sequence.** The first road event in a sequence of road events that together describe a full work zone or detour
- **next-in-sequence.** The next (subsequent) road event in a sequence of road events that together describe a full work zone or detour
- **first-occurrence.** The first road event in the first occurrence in time of a recurrent work zone
- **next-occurrence.** The first road event in the next occurrence in time of a recurrent work zone
- **related-work-zone.** The first road event of related work zones (i.e., not part of a sequence of road events or recurrent work zone)
- **related-detour.** The first road event of related detours (i.e., not part of a sequence of road events)
- **planned-moving-operation.** The first road event of a related planned moving operation work zones (i.e., not part of a sequence of road events)
- **active-moving-operation.** The first road event of a related active moving operation work zones (i.e., not part of a sequence of road events)

3.7 DeviceFeed Requirements

The DeviceFeed includes the following data definitions, some of which are defined as optional.

3.7.1 Contents of DeviceFeed

The DeviceFeed shall consist of the following mandatory and optional requirements:

a) **feed_info.** Information about the data feed. This is a standard-specific foreign member and is not part of the GeoJSON specification. See 3.5 FeedInfo Requirements. **Required.**

b) **type.** The GeoJSON object type. For this standard, this must be the string 'FeatureCollection'. This is a GeoJSON property. **Required.**

c) **features.** An array of GeoJSON Feature objects which each represent a field device deployed in a work zone. This is a GeoJSON property. See 3.7.2 Contents of FieldDeviceFeature. **Required.**

d) **bbox.** Coordinate range for all 'FieldDeviceFeature's in the feed. The value must be an array of length '2n', where 'n' is the number of dimensions represented in the contained geometries, with all axes of the most southwesterly point followed by all axes of the more northeasterly point. The axes order of a 'bbox' follows the axes order of geometries. This is a GeoJSON property. See 3.9 BoundingBox Requirements. **Optional.**

3.7.2 Contents of FieldDeviceFeature

The FieldDeviceFeature shall consist of the following mandatory and optional requirements:

- **a) id.** A unique identifier issued by the data feed provider to identify the field device. This identifier is a Universally Unique Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds and over time. This is a GeoJSON property. **Required.**
- **b) type.** The GeoJSON object type. This MUST be the string 'Feature'. This is a GeoJSON property. **Required.**
- **c) properties.** The specific details of the field device. This is a GeoJSON property. See 3.7.3 FieldDeviceCoreDetails. **Required.**
- **d) geometry.** The geometry of the field device, indicating its location. The Geometry object's 'type' property MUST be Point (RFC 7946 Section 3.1.2). This is a GeoJSON property. **Required.**
- **e) bbox.** The coordinate range for this field device. Must be an array of length '2n', where 'n' is the number of dimensions represented in the 'geometry' property, with all axes of the most southwesterly point followed by all axes of the more northeasterly point. The axes order of a bbox follows the axes order of the 'geometry'. This is a GeoJSON property. See 3.9 BoundingBox Requirements. **Optional.**

3.7.3 Contents of FieldDeviceCoreDetails

The FieldDeviceCoreDetails shall consist of the following mandatory and optional requirements:

- **a) device_type**. The type of field device. See 3.7.17 Enumeration of FieldDeviceType. **Required**.
- **b) data_source_id**. Identifies the data source from which the field device data originates. **Required**.
- **c) device_status**. The operational status of the field device, indicating whether the device is functioning properly or is in an error or warning state. See 3.7.18 Enumeration of FieldDeviceStatus. **Required**.
- **d) update_date**. The UTC time and date when the field device information was last updated. **Required**.
- **e) has_automatic_location**. A yes/no value indicating if the field device location (parent FieldDeviceFeature's 'geometry') is determined automatically by an onboard GPS ('true') or manually set/overridden ('false'). **Required**.
- **f) road_direction**. The direction of the road that the field device is on. This value indicates the direction of the traffic flow of the road, not a real heading angle. See 3.8 Direction Requirements. **Optional**.
- **g) road_names**. A list of publicly known names of the road on which the device is located. This may include the road number designated by a jurisdiction such as a county, state, or interstate (e.g., I-5, VT 133). **Optional.**
- **h) name**. A human-readable name for the field device. **Optional.**
- **i) description**. A description of the field device. **Optional.**
- **j) status_messages**. A list of messages associated with the device's status, if applicable, providing additional information about the status such as specific warning or error messages. **Optional**. Note: The content of this property is determined by the producer.
- **k) is_moving**. A yes/no value indicating if the device is actively moving (not statically placed) as part of a mobile work zone operation. **Optional**. Note: The 'is_moving' property is optional and should not be provided if it is not known whether the device is moving.
- **l) road_event_ids**. A list of one or more IDs of a road event feature. See RoadEventFeature that the device is associated with. **Optional.**
- **m) project_id.** An identifier for the project associated with the device. A project is the highest-level representation of an area where road work takes place and may include multiple roadways if they are adjacent or intersecting. This project ID does not correspond to an object in a WorkZoneFeed. It is used to group devices (and events, see RoadEventCoreDetails). This identifier is a Universally Unique Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds and over time. **Optional.**
- **n) reference_post**. The linear distance measured against a reference post (such as a milepost marker) along the roadway where the device is located. **Optional.**

o) **reference_post_unit.** Unit of measurement for the FieldDeviceCoreDetails 'reference_post', if applicable. See 3.7.15 Enumeration of UnitOfMeasurement. **Conditional:** Required if 'reference_post' is not null.
p) **make**. The make or manufacturer of the device. **Optional.**
q) **model**. The model of the device. **Optional.**
r) **serial_number**. The serial number of the device. **Optional.**
s) **firmware_version**. The version of firmware the device is using to operate. **Optional.**
t) **velocity_kph**. The velocity of the device in kilometers per hour. **Optional.**
u) **is_in_transport_position.** A yes/no value indicating if the device is in the stowed/transport position ('true') or deployed/upright position ('false'). **Optional.**

3.7.4 Contents of ArrowBoard

The ArrowBoard shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all types of field devices, not specific to arrow boards. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **pattern.** The current pattern displayed on the arrow board. Note this includes 'blank', which indicates that no pattern is shown on the arrow board. See 3.7.16 Enumeration of ArrowBoardPattern. **Required.**

3.7.5 Contents of Camera

The Camera shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all types of field devices, not specific to cameras. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **image_url.** A URL pointing to an image file of the camera's current still image. **Optional.**
c) **is_image_url_public.** Identifies whether the image_url is publicly accessible. **Optional.**
d) **image_timestamp.** The UTC date and time when the image was captured. See Business Rule #5. **Conditional;** required if 'image_url' is provided.
e) **video_url.** A URL pointing to a video file for the camera video. **Optional.**
f) **is_video_url_public.** Identifies whether the video_url is publicly accessible. **Optional.**
g) **video_update_frequency.** The frequency at which the video feed is updated. A value of '-1' indicates that the video feed is not being updated (i.e., a video clip). A value of '0' indicates that the video feed is live. A positive integer value indicates that the video feed is being recorded on a loop where the value is the length of one loop in minutes. **Conditional:** Required if 'video_url' is not null.

3.7.6 Contents of DynamicMessageSign

The DynamicMessageSign shall consist of the following requirements:

a) **core_details.** The core details shared by all types of field devices, not specific to dynamic message signs. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **message_multi_string.** The MULTI-formatted string (Mark-Up Language for Transportation Information, see NTCIP 1203 v03) describing the message currently posted to the sign. If the message is unknown due to an error, the empty string ('') can be used. **Required.**

3.7.7 Contents of FlashingBeacon

The FlashingBeacon shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all types of field devices, not specific to flashing beacons. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **function.** Describes the function or purpose of the flashing beacon, i.e., i.e., what it is being used to indicate. See 3.7.19 Enumeration of FlashingBeaconFunction. **Required.**

c) **is_flashing.** A yes/no value indicating if the flashing beacon is currently in use and flashing. The 'is_flashing' property is optional and should not be provided if the producer does not know if the beacon is flashing (e.g., if it's in an error state). **Optional.**
d) **sign_text.** The message on the sign the beacon is mounted on. **Optional.**

3.7.8 Contents of HybridSign

The HybridSign shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all field device types, not specific to hybrid signs. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **dynamic_message_function.** The function the dynamic message displayed (e.g., a speed limit). See 3.7.20 Enumeration of HybridSignDynamicMessageFunction. **Required.**
c) **dynamic_message_text.** A text representation of the message currently posted to the electronic component of the hybrid sign. **Optional.**
d) **static_sign_text.** The static text on the non-electronic component of the hybrid sign. This property is currently optional, but it is advisable to provide it as it will be required in a future release. **Optional.**

3.7.9 Contents of LocationMarker

The LocationMarker shall consist of the following requirements:

a) **core_details.** The core details shared by all field device types, not specific to the location marker. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **marked_locations.** A list of locations that the 'LocationMarker' is marking. See 3.7.10 Contents of MarkedLocation. **Required.**

3.7.10 Contents of MarkedLocation

The MarkedLocation shall consist of the following mandatory and optional requirements:

a) **type.** The type of location (e.g., start or end) that is marked. See 3.7.21 Enumeration of MarkedLocationType. **Required.**
b) **road_event_id.** The ID of a RoadEventFeature that the 'MarkedLocation' applies to. This property is optional because the field device information producer may not have road event information. **Optional.**

3.7.11 Contents of TrafficSensor

The TrafficSensor shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details shared by all field device types, not specific to traffic sensors. This property appears on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **collection_interval_start_date.** The UTC date and time when the collection of 'TrafficSensor' data began.. The averages and totals contained in the 'TrafficSensor' data apply to the inclusive interval of 'collection_interval_start_date' to 'collection_interval_end_date'. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
c) **collection_interval_end_date.** The UTC date and time when the 'TrafficSensor' collection interval ended. The averages and totals contained in the 'TrafficSensor' data apply to the inclusive interval of 'collection_interval_start_date' to 'collection_interval_end_date'. All date-time formats shall follow RFC 3339 Section 5.6. Example: '2016-11-03T19:37:00Z'. See Business Rule #5. **Required.**
d) **average_speed_kph.** The average speed of vehicles across all lanes over the collection interval in kilometers per hour. **Optional.**
e) **volume_vph.** The rate of vehicles passing by the sensor during the collection interval, in vehicles per hour. **Optional**.

f) **occupancy_percent.** The percentage of time that the roadway section monitored by the sensor was occupied by a vehicle during the collection interval. **Optional.**
g) **lane_data.** A list of objects each describing traffic data for a specific lane. See 3.7.12 Contents of TrafficSensorLaneData. **Optional.**

3.7.12 Contents of TrafficSensorLaneData

The TrafficSensorLaneData shall consist of the following mandatory and optional requirements:

a) **lane_order.** The lane's position in sequence on the roadway. If 'road_event_id' is provided, the value of this property corresponds to the associated road event's Lane's 'order' property. See Business Rule #3. **Required.**
b) **road_event_id.** The ID of a RoadEventFeature that the measured lane is associated with, if applicable. **Optional.**
c) **average_speed_kph.** The average speed of traffic in the lane during the collection interval (in kilometers per hour). **Optional.**
d) **volume_vph.** The rate of vehicles passing by the sensor in the lane during the collection interval (in vehicles per hour). **Optional.**
e) **occupancy_percent.** The percentage of time the lane monitored by the sensor was occupied by a vehicle during the collection interval. **Optional.**

3.7.13 Contents of TrafficSignal

The TrafficSignal shall consist of the following requirements:

a) **core_details.** The core details of the traffic signal device. This property occurs on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **mode.** The current operating mode of the traffic signal. See 3.7.22 Enumeration of TrafficSignalMode. **Required.**

3.7.14 Contents of RoadsideUnit

The RoadsideUnit shall consist of the following mandatory and optional requirements:

a) **core_details.** The core details of the roadside unit. This property occurs on all field devices. See 3.7.3 Contents of FieldDeviceCoreDetails. **Required.**
b) **message_types.** An array of message types being broadcast by the roadside unit. See 3.7.23 Enumeration of RoadsideUnitMessageTypes. **Optional.**

3.7.15 Enumeration of UnitOfMeasurement

The UnitOfMeasurement Enumerated Type indicates the unit of measurement. This enumerated type is intended for use across the specification and more values can be added in the future if needed.
The following identifies the enumerations for UnitOfMeasurement:

- **feet.** Imperial system 'feet'
- **inches.** Imperial system 'inches'
- **centimeters.** Metric system 'centimeters'
- **pounds.** Imperial system 'pounds'
- **tons.** Imperial system 'tons'
- **kilograms.** Metric system 'kilograms'
- **miles.** Imperial system 'miles'
- **kilometers.** Metric system 'kilometers'

3.7.16 Enumeration of ArrowBoardPattern

The ArrowBoardPattern Enumerated Type defines a list of options for the posted pattern on an ArrowBoard.

If the arrow board pattern does not exactly match one of the values described, the closest pattern should be used.
The following identifies the enumerations for ArrowBoardPattern:

- **blank.** No pattern; the board is not displaying anything.
- **right-arrow-static.** Merge right represented by an arrow pattern (e.g., '-->') that does not flash or move.
- **right-arrow-flashing.** Merge right represented by an arrow pattern (e.g., '-->') that flashes on/off.
- **right-arrow-sequential.** Merge right represented by an arrow pattern (e.g., '-->') that is displayed in a progressing sequence (e.g., '>' '->' '-->' or '-' '--' '-->').
- **right-chevron-static.** Merge right represented by a pattern of chevrons (e.g., '>>>') that does not flash or move.
- **right-chevron-flashing.** Merge right represented by a pattern of chevrons (e.g., '>>>') that flashes on/off.
- **right-chevron-sequential.** Merge right represented by a pattern of chevrons that is displayed in a progressing sequence.
- **left-arrow-static.** Merge left represented by an arrow pattern (e.g., '<--') that does not flash or move.
- **left-arrow-flashing.** Merge left represented by an arrow pattern (e.g., '<--') that flashes on/off.
- **left-arrow-sequential.** Merge left represented by an arrow pattern (e.g., '<--') that is displayed in a progressing sequence (e.g., '<' '<-' '<--' or '-' '--' '<--').
- **left-chevron-static.** Merge left represented by a pattern of chevrons (e.g., '<<<') that does not flash or move.
- **left-chevron-flashing.** Merge left represented by a pattern of chevrons (e.g., '<<<') that flashes on/off.
- **left-chevron-sequential.** Merge left represented by a pattern of chevrons that is displayed in a progressing sequence.
- **bidirectional-arrow-static.** Split (merge left or right) represented by arrows pointing both left and right (e.g., '<-->') that does not flash or move.
- **bidirectional-arrow-flashing.** Split (merge left or right) represented by arrows pointing both left and right (e.g., '<-->') that flashes on/off.
- **line-flashing.** A flashing line or bar (e.g., '---'), indicating warning/caution, not a merge.
- **diamonds-alternating.** An alternating display of two diamond shapes (e.g., '◇ ◇'), indicating warning/caution, not a merge.
- **four-corners-flashing.** Four flashing dots on the corners of the board, indicating warning/caution, not a merge.
- **unknown.** The arrow board pattern is not known.

3.7.17 Enumeration of FieldDeviceType

The FieldDeviceType Enumerated Type enumerates all types of field devices described by the specification.
The following identifies the enumerations for FieldDeviceType:

- **arrow-board.** An electronic, connected arrow board which can display an arrow pattern to direct traffic. See ArrowBoard.
- **camera.** A camera device deployed in the field, capable of capturing still images. See Camera.
- **dynamic-message-sign.** An electronic traffic sign deployed on the roadway, used to provide information to travelers. See DynamicMessageSign.
- **flashing-beacon.** A flashing warning beacon used to supplement a temporary traffic control device. See FlashingBeacon.
- **hybrid-sign.** A message sign that contains both static text (e.g., on an aluminum board) along with a variable electronic message sign, used to provide information to travelers. See HybridSign.

- **location-marker.** Any GPS-enabled ITS device that is placed at a point on a roadway to mark a location (often the beginning or end of a road event). See LocationMarker.
- **traffic-sensor.** A device deployed on a roadway which captures traffic metrics such as speed, volume, and/or occupancy. See TrafficSensor.
- **traffic-signal.** A temporary traffic signal deployed on a roadway. See TrafficSignal.
- **roadside-unit.** A transceiver able to communicate with on-board units and other connected vehicle environment equipment.

3.7.18 Enumeration of FieldDeviceStatus

The FieldDeviceStatus enumerated type describes the operational status of a field device. The status indicates the health of the device.
The following identifies the enumerations for FieldDeviceStatus:

- **ok.** The device is turned on and working without issue.
- **warning.** The device is functional but has an impairment or issue that is not critical to its operation.
- **error.** The device is impaired such that it cannot perform one or more necessary functions.
- **unknown.** The device's operational status is not known.

3.7.19 Enumeration of FlashingBeaconFunction

The FlashingBeaconFunction Enumerated Type lists the purposes the FlashingBeacon is being used to indicate.
The following identifies the enumerations for FlashingBeaconFunction:

- **vehicle-entering.** Vehicles are entering the roadway.
- **queue-warning.** There is a queue of vehicles.
- **reduced-speed.** There is a reduced speed limit.
- **workers-present.** There are workers present on or near the roadway.
- **other.** The FlashingBeacon is being used to indicate something other than any of the other values.

3.7.20 Enumeration of HybridSignDynamicMessageFunction

The HybridSignDynamicMessageFunction Enumerated Type describes the purposes of the dynamic messages displayed by the electronic display on a HybridSign.
The following identifies the enumerations for HybridSignDynamicMessageFunction:

- **speed-limit.** The message is a speed limit.
- **travel-time.** The message is a travel time.
- **other.** The hybrid sign message function is not one of the other options described by this enumerated type.

3.7.21 Enumeration of MarkedLocationType

The MarkedLocationType enumerated type describes options that a MarkedLocation can indicate, such as the start or end of a work zone.
The following identifies the enumerations for MarkedLocationType:

- **afad.** An automatic flagger assistance device.
- **delineator.** A generic delineation point in a work zone. This value can be used for most types of marked locations that don't match any of the other values.
- **flagger.** A human who is directing traffic.
- **lane-shift.** A lane shift.

- **lane-closure.** One or more lanes are closed.
- **personal-device.** A connected device that is worn or carried by an individual worker in a work zone.
- **ramp-closure.** The start of a closed ramp onto or off a main road or highway.
- **road-closure.** The start of a closed road.
- **work-truck-with-lights-flashing.** A work truck with lights flashing, actively engaged in construction or maintenance activity on the roadway.
- **work-zone-start.** The start point of a work zone.
- **work-zone-end.** The end point of a work zone.
- **attenuator-vehicle.** A vehicle intended to reduce damage resulting from a collision.
- **construction-vehicle.** A vehicle used in the process of roadway construction.
- **maintenance-vehicle.** A vehicle used in the process of roadway maintenance.
- **emergency-vehicle.** A vehicle used in the process of public safety on roadways.
- **stalled-or-disabled-vehicle.** A stalled or disabled vehicle.
- **pavement-marking-vehicle.** A vehicle used for pavement marking.
- **other.**

3.7.22 Enumeration of TrafficSignalMode

The TrafficSignalMode Enumerated Type describes the current operating mode of a TrafficSignal.
The following identifies the enumerations for TrafficSignalMode:

- **blank.** The signal is not displaying anything.
- **flashing-red.** The signal is in a flashing red state that could be part of startup or fault.
- **flashing-yellow.** The signal is in a flashing yellow state that could be part of startup or fault.
- **fully-actuated.** The signal is using an external trigger for all movements.
- **manual.** The signal is using a manual trigger.
- **pre-timed.** The signal operates on a timed cycle.
- **semi-actuated.** The signal is using an external trigger only for minor movements.
- **unknown.** The current operating mode is not known.

3.7.23 Enumeration of RoadsideUnitMessageTypes

The RoadsideUnitMessageTypes Enumerated Type describes the message types being broadcast by a RoadsideUnit.
The following identifies the enumerations for RoadsideUnitMessageTypes:

- **rsm.** The RSU is broadcasting RSM messages.
- **tim.** The RSU is broadcasting TIM messages.
- **spat.** The RSU is broadcasting SPaT messages.
- **map.** The RSU is broadcasting MAP messages.
- **other.** The RSU is broadcasting messages other than the options listed.

3.8 Direction Requirements

The Direction includes the following data definition.

3.8.1 Enumeration of Direction

The Direction Enumerated Type describes the direction of a roadway. The values are based on the standard naming for U.S. roadways and indicate the direction of the traffic flow regardless of the real heading angle of the roadway.
The following identifies the enumerations for Direction:

- **northbound.** Road flow is in the northbound direction.

- **eastbound.** Road flow is in the eastbound direction.
- **southbound.** Road flow is in the southbound direction.
- **westbound.** Road flow is in the westbound direction.
- **inner-loop.** Road flow is on the inner loop of a ring road or beltway. In countries that drive on the right side of the road, this is the clockwise direction.
- **outer-loop.** Road flow is on the outer loop of a ring road or beltway. In countries that drive on the right side of the road, this is the counterclockwise direction.
- **undefined.** Road flow does not have a signed direction. For a RoadEventFeature, the first and last coordinates in the feature's geometry represent the beginning and end of the road event in the direction of travel it impacts.
- **unknown.** Road flow may have a signed direction, but the affected direction of travel is not known.

Additional Information
The 'Direction' enumerated type values were based on the TMDD Link-alignment Enumeration, which contains the following values:

- northbound (1)
- eastbound (2)
- southbound (3)
- westbound (4)
- inner-loop (5)
- outer-loop (6)

3.8.2 Reserved for Future Requirements

Reserved for future use.

3.9 BoundingBox Requirements

The BoundingBox includes the following data definition.

3.9.1 Contents of BoundingBox

See RFC 7946 Section 5.

3.9.2 Reserved for Future Requirements

Reserved for future use.

3.10 Protocol Requirements List (PRL)

The PRL described in this document maps the needs identified in Section 2 to the requirements defined in Section 3. The PRL can be used by the following:

- A user or specification writer to indicate which requirements are to be implemented in a project-specific deployment.
- The device manufacturer and user, as a detailed indication of the capabilities of the implementation.
- A user, as a basis for initially checking the potential interoperability with another implementation.
- A tester, as a checklist to compare against a specification and provide basis for test planning.

3.10.1 Notation [Informative]

The following notations and symbols are used to indicate status and conditional status in the PRL. Not all of these notations and symbols appear within this implementation guide.

3.10.1.1 Conformance Symbols

The symbols in

Table 2 are used to indicate status under the Conformance column in the PRL.

Table 2. Conformance Symbols

Symbol	Status
M	Mandatory
M.#	Support of every item of the group labeled by the same numeral # is required, but only one is active at a time
O	Optional
O.# (range)	Part of an option group. Support of the number of items indicated by the '(range)' is required from all options labeled with the same numeral #
C	Conditional
NA	Not-applicable (i.e., logically impossible in the scope of the standard)
X	Excluded or prohibited

The O.# (range) notation is used to show a set of selectable options. For example, O.2 (1..*) would indicate that one or more options from option group 2 must be implemented. Two-character combinations are used for dynamic requirements. In this context, the first character refers to the static (implementation) status, and the second refers to the dynamic (use); thus, "MO" means the requirement is "mandatory to implement, but optional to use."

3.10.1.2 Conditional Status Notation

The predicate notations in Table 3 may be used.

Table 3. Conditional Status Notation

Predicate	Notation
<predicate>:	This notation introduces a single item that is conditional on the <predicate>.
<predicate>::	This notation introduces a table or a group of tables, all of which are conditional on the <predicate>.
(predicate)	This notation introduces the first occurrence of the predicate. The feature associated with this notation is the base feature for all options that have this predicate in their conformance column.

The <predicate>: notation means that the status following it applies only when the PRL states that the feature or features identified by the predicate are supported. In the simplest case, <predicate> is the identifying tag of a single PRL item. The <predicate> notation may also precede a table or group of tables in a section or subsection. When the group predicate is true then the associated section shall be completed. The symbol <predicate> can also represent a Boolean expression composed of several indices. "AND," "OR," and "NOT" shall be used to indicate the Boolean logical operations.

The predicates used in this standard map to the sections indicated in Table 4.

Table 4. Predicate Mapping

Predicate	Section
RefPost	Mandatory if reference_post is selected: 3.6.2 f) 3.6.3 f)3.7.3 n)
WorkerMethod	Mandatory if value is selected: 3.6.11 b)
ResValue	Mandatory if value is selected: 3.6.9 c)
ImgURL	Mandatory if image_url is selected. 3.7.5 c)
VideoURL	Mandatory if video_url is selected. 3.7.5 e)

3.10.1.3 Support Column Symbols

The Support column in the PRL can be used by a procurement specification to identify the required features for the given procurement or by an implementer to identify which features have been implemented. In either case, the user circles the appropriate answer (Yes, No, or N/A) in the support column. When a user circles YES for an optional requirement, the requirement becomes mandatory for the procurement specification.

Table 5. Support Column Entries

Entry	Identifier
Yes	Supported by the implementation
No	Not supported by the implementation
N/A	Not applicable

3.10.2 Instructions for Completing the PRL [Informative]

In the 'Support' column, each response shall be selected either from the indicated set of responses (for example: Yes / No / NA), or it shall reference additional items that are to be attached (for example, a list of traffic signal controllers to be supported by an implementation). If a conditional requirement is inapplicable, use the Not Applicable (N/A) choice.

NOTE: A specification can allow for flexibility in a deliverable by leaving the selection in the Support column blank for a given row.

3.10.2.1 Conformance Definition

To claim "Conformance" to this standard and guide, deployers must fulfill at least the mandatory requirements identified in the PRL.

NOTE: The reader and user of this standard and guide is advised that 'conformance' should not be confused with 'compliance' to a specification. The CWZ Standard and Implementation Guide is as broad as possible to allow a very simple CWZ deployment to be 'conformant.' For agency use, the specification

writer should match project-specific requirements with the corresponding standardized requirements in this standard and guide to achieve interoperability. This means that requirements defined as 'optional' in the PRL might need to be made mandatory for specific project needs.

NOTE: Off-the-shelf interoperability and interchangeability can only be achieved through well-documented features broadly supported by the industry as a whole. Designing a system that uses features not defined in a standard or not typically deployed in combination with one another inhibits the goals of interoperability and interchangeability, especially if the documentation of these features is not available for system integrators. Standards allow the use of additional features to support innovation, which is constantly needed within the industry; but users should be aware of the risks of incorporating such features.

3.10.3 Protocol Requirements List Table

In addition to the Conformance and Support columns discussed in Sections 3.10.1.1 and 3.10.1.3, the PRL table contains columns for the Need ID, Need, Req ID, Requirements, Conformance, Support, and Additional Specifications. These are described as follows:

- **Need ID.** The number assigned to the user need statement. The needs are defined within Section 2 and the PRL is based upon the user needs within that Section.
- **Need.** A short descriptive title identifying the user need.
- **Req ID.** The number assigned to the requirement statement. The requirements are defined within Section 3, and the PRL traces the relationship between needs and the corresponding requirements.
- **Requirement.** A short descriptive title identifying the requirement.
- **Conformance.** Identifies whether the requirement is mandatory or optional and notes any conformance dependencies.
- **Support.** Used by specification developers to identify whether the requirement should be supported.
- **Additional Specifications.** Identifies other requirements to satisfy, including user-selectable range values. The "Additional Specifications" column may (and should) be used in procurement specifications to provide additional notes and requirements for the product to be procured or by an implementer to detail the implementation. In some cases, default text may already exist in this field and should be completed to fully specify the equipment. Additional text can be added to this field as needed to further detail a feature.

Table 6. Protocol Requirements List

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
2.5.1	**Architectural Needs**					
2.5.1.1	**Compatibility with the WZDx Specification**					
		3.2	**Architectural Requirements**			
		3.2.1	**Compatibility with the WZDx Specification**	M	Yes	
		3.2.2	**GeoJSON Data Format**	M	Yes	
		3.2.3	**GeoJSON Data Validation**	M	Yes	
		3.2.4	**Business Rules**	**M**	**Yes**	
		3.2.4.1	Event Segments Follow Lane Geometry Changes	M	Yes	
		3.2.4.2	WorkZoneRoadEvent Lanes	M	Yes	
		3.2.4.3	Lane Order	M	Yes	
		3.2.4.4	Data Source ID Referential Integrity	M	Yes	
		3.2.4.5	UTC Date-Time Format Specification	M	Yes	
		3.2.4.6	UUID Format Specification	M	Yes	
		3.5.1	**Contents of FeedInfo**			
		3.5.1 f)	version	M	Yes	
		3.3	**Data Exchange Requirements**			
		3.3.1	**Exchange WorkZoneFeed Information**			
		3.3.1.1	Send WorkZoneFeed Information Upon Request	M	Yes	
		3.3.2	**Exchange DeviceFeed Information**			
		3.3.2.1	Send DeviceFeed Information Upon Request	M	Yes	
		3.4	**WorkZoneFeed Requirements**			
		3.4.1	**Contents of WorkZoneFeed**			
		3.4.1 a)	feed_info	M	Yes	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.4.1 b)	type	M	Yes	
		3.4.1 c)	features	M	Yes	
		3.4.1 d)	bbox	O	Yes / No	
		3.5	**FeedInfo Requirements**			
		3.5.1	**Contents of FeedInfo**			
		3.5.1 a)	publisher	M	Yes	
		3.5.1 b)	contact_name	O	Yes / No	
		3.5.1 c)	contact_email	O	Yes / No	
		3.5.1 d)	update_frequency	O	Yes / No	
		3.5.1 e)	update_date	M	Yes	
		3.5.1 f)	version	M	Yes	
		3.5.1 g)	license	O	Yes / No	
		3.5.1 h)	data_sources	M	Yes	
		3.5.2	**Contents of FeedDataSource**			
		3.5.2 a)	data_source_id	M	Yes	
		3.5.2 b)	organization_name	M	Yes	
		3.5.2 c)	contact_name	O	Yes / No	
		3.5.2 d)	contact_email	O	Yes / No	
		3.5.2 e)	update_frequency	M	Yes	
		3.5.2 f)	update_date	M	Yes	
		3.6	**RoadEventFeature Requirements**			
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 a)	id	M	Yes	
		3.6.1 b)	type	M	Yes	
		3.6.1 c)	properties	M	Yes	
		3.6.1 d)	geometry	M	Yes	
		3.6.1 e)	bbox	O	Yes / No	
		3.6.2	**Contents of WorkZoneRoadEvent**			

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.2 a)	core_details	M	Yes	
		3.6.2 b)	beginning_cross_street	O	Yes / No	
		3.6.2 c)	ending_cross_street	O	Yes / No	
		3.6.2 d)	beginning_reference_post	O	Yes / No	
		3.6.2 e)	ending_reference_post	O	Yes / No	
		3.6.2 f)	reference_post_unit	RefPost:O	Yes / No	
		3.6.2 g)	is_start_position_verified	M	Yes	
		3.6.2 h)	is_end_position_verified	M	Yes	
		3.6.2 i)	start_date	M	Yes	
		3.6.2 j)	end_date	M	Yes	
		3.6.2 k)	is_start_date_verified	M	Yes	
		3.6.2 l)	is_end_date_verified	M	Yes	
		3.6.2 m)	work_zone_type	O	Yes / No	
		3.6.2 n)	vehicle_impact	M	Yes	
		3.6.2 o)	location_method	M	Yes	
		3.6.2 p)	worker_presence	O	Yes / No	
		3.6.2 q)	reduced_speed_limit_kph	O	Yes / No	
		3.6.2 r)	restrictions	O	Yes / No	
		3.6.2 s)	types_of_work	O	Yes / No	
		3.6.2 t)	lanes	O	Yes / No	
		3.6.2 u)	impacted_cds_curb_zones	O	Yes / No	
		3.6.3	**Contents of DetourRoadEvent**			
		3.6.3 a)	core_details	M	Yes	
		3.6.3 b)	beginning_cross_street	O	Yes / No	
		3.6.3 c)	ending_cross_street	O	Yes / No	
		3.6.3 d)	beginning_reference_post	O	Yes / No	
		3.6.3 e)	ending_reference_post	O	Yes / No	
		3.6.3 f)	reference_post_unit	RefPost:O	Yes / No	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.3 g)	start_date	M	Yes	
		3.6.3 h)	end_date	M	Yes	
		3.6.3 i)	is_start_date_verified	M	Yes	
		3.6.3 j)	is_end_date_verified	M	Yes	
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 a)	data_source_id	M	Yes	
		3.6.4 b)	event_type	M	Yes	
		3.6.4 c)	related_road_events	O	Yes / No	
		3.6.4 d)	road_names	M	Yes	
		3.6.4 e)	direction	M	Yes	
		3.6.4 f)	name	O	Yes / No	
		3.6.4 g)	description	O	Yes / No	
		3.6.4 h)	creation_date	O	Yes / No	
		3.6.4 i)	update_date	O	Yes / No	
		3.6.5	**Enumeration of LocationMethod**	**NA**		
		3.6.6	**Contents of RelatedRoadEvent**			
		3.6.6 a)	type	M	Yes	
		3.6.6 b)	id	M	Yes	
		3.6.7	**Contents of TypeOfWork**			
		3.6.7 a)	type_name	M	Yes	
		3.6.7 b)	is_architectural_change	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 b)	status	M	Yes	
		3.6.8 c)	type	M	Yes	
		3.6.8 e)	restrictions	O	Yes / No	
		3.6.9	**Contents of Restriction**			
		3.6.9 a)	type	M	Yes	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.9 b)	value	O	Yes / No	
		3.6.9 c)	unit	ResValue:O	Yes / No	
		3.6.10	**Contents of CdsCurbZonesReference**			
		3.6.10 a)	cds_curb_zone_ids	M	Yes	
		3.6.10 b)	cds_curbs_api_url	M	Yes	
		3.6.11	**Contents of WorkerPresence**			
		3.6.11 a)	are_workers_present	M	Yes	
		3.6.11 b)	method	O	Yes / No	
		3.6.11 c)	worker_presence_last_confirmed_date	O	Yes / No	
		3.6.11 d)	confidence	O	Yes / No	
		3.6.12	**Enumeration of EventType**	**NA**		
		3.6.13	**Enumeration of WorkZoneType**	**NA**		
		3.6.14	**Enumeration of VehicleImpact**	**NA**		
		3.6.15	**Enumeration of RestrictionType**	**NA**		
		3.6.16	**Enumeration of WorkTypeName**	**NA**		
		3.6.17	**Enumeration of LaneStatus**	**NA**		
		3.6.18	**Enumeration of LaneType**	**NA**		
		3.6.19	**Enumeration of UnitOfMeasurement**	**NA**		
		3.6.20	**Enumeration of WorkerPresenceMethod**	**NA**		
		3.6.21	**Enumeration of WorkerPresenceDefinition**	**NA**		
		3.6.22	**Enumeration of WorkerPresenceConfidence**	**NA**		
		3.6.23	**Enumeration of RelatedRoadEventType**	**NA**		
		3.7	**DeviceFeed Requirements**			
		3.7.1	**Contents of DeviceFeed**			
		3.7.1 a)	feed_info	M	Yes	
		3.7.1 b)	type	M	Yes	
		3.7.1 c)	features	M	Yes	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.7.1 d)	bbox	O	Yes / No	
		3.7.2	**Contents of FieldDeviceFeature**			
		3.7.2 a)	id	M	Yes	
		3.7.2 b)	type	M	Yes	
		3.7.2 c)	properties	M	Yes	
		3.7.2 d)	geometry	M	Yes	
		3.7.2 e)	bbox	O	Yes / No	
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 a)	device_type	M	Yes	
		3.7.3 b)	data_source_id	M	Yes	
		3.7.3 c)	device_status	M	Yes	
		3.7.3 d)	update_date	M	Yes	
		3.7.3 e)	has_automatic_location	M	Yes	
		3.7.3 f)	road_direction	O	Yes / No	
		3.7.3 g)	road_names	O	Yes / No	
		3.7.3 h)	name	O	Yes / No	
		3.7.3 i)	description	O	Yes / No	
		3.7.3 j)	status_messages	O	Yes / No	
		3.7.3 k)	is_moving	O	Yes / No	
		3.7.3 l)	road_event_ids	O	Yes / No	
		3.7.3 m)	reference_post	O	Yes / No	
		3.7.3 n)	reference_post_unit	RefPost:O	Yes / No	
		3.7.3 o)	make	O	Yes / No	
		3.7.3 p)	model	O	Yes / No	
		3.7.3 q)	serial_number	O	Yes / No	
		3.7.3 r)	firmware_version	O	Yes / No	
		3.7.3 s)	velocity_kph	O	Yes / No	
		3.7.3 t)	is_in_transport_position	O	Yes / No	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.7.4	**Contents of ArrowBoard**			
		3.7.4 a)	core_details	M	Yes	
		3.7.4 b)	pattern	M	Yes	
		3.7.5	**Contents of Camera**			
		3.7.5 a)	core_details	M	Yes	
		3.7.5 b)	image_url	O	Yes / No	
		3.7.5 c)	is_image_url_public	O	Yes / No	
		3.7.5 d)	image_timestamp	ImgURL:O	Yes / No	
		3.7.5 e)	video_url	O	Yes / No	
		3.7.5 f)	is_video_url_public	O	Yes / No	
		3.7.5 g)	video_update_frequency	VideoUrl:O	Yes / No	
		3.7.6	**Contents of DynamicMessageSign**			
		3.7.6 a)	core_details	M	Yes	
		3.7.6 b)	message_multi_string	M	Yes	
		3.7.7	**Contents of FlashingBeacon**			
		3.7.7 a)	core_details	M	Yes	
		3.7.7 b)	function	M	Yes	
		3.7.7 c)	is_flashing	O	Yes / No	
		3.7.7 d)	sign_text	O	Yes / No	
		3.7.8	**Contents of HybridSign**			
		3.7.8 a)	core_details	M	Yes	
		3.7.8 b)	dynamic_message_function	M	Yes	
		3.7.8 c)	dynamic_message_text	O	Yes / No	
		3.7.8 d)	static_sign_text	O	Yes / No	
		3.7.9	**Contents of LocationMarker**			
		3.7.9 a)	core_details	M	Yes	
		3.7.9 b)	marked_locations	M	Yes	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.7.10	**Contents of MarkedLocation**			
		3.7.10 a)	type	M	Yes	
		3.7.10 b)	road_event_id	O	Yes / No	
		3.7.11	**Contents of TrafficSensor**			
		3.7.11 a)	core_details	M	Yes	
		3.7.11 b)	collection_interval_start_date	M	Yes	
		3.7.11 c)	collection_interval_end_date	M	Yes	
		3.7.11 d)	average_speed_kph	O	Yes / No	
		3.7.11 e)	volume_vph	O	Yes / No	
		3.7.11 f)	occupancy_percent	O	Yes / No	
		3.7.11 g)	lane_data	O	Yes / No	
		3.7.12	**Contents of TrafficSensorLaneData**			
		3.7.12 a)	lane_order	M	Yes	
		3.7.12 b)	road_event_id	O	Yes / No	
		3.7.12 c)	average_speed_kph	O	Yes / No	
		3.7.12 d)	volume_vph	O	Yes / No	
		3.7.12 e)	occupancy_percent	O	Yes / No	
		3.7.13	**Contents of TrafficSignal**			
		3.7.13 a)	core_details	M	Yes	
		3.7.13 b)	mode	M	Yes	
		3.7.16	**Enumeration of ArrowBoardPattern**	**NA**		
		3.7.17	**Enumeration of FieldDeviceType**	**NA**		
		3.7.18	**Enumeration of FieldDeviceStatus**	**NA**		
		3.7.19	**Enumeration of FlashingBeaconFunction**	**NA**		
		3.7.20	**Enumeration of HybridSignDynamicMessageFunction**	**NA**		
		3.7.21	**Enumeration of MarkedLocationType**	**NA**		
		3.7.22	**Enumeration of TrafficSignalMode**	**NA**		

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.8	**Direction Requirements**			
		3.8.1	**Enumeration of Direction**	**NA**		
		3.9	**BoundingBox Requirements**			
		3.9.1	**Contents of BoundingBox**	**O**		
2.5.1.2	**GeoJSON Data Exchange**					
2.5.1.2.1	**Poll for Data**					
		3.3.1.1	Send WorkZoneFeed Information Upon Request	M	Yes	
		3.3.2.1	Send DeviceFeed Information Upon Request	M	Yes	
2.5.1.3	**GeoJSON Data Format**					
		3.2.3	**GeoJSON Data Format**	M	Yes	
2.5.1.4	**GeoJSON Data Validation**					
		3.2.4	**GeoJSON Data Validation**	M	Yes	
2.5.1.5	**Frequency of Updates**					
		3.5.2	**Contents of FeedDataSource**	M	Yes	
		3.5.2 e)	update_frequency	M	Yes	
		3.5.2 f)	update_date	M	Yes	
2.5.1.6	**UTC Date-Time Format Specification**					
		3.2.4.5	UTC Date-Time Format Specification	M	Yes	
2.5.2	**Data Exchange Needs**					
2.5.2.1	**Zone Metadata**					
2.5.2.1.1	Zone Data Standard Version					
		3.5.1	**Contents of FeedInfo**			
		3.5.1 f)	version	M	Yes	
2.5.2.1.2	Zone Identifier					

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
2.5.2.1.2.1	Support Zone Identifier for Zones					
		3.2.4.4	Data Source ID Referential Integrity	M	Yes	
		3.2.4.6	UUID Format Specification	M	Yes	
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 a)	id	M	Yes	
2.5.2.1.2.2	Support Unique Zone Identifiers					
		3.2.4.6	UUID Format Specification	M	Yes	
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 a)	id	M	Yes	
2.5.2.1.2.3	Support Unique Zone Group Identifiers					
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 c)	project_id	O	Yes / No	
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 m)	project_id	O	Yes / No	
2.5.2.1.2.4	Zone Identifier for VRUs, Devices, Work Zone Vehicles, Lanes, Speed Limit Zones					
		3.2.4.6	UUID Format Specification	M	Yes	
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 a)	id	M	Yes	
2.5.2.1.3	Zone Activity Type					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 s)	types_of_work	O	Yes / No	
2.5.2.1.4	Zone Data Timestamp					
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 h)	creation_date	O	Yes / No	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.4 i)	update_date	O	Yes / No	
2.5.2.1.5	Zone Data Source					
		3.2.4.4	Data Source ID Referential Integrity	M	Yes	
		3.5.1	**Contents of FeedInfo**			
		3.5.1 h)	data_sources	M	Yes	
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 a)	data_source_id	M	Yes	
2.5.2.2	**Zone Location**					
2.5.2.2.1	Zone Geometry					
		3.2.4.1	Event Segments Follow Attribute Changes	M	Yes	
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 d)	geometry	M	Yes	
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 g)	is_start_position_verified	M	Yes	
		3.6.2 h)	is_end_position_verified	M	Yes	
2.5.2.3	**Zone Schedule**					
2.5.2.3.1	Date Times					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 i)	start_date	M	Yes	
		3.6.2 j)	end_date	M	Yes	
		3.6.2 k)	is_start_date_verified	M	Yes	
		3.6.2 l)	is_end_date_verified	M	Yes	
2.5.2.4	**Zone Segmentation**					
2.5.2.4.1	Geometry					
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 c)	project_id	O	Yes / No	
		3.7.3	**Contents of FieldDeviceCoreDetails**			

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.7.3 m)	project_id	O	Yes / No	
2.5.2.4.2	Date Times					
		3.6.4	**Contents of RoadEventCoreDetails**			
		3.6.4 c)	project_id	O	Yes / No	
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 m)	project_id	O	Yes / No	
2.5.2.5	**Zone Status**					
2.5.2.5.1	Is Active					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 k)	is_start_date_verified	M	Yes	
		3.6.2 l)	is_end_date_verified	M	Yes	
2.5.2.5.2	Length					
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 d)	geometry	M	Yes	Calculated using coordinate information contained in the linestring
2.5.2.5.3	Number of Lanes Open					
		3.6.8	**Contents of Lane**			
		3.6.8 b)	status	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
2.5.2.5.4	Ad-hoc (Unscheduled/Unplanned)					
		3.6.14	**Enumeration of VehicleImpact**			
		3.6.15	**Enumeration of RestrictionType**			
2.5.2.5.5	Is Rolling/Moving					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 m)	work_zone_type	O	Yes / No	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.13	**Enumeration of WorkZoneType**			
2.5.2.6	**Zone Lanes**					
2.5.2.6.1	Numbering and Identification					
		3.2.4.2	WorkZoneRoadEvent Lanes	M	Yes	
2.5.2.6.1.1	Nationally Consistent Method of Lane Numbering					
		3.2.4.3	Lane Order	M	Yes	
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
2.5.2.6.1.2	Lane Numbering is Left-to-Right or Right-to-Left					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
2.5.2.6.2	Lane Type					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 c)	type	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
		3.6.18	**Enumeration of LaneType**			
2.5.2.6.2.1	Lane is Drivable					
		3.6.2	**Contents of WorkZoneRoadEvent**			

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 c)	type	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
		3.6.18	**Enumeration of LaneType**			
2.5.2.6.2.2	Special Use Lane					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 c)	type	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
		3.6.18	**Enumeration of LaneType**			
2.5.2.6.2.3	Reversible Lane					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 c)	type	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
		3.6.18	**Enumeration of LaneType**			
2.5.2.6.3	CVE Roadside Safety Applications					
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 d)	geometry	M	Yes	
		3.7.14	**Contents of RoadsideUnit**			
		3.7.14 b)	message_types	O	Yes / No	
2.5.2.6.4	Lane Tapers					

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
		3.2.4.1	Event Segments Follow Lane Geometry Changes	M	Yes	
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 n)	vehicle_impact	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
2.5.2.6.5	Lane Closure Status					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 t)	lanes	O	Yes / No	
		3.6.8	**Contents of Lane**			
		3.6.8 a)	order	M	Yes	
		3.6.8 b)	status	M	Yes	
		3.6.17	**Enumeration of LaneStatus**			
2.5.2.7	**Zone Speed Limit**					
2.5.2.7.1	Position/Geometry					
		3.6.1	**Contents of RoadEventFeature**			
		3.6.1 d)	geometry	M	Yes	
2.5.2.7.2	Speed Limit Change					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 q)	reduced_speed_limit_kph	O	Yes / No	
2.5.2.8	**Zone Traffic Data**					
2.5.2.8.1	Speed, Volume, and Occupancy					
		3.7.11	**Contents of Traffic Sensor**			
		3.7.11 d)	average_speed_kph	O	Yes / No	
		3.7.11 e)	volume_vph	O	Yes / No	
		3.7.11 f)	occupancy_percent	O	Yes / No	
2.5.2.8.2	Queue Warning					
		3.7.17	**Enumeration of FlashingBeaconFunction**			

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
2.5.2.9	**Zone Device**					
2.5.2.9.1	Inventory and Status					
		3.7.2	**Contents of FieldDeviceFeature**			
		3.7.2 d)	geometry	M	Yes	
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 a)	device_type	M	Yes	
		3.7.3 c)	device_status	M	Yes	
		3.7.3 l)	road_event_ids	O	Yes / No	
		3.7.17	**Enumeration of FieldDeviceType**			
		3.7.18	**Enumeration of FieldDeviceStatus**			
		3.7.21	**Enumeration of MarkedLocationType**			
2.5.2.9.2	Location Marker Type					
		3.7.21	**Enumeration of MarkedLocationType**			
2.5.2.9.3	Device Type					
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 a)	device_type	M	Yes	
		3.7.17	**Enumeration of FieldDeviceType**			
2.5.2.9.4	Position/Geometry					
		3.7.2	**Contents of FieldDeviceFeature**			
		3.7.2 d)	geometry	M	Yes	
2.5.2.9.5	Device Status					
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 c)	device_status	M	Yes	
		3.7.18	**Enumeration of FieldDeviceStatus**			
2.5.2.9.6	Zone Identifier					
		3.7.3	**Contents of FieldDeviceCoreDetails**			
		3.7.3 l)	road_event_ids	O	Yes / No	

PROTOCOL REQUIREMENTS LIST						
Need ID	**Need**	**Req ID**	**Requirement**	**Conformance**	**Support**	**Additional Specifications**
2.5.2.10	**Zone VRU Device**					
2.5.2.10.1	Worker Presence Status/Activity					
		3.6.2	**Contents of WorkZoneRoadEvent**			
		3.6.2 o)	worker_presence	O	Yes / No	
		3.6.11	**Contents of WorkerPresence**			
		3.6.11 a)	are_workers_present	M	Yes	
		3.6.11 b)	method	O	Yes / No	
		3.6.11 c)	worker_presence_last_confirmed_date	O	Yes / No	
		3.6.11 d)	confidence	O	Yes / No	
		3.6.11 e)	definition	O	Yes / No	
		3.6.11 f)	other_method	WorkerMethod:O	Yes / No	
2.5.2.10.2	VRU Position/Geometry					
		3.7.2	**Contents of FieldDeviceFeature**			
		3.7.2 d)	Geometry	M	Yes	
		3.7.21	**Enumeration of MarkedLocationType**			
2.5.2.11	**Zone Work Vehicle Device**					
2.5.2.11.1	Vehicle Type					
		3.7.21	**Enumeration of MarkedLocationType**			
2.5.2.11.2	Vehicle Position					
		3.7.2	**Contents of FieldDeviceFeature**			
		3.7.2 d)	geometry	M	Yes	
		3.7.21	**Enumeration of MarkedLocationType**			

Section 4
System Interface Design Details: Data Exchange Dialogs

4.1 Introduction [Informative]

This section specifies the data exchange dialogs to be used with this standard.

4.2 Poll for Data Dialog

The Poll for Data Dialog is an HTTP-based mechanism used to transfer work zone information across a system interface. The subsections below enumerate the referenced standards and role of the standard specified for the Poll for Data Dialog.

4.2.1 GeoJSON Format – Geospatial Data Interchange Format based on JSON

The IETF RFC 7946 The GeoJSON Format is a normative reference of this standard.

The IETF RFC 7946 abstract contains the following definition.

> "GeoJSON is a geospatial data interchange format based on JavaScript Object Notation (JSON). It defines several types of JSON objects and the manner in which they are combined to represent data about geographic features, their properties, and their spatial extents. GeoJSON uses a geographic coordinate reference system, World Geodetic System 1984, and units of decimal degrees."

GeoJSON is the data format for the Work Zone Feed and Device Feed.

4.2.2 JSON - JavaScript Object Notation

The IETF RFC 8259 The JavaScript Object Notation (JSON) Data Interchange Format, also known as ISO/IEC 21778:2017 is a normative reference of this standard.

The IETF RFC 8259 abstract contains the following definition.

> "JavaScript Object Notation (JSON) is a lightweight, text-based, language-independent data interchange format. It was derived from the ECMAScript Programming Language Standard. JSON defines a small set of formatting rules for the portable representation of structured data.

The Work Zone Feed and Device Feed data are in JSON format and can be validated with a JSON Schema.

4.2.3 HTTP - HyperText Transfer Protocol

The IETF RFC 9110 HTTP Semantics is a normative reference of this standard. The IETF RFC 9110 HTTP outlines requirements and design principles, including the use of HTTP over TLS, a type of secure messaging protocol.

The IETF RFC 9110 abstract contains the following definition.

> "The Hypertext Transfer Protocol (HTTP) is a stateless application-level protocol for distributed, collaborative, hypertext information systems. This document describes the overall architecture of HTTP, establishes common terminology, and defines aspects of the protocol that are shared by all versions. In this definition are core protocol elements, extensibility mechanisms, and the "http" and "https" Uniform Resource Identifier (URI) schemes.

HTTP is used to securely transmit Work Zone Feed and Device Feed data between two systems.

4.2.4 URI – Uniform Resource Identifier

The IETF RFC 3986 Uniform Resource Identifier (URI): Generic Syntax is a normative reference of this standard.

The IETF RFC 3986 abstract contains the following definition.

> "A Uniform Resource Identifier (URI) is a compact sequence of characters that identifies an abstract or physical resource. This specification defines the generic URI syntax and a process for resolving URI references that might be in relative form, along with guidelines and security considerations for the use of URIs on the Internet. The URI syntax defines a grammar that is a superset of all valid URIs, allowing an implementation to parse the common components of a URI reference without knowing the scheme-specific requirements of every possible identifier. This specification does not define a generative grammar for URIs; that task is performed by the individual specifications of each URI scheme.

As described in Section 2.7.3 Operational Policies and Constraints – Uniform Resource Identifiers, each feed provider defines their own URI based on their operational policies. It is the expectation of this standard that the URI defined by a data feed provider conforms with IETF RFC 3986.

Section 5
System Interface Design Details: Data Concepts

5.1 Introduction [Informative]

This section specifies the Work Zone and Device Feed JSON Schemas.

5.2 WorkZoneFeed Schema

```
{
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/WorkZoneFeed.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "CWZ v1.0 Work Zone Feed",
  "description": "The GeoJSON output of a CWZ Work Zone Feed v1.0.",
  "type": "object",
  "required": ["feed_info", "type", "features"],
```

5.2.1 Properties

```
  "properties": {
```

5.2.1.1 feed_info

```
    "feed_info": {
      "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/FeedInfo.json"
    },
```

5.2.1.2 type

```
    "type": {
      "description": "The GeoJSON type.",
      "enum": ["FeatureCollection"]
    },
```

5.2.1.3 features

```
    "features": {
      "description": "An array of GeoJSON Feature objects which represent CWZ
road events.",
      "type": "array",
      "items": {
        "allOf": [
          {
            "properties": {
              "properties": {
                "properties": {
```

```
                "core_details": {
                  "properties": {
                    "event_type": {
                      "enum": ["work-zone", "detour"]
                    }
                  },
                  "required": ["event_type"]
                }
              },
              "required": ["core_details"]
            }
          },
          "required": ["properties"]
        },
        {
          "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/RoadEventFeature.json"
        }
      ]
    }
  },
```

5.2.1.4 bbox

```
  "bbox": {
    "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/BoundingBox.json"
  }
 }
}
```

5.3 FeedInfo Schema

```
{
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/FeedInfo.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "CWZ Feed Information",
  "description": "Describes CWZ feed header information such as metadata, contact
information, and data sources.",
  "type": "object",
  "required": [
    "publisher",
    "update_frequency",
    "update_date",
    "version",
    "license",
    "data_sources"
```

```
  ],
```

5.3.1 Properties

```
  "properties": {
```

5.3.1.1 publisher

```
    "publisher": {
      "description": "The organization responsible for publishing the feed.",
      "type": "string"
    },
```

5.3.1.2 contact_name

```
    "contact_name": {
      "description": "The name of the individual or group responsible for the
data feed.",
      "type": "string"
    },
```

5.3.1.3 contact_email

```
    "contact_email": {
      "description": "The email address of the individual or group responsible
for the data feed.",
      "type": "string",
      "format": "email"
    },
```

5.3.1.4 update_frequency

```
    "update_frequency": {
      "description": "The frequency in seconds at which the data feed is
updated.",
      "type": "integer",
      "minimum": -1
    },
```

5.3.1.5 update_date

```
    "update_date": {
      "description": "The UTC date and time when the GeoJSON file (representing
the instance of the feed) was generated.",
      "type": "string",
      "format": "date-time"
    },
```

5.3.1.6 version

```
    "version": {
      "description": "The CWZ specification version used to create the data feed,
in 'major.minor' format.",
      "type": "string",
```

```
      "pattern": "^(0|[1-9][0-9]*)\\.(0|[1-9][0-9]*)$"
    },
```

5.3.1.7 license

```
    "license": {
      "description": "The URL of the license that applies to the data in the CWZ
feed. This *must* be the string
\"https://creativecommons.org/publicdomain/zero/1.0/\".",
      "enum": [
        "https://creativecommons.org/publicdomain/zero/1.0/"
      ]
    },
```

5.3.1.8 data_sources

```
    "data_sources": {
      "description": "A list of specific data sources for the road event data in
the feed.",
      "type": "array",
      "items": {
        "$ref": "#/definitions/FeedDataSource"
      },
      "minItems": 1
    }
  },
```

5.3.2 Definitions

```
  "definitions": {
```

5.3.2.1 FeedDataSource

```
    "FeedDataSource": {
      "title": "CWZ Feed Data Source",
      "description": "Describes information about a specific data source used to
build the work zone data feed.",
      "type": "object",
      "required": [
        "data_source_id",
        "organization_name",
        "update_frequency",
        "update_date"
      ],
      "properties": {
```

5.3.2.1.1 data_source_id

```
        "data_source_id": {
          "description": "Unique identifier for the organization providing work
zone data. This identifier is a Universally Unique Identifier (UUID) as defined
in [RFC 4122](https://datatracker.ietf.org/doc/html/rfc4122).",
```

```
          "type": "string"
        },
```

5.3.2.1.2 organization_name

```
        "organization_name": {
          "description": "The name of the organization for the authoritative
source of the work zone data.",
          "type": "string"
        },
```

5.3.2.1.3 contact_name

```
        "contact_name": {
          "description": "The name of the individual or group responsible for the
data source.",
          "type": "string"
        },
```

5.3.2.1.4 contact_email

```
        "contact_email": {
          "description": "The email address of the individual or group
responsible for the data source.",
          "type": "string",
          "format": "email"
        },
```

5.3.2.1.5 update_frequency

```
        "update_frequency": {
          "description": "The frequency in seconds at which the data source is
updated.",
          "type": "integer",
          "minimum": -1
        },
```

5.3.2.1.6 update_date

```
        "update_date": {
          "description": "The UTC date and time when the data source was last
updated.",
          "type": "string",
          "format": "date-time"
        }
      }
    }
  }
}
```

5.4 RoadEventFeature Schema

```
{
```

```
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/RoadEventFeature.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "Road Event Feature (GeoJSON Feature)",
  "description": "The container object for a specific CWZ road event; an instance
of a GeoJSON Feature.",
  "type": "object",
  "required": ["id","type","properties","geometry"],
```

5.4.1 Properties

```
  "properties": {
```

5.4.1.1 id

```
    "id": {
      "description": "A unique identifier issued by the data feed provider to
identify the CWZ road event. This identifier is a Universally Unique Identifier
(UUID) as defined in [RFC 4122](https://datatracker.ietf.org/doc/html/rfc4122).",
      "type": "string"
    },
```

5.4.1.2 type

```
    "type": {
      "description": "The GeoJSON object type; must be 'Feature'.",
      "enum": ["Feature"]
    },
```

5.4.1.3 properties

```
    "properties": {
      "type": "object",
      "properties": {
        "core_details": {
          "$ref": "#/definitions/RoadEventCoreDetails"
        }
      },
      "required": ["core_details"],
      "oneOf": [
        {
          "$ref": "#/definitions/WorkZoneRoadEvent"
        },
        {
          "$ref": "#/definitions/DetourRoadEvent"
        }
      ]
    },
```

5.4.1.4 geometry

```
    "geometry": {
```

```
      "oneOf": [
        {
          "$ref": "https://geojson.org/schema/LineString.json"
        },
        {
          "$ref": "https://geojson.org/schema/Point.json"
        }
      ]
    },
```

5.4.1.5 bbox

```
    "bbox": {
      "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/BoundingBox.json"
    }
  },
```

5.4.2 Definitions

```
  "definitions": {
```

5.4.2.1 WorkZoneRoadEvent

```
    "WorkZoneRoadEvent": {
      "title": "Work Zone Road Event",
      "description": "Describes a work zone road event including where, when, and
what activities are taking place within a work zone on a roadway.",
      "type": "object",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "event_type": {
                  "const": "work-zone"
                }
              },
              "required": ["event_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "is_start_position_verified",
            "is_end_position_verified",
            "start_date",
```

```
            "end_date",
            "is_start_date_verified",
            "is_end_date_verified",
            "vehicle_impact",
            "location_method"
          ],
          "dependencies": {
            "beginning_reference_post": ["reference_post_unit"],
            "ending_reference_post": ["reference_post_unit"]
          },
          "properties": {
```

5.4.2.1.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/RoadEventCoreDetails"
            },
```

5.4.2.1.2 beginning_cross_street

```
            "beginning_cross_street": {
              "description": "Name or number of the nearest cross street along
the roadway where the event begins.",
              "type": "string"
            },
```

5.4.2.1.3 ending_cross_street

```
            "ending_cross_street": {
              "description": "Name or number of the nearest cross street along
the roadway where the event ends.",
              "type": "string"
            },
```

5.4.2.1.4 beginning_reference_post

```
            "beginning_reference_post": {
              "description": "The linear distance measured against a reference
post marker along a roadway where the event begins.",
              "type": "number",
              "minimum": 0
            },
```

5.4.2.1.5 ending_reference_post

```
            "ending_reference_post": {
              "description": "The linear distance measured against a reference
post marker along a roadway where the event ends.",
              "type": "number",
              "minimum": 0
            },
```

5.4.2.1.6 reference_post_unit

```
            "reference_post_unit ": {
              "description": "The unit used for reference post.",
              "$ref": "#/definitions/UnitOfMeasurement"
            },
```

5.4.2.1.7 is_start_position_verified

```
            "is_start_position_verified": {
              "description": "Indicates if the start position (first geometric
coordinate pair) is based on actual reported data from a GPS-equipped device that
measured the location of the start of the work zone.",
              "type": "boolean"
            },
```

5.4.2.1.8 is_end_position_verified

```
            "is_end_position_verified": {
              "description": "Indicates if the end position (last geometric
coordinate pair) is based on actual reported data from a GPS-equipped device that
measured the location of the end of the work zone.",
              "type": "boolean"
            },
```

5.4.2.1.9 start_date

```
            "start_date": {
              "description": "The UTC date and time (formatted according to RFC
3339, Section 5.6) when the road event begins (e.g., 2020-11-03T19:37:00Z).",
              "type": "string",
              "format": "date-time"
            },
```

5.4.2.1.10 end_date

```
            "end_date": {
              "description": "The UTC date and time (formatted according to RFC
3339, Section 5.6) when the road event ends (e.g., 2020-11-03T19:37:00Z).",
              "type": "string",
              "format": "date-time"
            },
```

5.4.2.1.11 is_start_date_verified

```
            "is_start_date_verified": {
              "description": "Indicates if work has been confirmed to have
started, such as from a person or field device.",
              "type": "boolean"
            },
```

5.4.2.1.12 is_end_date_verified

```
            "is_end_date_verified": {
```

```
            "description": "Indicates if work has been confirmed to have ended,
such as from a person or field device.",
            "type": "boolean"
          },
```

5.4.2.1.13 work_zone_type

```
          "work_zone_type": {
            "description": "The type of work zone road event.",
            "$ref": "#/definitions/WorkZoneType"
          },
```

5.4.2.1.14 vehicle_impact

```
          "vehicle_impact": {
            "$ref": "#/definitions/VehicleImpact"
          },
```

5.4.2.1.15 location_method

```
          "location_method": {
            "$ref": "#/definitions/LocationMethod"
          },
```

5.4.2.1.16 worker_presence

```
          "worker_presence": {
            "$ref": "#/definitions/WorkerPresence"
          },
```

5.4.2.1.17 reduced_speed_limit_kph

```
          "reduced_speed_limit_kph": {
            "description": "If applicable, the reduced speed limit posted
within the road event, in kilometers per hour.",
            "type": "number",
            "minimum": 0
          },
```

5.4.2.1.18 restrictions

```
          "restrictions": {
            "description": "A list of zero or more restrictions applying to the
road event.",
            "type": "array",
            "items": {
              "$ref": "#/definitions/Restriction"
            }
          },
```

5.4.2.1.19 types_of_work

```
          "types_of_work": {
```

```
              "description": "A list of the types of work being done in a road
event.",
              "type": "array",
              "items": {
                "$ref": "#/definitions/TypeOfWork"
              }
            },
```

5.4.2.1.20 lanes

```
            "lanes": {
              "description": "A list of individual lanes within a road event
(roadway segment).",
              "type": "array",
              "items": {
                "$ref": "#/definitions/Lane"
              }
            },
```

5.4.2.1.21 impacted_cds_curb_zones

```
            "impacted_cds_curb_zones": {
               "description": "A list of references to external CDS Curb Zones
impacted by the work zone.",
               "type": "array",
               "items": {
                  "$ref": "#/definitions/CdsCurbZonesReference"
              }
            }
          }
        }
      ]
    },
```

5.4.2.2 DetourRoadEvent

```
    "DetourRoadEvent": {
      "title": "Detour Road Event",
      "description": "Describes a detour on a roadway.",
      "type": "object",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "event_type": {
                  "const": "detour"
                }
              },
```

```
            "required": ["event_type"]
          }
        },
        "required": ["core_details"]
      },
      {
        "required": [
          "core_details",
          "start_date",
          "end_date",
          "is_start_date_verified",
          "is_end_date_verified"
        ],
        "dependencies": {
          "beginning_reference_post": ["reference_post_unit"],
          "ending_reference_post": ["reference_post_unit"]
        },
        "properties": {
```

5.4.2.2.1 core_details

```
          "core_details": {
            "$ref": "#/definitions/RoadEventCoreDetails"
          },
```

5.4.2.2.2 beginning_cross_street

```
          "beginning_cross_street": {
            "description": "Name or number of the nearest cross street along
the roadway where the event begins.",
            "type": "string"
          },
```

5.4.2.2.3 ending_cross_street

```
          "ending_cross_street": {
            "description": "Name or number of the nearest cross street along
the roadway where the event ends.",
            "type": "string"
          },
```

5.4.2.2.4 beginning_reference_post

```
          "beginning_reference_post": {
            "description": "The linear distance measured against a reference
post marker along a roadway where the event begins.",
            "type": "number",
            "minimum": 0
          },
```

5.4.2.2.5 ending_reference_post

```
            "ending_reference_post": {
              "description": "The linear distance measured against a reference
post marker along a roadway where the event ends.",
              "type": "number",
              "minimum": 0
            },
```

5.4.2.2.6 reference_post_unit

```
            "reference_post_unit": {
              "description": "The unit used for reference post.",
              "$ref": "#/definitions/UnitOfMeasurement"
            },
```

5.4.2.2.7 start_date

```
            "start_date": {
              "description": "The UTC date and time (formatted according to RFC
3339, Section 5.6) when the road event begins (e.g., 2020-11-03T19:37:00Z).",
              "type": "string",
              "format": "date-time"
            },
```

5.4.2.2.8 end_date

```
            "end_date": {
              "description": "The UTC date and time (formatted according to RFC
3339, Section 5.6) when the road event ends (e.g., 2020-11-03T19:37:00Z).",
              "type": "string",
              "format": "date-time"
            },
```

5.4.2.2.9 is_start_date_verified

```
            "is_start_date_verified": {
              "description": "Indicates if the detour has been confirmed to have
started, such as from a person or device in the field or a report from a traffic
management center.",
              "type": "boolean"
            },
```

5.4.2.2.10 is_end_date_verified

```
            "is_end_date_verified": {
              "description": "Indicates if the detour has been confirmed to have
ended, such as from a person or device in the field or a report from a traffic
management center.",
              "type": "boolean"
            }
          }
        }
```

```
      ]
    },
```

5.4.2.3 RoadEventCoreDetails

```
    "RoadEventCoreDetails": {
      "title": "Road Event Core Details",
      "description": "The core details of an event occurring on a roadway (i.e. a
road event) that is shared by all types of road events.",
      "type": "object",
      "required": [
        "data_source_id",
        "event_type",
        "road_names",
        "direction"
      ],
      "properties": {
```

5.4.2.3.1 data_source_id

```
        "data_source_id": {
          "description": "Identifies the data source from which the road event
data is sourced from.",
          "type": "string"
        },
```

5.4.2.3.2 event_type

```
        "event_type": {
          "$ref": "#/definitions/EventType"
        },
```

5.4.2.3.3 related_road_events

```
        "related_road_events": {
          "description": "A list describing one or more road events which are
related to this road event, such as a work zone project it is part of or another
road event that occurs before or after it in sequence.",
          "type": "array",
          "items": {
            "$ref": "#/definitions/RelatedRoadEvent"
          }
        },
```

5.4.2.3.4 project_id

```
        "project_id": {
          "description": " An identifier for the project that the event is part
of. A project is the highest-level representation of an area where road work
takes place and may cover multiple roadways if adjacent or intersecting. A
project will contain one or more RoadEventFeatures. This project ID does not
correspond to an object in a WorkZoneFeed. It is used to group events (and
```

```
devices, see FieldDeviceCoreDetails). This identifier is a Universally Unique
Identifier (UUID) as defined in RFC 4122 to guarantee uniqueness between feeds
and over time.",
          "type": "string"
        },
```

5.4.2.3.5 road_names

```
        "road_names": {
          "description": "A list of publicly known names of the road on which the
event occurs. This may include the road number designated by a jurisdiction such
as a county, state or interstate (e.g., I-5, VT 133).",
          "type": "array",
          "minItems": 1,
          "items": {
            "type": "string"
          }
        },
```

5.4.2.3.6 direction

```
        "direction": {
          "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/Direction.json"
        },
```

5.4.2.3.7 name

```
        "name": {
          "description": "A human-readable name for the road event.",
          "type": "string"
        },
```

5.4.2.3.8 description

```
        "description": {
          "description": "Short free text description of the road event.",
          "type": "string"
        },
```

5.4.2.3.9 creation_date

```
        "creation_date": {
          "description": "The UTC date and time (formatted according to RFC 3339,
Section 5.6) when the road event was created (e.g., 2020-11-03T19:37:00Z).",
          "type": "string",
          "format": "date-time"
        },
```

5.4.2.3.10 update_date

```
        "update_date": {
```

```
          "description": "The UTC date and time (formatted according to RFC 3339,
Section 5.6) when any information in the RoadEventFeature (including child
objects) that the RoadEventCoreDetails applies to was most recently updated or
confirmed as up to date.",
          "type": "string",
          "format": "date-time"
        }
      }
    },
```

5.4.2.4 LocationMethod

```
    "LocationMethod": {
      "title": "Location Method Enumerated Type",
      "description": "The typical method used to locate the beginning and end of
a work zone impact area.",
      "enum": [
        "channel-device-method",
        "sign-method",
        "junction-method",
        "other",
        "unknown"
      ]
    },
```

5.4.2.5 RelatedRoadEvent

```
    "RelatedRoadEvent": {
      "title": "RelatedRoadEvent",
      "description": "Identifies a road event that is related to the road event
that the RelatedRoadEvent object occurs on.",
      "type": "object",
      "required": ["type", "id"],
      "properties": {
```

5.4.2.5.1 type

```
        "type": {
          "description": "The type of road event being identified, such as
another sequence of related work zones, a detour, or next road event in
sequence.",
          "$ref": "#/definitions/RelatedRoadEventType"
        },
```

5.4.2.5.2 id

```
        "id": {
          "description": "An identifier for the related road event by the type
property.",
          "type": "string"
```

```
        }
      }
    },
```

5.4.2.6 TypeOfWork

```
    "TypeOfWork": {
      "title": "Type of Work",
      "description": "A description of the type of work being done in a road
event and an indication of if that work will result in an architectural change to
the roadway.",
      "type": "object",
      "required": ["type_name"],
      "properties": {
```

5.4.2.6.1 type_name

```
        "type_name": {
          "$ref": "#/definitions/WorkTypeName"
        },
```

5.4.2.6.2 is_architectural_change

```
        "is_architectural_change": {
          "description": "A flag indicating whether the type of work will result
in an architectural change to the roadway.",
          "type": "boolean"
        }
      }
    },
```

5.4.2.7 Lane

```
    "Lane": {
      "title": "Lane",
      "description": "An individual lane within a road event.",
      "type": "object",
      "required": ["order", "status", "type"],
      "properties": {
```

5.4.2.7.1 order

```
        "order": {
          "description": "The position (index) of the lane in sequence on the
roadway, where '1' represents the left-most lane.",
          "type": "integer",
          "minimum": 1
        },
```

5.4.2.7.2 status

```
        "status": {
          "$ref": "#/definitions/LaneStatus"
```

```
        },
```

5.4.2.7.3 type

```
        "type": {
          "$ref": "#/definitions/LaneType"
        },
```

5.4.2.7.4 restrictions

```
        "restrictions": {
          "description": "A list of zero or more restrictions specific to the
lane.",
          "type": "array",
          "items": {
            "$ref": "#/definitions/Restriction"
          }
        }
      },
```

5.4.2.8 Restriction

```
    "Restriction": {
      "title": "Restriction",
      "description": "A restriction on a roadway or lane, including type and
value.",
      "type": "object",
      "required": ["type"],
      "dependencies": {
        "value": ["unit"]
      },
      "properties": {
```

5.4.2.8.1 type

```
        "type": {
          "$ref": "#/definitions/RestrictionType"
        },
```

5.4.2.8.2 value

```
        "value": {
          "type": "number"
        },
```

5.4.2.8.3 unit

```
        "unit": {
          "$ref": "#/definitions/UnitOfMeasurement"
        }
      }
    },
```

5.4.2.9 CdsCurbZonesReference

```
    "CdsCurbZonesReference": {
      "title": "CdsCurbZonesReference",
      "description": "A reference to one or more CDS curb zones that are impacted
by road work.",
      "type": "object",
      "required": ["cds_curb_zone_ids", "cds_curbs_api_url"],
      "properties": {
```

5.4.2.9.1 cds_curb_zone_ids

```
        "cds_curb_zone_ids": {
           "description": "A list of CDS Curb Zone ids.",
           "type": "array",
           "items": {
              "type": "string"
           }
        },
```

5.4.2.9.2 cds_curbs_api_url

```
        "cds_curbs_api_url": {
          "description": "An identifier for the source of the requested CDS
Curbs API.",
          "type": "string",
          "format": "uri"
        }
      }
  },
```

5.4.2.10 WorkerPresence

```
    "WorkerPresence": {
      "title": "Worker Presence",
      "description": "Information about the presence of workers in the work zone
event area.",
      "type": "object",
      "required": ["are_workers_present"],
      "properties": {
```

5.4.2.10.1 are_workers_present

```
        "are_workers_present": {
          "description": "Whether workers are present in the work zone event
area, following the definition provided in the 'definition' property on the
WorkerPresence object.",
          "type": "boolean"
        },
```

5.4.2.10.2 method

```
        "method": {
```

```
          "$ref": "#/definitions/WorkerPresenceMethod"
        },
```

5.4.2.10.3 worker_presence_last_confirmed_date

```
        "worker_presence_last_confirmed_date": {
          "description": "The UTC date and time at which the presence of workers
was last confirmed.",
          "type": "string",
          "format": "date-time"
        },
```

5.4.2.10.4 confidence

```
        "confidence": {
          "$ref": "#/definitions/WorkerPresenceConfidence"
        },
```

5.4.2.10.5 definition

```
        "definition": {
          "description": "A list of situations in which workers are considered to
be present in the jurisdiction of the data provider.",
          "type": "array",
          "items": {
            "$ref": "#/definitions/WorkerPresenceDefinition"
          },
          "uniqueItems": true
        },
```

5.4.2.10.6 other_method

```
        "other_method": {
          "description": "Provides more information about how worker presence in
a work zone event area is determined when method enumeration selected is
'other'.",
          "type": "string"
        }
      }
    },
```

5.4.2.11 EventType

```
    "EventType": {
      "title": "Road Event Type Enumerated Type",
      "description": "The type of CWZ road event.",
      "enum": ["work-zone", "detour"]
    },
```

5.4.2.12 WorkZoneType

```
    "WorkZoneType": {
      "title": "Work Zone Type Enumerated Type",
```

```
      "description": "The type of work zone road event.",
      "enum": ["static", "moving", "planned-moving-area"]
    },
```

5.4.2.13 VehicleImpact

```
    "VehicleImpact": {
      "title": "Vehicle Impact Enumerated Type",
      "description": "The impact to vehicular lanes along a single road in a
single direction.",
      "enum": ["all-lanes-closed", "some-lanes-closed", "all-lanes-open",
"alternating-one-way", "some-lanes-closed-merge-left", "some-lanes-closed-merge-
right", "all-lanes-open-shift-left", "all-lanes-open-shift-right", "some-lanes-
closed-split", "flagging", "temporary-traffic-signal", "unknown"]
    },
```

5.4.2.14 RestrictionType

```
    "RestrictionType": {
      "title": "Restriction Type Enumerated Type",
      "description": "The type of vehicle restriction on a roadway.",
      "enum": [
        "local-access-only",
        "no-trucks",
        "travel-peak-hours-only",
        "hov-3",
        "hov-2",
        "no-parking",
        "reduced-width",
        "reduced-height",
        "reduced-length",
        "reduced-weight",
        "axle-load-limit",
        "gross-weight-limit",
        "towing-prohibited",
        "permitted-oversize-loads-prohibited",
        "no-passing"
      ]
    },
```

5.4.2.15 WorkTypeName

```
    "WorkTypeName": {
      "title": "Work Type Name Enumerated Type",
      "description": "A high-level text description of the type of work being
done in a road event.",
      "enum": [
        "non-encroachment",
        "minor-road-defect-repair",
```

```
        "roadside-work",
        "overhead-work",
        "below-road-work",
        "barrier-work",
        "surface-work",
        "painting",
        "roadway-relocation",
        "roadway-creation"
      ]
    },
```

5.4.2.16 LaneStatus

```
    "LaneStatus": {
      "title": "Lane Status Enumerated Type",
      "description": "The status of the lane for the traveling public.",
      "enum": ["open", "closed", "shift-left", "shift-right", "merge-left",
"merge-right", "alternating-flow"]
    },
```

5.4.2.17 LaneType

```
    "LaneType": {
      "title": "Lane Type Enumerated Type",
      "description": "An indication of the type of lane or shoulder.",
      "enum": [
        "general",
        "exit-lane",
        "exit-ramp",
        "entrance-lane",
        "entrance-ramp",
        "sidewalk",
        "bike-lane",
        "shoulder",
        "parking",
        "median",
        "two-way-center-turn-lane"
      ]
    },
```

5.4.2.18 UnitOfMeasurement

```
    "UnitOfMeasurement": {
      "title": "Unit of Measurement Enumerated Type",
      "description": "Unit of measurement, used when providing a unit to
accompany a value.",
      "enum": ["feet", "inches", "centimeters", "pounds", "tons", "kilograms",
"miles", "kilometers"]
    },
```

5.4.2.19 WorkerPresenceMethod

```
    "WorkerPresenceMethod": {
      "title": "Worker Presence Method Enumerated Type",
      "description": "Describes methods for how worker presence in a work zone
event area is determined.",
      "enum": [
        "camera-monitoring",
        "maintenance-vehicle-present",
        "wearables-present",
        "mobile-device-present",
        "check-in-app",
        "check-in-verbal",
        "other"
      ]
    },
```

5.4.2.20 WorkerPresenceDefinition

```
    "WorkerPresenceDefinition": {
      "title": "Worker Presence Definition Enumerated Type",
      "description": "Situations in which workers may be considered present in a
work zone.",
      "enum": [
        "workers-in-work-zone-working",
        "workers-in-work-zone-not-working",
        "mobile-equipment-in-work-zone-moving",
        "mobile-equipment-in-work-zone-not-moving",
        "fixed-equipment-in-work-zone",
        "humans-behind-barrier",
        "humans-in-right-of-way"
      ]
    },
```

5.4.2.21 WorkerPresenceConfidence

```
    "WorkerPresenceConfidence": {
      "title": "Worker Presence Confidence Enumerated Type",
      "description": "A high-level description of the feed publisher's confidence
in the reported WorkerPresence value of are_workers_present.",
      "enum": [
        "low",
        "medium",
        "high"
      ]
    },
```

5.4.2.22 RelatedRoadEventType

```
    "RelatedRoadEventType": {
```

```
      "title": "Related Road Event Type Enumerated Type",
      "description": "Describes how a road event is related to the road event
that the RelatedRoadEvent object occurs on.",
      "enum": [
        "first-in-sequence",
        "next-in-sequence",
        "first-occurrence",
        "next-occurrence",
        "related-work-zone",
        "related-detour",
        "planned-moving-operation",
        "active-moving-operation"
      ]
    }
  }
}
```

5.5 DeviceFeed Schema

```
{
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/DeviceFeed.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "CWZ v1.0 DeviceFeed",
  "description": "The GeoJSON output of a CWZ Device Feed v1.0.",
  "type": "object",
  "required": ["feed_info", "type", "features"],
```

5.5.1 Properties

```
  "properties": {
```

5.5.1.1 feed_info

```
    "feed_info": {
      "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/FeedInfo.json"
    },
```

5.5.1.2 type

```
    "type": {
      "description": "The GeoJSON type.",
      "enum": ["FeatureCollection"]
    },
```

5.5.1.3 features

```
    "features": {
      "description": "An array of GeoJSON Feature objects which represent field
devices deployed in a work zone.",
      "type": "array",
```

```
      "items": {
        "$ref": "#/definitions/FieldDeviceFeature"
      }
    },
```

5.5.1.4 bbox

```
    "bbox": {
      "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/BoundingBox.json"
    }
  },
```

5.5.2 Definitions

```
  "definitions": {
```

5.5.2.1 FieldDeviceFeature

```
    "FieldDeviceFeature": {
      "title": "Field Device Feature (GeoJSON Feature)",
      "description": "The GeoJSON feature container for a CWZ field device.",
      "type": "object",
      "required": ["id","type","properties","geometry"],
      "properties": {
```

5.5.2.1.1 id

```
        "id": {
          "description": "A unique identifier issued by the data feed provider to
identify the field device. This identifier is a Universally Unique Identifier
(UUID) as defined in [RFC 4122](https://datatracker.ietf.org/doc/html/rfc4122).",
          "type": "string"
        },
```

5.5.2.1.2 type

```
        "type": {
          "description": "The GeoJSON object type; must be 'Feature'.",
          "enum": ["Feature"]
        },
```

5.5.2.1.3 properties

```
        "properties": {
          "type": "object",
          "properties": {
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            }
          },
          "required": ["core_details"],
          "oneOf": [
```

```
            {
              "$ref": "#/definitions/ArrowBoard"
            },
            {
              "$ref": "#/definitions/Camera"
            },
            {
              "$ref": "#/definitions/DynamicMessageSign"
            },
            {
              "$ref": "#/definitions/FlashingBeacon"
            },
            {
              "$ref": "#/definitions/HybridSign"
            },
            {
              "$ref": "#/definitions/LocationMarker"
            },
            {
              "$ref": "#/definitions/RoadsideUnit"
            },
            {
              "$ref": "#/definitions/TrafficSensor"
            },
            {
              "$ref": "#/definitions/TrafficSignal"
            }
          ]
        },
```

5.5.2.1.4 geometry

```
        "geometry": {
          "oneOf": [
            {
              "$ref": "https://geojson.org/schema/Point.json"
            }
          ]
        },
```

5.5.2.1.5 bbox

```
        "bbox": {
          "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/BoundingBox.json"
        }
      }
    },
```

5.5.2.2 FieldDeviceCoreDetails

```
    "FieldDeviceCoreDetails": {
      "title": "Field Device Core Details",
      "description": "The core details—both configuration and current state—of a
field device that are shared by all types of field devices.",
      "type": "object",
      "required": [
        "device_type",
        "data_source_id",
        "device_status",
        "update_date",
        "has_automatic_location"
      ],
      "dependencies": {
        "reference_post": ["reference_post_unit"]
      },
      "properties": {
```

5.5.2.2.1 device_type

```
        "device_type": {
          "$ref": "#/definitions/FieldDeviceType"
        },
```

5.5.2.2.2 data_source_id

```
        "data_source_id": {
          "description": "Identifies the data source from which the field device
information is sourced from.",
          "type": "string"
        },
```

5.5.2.2.3 device_status

```
        "device_status": {
          "$ref": "#/definitions/FieldDeviceStatus"
        },
```

5.5.2.2.4 update_date

```
        "update_date": {
          "description": "The UTC date and time (formatted according to RFC 3339,
Section 5.6) when any information in the FieldDeviceFeature (including child
objects) that the FieldDeviceCoreDetails applies to was most recently updated or
confirmed as up to date.",
          "type": "string",
          "format": "date-time"
        },
```

5.5.2.2.5 has_automatic_location

```
        "has_automatic_location": {
```

```
          "description": "A yes/no value indicating if the field device location
(parent FieldDeviceFeature's geometry) is determined automatically from an
onboard GPS (true) or manually set/overridden (false).",
          "type": "boolean"
        },
```

5.5.2.2.6 road_direction

```
        "road_direction": {
          "$ref": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/Direction.json",
          "description": "The direction of the road that the field device is on.
This value indicates the direction of the traffic flow of the road, not a real
heading angle."
        },
```

5.5.2.2.7 road_names

```
        "road_names": {
          "description": "A list of publicly known names of the road on which the
field device is located. This may include the road number designated by a
jurisdiction such as a county, state or interstate (e.g., I-5, VT 133).",
          "type": "array",
          "minItems": 1,
          "items": {
            "type": "string"
          }
        },
```

5.5.2.2.8 name

```
        "name": {
          "type": "string",
          "description": "A human-readable name for the field device."
        },
```

5.5.2.2.9 description

```
        "description": {
          "type": "string",
          "description": "A description of the field device."
        },
```

5.5.2.2.10 status_messages

```
        "status_messages": {
          "type": "array",
          "description": "A list of messages associated with the device's status,
if applicable. Used to provide additional information about the status such as
specific warning or error message.",
          "items": {
            "type": "string"
```

```
        }
      },
```

5.5.2.2.11 is_moving

```
      "is_moving": {
        "type": "boolean",
        "description": "A yes/no value indicating if the device is actively
moving (not statically placed) as part of a mobile work zone operation."
      },
```

5.5.2.2.12 road_event_ids

```
      "road_event_ids": {
        "type": "array",
        "description": "A list of one or more IDs of a RoadEventFeatures that
the device is associated with.",
        "items": {
          "type": "string"
        }
      },
```

5.5.2.2.13 project_id

```
      "project_id": {
        "type": "string",
        "description": " An identifier for the project that the device is
associated with. A project is the highest-level representation of an area where
road work takes place and may cover multiple roadways if adjacent or
intersection. This project ID does not correspond to an object in a WorkZoneFeed.
It is used to group devices (and events, see RoadEventCoreDetails)."
      },
```

5.5.2.2.14 reference_post

```
      "reference_post": {
        "type": "number",
        "description": "The linear distance measured against a reference post
marker along a roadway where the device is located."
      },
```

5.5.2.2.15 reference_post_unit

```
      "reference_post_unit": {
        "description": "The unit used for reference post.",
        "$ref": "#/definitions/UnitOfMeasurement"
      },
```

5.5.2.2.16 make

```
      "make": {
        "type": "string",
```

```
          "description": "The make or manufacturer of the device."
        },
```

5.5.2.2.17 model

```
        "model": {
          "type": "string",
          "description": "The model of the device."
        },
```

5.5.2.2.18 serial_number

```
        "serial_number": {
          "type": "string",
          "description": "The serial number of the device."
        },
```

5.5.2.2.19 firmware_version

```
        "firmware_version": {
          "type": "string",
          "description": "The version of firmware the device is using to
operate."
        },
```

5.5.2.2.20 velocity_kph

```
        "velocity_kph": {
          "type": "number",
          "description": "The velocity of the device in kilometers per hour."
        },
```

5.5.2.2.21 is_in_transport_position

```
            "is_in_transport_position": {
              "type": "boolean",
              "description": "A yes/no value indicating if the device is in the
stowed/transport position (true) or deployed/upright position (false)."
            }


      }
    },
```

5.5.2.3 ArrowBoard

```
    "ArrowBoard": {
      "title": "Arrow Board Field Device",
      "description": "An electronic, connected arrow board which can display an
arrow pattern to direct traffic.",
      "type": "object",
      "allOf": [
        {
          "properties": {
```

```
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "arrow-board"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "pattern"
          ],
          "properties": {
```

5.5.2.3.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.3.2 pattern

```
            "pattern": {
              "$ref": "#/definitions/ArrowBoardPattern"
            }
          }
        }
      ]
    },
```

5.5.2.4 Camera

```
    "Camera": {
      "title": "Camera Field Device",
      "description": "A camera device deployed in the field, capable of capturing
still images.",
      "type": "object",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "camera"
                }
```

```
            },
            "required": ["device_type"]
          }
        },
        "required": ["core_details"]
      },
      {
        "required": [
          "core_details"
        ],
        "dependencies": {
          "image_url": ["image_timestamp"],
          "video_url": ["video_update_frequency"]
        },
        "properties": {
```

5.5.2.4.1 core_details

```
          "core_details": {
            "$ref": "#/definitions/FieldDeviceCoreDetails"
          },
```

5.5.2.4.2 image_url

```
          "image_url": {
            "type": "string",
            "format": "uri",
            "description": "A URL pointing to an image file for the camera
video."
          },
```

5.5.2.4.3 is_image_url_public

```
          "is_image_url_public": {
            "type": "boolean",
            "description": "Identifies whether image_url is publicly
accessible."
          },
```

5.5.2.4.4 image_timestamp

```
          "image_timestamp": {
            "type": "string",
            "format": "date-time",
            "description": "The UTC date and time when the image was captured."
          },
```

5.5.2.4.5 video_url

```
          "video_url": {
            "type": "string",
```

```
              "format": "uri",
              "description": "A URL pointing to a video file for the camera
video."
            },
```

5.5.2.4.6 is_video_url_public

```
            "is_video_url_public": {
              "type": "boolean",
              "description": "Identifies whether video_url is publicly
accessible."
            },
```

5.5.2.4.7 video_update_frequency

```
            "video_update_frequency": {
              "description": "The frequency at which the video feed is updated,
in seconds.",
              "type": "integer",
              "minimum": -1
            }
          }
        }
      ]
    },
```

5.5.2.5 DynamicMessageSign

```
    "DynamicMessageSign": {
      "title": "Dynamic Message Sign Field Device",
      "description": "An electronic traffic sign deployed on the roadway, used to
provide information to travelers.",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "dynamic-message-sign"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
```

```
            "core_details",
            "message_multi_string"
          ],
          "properties": {
```

5.5.2.5.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.5.2 message_multi_string

```
            "message_multi_string": {
              "type": "string",
              "description": "A MULTI-formatted string describing the message
currently posted to the sign."
            }
          }
        }
      ]
    },
```

5.5.2.6 FlashingBeacon

```
    "FlashingBeacon": {
      "title": "Flashing Beacon Field Device",
      "description": "A flashing warning beacon used to supplement a temporary
traffic control device.",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "flashing-beacon"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "function"
          ],
          "properties": {
```

5.5.2.6.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.6.2 function

```
            "function": {
              "$ref": "#/definitions/FlashingBeaconFunction"
            },
```

5.5.2.6.3 is_flashing

```
            "is_flashing": {
              "type": "boolean",
              "description": "A yes/no value indicating if the flashing beacon is
currently in use and flashing."
            },
```

5.5.2.6.4 sign_text

```
            "sign_text": {
              "type": "string",
              "description": "The text on the sign the beacon is mounted on, if
applicable."
            }
          }
        }
      ]
    },
```

5.5.2.7 HybridSign

```
    "HybridSign": {
      "title": "Hybrid Sign Field Device",
      "description": "A hybrid sign that contains static text (e.g., on an
aluminum sign) along with a single electronic message display, used to provide
information to travelers.",
      "type": "object",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "hybrid-sign"
                }
              },
              "required": ["device_type"]
            }
```

```
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "dynamic_message_function"
          ],
          "properties": {
```

5.5.2.7.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.7.2 dynamic_message_function

```
            "dynamic_message_function": {
              "$ref": "#/definitions/HybridSignDynamicMessageFunction"
            },
```

5.5.2.7.3 dynamic_message_text

```
            "dynamic_message_text": {
              "type": "string",
              "description": "A text representation of the message currently
posted to the dynamic electronic component of the hybrid sign."
            },
```

5.5.2.7.4 static_sign_text

```
            "static_sign_text": {
              "type": "string",
              "description": "The static text on the non-electronic component of
the hybrid sign."
            }
          }
        }
      ]
    },
```

5.5.2.8 LocationMarker

```
    "LocationMarker": {
      "title": "Location Marker Field Device",
      "description": "Any GPS-enabled ITS device that is placed at a point on a
roadway to dynamically know the location of something (often the beginning or end
of a work zone).",
      "type": "object",
      "allOf": [
        {
```

```
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "location-marker"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": ["core_details", "marked_locations"],
          "properties": {
```

5.5.2.8.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.8.2 marked_locations

```
            "marked_locations": {
              "type": "array",
              "minItems": 1,
              "items": {
                "$ref": "#/definitions/MarkedLocation"
              }
            }
          }
        }
      ]
    },
```

5.5.2.9 MarkedLocation

```
    "MarkedLocation": {
      "title": "Marked Location",
      "description": "Describes a specific location where a LocationMarker is
placed, such as the start or end of a work zone road event.",
      "required": ["type"],
      "properties": {
```

5.5.2.9.1 type

```
        "type": {
          "$ref": "#/definitions/MarkedLocationType"
        },
```

5.5.2.9.2 road_event_id

```
        "road_event_id": {
          "type": "string",
          "description": "The ID of a RoadEventFeature that the MarkedLocation
applies to."
        }
      }
    },
```

5.5.2.10 TrafficSensor

```
    "TrafficSensor": {
      "title": "Traffic Sensor Field Device",
      "description": "A traffic sensor deployed on a roadway which captures
traffic metrics (e.g., speed, volume, occupancy) over a collection interval.",
      "type": "object",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "traffic-sensor"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "collection_interval_start_date",
            "collection_interval_end_date"
          ],
          "properties": {
```

5.5.2.10.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.10.2 collection_interval_start_date

```
            "collection_interval_start_date": {
              "type": "string",
              "format": "date-time",
```

```
            "description": "The UTC date and time where the TrafficSensor data
collection started. The averages and totals contained in the TrafficSensor data
apply to the inclusive interval of 'collection_interval_start_date' to
'collection_interval_end_date'."
          },
```

5.5.2.10.3 collection_interval_end_date

```
          "collection_interval_end_date": {
            "type": "string",
            "format": "date-time",
            "description": "The UTC date and time where the TrafficSensor data
collection ended. The averages and totals contained in the TrafficSensor data
apply to the inclusive interval of 'collection_interval_start_date' to
'collection_interval_end_date'."
          },
```

5.5.2.10.4 average_speed_kph

```
          "average_speed_kph": {
            "type": "number",
            "minimum": 0,
            "description": "The average speed of vehicles across all lanes over
the collection interval in kilometers per hour."
          },
```

5.5.2.10.5 volume_vph

```
          "volume_vph": {
            "type": "number",
            "minimum": 0,
            "description": "The rate of vehicles passing by the sensor during
the collection interval in vehicles per hour."
          },
```

5.5.2.10.6 occupancy_percent

```
          "occupancy_percent": {
            "type": "number",
            "minimum": 0,
            "description": "The percent of time the roadway section monitored
by the sensor was occupied by a vehicle over the collection interval."
          },
```

5.5.2.10.7 lane_data

```
          "lane_data": {
            "type": "array",
            "items": {
              "$ref": "#/definitions/TrafficSensorLaneData"
            }
          }
```

```
        }
      }
    ]
  },
```

5.5.2.11 TrafficSensorLaneData

```
  "TrafficSensorLaneData": {
    "title": "Traffic Sensor Lane Data",
    "description": "Data for a single lane measured by a TrafficSensor deployed
on the roadway.",
    "required": [
      "lane_order"
    ],
    "properties": {
```

5.5.2.11.1 lane_order

```
      "lane_order": {
        "type": "integer",
        "minimum": 1,
        "description": "The lane's position in sequence on the roadway."
      },
```

5.5.2.11.2 road_event_id

```
      "road_event_id": {
        "type": "string",
        "description": "The ID of a RoadEventFeature that the measured lane
occurs in."
      },
```

5.5.2.11.3 average_speed_kph

```
      "average_speed_kph": {
        "type": "number",
        "minimum": 0,
        "description": "The average speed of traffic in the lane over the
collection interval (in kilometers per hour)."
      },
```

5.5.2.11.4 volume_vph

```
      "volume_vph": {
        "type": "number",
        "minimum": 0,
        "description": "The rate of vehicles passing by the sensor in the lane
during the collection interval (in vehicles per hour)."
      },
```

5.5.2.11.5 occupancy_percent

```
      "occupancy_percent": {
```

```
          "type": "number",
          "minimum": 0,
          "description": "The percent of time the lane monitored by the sensor
was occupied by a vehicle over the collection interval."
        }
      }
    },
```

5.5.2.12 TrafficSignal

```
    "TrafficSignal": {
      "title": "Traffic Signal",
      "description": "Describes a temporary traffic signal deployed on a
roadway.",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "traffic-signal"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details",
            "mode"
          ],
          "properties": {
```

5.5.2.12.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.12.2 mode

```
            "mode": {
              "$ref": "#/definitions/TrafficSignalMode"
            }
          }
        }
```

```
      ]
    },
```

5.5.2.13 RoadsideUnit

```
    "RoadsideUnit": {
      "title": "Roadside Unit",
      "description": "Describes a roadside unit deployed on a roadway.",
      "allOf": [
        {
          "properties": {
            "core_details": {
              "properties": {
                "device_type": {
                  "const": "roadside-unit"
                }
              },
              "required": ["device_type"]
            }
          },
          "required": ["core_details"]
        },
        {
          "required": [
            "core_details"
          ],
          "properties": {
```

5.5.2.13.1 core_details

```
            "core_details": {
              "$ref": "#/definitions/FieldDeviceCoreDetails"
            },
```

5.5.2.13.2 message_types

```
            "message_types": {
              "description": "A list of message types being broadcast by a
RoadsideUnit.",
              "type": "array",
              "items": {
                "$ref": "#/definitions/RoadsideUnitMessageTypes"
              },
              "uniqueItems": true
            }
          }
        }
      ]
    },
```

5.5.2.14 UnitOfMeasurement

```
    "UnitOfMeasurement": {
      "title": "Unit of Measurement Enumerated Type",
      "description": "Unit of measurement, used when providing a unit to
accompany a value.",
      "enum": ["feet", "inches", "centimeters", "pounds", "tons", "kilograms",
"miles", "kilometers"]
    },
```

5.5.2.15 ArrowBoardPattern

```
    "ArrowBoardPattern": {
      "title": "Arrow Board Pattern Enumerated Type",
      "description": "A list of options for the posted pattern on an
ArrowBoard.",
      "enum": [
        "blank",
        "right-arrow-static",
        "right-arrow-flashing",
        "right-arrow-sequential",
        "right-chevron-static",
        "right-chevron-flashing",
        "right-chevron-sequential",
        "left-arrow-static",
        "left-arrow-flashing",
        "left-arrow-sequential",
        "left-chevron-static",
        "left-chevron-flashing",
        "left-chevron-sequential",
        "bidirectional-arrow-static",
        "bidirectional-arrow-flashing",
        "line-flashing",
        "diamonds-alternating",
        "four-corners-flashing",
        "unknown"
      ]
    },
```

5.5.2.16 FieldDeviceType

```
    "FieldDeviceType": {
      "title": "Field Device Type Enumerated Type",
      "description": "The type of field device.",
      "enum": [
        "arrow-board",
        "camera",
        "dynamic-message-sign",
```

```
        "flashing-beacon",
        "hybrid-sign",
        "location-marker",
        "traffic-sensor",
        "traffic-signal",
        "roadside-unit"
      ]
    },
```

5.5.2.17 FieldDeviceStatus

```
    "FieldDeviceStatus": {
      "title": "Field Device Status Enumerated Type",
      "description": "The operational status of a field device.",
      "enum": ["ok", "warning", "error", "unknown"]
    },
```

5.5.2.18 FlashingBeaconFunction

```
    "FlashingBeaconFunction": {
      "title": "Flashing Beacon Function Enumerated Type",
      "description": "Options for what a FlashingBeacon is being used to
indicate.",
      "enum": ["vehicle-entering", "queue-warning", "reduced-speed", "workers-
present", "other"]
    },
```

5.5.2.19 HybridSignDynamicMessageFunction

```
    "HybridSignDynamicMessageFunction": {
      "title": "Hybrid Sign Dynamic Message Function Enumerated Type",
      "description": "Options for the function of the dynamic message displayed
by the electronic display on a HybridSign.",
      "enum": ["speed-limit", "travel-time", "other"]
    },
```

5.5.2.20 MarkedLocationType

```
    "MarkedLocationType": {
      "title": "Marked Location Type Enumerated Type",
      "description": "Options for what a MarkedLocation can mark, such as the
start or end of a road event.",
      "enum": [
        "afad",
        "delineator",
        "flagger",
        "lane-shift",
        "lane-closure",
        "personal-device",
        "ramp-closure",
```

```
        "road-closure",
        "work-truck-with-lights-flashing",
        "work-zone-start",
        "work-zone-end",
        "attenuator-vehicle",
        "construction-vehicle",
        "maintenance-vehicle",
        "emergency-vehicle",
        "stalled-or-disabled-vehicle",
        "pavement-marking-vehicle",
        "other"
      ]
    },
```

5.5.2.21 TrafficSignalMode

```
    "TrafficSignalMode": {
      "title": "Traffic Signal Mode Enumerated Type",
      "description": "Describes the current operating mode of a TrafficSignal.",
      "enum": [
        "blank",
        "flashing-red",
        "flashing-yellow",
        "fully-actuated",
        "manual",
        "pre-timed",
        "semi-actuated",
        "unknown"
      ]
    },
```

5.5.2.22 RoadsideUnitMessageTypes

```
    "RoadsideUnitMessageTypes": {
      "title": "Roadside Unit Message Types Enumerated Type",
      "description": "Describes the message types being broadcast by a
RoadsideUnit.",
      "enum": [
        "rsm",
        "tim",
        "spat",
        "map",
        "other"
      ]
    }
  }
}
```

5.6 Direction Schema


```
{
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/Direction.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "Direction Enumerated Type",
  "description": "The direction of a road based on standard naming for US roads;
indicates the direction the traffic flow not the real heading angle.",
  "enum": ["northbound", "eastbound", "southbound", "westbound", "inner-loop",
"outer-loop", "undefined", "unknown"]
}
```


5.7 BoundingBox Schema


```
{
  "$id": "https://raw.githubusercontent.com/ite-
org/cwz/main/schemas/1.0/BoundingBox.json",
  "$schema": "http://json-schema.org/draft-07/schema#",
  "title": "GeoJSON Bounding Box",
  "description": "Information on the coordinate range for a Geometry, Feature, or
FeatureCollection.",
  "type": "array",
  "minItems": 4,
  "items": {
    "type": "number"
  }
}
```

Annex A
Requirements Traceability Matrix

A.1 Notation [Informative]

A.1.1 Requirement Columns

The requirements are defined within Section 3, and the RTM is derived from those requirements. The section number and the functional requirement name are indicated within these columns.

A.1.2 Design Details

The "Design Details" column provides one of the following:

- a hyperlinked reference to a section number in Section 4 or Section 5 where the design details are defined.
- an external, normative reference detailing how to fulfill the requirement.
- The phrase "No Further Design Details" because no additional design information is necessary (i.e., the requirement is self-explanatory).

A.1.3 Additional Specifications

The "Additional Specifications" column may be used to provide additional notes and requirements or may be used by an implementer to provide any additional details about the implementation.

A.1.4 Instructions for Completing the RTM [Informative]

To find the conformant design content for a requirement, search for the requirement identification (section) number or name under the appropriate column. Next to the functional requirements column are columns that define the conformant design details that fulfill the requirement. The columns either reference a section within this standard describing how the requirement is to be fulfilled; points to a normative reference that explains how to fulfill the requirement; or indicates "No Further Design Details" because no additional design information is necessary. The "Additional Specifications" column provides additional notes or details about the design content, as needed.

A.2 Requirements Traceability Matrix Table

Table 7. Requirements Traceability Matrix

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
3.2	**Architectural Requirements**					
3.2.1	**Compatibility with the WZDx Specification**	**4.2**	**Dialog**			
3.2.2	**GeoJSON Data Format**		Message	5.2	WorkZoneFeed Schema	See 4.2.1, 4.2.2
			Message	5.5	DeviceFeed Schema	See 4.2.1, 4.2.2
3.2.3	**GeoJSON Data Validation**		Message	5.2	WorkZoneFeed Schema	See 4.2.1, 4.2.2
			Message	5.5	DeviceFeed Schema	See 4.2.1, 4.2.2
3.2.4	**Business Rules**	**NA**				
3.3	**Data Exchange Requirements**					
3.3.1	**Exchange WorkZoneFeed Information**					
3.3.1.1	Send WorkZoneFeed Information Upon Request	4.2	Dialog	5.2	WorkZoneFeed Schema	See 4.2.3, 4.2.4
3.3.2	**Exchange DeviceFeed Information**					
3.3.2.1	Send DeviceFeed Information Upon Request	4.2	Dialog	5.5	DeviceFeed Schema	See 4.2.3, 4.2.4
3.4	**WorkZoneFeed Requirements**		**Message**	**5.2**	**WorkZoneFeed Schema**	
3.4.1	**Contents of WorkZoneFeed**		**Data Frame**	**5.2.1**	**Properties**	
a)	feed_info		Data Frame	5.2.1.1	feed_info	
b)	type		Data Element	5.2.1.2	type	
c)	features		Data Frame	5.2.1.3	features	
d)	bbox		Data Frame	5.2.1.4	bbox	
3.5	**FeedInfo Requirements**			**5.3**	**FeedInfo Schema**	
3.5.1	**Contents of FeedInfo**		**Data Frame**	**5.3.1**	**Properties**	
a)	publisher		Data Element	5.3.1.1	publisher	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
b)	contact_name		Data Element	5.3.1.2	contact_name	
c)	contact_email		Data Element	5.3.1.3	contact_email	
d)	update_frequency		Data Element	5.3.1.4	update_frequency	
e)	update_date		Data Element	5.3.1.5	update_date	
f)	version		Data Element	5.3.1.6	version	
g)	license		Data Element	5.3.1.7	license	
h)	data_sources		Data Frame	5.3.1.8	data_sources	
3.5.2	**Contents of FeedDataSource**		**Data Frame**	**5.3.2.1**	**FeedDataSource**	
a)	data_source_id		Data Element	5.3.2.1.1	data_source_id	
b)	organization_name		Data Element	5.3.2.1.2	organization_name	
c)	contact_name		Data Element	5.3.2.1.3	contact_name	
d)	contact_email		Data Element	5.3.2.1.4	contact_email	
e)	update_frequency		Data Element	5.3.2.1.5	update_frequency	
f)	update_date		Data Element	5.3.2.1.6	update_date	
3.6	**RoadEventFeature Requirements**			**5.4**	**RoadEventFeature Schema**	
3.6.1	**Contents of RoadEventFeature**		**Data Frame**	**5.4.1**	**Properties**	
a)	id		Data Element	5.4.1.1	id	
b)	type		Data Element	5.4.1.2	type	
c)	properties		Data Frame	5.4.1.3	properties	
d)	geometry		Data Frame	5.4.1.4	geometry	
e)	bbox		Data Frame	5.4.1.5	bbox	
3.6.2	**Contents of WorkZoneRoadEvent**		**Data Frame**	**5.4.2.1**	**WorkZoneRoadEvent**	
a)	core_details		Data Frame	5.4.2.1.1	core_details	
b)	beginning_cross_street		Data Element	5.4.2.1.2	beginning_cross_street	
c)	ending_cross_street		Data Element	5.4.2.1.3	ending_cross_street	
d)	beginning_reference_post		Data Element	5.4.2.1.4	beginning_reference_post	
e)	ending_reference_post		Data Element	5.4.2.1.5	ending_reference_post	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
f)	reference_post_unit		Data Element	5.4.2.1.6	reference_post_unit	
g)	is_start_position_verified		Data Element	5.4.2.1.7	is_start_position_verified	
h)	is_end_position_verified		Data Element	5.4.2.1.8	is_end_position_verified	
i)	start_date		Data Element	5.4.2.1.9	start_date	
j)	end_date		Data Element	5.4.2.1.10	end_date	
k)	is_start_date_verified		Data Element	5.4.2.1.11	is_start_date_verified	
l)	is_end_date_verified		Data Element	5.4.2.1.12	is_end_date_verified	
m)	work_zone_type		Data Element	5.4.2.1.13	work_zone_type	
n)	vehicle_impact		Data Element	5.4.2.1.14	vehicle_impact	
o)	location_method		Data Element	5.4.2.1.15	location_method	
p)	worker_presence		Data Element	5.4.2.1.16	worker_presence	
q)	reduced_speed_limit_kph		Data Element	5.4.2.1.17	reduced_speed_limit_kph	
r)	restrictions		Data Frame	5.4.2.1.18	restrictions	
s)	types_of_work		Data Frame	5.4.2.1.19	types_of_work	
t)	lanes		Data Frame	5.4.2.1.20	lanes	
u)	impacted_cds_curb_zones		Data Frame	5.4.2.1.21	impacted_cds_curb_zones	
3.6.3	**Contents of DetourRoadEvent**		**Data Frame**	**5.4.2.2**	**DetourRoadEvent**	
a)	core_details		Data Frame	5.4.2.2.1	core_details	
b)	beginning_cross_street		Data Element	5.4.2.2.2	beginning_cross_street	
c)	ending_cross_street		Data Element	5.4.2.2.3	ending_cross_street	
d)	beginning_reference_post		Data Element	5.4.2.2.4	beginning_reference_post	
e)	ending_reference_post		Data Element	5.4.2.2.5	ending_reference_post	
f)	reference_post_unit		Data Element	5.4.2.2.6	reference_post_unit	
g)	start_date		Data Element	5.4.2.2.7	start_date	
h)	end_date		Data Element	5.4.2.2.8	end_date	
i)	is_start_date_verified		Data Element	5.4.2.2.9	is_start_date_verified	
j)	is_end_date_verified		Data Element	5.4.2.2.10	is_end_date_verified	
3.6.4	**Contents of RoadEventCoreDetails**		**Data Frame**	**5.4.2.3**	**RoadEventCoreDetails**	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
a)	data_source_id		Data Element	5.4.2.3.1	data_source_id	
b)	event_type		Data Element	5.4.2.3.2	event_type	
c)	related_road_events		Data Frame	5.4.2.3.3	related_road_events	
d)	project_id		Data Frame	5.4.2.3.4	project_id	
e)	road_names		Data Frame	5.4.2.3.5	road_names	
f)	direction		Data Element	5.4.2.3.6	direction	
g)	name		Data Element	5.4.2.3.7	name	
h)	description		Data Element	5.4.2.3.8	description	
i)	creation_date		Data Element	5.4.2.3.9	creation_date	
j)	update_date		Data Element	5.4.2.3.10	update_date	
3.6.5	**Enumeration of LocationMethod**		**Data Element**	**5.4.2.4**	**LocationMethod**	
3.6.6	**Contents of RelatedRoadEvent**		**Data Frame**	**5.4.2.5**	**RelatedRoadEvent**	
a)	type		Data Element	5.4.2.5.1	type	
b)	id		Data Element	5.4.2.5.2	id	
3.6.7	**Contents of TypeOfWork**		**Data Frame**	**5.4.2.6**	**TypeOfWork**	
a)	type_name		Data Element	5.4.2.6.1	type_name	
b)	is_architectural_change		Data Element	5.4.2.6.2	is_architectural_change	
3.6.8	**Contents of Lane**		**Data Frame**	**5.4.2.7**	**Lane**	
a)	order		Data Element	5.4.2.7.1	order	
b)	status		Data Element	5.4.2.7.2	status	
c)	type		Data Element	5.4.2.7.3	type	
d)	restrictions		Data Frame	5.4.2.7.4	restrictions	
3.6.9	**Contents of Restriction**		**Data Frame**	**5.4.2.8**	**Restriction**	
a)	type		Data Element	5.4.2.8.1	type	
b)	value		Data Element	5.4.2.8.2	value	
c)	unit		Data Element	5.4.2.8.3	unit	
3.6.10	**Contents of CdsCurbZonesReference**		**Data Frame**	**5.4.2.9**	**CdsCurbZonesReference**	
a)	cds_curb_zone_ids		Data Frame	5.4.2.9.1	cds_curb_zone_ids	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
b)	cds_curbs_api_url		Data Element	5.4.2.9.2	cds_curbs_api_url	
3.6.11	**Contents of WorkerPresence**		**Data Frame**	**5.4.2.10**	**WorkerPresence**	
a)	are_workers_present		Data Element	5.4.2.10.1	are_workers_present	
b)	method		Data Element	5.4.2.10.2	method	
c)	worker_presence_last_confirmed_date		Data Element	5.4.2.10.3	worker_presence_last_confirmed_date	
d)	confidence		Data Element	5.4.2.10.4	confidence	
e)	definition		Data Frame	5.4.2.10.5	definition	
f)	other_method		Data Element	5.4.2.10.6	other_method	
3.6.12	**Enumeration of EventType**		**Data Element**	**5.4.2.11**	**EventType**	
3.6.13	**Enumeration of WorkZoneType**		**Data Element**	**5.4.2.12**	**WorkZoneType**	
3.6.14	**Enumeration of VehicleImpact**		**Data Element**	**5.4.2.13**	**VehicleImpact**	
3.6.15	**Enumeration of RestrictionType**		**Data Element**	**5.4.2.14**	**RestrictionType**	
3.6.16	**Enumeration of WorkTypeName**		**Data Element**	**5.4.2.15**	**WorkTypeName**	
3.6.17	**Enumeration of LaneStatus**		**Data Element**	**5.4.2.16**	**LaneStatus**	
3.6.18	**Enumeration of LaneType**		**Data Element**	**5.4.2.17**	**LaneType**	
3.6.19	**Enumeration of UnitOfMeasurement**		**Data Element**	**5.4.2.18**	**UnitOfMeasurement**	
3.6.20	**Enumeration of WorkerPresenceMethod**		**Data Element**	**5.4.2.19**	**WorkerPresenceMethod**	
3.6.21	**Enumeration of WorkerPresenceDefinition**		**Data Element**	**5.4.2.20**	**WorkerPresenceDefinition**	
3.6.22	**Enumeration of WorkerPresenceConfidence**		**Data Element**	**5.4.2.21**	**WorkerPresenceConfidence**	
3.6.23	**Enumeration of RelatedRoadEventType**		**Data Element**	**5.4.2.22**	**RelatedRoadEventType**	
3.7	**DeviceFeed Requirements**		**Message**	**5.5**	**DeviceFeed Schema**	
3.7.1	**Contents of DeviceFeed**		**Data Frame**	**5.5.1**	**Properties**	
a)	feed_info		Data Frame	5.5.1.1	feed_info	
b)	type		Data Element	5.5.1.2	type	
c)	features		Data Frame	5.5.1.3	features	
d)	bbox		Data Frame	5.5.1.4	bbox	
3.7.2	**Contents of FieldDeviceFeature**		**Data Frame**	**5.5.2.1**	**FieldDeviceFeature**	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
a)	id		Data Element	5.5.2.1.1	id	
b)	type		Data Element	5.5.2.1.2	type	
c)	properties		Data Frame	5.5.2.1.3	properties	
d)	geometry		Data Frame	5.5.2.1.4	geometry	
e)	bbox		Data Frame	5.5.2.1.5	bbox	
3.7.3	**Contents of FieldDeviceCoreDetails**		**Data Frame**	**5.5.2.2**	**FieldDeviceCoreDetails**	
a)	device_type		Data Element	5.5.2.2.1	device_type	
b)	data_source_id		Data Element	5.5.2.2.2	data_source_id	
c)	device_status		Data Element	5.5.2.2.3	device_status	
d)	update_date		Data Element	5.5.2.2.4	update_date	
e)	has_automatic_location		Data Element	5.5.2.2.5	has_automatic_location	
f)	road_direction		Data Element	5.5.2.2.6	road_direction	
g)	road_names		Data Frame	5.5.2.2.7	road_names	
h)	name		Data Element	5.5.2.2.8	name	
i)	description		Data Element	5.5.2.2.9	description	
j)	status_messages		Data Frame	5.5.2.2.10	status_messages	
k)	is_moving		Data Element	5.5.2.2.11	is_moving	
l)	road_event_ids		Data Frame	5.5.2.2.12	road_event_ids	
m)	project_id		Data Element	5.5.2.2.13	project_id	
n)	reference_post		Data Element	5.5.2.2.14	reference_post	
o)	reference_post_unit		Data Element	5.5.2.2.15	reference_post_unit	
p)	make		Data Element	5.5.2.2.16	make	
q)	model		Data Element	5.5.2.2.17	model	
r)	serial_number		Data Element	5.5.2.2.18	serial_number	
s)	firmware_version		Data Element	5.5.2.2.19	firmware_version	
t)	velocity_kph		Data Element	5.5.2.2.20	velocity_kph	
u)	is_in_transport_position		Data Element	5.5.2.2.21	is_in_transport_position	
3.7.4	**Contents of ArrowBoard**		**Data Frame**	**5.5.2.3**	**ArrowBoard**	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
a)	core_details		Data Frame	5.5.2.3.1	core_details	
b)	pattern		Data Element	5.5.2.3.2	Pattern	
3.7.5	**Contents of Camera**		**Data Frame**	**5.5.2.4**	**Camera**	
a)	core_details		Data Frame	5.5.2.4.1	core_details	
b)	image_url		Data Element	5.5.2.4.2	image_url	
c)	Is_image_url_public		Data Element	5.5.2.4.3	is_image_url_public	
d)	image_timestamp		Data Element	5.5.2.4.4	image_timestamp	
e)	video_url		Data Element	5.5.2.4.5	video_url	
f)	Is_video_url_public		Data Element	5.5.2.4.6	is_video_url_public	
g)	video_update_frequency		Data Element	5.5.2.4.7	video_update_frequency	
3.7.6	**Contents of DynamicMessageSign**		**Data Frame**	**5.5.2.5**	**DynamicMessageSign**	
a)	core_details		Data Frame	5.5.2.5.1	core_details	
b)	message_multi_string		Data Element	5.5.2.5.2	message_multi_string	
3.7.7	**Contents of FlashingBeacon**		**Data Frame**	**5.5.2.6**	**FlashingBeacon**	
a)	core_details		Data Frame	5.5.2.6.1	core_details	
b)	function		Data Element	5.5.2.6.2	Function	
c)	is_flashing		Data Element	5.5.2.6.3	is_flashing	
d)	sign_text		Data Element	5.5.2.6.4	sign_text	
3.7.8	**Contents of HybridSign**		**Data Frame**	**5.5.2.7**	**HybridSign**	
a)	core_details		Data Frame	5.5.2.7.1	core_details	
b)	dynamic_message_function		Data Element	5.5.2.7.2	dynamic_message_function	
c)	dynamic_message_text		Data Element	5.5.2.7.3	dynamic_message_text	
d)	static_sign_text		Data Element	5.5.2.7.4	static_sign_text	
3.7.9	**Contents of LocationMarker**		**Data Frame**	**5.5.2.8**	**LocationMarker**	
a)	core_details		Data Frame	5.5.2.8.1	core_details	
b)	marked_locations		Data Frame	5.5.2.8.2	marked_locations	
3.7.10	**Contents of MarkedLocation**		**Data Frame**	**5.5.2.9**	**MarkedLocation**	
a)	type		Data Element	5.5.2.9.1	Type	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
b)	road_event_id		Data Element	5.5.2.9.2	road_event_id	
3.7.11	**Contents of TrafficSensor**		**Data Frame**	**5.5.2.10**	**TrafficSensor**	
a)	core_details		Data Frame	5.5.2.10.1	core_details	
b)	collection_interval_start_date		Data Element	5.5.2.10.2	collection_interval_start_date	
c)	collection_interval_end_date		Data Element	5.5.2.10.3	collection_interval_end_date	
d)	average_speed_kph		Data Element	5.5.2.10.4	average_speed_kph	
e)	volume_vph		Data Element	5.5.2.10.5	volume_vph	
f)	occupancy_percent		Data Element	5.5.2.10.6	occupancy_percent	
g)	lane_data		Data Frame	5.5.2.10.8	lane_data	
3.7.12	**Contents of TrafficSensorLaneData**		**Data Frame**	**5.5.2.11**	**TrafficSensorLaneData**	
a)	lane_order		Data Element	5.5.2.11.1	lane_order	
b)	road_event_id		Data Element	5.5.2.11.2	road_event_id	
c)	average_speed_kph		Data Element	5.5.2.11.3	average_speed_kph	
d)	volume_vph		Data Element	5.5.2.11.4	volume_vph	
e)	occupancy_percent		Data Element	5.5.2.11.5	occupancy_percent	
3.7.13	**Contents of TrafficSignal**		**Data Frame**	**5.5.2.12**	**TrafficSignal**	
a)	core_details		Data Frame	5.5.2.12.1	core_details	
b)	mode		Data Element	5.5.2.12.2	mode	
3.7.14	**Contents of RoadsideUnit**		**Data Frame**	**5.5.2.13**	**RoadsideUnit**	
a)	core_details		Data Frame	5.5.2.13.1	core_details	
b)	message_types		Data Frame	5.5.2.13.2	message_types	
3.7.15	**Enumeration of UnitOfMeasurement**		**Data Element**	**5.5.2.14**	**UnitOfMeasurement**	
3.7.16	**Enumeration of ArrowBoardPattern**		**Data Element**	**5.5.2.15**	**ArrowBoardPattern**	
3.7.17	**Enumeration of FieldDeviceType**		**Data Element**	**5.5.2.16**	**FieldDeviceType**	
3.7.18	**Enumeration of FieldDeviceStatus**		**Data Element**	**5.5.2.17**	**FieldDeviceStatus**	
3.7.19	**Enumeration of FlashingBeaconFunction**		**Data Element**	**5.5.2.18**	**FlashingBeacon**	
3.7.20	**Enumeration of HybridSignDynamicMessageFunction**		**Data Element**	**5.5.2.19**	**HybridSignDynamicMessageFunction**	
3.7.21	**Enumeration of MarkedLocationType**		**Data Element**	**5.5.2.20**	**MarkedLocationType**	

REQUIREMENTS TRACEABILITY MATRIX						
Req ID	**Requirement**	**Dialog ID**	**Data Concept Type**	**Data Concept ID**	**Data Concept Name**	**Additional Specifications**
3.7.22	**Enumeration of TrafficSignalMode**		**Data Element**	**5.5.2.21**	**TrafficSignalMode**	
3.7.23	**Enumeration of RoadsideUnitMessageTypes**		**Data Element**	**5.5.2.22**	**RoadsideUnitMessageTypes**	
3.8	**Direction Requirements**			**5.6**	**Direction Schema**	
3.8.1	**Enumeration of Direction**		**Data Element**	**5.6**	**Direction Schema**	
3.9	**BoundingBox Requirements**			**5.7**	**BoundingBox Schema**	
3.9.1	**Contents of BoundingBox**		**Data Frame**	**5.7**	**BoundingBox Schema**	

Annex B

Connected Work Zones Guidance Needs [Informative]

This section addresses potential Guidance Needs for CWZ Deployers and is organized into the following sub-sections:

- Challenges to Developing a CWZ Program
- Technical/Deployment Challenges
- Data Quality Challenges
- Training and Retraining
- Data Aggregation and the Future of Feed Registries
- Now You're Ready! Setting up a Work Zone Feed.

The intended audience for this section is the collective group of stakeholders, including: IOOs, integrators, developers, contractors, equipment vendors, and third-party organizations typically involved in a connected work zone deployment.

Developing a comprehensive guide to implementing connected work zones from concept to deployment is beyond the scope of this effort. However, we present key topic areas to help the reader conceptualize their efforts, build stakeholder involvement, provide training for new skills, and engineer, design, deploy, and test interoperable connected work zones.

B.1 Guidance Needs – Challenges to Developing a CWZ Program

B.1.1 Guidance Needs – Getting Started with CWZs

Before jumping in and getting started with implementing CWZs, deployers need a plan and a program. This section highlights considerations for creating a program to address deploying CWZs.

Pilot Projects. To gain experience and to help pull together stakeholders and separate aspects of CWZ, deployers may want to consider deploying one or more pilot projects. Acquiring the expertise needed to manage an ongoing program of projects that deliver accurate and reliable connected work zones demands substantial effort and dedication. Pilots can provide valuable experience.

Education and Training. Deployers should also consider developing an educational and training element as part of their CWZ program to address the need for new knowledge, practices, and skillsets needed to build CWZs. These efforts contribute to industry-wide improvements in knowledge -sharing and CWZ deployment.

Technology and Best Practices. The transportation industry is exploring new approaches—many of which are untested or have only yielded preliminary results—to determine the most effective technologies from a transportation operations viewpoint. The paragraphs below identify challenges you may encounter during your journey to deploy CWZs.

While technology is not a bottleneck, adopting new practices and institutionalizing them within stakeholder organizations is a significant challenge. Creating training programs and clearly communicating well-defined rules and tasks with stakeholders is crucial to overcoming this barrier.

That said, because some of the technologies may be new to deployers and their staff, They'll require an understandable architecture, described in layperson terms, to help define a CWZ technology program and establish good project definitions. Good project definitions should articulate the rationale for doing the project, such as improving work zone safety, offering foundational training, and gaining experience.

Setting Expectations. Initial CWZ pilot projects may not deliver additional information beyond what is provided from a 511 traveler information system, or an ATMS reporting on construction. However, it is clear that building a business case for CWZs requires demonstrating benefits that extend beyond today's current capabilities.

Current Challenges. Many IOOs face challenges in knowing the exact locations and operational status of work zones after contracts are approved**.** . Building coalitions among IOOs, or perhaps regional IOOs, device and equipment manufacturers, and contractors is key to timely dissemination of quality work zone information. Such efforts are crucial for saving lives— both workers and drivers passing through work zones.

The broader benefits of CWZs, related to driver and worker safety, can be summarized through the following objectives:

- CWZs will identify in near real-time when a CWZ is active.
- CWZs will identify locations of work zones: where the work zone starts and ends, approach(es) start and end, truck early-merge locations, taper locations, speed limit reduction zones, worker presence, etc., all reported in near real-time.

Data and Workflow Needs. Your program's data and workflow needs will depend on your intended outcomes.

Leverage the consensus flow that works for your organization and for your pilot projects. For example, larger projects may use smart devices more frequently than smaller scale projects. Regardless, coalition building, experience, and experimentation remain the same, though the results may be more or less visible to the casual observer.

Connecting the Dots. Ultimately, your program and experience from pilot projects will enable you to "connect the dots" so you can implement a data and workflow that gathers and disseminates work zone data that is beneficial for your specific needs, and the needs of your end-users.

B.1.2 Guidance Needs – Cross-cutting Organizational Challenges

CWZ stakeholders, whether in separate organizations or within the same organization, have different priorities and missions, which may pose challenges in reaching agreement on direction and details.

Stakeholder participation is key to success; therefore, early buy-in and commitment from partners is vital. One of the key benefits of pilot projects is building relationships that enable CWZs. Cultivating partnerships is just as important, if not more so, than developing the technical requirements for a successful CWZ.

In addition, CWZ deployers need a champion to articulate and balance the goals of numerous stakeholder organizations, including IOOs, integrators, contractors, equipment vendors, and third parties.

Additional considerations when building organizational relationships include:

- **Collaboration.** Developing CWZs may involve cross-cutting needs for your organization involving multiple departments that don't typically share information about construction projects or work zones.
- **Roles and Responsibilities**. Deployers must establish clear roles and responsibilities, highlighting the benefits of each role to motivate continued participation.

B.1.3 Guidance Needs – Explaining the Benefits of CWZs

CWZ deployers need guidance on how to explain the benefits of connected work zones (and deployment options) to potential project stakeholders.

While the technology behind CWZs is relatively straight-forward, the complexities of deployment—such as ensuring accurate, timely, and reliable information—are less .Stakeholders' levels of experience often vary significantly. .

While the safety and efficiency improvements offered by a CWZ are generally easy to understand, some organizations may require specialized expertise to identify which technologies and strategies will work best for their particular needs, and which technologies and strategies correlate with the safety improvements they prioritize.

B.2 Guidance Needs – Technical/Deployment Challenges

B.2.1 Guidance Needs – Lack of Real-Time Information About Work Zone Location and Status

While CWZ deployers may have general information about work zones and the associated road activities, they often lack real-time data the specific dates, times, and locations of work zones, as well as the real-time status of activities. To enable safety and trip-planning improvements, deployers must accurately identify what is happening in a work zone and where it is happening.

Short-term projects present a new set of challenges because they are often not scheduled in advance and involve setting up a work zone for only a short period, sometimes rolling/moving operations. For example, a municipality may set up a work zone and shut down a lane for 6 hours for a roadway repair, or a utility company might close down a local street for 2 to 4 hours to perform maintenance safely..

Electronic work zone equipment with communications capabilities can address the need for real-time status updates, location data, and activity descriptions. While electronic work zone equipment that are communications enabled (referred to as "IOT devices") are suitable as a solution, their use today is limited. CWZ deployers may consider having a work zone worker manually enter the data on a phone app or laptop to fill the information gap between an IOT-device and a non-communications enabled device. The rationale for the approach of involving workers to do data entry is that the value of using traditional equipment (enhanced with data entry performed by a work zone worker) is very high or equal to that of data sourced from automated digital IOT-type devices (such as a smart sign).

Another key consideration is determining the frequency of updates and balancing the cost of communications against the benefits of more frequently available updates. This is especially true for rolling/moving work zones.

B.2.2 Guidance Needs – Limited Coverage and Participation of Potential CWZ Operators

One question that might arise in the mind of a reader is, "How will we incorporate all levels of transportation agencies and work zone deployers, including counties, cities, and states?" For example, one could estimate 3,000+ organizations in U.S. counties alone. Or in the case of utility companies and other private organizations that have work zones, the number of potential CWZ deployers could number into the thousands.

Anecdotal evidence from state and large metropolitan area DOTs suggests that in general, the smaller the project, and the lower the volume of traffic on the roadway, the more likely that the work zone is ad-hoc and uses traditional, non-communicative equipment. In such cases, a simple permit might provide an approximation of the work zone's area and duration.

B.2.3 Guidance Needs - High-Level Deployment Considerations

B.2.3.1 Project Definition

CWZ deployers have a various project types to consider, ranging from large-scale projects to small or ad-hoc projects (e.g., unplanned, utility work). Developing a project definition depends on a number of factors, such as coordinating internal departments in your organization, identifying the lead department, determining whether connected work zone equipment needs to be specified in an RFP, and assigning contractors responsibilities for setting up, moving, and maintaining a connected work zone.

Deployers might start with smaller, internal projects or ad-hoc projects, where some aspect of connected work zones and equipment are deployed, tested, and evaluated. This approach allows deployers to gain hands-on knowledge and experience without public scrutiny.

Another consideration when deciding on projects to pursue is that CWZs require set-up / take-down time, and therefore may be more appropriate for a larger project. That said, ad-hoc and shorter-term work zone projects make up an overwhelming percentage of work zones deployed.

Most important to project definition is developing clear goals, objectives and milestones to measure progress.

B.2.3.2 Engineering Specifications

While this document focuses on system architecture and interface designs to support interoperability, it is important to state awareness of processes and reference documentation (e.g., MUTCD, HCM, NCHRP 350) that are required for conformance and the development of engineering specifications. For example, these references are critical for defining approaches, taper segments, and details related to placement of equipment.

It is necessary to involve roadway/roadwork engineering professionals when specifying connected work zones. These professionals can help identify what activities need to take place and what locations associated with the work zone need to be marked.

B.2.3.3 System Architecture and Interface Design

One best practice for implementing an interface based on this standard is to develop a system architecture— a high-level design showing the components and their interfaces.

Deploying CWZs presents challenges in implementing key parts of the system architecture, and deployers should be prepared to collaborate with their organization's IT department.

Key design issues related to deploying a system architecture to satisfy the needs of CWZs are discussed below.

- **Frequency of Updates.** Determine how often the data should be generated and whether your deployment will support change-driven (update-driven) communications. The type of information will drive how often a device needs to communicate information. For example, the device marking location of the start of a work zone may not need to communicate frequently.
- **Security-Trust.** Deployers need to know who is authorized to request work zone information. Solution might include using API keys to authenticate authorized data requests. When determining whether the providers of work zone information are trusted sources, deployers could consider using electronically signed certificates to verify data providers. If a CWZ deployer is looking to deploy equipment for Connected Vehicles, then the devices and computing systems used in the CWZ may need to become part of the Security Credential Management System (SCMS) that ensures secure communications with consumers.
- **Network Connection Management.** Deployers must verify that all work zone equipment is connected to the work zone center. Connection management should include verification that components are able to communicate with each other and include fault detection and alarms and notifications to ensure predictable responses to components failures.
- **Interface Design Specification.** A frequently used term to describe a system interface is Interface Control Document (ICD). An ICD is deployer-specific. One resource for developing ICDs is IEEE Std 1016-1998.
- **Testing.** Deployers need to verify that CWZ component interfaces conform with standards and comply with deployer's specifications. Testing can be done in a laboratory environment, in a small

field setting, or as part of regular maintenance of a system. For more information on Testing, see IEEE Std 829-2008.

- **Data Archiving.** Agencies interested in historical data analysis may want to consider archiving CWD data for metrics-based analysis. This requires addressing storage requirements.
- **Data Inputs and Sources.** Deployers need to identify which datasets need to be ingested into a work zone information feed.

B.2.3.4 Configuring CWZ Components – Devices, VRUs, Work Vehicles, Lanes, etc.

Proper guidance on configuration of work zone equipment is critical. Deployers face several challenges in setting up devices, work zone vehicles, and VRUs. Several aspects of equipment configuration are identified below.

Assigning Identifiers: Equipment in CWZs need unique identifiers and know what work zone they are associated with, what type of equipment they are, and their geographic position, to name a few items. Some equipment may be able to automatically self-configure while others require manual setup.

Defining Work Zone Information: Deployers must define elements like lane closures, taper start and end points, number of lanes to taper, and direction of taper. Similar handling may be required for other components, such as speed reduction zones and work zone approaches.

B.2.3.5 Connected Vehicle (CV) Environment Deployments

The factors described below apply to any alternative for deploying CWZs. Each factor includes a brief discussion specific to CV environments.

- **Power Consumption.** CV devices currently consume more power than typical communications-enabled work zone devices, such as arrow boards. Deployers should consider engineering requirements for powering CV devices when considering alternatives.
- **Time to Configure.** Deploying RSUs and other CVs requires preparation. Deployers will need to factor in time for setting up CV equipment for ad-hoc and short-term jobs.
- **Lane Geometry / MAP message.** Deploying CV equipment in work zones often requires the creation of a MAP message. It is also necessary to keep in mind that there is no current standard for dealing with roadway sections, i.e., zones. The MAP message has been deployed for intersection-oriented applications.
- **Cost.** CWZ deployers considering CV technologies may want to include cost as a factor when considering alternatives.
- **Positioning / RTCM Message.** Deployers will need to identify their positioning accuracy needs and determine how best to deploy RTCM networks or devices. There are currently alternative methods for deploying RTCM networks/devices and ensuring consistency is an ongoing nationwide challenge.

B.2.4 Guidance Needs – Applying ITS Standards

Work zones show up in multiple ITS standards. While standards are good, applying multiple ITS standards and keeping up with their progress to address growing needs can be tricky. We address two key issues below:

1) Approaches to keeping up with ITS standards development and progress.
2) Approaches to using multiple ITS standards in CWZ deployments.

B.2.4.1 Guidance Needs – Keeping up with the Development and Progress of ITS Standards

Connected work zones crosscut into many areas where standardization efforts have been applied, including traffic management, work zone equipment, and connected vehicle environments. As CWZs evolve, new standards emerge, and existing ones are being updated.

Specific challenges for CWZ deployers include identifying which standards to support. For developers, staying updated with multiple standard versions is a challenge, as different versions may need to be simultaneously supported.

B.2.4.2 Guidance Needs – Using Multiple Standards in a CWZ Deployment

As stated previously, work zones are addressed in multiple standards. One objective of this document is to provide technical guidance where applicable on applying multiple ITS standards, including the following:

- **Work Zone Data Exchange (WZDx) Specification.** The objective is that this standard and guidance will, based on consensus working group input, provide backward- compatible designs aligned with the WZDx specification.
- **ngTMDD.** The ngTMDD standard provides a data dictionary that was developed concurrently with this CWZ standard, facilitating work zone information exchange between zones and centers.
- **SAE J2945/4.** Compatibility with the Roadside Safety Message (RSM) in terms of enumerated lists and guidance on mapping from this standard to the J2945/4 RSM where needed. We anticipate that the J2945/4 standard will replace and resolve ambiguities in deployments that are using the SAE J2735 Roadside Safety Message and/or Traveler Information Message.

Deployers involved in long-term CWZs may consider participating in standards development efforts to track and influence the standards related to CWZs.

B.3 Guidance Needs – Data Quality Challenges

B.3.1 Guidance Needs – Inconsistent Data and Quality from Data Providers

Currently, the quality of work zone data depends on the producer of the information and what project data is available.

Not all roads are the same when it comes to available work zone information. But generally:

- Planned work zone information is available for larger roadways, and larger construction projects.
- Smaller roadways, minor projects, and utility companies do not track and, therefore, have limited, if any, electronic data for their work zones.

B.3.2 Guidance Needs – Map Accuracy

Map accuracy is constrained by publicly available data sources and low-cost GNSS. Overall, CWZ deployers do not have the resources to make and measure high-definition map data. Currently, this is not a major concern, as OEMs are developing proprietary high-definition maps, tailored to their specific applications. This standard has been designed with these limitations in mind, addressing the level of detail necessary for CWZ deployers to provide to an OEM's back office. For the most part, CWZ deployers will not need to provide lane-specific work zone geometry, except for internal purposes or for sharing geographic datasets with the public and internally.

B.3.3 Guidance Needs – Verification & Validation

CWZ deployers need to develop a process / workflow to validate that their work zone information feed is current and correct. This includes the following:

- CWZ deployers need to validate that work zone technologies are in place and functional.
- CWZ deployers need to assess and verify the reliability and availability (uptime) of devices in the work zone. For example, testing a device may entail running tests over a period of time. This may require a CWZ deployer may need to have the device remain dark (to travelers), but accessible to be monitored for the purposes of test from a remote location.
- CWZ deployers need to assess and verify the reliability and availability (uptime) for their work zone information feeds used by external centers, third parties, and the public.

B.4 Guidance Needs – Training and Re-training

B.4.1 Guidance Needs – Emerging Technologies and Methods of Data Acquisition

CWZ deployers will need to factor in the additional time for onboarding all involved parties. Deployers need guidance on:

- C/AV User Needs. Developing pilots for C/AV implementations that satisfy the needs of end-users.
- Best Practices. Understanding best practices for deploying new technologies and methods for real-time WZ data acquisition.
- Data Quality. Verifying the accuracy and currency of work zone information (e.g., verify the geometry of the work zone) and ensuring that status information is accurate and up-to-date.
- Training Resources. Accessing links to research and documentation.
- Lab and Training Environment. Establishing a lab and/or training facility for hands-on training on equipment and for conducting lab testing of CWZs in a controlled environment.

B.4.2 Guidance Needs – Developing New Skills

Deployers should consider developing training programs as part of their overall CWZ deployment program, to equip staff with the knowledge and skills necessary to develop work zones.

A representative example of types of new skills organized by staff/labor category is shown below.

- Project Managers. Need to understand the benefits of CWZ deployments. For example, CWZs provide traveler information, which yields mobility and safety benefits.
- Contractors and Field Staff. More training is required for work zone workers. For example, how to set up, configure, and take down equipment. Training on Connected Arrow Boards or Dynamic Message Signs are ways to get started with a training program.
- Roadway Engineers. Need to understand best practices for engineering hybrid CWZ design combining traditional equipment and newer technologies.
- System Architects. Although the high-level architecture of a connected work zone is generally understood by experienced ITS professionals, CWZ deployers may need to support staff who do not understand how connected work zones are put together.
- System Integrators. There is a lack of knowledge by deployers/agencies about how to fill in the work zone data if they do not have it.

B.5 Guidance Needs – Data Aggregation and the Future of Feed Registries

Regional stakeholders, such as a metropolitan area or a rural state, often need to aggregate—collect, harmonize, and redistribute—data into a regional view of transportation information. In our case, the focus would be regional work zone information.

Currently, the WZDx initiative includes a data feed registry for discovery of WZDx data sources. However, The fate of the WZDx feed registry is uncertain, and therefore, regions may decide to develop their own discovery mechanism or create a data hub to maintain the work zone information in a historical context.

Listed below are some things to consider if this path suits the needs of regional stakeholders.

- Benefits. A feed registry can be used to promote safety for work zone workers and the driving public.
- Unique IDs. To aggregate data, regions will likely need some mechanism for assigning unique identifiers for work zones in the region.
- Who maintains and pays for upkeep. The public agencies will need to secure funding, while private entities would need to make a business case and identify how to monetize the data feed. We don't look at this as a conflict of interest as much as a difference in approach to satisfy the need for high quality work zone information for a region.

B.6 Guidance Needs – Assess Your Readiness to Deploy CWZs

Hopefully, this section of the standard and guide has provided readers with high-level information to help assess a deployer's readiness to implement connected work zones using this standard.

CWZ deployers require software capable of managing the complex of data and interrelationships that define a work zone, including locations, lane details and configurations, schedules, devices, vehicles, VRUs, and traffic flow. Each CWZ deployer will need to assess existing systems and available data. For example, a potential deployer may have legacy implementations, such as an ATMS or 511 system, that can serve as a starting point for their CWZ program.

B.7 Guidance Needs – Leverage What Others Have Started

Leveraging what others have done before is a valuable strategy. One method is to download WZDx data, which can be input directly into a GIS. Then, revisit this Guide and Standard to review topics that can help you in planning your CWZ Program.

Annex C
Guidance for Deployments Involving Connected Vehicle Environment Work Zone-related Standards [Informative]

This annex provides guidance for CWZ deployers who may need to use this standard in addition to other standards related with the Connected Vehicle Environment.

C.1 Physical Architecture – CVE Compatibility Roadside Safety Message

The figure below provides a context for the use of CWZ WorkZoneFeed and DeviceFeed together with other standards of the Connected Vehicle Environment.

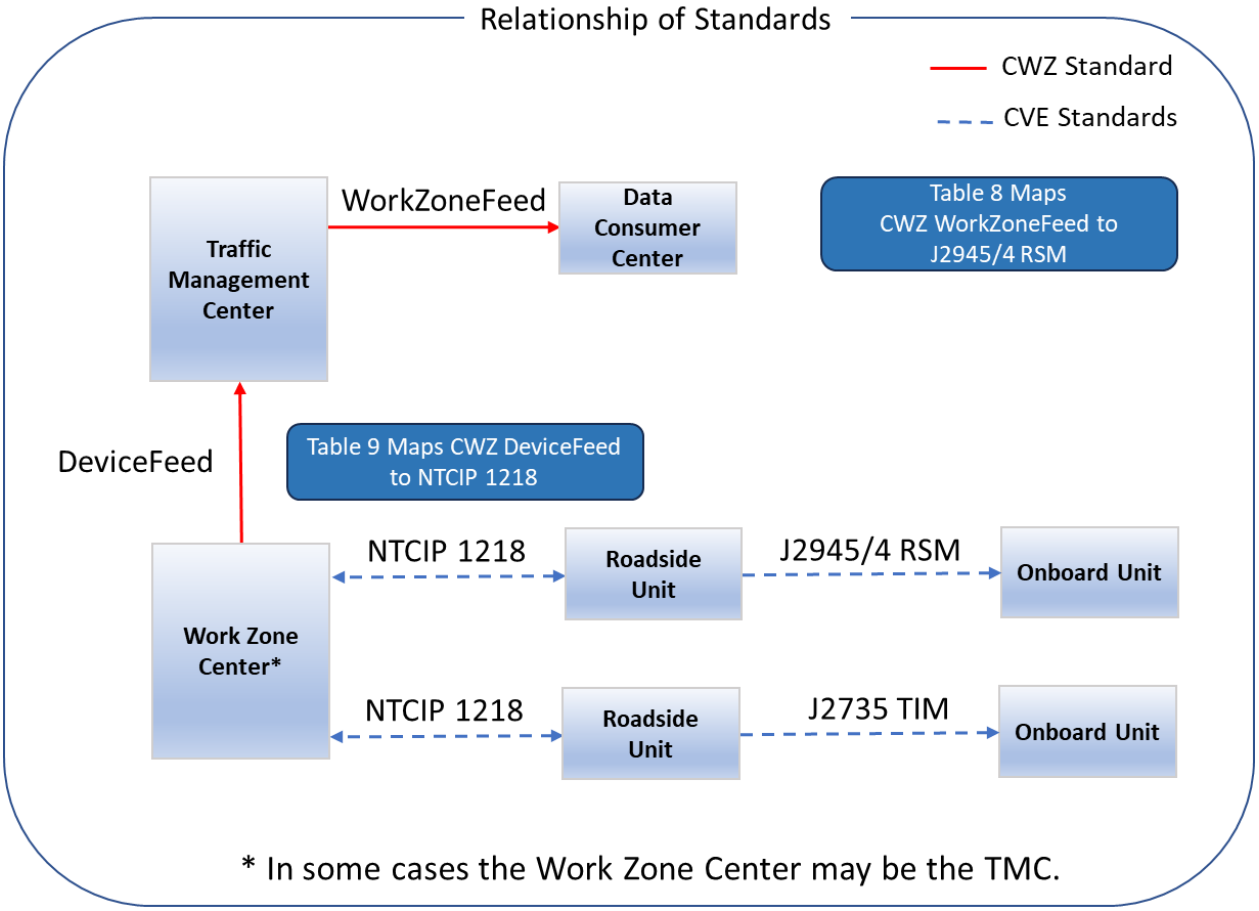
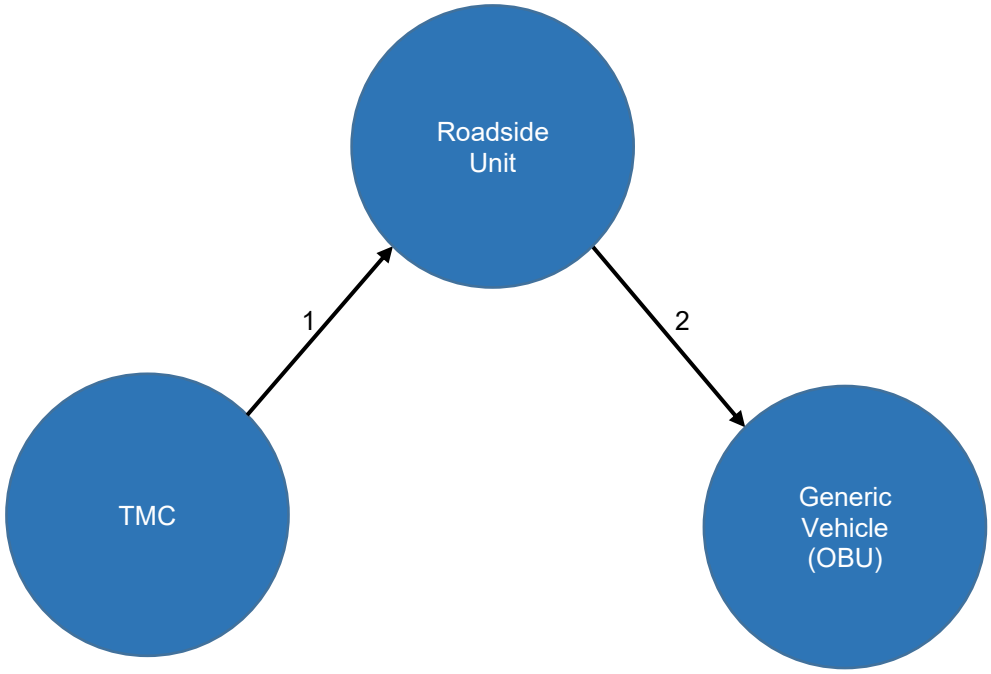


Figure 5. Physical Architecture: Connected Vehicle Environment Roadside Safety Application

Note: Describing how to configure an RSU using NTCIP 1218 is out of scope of this project.

C.2 Operational Scenario – CVE Compatibility Roadside Safety Message

Title	Connected Vehicle Environment Compatibility – Roadside Safety Message
Problem Aspect	Work zone RSUs may provide messages using the connected vehicle environment standards to communicate with connected vehicle OBUs.
Description	The traffic management center may want to broadcast roadside safety messages to drivers in connected vehicles. This can be done with an RSU in the work zone. Possible messages may be a reduced speed zone warning or lane closure information.
Pre-Conditions	• The traffic management center is connected to the connected vehicle environment (C-V2X/DSRC/other). • The RSU is configured using communications standard NTCIP 1218. • The RSU is configured to broadcast the Roadside Safety Message per communications standard J2945/4.
Optional Diagram	
Narrative and Sequence of Steps	1) The TMC transmits an NTCIP 1218 message to the RSU to configure the RSU to send Roadside Safety Messages (RSM) to the OBU. 2) The RSU transmits an J2945/4 RSM message to the OBU.
End Conditions or State	CVs (OBUs in vehicles) receive Roadside Safety Message from the RSU so that the driver may be alerted.

C.3 Design Guidance – WorkZoneFeed and SAE J2945/4 Compatibility

The information below represents preliminary recommendations from the CWZ Working Group.

Table 8. Mapping of CWZ WorkZoneFeed Data Concepts to SAE J2945/4 Data Concepts

CWZ WorkZoneFeed Data Concept	SAE J2945/4 Data Concept	Additional Information and Notes
	3.5.1 Message Content and Structure Requirements	
5.4 RoadEventFeature 5.4.1.1 id	3.5.2 Event Identification In this case the event is the work zone.	
5.4.2.1 WorkZoneRoadEvent 5.4.2.3 RoadEventCoreDetails	3.5.3 Event Context	
5.4.2.3 RoadEventCoreDetails 5.4.2.3.2 event_type work-zone detour	3.5.3.1 Event Type (Section G.2 Cause code) ITISGroup-Closures (3)	
5.4.2.1 WorkZoneRoadEvent 5.4.2.1.18 types_of_work 5.4.2.7.1 type_name maintenance, minor-road-defect-repair, roadside-work, overhead-work below-road-work barrier-work surface-work painting roadway-relocation roadway-creation	3.5.3.2 Event Subtype (Section G.2 Subcause code) accident (513) closed-to-traffic (769) closed-ahead (771) closed-intermittently (772) closed-for-repairs (773) closed-for-the-season (774) blocked (775) blocked-ahead (776) reduced-to-one-lane (777) reduced-to-two-lanes (778) reduced-to-three-lanes (779) collapse (780) road-construction (1025) major-road-construction (1026) long-term-road-construction (1027) construction-work (1028)	A recommendation is provided in Annex D. There are challenges to providing a one-to-one mapping between the CWZ elements and those of SAE. The current state of the practice in some DOTs is to use a script that contains an algorithm to translate between the values shown in the columns at right. Currently, agencies have different and potentially conflicting approaches to expressing the information about a work zone using the SAE ITIS codes as described in the center column.

CWZ WorkZoneFeed Data Concept	SAE J2945/4 Data Concept	Additional Information and Notes
	paving-operations (1029) work-in-the-median (1030) road-reconstruction (1031) opposing-traffic (1032) narrow-lanes (1033) construction-traffic-merging (1034) single-line-traffic-alternating-directions (1035) road-maintenance-operations (1036) road-marking-operations (1037) road-widening (1061)	
5.4 RoadEventFeature 5.4.1.4 geometry	3.5.4 Event Location	
	Reference Point	No direct translation
	Applicable Heading	Not a CWZ Standard data concept
5.4.1.4 geometry – LineString	Location Type = BroadPatch 5.2.24 DF_Path	
	3.5.5 Event Time	
5.4.2.1.8 start_date	3.5.1.1 Event Start Time – Planned Event	
5.4.2.1.8 start_date 5.4.2.1.10 is_start_date_verified	3.5.5.1.2 Event Start Time – Current Event	Potentially, 5.4.2.3.8 creation_date
5.4.2.1.9 end_date	3.5.5.2 Event End Time	
5.4.2.1.16 reduced_speed_limit_kph Speed limit units are in kilometers per hour	3.5.12.2 Reduced Speed Event Requirements - Speed Limit Units in meters per second	Requires conversion between kilometer-per-second and meter-per-second
5.4.2.8 Lane	3.5.12.3 Lane Closure Event Requirements	
5.4.2.8 Lane 5.4.2.8.1 order 5.4.2.8.2 status = open	3.5.12.3.1 Provide Number of Lanes Nominally Open	
5.4.2.8 Lane 5.4.2.8.1 order 5.4.2.8.2 status = closed	3.5.12.3.2 Provide Indication of the Close Lanes	
5.4.2.8 Lane 5.4.2.8.1 order order. Integer. 1 = left most lane	3.5.12.3.3 Provide Lane Closure Locations RSMLanePosition	There is direct alignment between the data concepts in both standards.

CWZ WorkZoneFeed Data Concept	SAE J2945/4 Data Concept	Additional Information and Notes
	- 5.5.7 DE_RSMLanePosition. Range (1..32). 1 is the left most lane.	

A couple of noteworthy items are presented below:

- The J2735 Sep 2023 version contains Section 5.17 Message: MSG_RoadSafetyMessage (RSM). The text in this section states that it is 'Reserved for future use.' The CWZ Working Group assumes that this section is a placeholder for the same RSM message as described in SAE J2945/4.
- At the time of this writing, the CWG Working Group has learned that at least one organization, Ohio DOT, is developing a guide for usage of the J2945/4 RSM.

C.4 Design Guidance – DeviceFeed and NTCIP 1218 Compatibility

The information below represents preliminary recommendations of the CWZ Working Group.

Table 9. Mapping of CWZ DeviceFeed Data Concepts to NTCIP 1218 Data Concepts

CWZ DeviceFeed Data Concept	NTCIP 1218 Data Concept	Additional Information and Notes
5.5.2.13 RoadSideUnit		
5.5.2.1 FieldDeviceFeature		
5.5.2.1.4 geometry	5.7.6 GNSS Reported Latitude 5.7.7 GNSS Reported Longitude	Value = GeoJSON type 'Point'
5.5.2.13.1 core_details		
5.5.2.2 FieldDeviceCoreDetails		
5.5.2.2.1 device_type		Value = 'roadside_unit'
5.5.2.2.2 data_source_id		Determined by data provider
5.5.2.2.3 device_status		Determined by data provider
5.5.2.2.4 update_date		Determined by data provider
5.5.2.2.5 has_automatic_location		Value = 'true'
5.5.2.13.2 message_types	5.4.2 Store and Repeat Table 5.4.2.2 Stored Message PSID	The Provider Service Identifier (PSID) is a reference to an application running on the roadside unit. The PSID may potentially be used to identify the type of message being broadcast by the RSU.

C.5 Discussion – SAE J2735 Traveler Information Message

One key finding from discussions leading to development of this section by the CWZ Working Group is the need for a national effort or standard to ensure consistent usage and interoperability of J2735 TIM messages as they relate to work zones.

Currently, several DOTs are independently developing guidance on the use and deployment of J2735 TIM messages These efforts include:

- Caltrans is developing a document titled “Connected Vehicle Traveler Information Guide.” This guide aims to specify how to configure the J2735 TIM message from ITIS Codes.
    - The ITIS Codes can be linked to graphics/icons, some of which are already included in the MUTCD.
    - The Caltrans guidance on J2735 TIM includes a mapping of ITIS Codes to the national MUTCD code, where applicable.
- Wyoming DOT (WyDOT) developed an early version of J2735 TIM message guidance as part of the Connected Vehicle Pilot Program.
- Colorado DOT has adopted and is following the guidance developed by WyDOT guidance.
- Michigan DOT actively broadcasts J2735 TIM from RSUs.

Annex D
Recommendations to SDOs [Informative]

This annex summarizes comments and recommendations from the CWZ Working Group or its task forces to Standards Development Organizations on existing standards that are referenced by this CWZ Implementation Guide and Standard.

D.1 SAE Recommendation Jointly with ITE

1. The CWZ WG recommends that SAE, perhaps jointly with other organizations, develop a decision tree or algorithm to map the CWZ WorkZoneFeed to its ITIS codes used by J2945/4, specifically the Event Subtypes of Event Type ITISGroup-Closures (3).
2. The CWZ WG recommends that SAE, perhaps jointly with other organizations, develop guidelines and standards for consistent usage and interoperability of J2735 TIM messages in relation to work zones.
3. The CWG WG suggests conducting a technical review to ensure vehicle communications standards effectively handle scenarios where a vehicle receives messages from two separate work zone in the same direction of travel For example, on I-95 north, one work zone might exists from mile marker 88 to mile marker 90, and another work zone from mile markers 91 to 92. While each work zone would have its' own unique identifier, we want to make sure that the vehicle communications standards can accommodate work zones having overlapping RSU ranges, which can exceed 8,000 feet, presenting the possibility of a vehicle receiving messages from multiple work zones.

A more detailed analysis of items 1 and 2 above is contained in Annex C.

D.2 ITE Recommendation

D.2.1 ITE CAV Committee Role

The CWZ WG suggests that ITE's CAV Committee undertake the challenge of a technical review of the User Comment Draft and provide a platform to address specific operational issues related to deploying Connected Work Zones that are beyond the scope of this standard.

As described on ITE's website, the scope of ITE's CAV Committee is the following:

> "The ITE CAV Steering Committee within the Transportation Systems Management & Operations (TSM&O) Council is a multi-disciplinary cross-cutting steering committee intended to give every ITE Council a voice in the conversation concerning the future of connected & automated vehicles. This group will function as a clearinghouse for ideas, issues, and concerns—ensuring that every stakeholder group within ITE (as represented by the different councils) has an opportunity to contribute, while enhancing collaboration and communication for the very cross-cutting nature of this subject." [Source: https://www.ite.org/about-ite/councils/transportation-systems-management-operations/cav-steering-committee/]
>
> The CWZ WG also recommends harmonizing CWZ and ngTMDD standards.

Annex E
User Requests [Informative]

This annex documents needs, requirements, and design details identified and considered by the CWZ Working Group or its task forces but not incorporated into this CWZ Implementation Guide and Standard. The rationale for excluding these elements is also provided. Thie items in this section may be revisited and considered for future editions of the CWZ Implementation Guide and Standard.

E.1 User Requests – Needs

This sub-section identifies user needs that were identified and considered by the CWZ Working Group but are not addressed by this CWZ Implementation Guide and Standard.

E.1.1 Tutorial – Data Exchange Roles and Mechanisms

2.4.3.1 Polling for Updates – An Alternative to Polling

Polling, which allows a data consumer to periodically request all available data, is easy to understand. An alternative, known as *polling for updates,* enables the data consume*r*. to retrieve only data that has changed within a specific timeframe (e.g., the last 12 hours).

The scenario below with Paula (the data provider) and Chris (the data consumer) illustrates how this approach allows Paula to make more efficient use of paper and enables Chris to pinpoint the specific timeframe relevant to his needs.

One benefit of polling for updates is the result of smaller transmissions of data.

One disadvantage of polling for updates is the risk that a data consumer may miss updates if the specified time in the past is incorrect.

2.4.3.2 Change-driven Updates Described as an Interaction Between Humans

Change-driven updates work differently: Paula sends only the pages that have changed, and she sends them immediately when a change occurs. This mechanism ensures that Chris's dataset remains current and synchronized with Paula's in real time.

Imagine that all the work zone information can fit on a single page for simplicity. Chris provides Paula with a piece of paper for authentication, which also includes his address. Let's imagine that mail service between Paula and Chris is practically instantaneous.

When Paula detects a change, she edits the page to reflect the update in her dataset (binder). She then sends the updated page along with its page number to all data consumers, including Chris. This ensures both Paula's and Chris's data sets (binders) are perfectly synchronized. For scenarios including multiple work zones, Paula would send updates for all that have changed, so Chris and other data consumers would receive multiple updated pages.

One benefit of change-driven updates is the result in smaller transmissions of data. A secondary benefit is that change-driven data exchange architectures scale well, supporting a growing number of data consumers and providers.

One disadvantage is that it requires data consumers to have confidence that they have received every change that has occurred.

Rationale: CWZ WG Discussion.

- Both the Polling for Update and Change-driven Update data exchange mechanisms offer advantages and disadvantages for deployers. However, these disadvantages do not exist with the current Polling mechanism of WZDx. Developing a satisfactory design to

overcome the disadvantages is a complex issue with many design considerations. inconsequently, the CRZ WG decided to postpone a design for a future update of the CWZ Standard. Therefore, the materials leading to the design, including this tutorial, associated needs, operational scenario, and requirements have been relocated to this Annex for future consideration.

E.1.2 Architectural Needs

2.5.1.1 Architectural Need - Software and Documentation Repository

CWZ deployers need open and public access to open-source software and documentation to foster experimentation and application of the CWZ standard. For example, since 2023, the WZDx open GitHub repository provides access for potential CWZ deployers to gain knowledge and experience in CWZ standards application.

Rationale:

- As stated, this is a goal.
- The requirements developed from this need would not be testable.

2.5.1.2 Architectural Need – Compatibility with Existing and Emerging Standards

CWZ deployers may need to use multiple standards (e.g., J2945/4 RSM, TMDD, J2735 TIM & RSM, and WZDx). To the extent practical, the CWZ Standard will strive to provide consistent data definitions and enumerations to facilitate the necessary conversions when moving data between formats governed by different standards. Where there is no consistency, the working group will provide guidance, such as a mapping table to translate from one standard to another.

Rationale:

- The requirements developed from this need would not be testable.
- As stated, this need is a goal.

2.5.1.2.2 GeoJSON Data Exchange – Poll for Data Updates

CWZ deployers need to share work zone information updates only, given a point in time in the past, where work zone information is provided in the GeoJSON data format. Poll for Data Updates is a synchronous method of communication.

2.5.1.2.3 GeoJSON Data Exchange – Change-driven Updates

CWZ data providers need the capability to asynchronously share updates only when changes occur.

Rationale: CWZ WG Discussion.

- The Polling for Update and Change-driven Update data exchange mechanisms have advantages and disadvantages for deployers. These disadvantages do not exist with the current Polling mechanism of WZDx. Developing a satisfactory design to overcome the disadvantages is a complex issue with many design considerations. It was the opinion of many in the WG to postpone a design for a future update of the CWZ Standard. Therefore, the materials leading to the design, including this tutorial, associated needs, and requirements have been relocated to this Annex for future consideration.

2.5.1.3 Architectural Need – Extensible Framework

This CWZ standardization effort will largely be based on what can be practically and currently collected from and by IOOs. The capabilities and data collection practices of IOOs will likely develop over time to reflect new practices. Therefore:

- CWZ deployers need a CWZ standard that will provide a consistent framework for data exchanges deployable today, while able to accommodate new needs that may arise over time.
- CWZ deployers need a CWZ standard that will extend to new areas and categories of disruptions.
- CWZ deployers need a CWZ standard that will extend to new areas and categories of VRUs.

Rationale:

- The requirements from this need overlap with the need for backward compatibility. Backward compatibility provides an extensible framework, as defined above.
- As stated, most of the content in this need is a goal.

2.5.1.5 Architectural Need – Time Source

Currently, devices use varying methods and time sources to determine time (for example, to generate a timestamp); some devices use the Network Time Protocol (NTP), while others depend on the time provided by a Global Navigation Satellite System (GNSS) receiver.

CWZ deployers need to maintain consistent time across various devices used in connected work zones.

Rationale:

- No requirements nor design were identified for this need by the CWZ WG.

2.5.1.6.2 Support Smaller, Condensed Packets of Information

The current JSON REST API provides all work zone activity for a particular data provider. That transferred information, when saved, results in a GeoJSON file that can be viewed with off-the-shelf software, such as a GIS. One drawback of this approach is that large datasets will likely not support the following:

- “over the air” interfaces
- the transfer of real-time or near real-time information.

CWZ deployers need to support the exchange of smaller, condensed packets of information.

CWZ deployers need to support a mechanism for data exchanges as follows:

- Based on the exchange of smaller packets of information;
- Supports updates for specific work zone information or subsets/fragments of work zone data (e.g., VRU locations, work vehicle, devices) without requiring the retransmission of static information that has not changed;
- Supports exchanges where the data provider initiates the transfer of information. This contrasts with the current JSON REST API, which relies on polling initiated by the data consumer.

Rationale: CWZ WG Discussion.

- Proposed to remove these texts.
- There was agreement to remove.
- The focus (scope) of this standard is center to center (Work Zone Center to External Center).
- The WZDx and this ConOps should not cover Work Zone Devices to Work Zone Center.
- General agreement.
- The scope does not include polling or control of devices from Work Zone Center.
- It was agreed to keep the change-driven discussion, which is included in another need.

2.5.1.6.3 Support Confirmation Receipts

CWZ deployers need data exchanges to contain a confirmation receipt that verifies delivery when a data provider sends data to a data consumer.

Rationale: CWZ WG Discussion.

- Objective is to account for both delivery and confirmation of interpretation of the data.
- Want acknowledgement that all data items in the “transaction” were read successfully. This is important for security and liability reasons.
- Providers need a “key code” that authorizes the end-user's use of the data. This may be used as a confirmation that the end-user agrees to comply with an agreement.
- It was agreed that this is a big topic and should be moved to the parking lot.

2.5.1.9 Architectural Need – Goal / Mandatory and Optional Elements

CWZ deployers have the following concerns about mandatory and optional elements:

- Optional items in the CWZ standard makes designs incompatible;
- Optional data elements greatly affect the desired outcome of a common data structure to handle the content of work zone information;
- Stakeholders involved in standards development tend to make data elements optional when:
  - They cannot reach consensus agreement, or
  - They anticipate that they will not be able to provide the data specified by the standard.

CWZ deployers need greater consensus agreement on what is essential (i.e., mandatory).

CWZ deployers need to handle mandatory elements when data is not available so they can use a common data structure, even if the data is not available.

Rationale: CWZ WG Discussion.

- Agreed that this is a challenge, but untestable, and there is not a process to support this goal.
- There is not much that can be done about this, and therefore should be removed from the standard.

2.5.1.10 Architectural Need – Goal / Machine Interpretable Data

CWZ deployers have systems that rely on data that does not require human interpretation, such as free-form fields.

CWZ deployers need data as specified in the standard to be interpretable by machines.

Rationale:

- As stated, this is a goal.
- The requirements developed from this need would not be testable.

2.5.1.11 Architectural Need – Goal / Data Structure

CWZ deployers have the following architectural design goals:

- Limit the use of 'choice' elements in the data structure that can enable multiple, if not infinite permutations of data structures, and non-interoperable designs, ambiguous interpretations of the data, and create errors in data interpretation.
- A flat data structure is better than a deeply-nested structure. The current data structure is tending toward becoming heavily nested. Moving forward, the CWZ Working Group should consider more favorable designs with a flatter structure.
- Enable an API to allow gathering of specific data for a CWZ.

CWZ deployers need a single, consistent data structure that handles multiple situations, across actor components, and designs.

Rationale: CWZ WG Discussion.

- The assertions are unproven and requirements developed from this need would not be testable.
- There is not much that can be done about this, and there is much engineering judgement involved.
- This should be removed from the standard.

2.5.1.12 Architectural Need – Zone Data Quality and Validation

2.5.1.12.1.1 Criteria for a Defined Quality of Information

CWZ deployers need criteria for evaluating the quality of work zone data.

2.5.1.12.1.2 Support Information to Support Decision-making for Operations

CWZ data consumers need accurate and correct information to support decision-making for operations.

2.5.1.12.1.3 Support Accurate and Correct Information to Facilitate Trip Planning

CWZ data consumers need accurate and correct information to support pre-trip route, and en-route trip planning.

Rationale: CWZ WG Discussion.

- If these are needs, will there be requirements and design to trace back to these needs? These items are not testable.
- If we use the term accurate, we need to specify how accurate.
- Equipment manufacturers do not typically provide information that is “interpreted.”

2.5.1.12.2 Architectural Need – Zone Data Quality – Position/Geometry Is Correct

CWZ providers need to provide correct and accurate (the best the provider has available) zone geometry information when providing work zone information to data consumers.

Rationale: CWZ WG Discussion.

- If we use the term accurate, we need to specify how accurate.
- Some feed providers can only provide a single point.
- Define the source.
- As defined above, quality is untestable.

2.5.1.12.3 Architectural Need – Zone Data Quality – Time Work Zone is Active Is Correct

CWZ providers need to provide correct and accurate zone active time information when providing work zone information to data consumers.

Rationale: As amended, this is a duplicate need.

2.5.1.13 Architectural Need – Security-Trust

2.5.1.13.1 Support Cyber Security

CWZ deployers need cybersecurity to be a vital element of the CWZ Standard architecture.

2.5.1.13.2 Verify Trusted Source of Information

CWZ deployers exchanging data need to verify whether a data provider is a trustworthy source. For example, one mechanism suggested by CWZ deployers is verification of a trusted source using security certificates and signing of data.

2.5.1.13.3 Verify Authentication for Access

CWZ data providers need a mechanism for authorizing data consumers. For example, one mechanism suggested by CWZ deployers is that API keys are used in conjunction with the JSON REST API.

2.5.1.13.4 Support SCMS for Connected Vehicle Environment Deployments

CWZ deployers working in Connected Vehicle Environments need to access the SCMS for security services.

> **Rationale:** These security needs were identified as an operational constraint and highly dependent on each agency's security policies, which are not subject to this standard.

2.5.1.15 Architectural Need – Feed Discovery

Potential CWZ data consumers need to know where to acquire work zone data being made available by data providers.

> **Rationale:** This need, the need for a mechanism and supporting systems to enable feed discovery, is outside the scope of this system interface standard.

2.5.1.16 Architectural Need – Data Hub

CWZ deployers need a mechanism to allow aggregation of data from multiple or many data providers.

> **Rationale:** This data hub need is outside the scope of this system interface standard, as we are not writing requirements for a data hub.

E.1.2.1 Architectural Needs – User Comment Draft Comments Received

The following comments were received during the User Comment Draft review.

- In certain implementations of a Data Consumer / Data Provider polling system, the Data Provider may need to limit the quantity of data provided in order to allow the Data Provider to ensure internal systems are not effectively shut down due to overloaded throughput (i.e., effectively a Denial-of-Service attack). Some Data Providers may have policies to mitigate potential Denial of Service failures on their internal systems. As is written, the CWZ Standard implies that all available work zone data will be provided by a Data Provider upon request from a Data Consumer via the Poll communication system. However, depending on the frequency at which a Data Consumer issues a Poll Request and/or the total quantity of available data, it may be overly burdensome to a Data Provider to respond with all of the available data to each request. A Best Practice method of handling this type of scenario is with an implementation of data pagination, whereby a segment of the total available data is provided to the Data Consumer along with a method for the Data Consumer to subsequently issue a new request for the next segment, continued until the Data Consumer eventually requests all available data segments. Such a mechanism allows a Data Provider to ensure that internal systems are provisioned to support a maximum quantity of data analysis, preparation, and transfer based upon the quantity of Data Consumers making Poll requests and the total quantity of available data.

- The ngTMDD has a new architectural need to support change-driven updates or event-driven updates. Designs developed by the ngTMDD may support the CWZ effort.

Rationale: At this time, the ngTMDD design is underway, and it is unclear what direction the ngTMDD is going to take with respect to handling of Change-driven Updates. Furthermore, it is unclear when the design effort will include handling of Change-driven Updates.

- Currently, the ngTMDD is planning an update to the TMDD location referencing scheme (node, link, route) to support lane-level granularity for new objects such as "link lane status" that can share the status (i.e., open, closed, or restricted) of specific lanes on an approach to a work zone. With respect to developing applications that could inform motorists which lanes are closed as they approach a work zone or other event, harmonization between CWZ (Section 3.6.17 Enumeration of LaneStatus) and ngTMDD lane status data concepts and objects would be beneficial.

  Rationale: At this time, the ngTMDD design is underway, and it is unclear what direction the ngTMDD is going to take with respect to roadway and general geographic referencing. Furthermore, it is unclear whether the ngTMDD design will be compatible with the GeoJSON approach used in CWZ.

E.1.3 Data Exchange Needs

2.5.2.1.2 Zone Metadata – Zone Data Acknowledge Receipt

CWZ consumers need to provide a confirmation receipt as a proof of delivery of work zone data upon receipt of data from a CWZ data provider.

Rationale: CWZ WG Discussion.

- This is a receipt from the data consumer that the feed file was successfully read with no errors.
- This would be optional, depending on the consumer.
- This could be built on top of the API mechanism.
- It was agreed that this is a big topic and should be moved to the parking lot. There is an accompanying need.

2.5.2.1.5 Zone Metadata – GNSS Position Accuracy in Meters

CWZ data providers need to provide the locational accuracy or method of location information acquisition to determine the accuracy of geographic information, in meters, when providing work zone information to data consumers.

A brief summary about the locational accuracy of work zone data collection methods is described below:

- IOOs typically use standard GNSS, which provides 5- to 7-meter accuracy.
- OEMs require high fidelity location data for lane determination. OEMs and navigation companies have digital maps with accuracies of approximately 10 centimeters. OEMs and navigation companies use LIDAR as measurement devices. OEMs state that this level of accuracy should not and does not have to be passed on to the IOOs.
- The accuracy of current GNSS on-board OEM vehicles (which relies on multiple GNSS devices on-board the vehicle) in open environments is about 2 meters. Therefore, vehicles cannot determine which lane they are in.
- Typical, standard GNSS cannot be used to acquire lane level detail of work zones. Therefore, creating lane-level geometry that depends on GNSS is unnecessary.
- Device manufacturers have stated that an arrow board will provide 2-meter accuracy.

Rationale: CWZ WG Discussion.

- It is not the intent of the standard to define a required level of accuracy for position data, which varies greatly.
- Most data providers cannot provide this right now.

2.5.2.1.6 Zone Metadata – Zone Data Expiration End Date-Time

CWZ data providers need to provide zone data expiration date-time when providing work zone information to data consumers. Data consumers need to know the timeframe for which data is accurate and reliable, for example, to support decision-making.

Rationale: CWZ WG Discussion.

- No expiration date on DeviceFeed.
- It is better to use end_date for the WorkZoneFeed.
- Consensus is to remove this need.

2.5.2.2.2 Zone Alerts and Notifications – VRU Position/Geometry

CWZ deployers want to notify/alert drivers when their vehicle is approaching a VRU's location. CWZ deployers may provide wearable devices to VRUs that can be used to locate a VRU within a CWZ. Vehicles warn their driver upon approach to the CWZ.

CWZ data providers need to provide VRU position/geometry when providing work zone information to data consumers.

Rationale: CWZ WG Discussion.

- There are no alerts and notifications.
- This is a redundant need.
- Remove.

2.5.2.2.3 Zone Alerts and Notifications – Zone Status, Speed Limits, and Lane Shifts

CWZ deployers use devices that automatically share status information to navigation companies. Typical information sent includes start of work zone, end of work zone, reduced speed limit zones, lane changes/shifts (and connections with arrow boards), and lane closures. Alerts show up in the navigation company's mobile applications or in OEMs' driver alert gadget.

CWZ data providers need to provide zone status, speed limit zones, speed limits, lane shifts, lane tapers, and direction of lane shift, number of lanes to taper, and lane closures when providing work zone information to data consumers.

Rationale: CWZ WG Discussion.

- There are no alerts and notifications.
- This is a redundant need.
- Remove.

2.5.2.2.4 Zone Alerts and Notifications – Intrusion Detection Geometry

CWZ deployers need work zone information to detect intrusions by vehicles into specific areas within the work zone. For example, areas where workers are present.

CWZ data providers need to provide notification alerts to drivers, VRUs, and work zone centers when intrusions are detected.

Rationale: CWZ WG Discussion.

- There are no alerts and notifications.
- This was determined to be out of scope.
- Keep for future consideration.

2.5.2.4.3 Zone Traffic – Crash Counts

2.5.2.4.3.1 Traffic Incident Management Performance Measures
CWZ deployers need to calculate incident durations related to crashes in a work zone consistent with the NOCOE Traffic Incident Management Performance Measures (TIM-PM) and Incident Timeline to assess the safety of work zone deployments.

2.5.2.4.3.2 Traffic Incident Type and Location
CWZ data providers need to provide crash information such as type and location when providing work zone information to work zone data consumers.

2.5.2.4.3.3 Crash Counts
CWZ data providers need to provide crash counts over a period of time when providing work zone information to work zone data consumers.

Rationale: CWZ WG Discussion.

- Data may come from:
  - Attenuators have crash counts.
  - Extract from CAN-bus data.
  - First responder records.
- Put in parking lot. There are different ways to get this information.

2.5.2.2.5 Zone Alerts and Notifications – Zone Identifier
CWZ data providers need to provide the zone identifier associated with zone alerts and notifications when providing work zone information to work zone data consumers.

2.5.2.3.6 Zone Status – Zone Identifier
CWZ data providers need to provide the zone identifier associated with zone status information when providing work zone information to work zone data consumers.

2.5.2.4.4 Zone Traffic – Zone Identifier
CWZ data providers need to provide the zone identifier associated with zone traffic information when providing work zone information to work zone data consumers.

2.5.2.5.6 Zone Lanes – Zone Identifier
CWZ data providers need to provide the zone identifier associated with zone lane information when providing work zone information to work zone data consumers.

2.5.2.6.3 Zone VRU – Zone Identifier
CWZ data providers need to provide the zone identifier associated with a VRU when providing work zone information to work zone data consumers.

2.5.2.7.3 Zone Work Vehicle – Zone Identifier
CWZ data providers need to provide the zone identifier associated with the work vehicle when providing work zone information to work zone data consumers.

2.5.2.9.2 Zone Schedule – Zone Identifier
CWZ data providers need to provide the zone identifier associated with the zone schedule information when providing work zone information to work zone data consumers.

2.5.2.10.3 Zone Speed Limit – Zone Identifier
CWZ data providers need to provide the zone identifier associated with the speed limit change information when providing work zone information to work zone data consumers.

Rationale: CWZ WG Discussion.

- Zone Identifiers are only needed for Devices to identify which zone the device is associated with.
  - VRU is covered under Device.
  - Work Vehicle is covered under Device.
- There is no need to identify zone identifiers for these attributes of work zones.
- Remove these identifiers.
- Separate need was identified to identify travel time through the zone, for example by blue-tooth devices.

E.1.4 Operational Scenarios

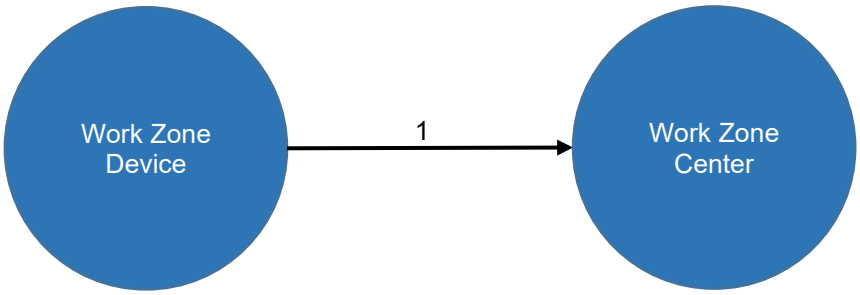
VRU Safety – Zone Intrusion Detection and Notification Alerts (OUT OF SCOPE)

Title	VRU Safety – Zone Intrusion Detection
Problem Aspect	A work zone may want a defined area to detect vehicle intrusions for VRU safety.
Description	Work zone equipment may be set up to detect vehicle intrusions into the work zone to provide VRUs with enough warning to get to a safe location. Detection equipment may include sensors, and alerting equipment may include flashing beacons, VRU electronic safety vests, or personal devices (smartphone).
Pre-Conditions	• The area being monitored for vehicle intrusion is defined. • Work zone device(s) monitoring this defined area is/are set up. • The work zone device(s) is/are connected to the work zone center. • (optional) The work zone devices are connected to each other. • VRUs in the area are wearing smart vests or carry a personal device connected to the alerting equipment. • A work zone device detects an intrusion.
Optional Diagram	
Narrative and Sequence of Steps	1a) The work zone device sends an intrusion alert to the work zone VRU. 1b) The work zone device sends the intrusion information to the work zone center. 1c) (optional) The work zone device sends the intrusion information to other work zone device(s) such as a flashing beacon. 2) (optional) The work zone center sends the intrusion information to other work zone device(s).
End Conditions or State	VRUs are alerted of the intrusion with enough time to get to safety (through an audio/haptic/visual alert on their vest or personal device and/or flashing beacons), and the work zone center receives information about the intrusion.
Scenario Extension	This may apply to other VRUs with a smartphone application.

Rationale: CWZ WG Discussion.

- This scenario is out of scope of this standard and should be removed.

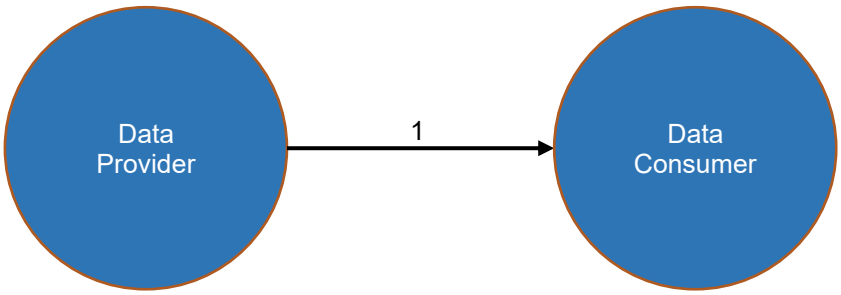
WZ Data Collection – From Devices (OUT OF SCOPE)

Title	WZ Data Collection – From Devices
Problem Aspect	A work zone center needs to collect information gathered by work zone devices.
Description	A connected work zone may require the use of devices that gather data such as GPS location or vehicle speeds. These devices may be directly connected to the work zone center for maximum utility. A device may be work zone equipment such as a camera or traffic sensor.
Pre-Conditions	The work zone device is powered on and configured. The work zone device is connected to the work zone center.
Optional Diagram	
Narrative and Sequence of Steps	The work zone device sends information to the work zone center continuously, periodically, or as relevant events happen.
End Conditions or State	The work zone center receives the data collected by the work zone device.
Scenario Extensions	This may also apply to work zone vehicles and VRUs.

Rationale: CWZ WG Discussion.

- This scenario is out of scope of this standard and should be removed.

2.6.6 Generic Work Zone Information Data Exchange (Change-driven Updates)

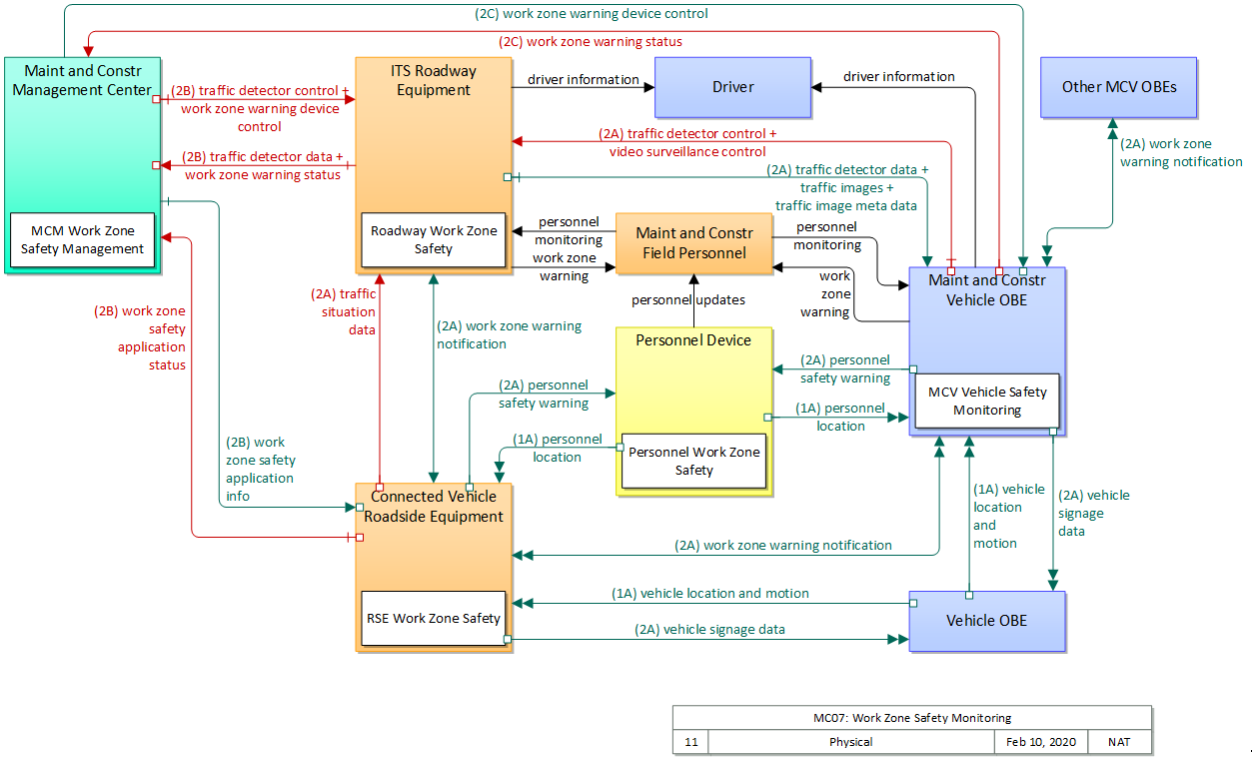
Title	Generic Work Zone Data Exchange (Change-driven Updates)
Problem Aspect	A data consumer has a prior data set of work zone information that needs to be updated. A data provider needs to send only information updates to allow the data consumer's data set to be current.
Description	When a data provider has new information, possibly due to an event, the data provider needs to update a data consumer with information to bring the data consumer's data set up-to-date. This may be a work zone needing to update a data consumer about a new vehicle or VRU position, or changes in speed limits within a zone.
Pre-Conditions	• The data consumer is an authorized connection to the data provider. • The data provider has new information that needs to be communicated to a data consumer.
Optional Diagram	
Narrative and Sequence of Steps	1) The data provider sends updated information to the data consumer.
End Conditions or State	The data consumer has up-to-date information about work zones and conditions.

Rationale: CWZ WG Discussion.

- The Polling for Update and Change-driven update data exchange mechanisms have advantages and disadvantages for deployers. These disadvantages do not exist with the current Polling mechanism of WZDx. Developing a satisfactory design to overcome the disadvantages is a complex issue with many design considerations. It was the opinion of many in the WG to postpone a design for a future update of the CWZ Standard. Therefore, the materials leading to the design, including this tutorial, associated needs, operational scenarios, and requirements have been relocated to this Annex for future consideration.

E.1.5 Relationship to ARC-IT

ARC-IT Work Zone Safety Monitoring Service Package [2.8.2] (OUT OF SCOPE)
MC07: Work Zone Safety Monitoring. This service package provides warnings to maintenance personnel within a work zone about potential hazards within the work zone. It enables vehicles or the infrastructure to provide warnings to workers in a work zone when a vehicle is moving in a manner that appears to create an unsafe condition (e.g., moving at high speed or entering the work zone).



ARC-IT – Work Zone Safety Service Package Diagram [Figure 6].

Rationale: CWZ WG Discussion.

- This portion of ARC-IT is out of scope of this standard and should be removed.

E.2 User Requests – Requirements

This sub-section identifies requirements that were identified and considered by the CWZ Working Group but are not addressed in this CWZ Implementation Guide and Standard.

3.3.1.2 Send WorkZoneFeed Upon Request for Updates

A data provider shall send WorkZoneFeed information upon request for updates from a data consumer.

3.3.1.3 Send WorkZoneFeed Information Updates Upon Change of Information

A data provider shall send WorkZoneFeed updates to data consumers upon change in information.

3.3.2.2 Send DeviceFeed Upon Request for Updates

A data provider shall send DeviceFeed information upon request for updates from a data consumer.

3.3.2.3 Send DeviceFeed Information Updates Upon Change of Information

A data provider shall send DeviceFeed updates to data consumers upon change in information.

Rationale: CWZ WG Discussion.

- The Polling for Update and Change-driven update data exchange mechanisms have advantages and disadvantages for deployers. These disadvantages do not exist with the current Polling mechanism of WZDx. Developing a satisfactory design to overcome the disadvantages is a complex issue with many design considerations. It was the opinion of many in the WG to postpone a design for a future update of the CWZ Standard. Therefore, the materials leading to the design, including this tutorial, associated needs,

operational scenarios, and requirements have been relocated to this Annex for future consideration.

E.3 User Requests – Design Details

This sub-section identifies design details that were identified and considered by the CWZ Working Group but are not addressed in this CWZ Implementation Guide and Standard.

E.4 User Requests – Guidance Needs

This sub-section identifies guidance needs that were identified and considered by the CWZ Working Group, but are not addressed in this CWZ Implementation Guide and Standard.

Guidance Needs - Contracting, Data Ownership, and Licensing [B.2]
CWZ deployers need guidance on how to develop contractor specs. For example, uptime requirements for contractors and penalties for downtime. Several IOOs are developing guidelines for testing connected work zone equipment; for example, equipment needs to pass a X-days of field test prior to using the device in an active work zone. These same IOOs, however, state that they are aware that some contractors will choose not to bid on the project due to the new testing requirements.

Guidance Needs – Roadway Construction Contractor Scopes do not Require the Provision of Electronic Work Zone Information and Status [B.2.1]
Device manufacturers work with IOOs and contractors to deploy electronic equipment to serve a host of needs, including safety applications, guidance for drivers to maneuver passage through a work zone, etc.

Contractors are not required by IOOs to deploy electronic field devices in work zones. Currently, the burden of communicating the benefits of connected work zones has traditionally fallen on the work zone device manufacturers, who are motivated to sell their equipment, and by some IOOs. Today, however, and moving forward, IOOs will need to take a larger role in communicating the benefits of CWZs within their own organizations, but also to assist with communicating the benefits to their contractors that ultimately will become responsible for the day-to-day operation of connected work zones.

A few examples of the type of things that need to be stated in contract specs are the following:

- the types of work zone equipment that needs to be planned, designed, engineered, and monitored
- specifications so equipment is deployed correctly, accurately, and reliably
- that workers need to use equipment to enable detection of worker presence and location within a work zone – workers may have wearable devices
- where to position location markers within the work zone
- for connected vehicle deployments, the details of configuration of RSUs

Contractor equipment needs to be supported and tested to conform with standards for data communications. In addition, contractors may need to do data entry, keeping data available and up-to-date, based on real-time requirements.

Along with specifying contractual requirements, IOOs will need to enforce contractual requirements.

Guidance Needs – Data Ownership and Licensing [B.2.2]
The topics of data ownership and licensing are closely related, and discussed briefly, below.

Guidance Needs – Data Ownership [B.2.2.1]
In today's technology and data-driven environment, data is an asset and a source of intellectual property (IP) for data owners. Data owners add value to raw data through first acquiring the data, and then becoming responsible for maintenance, reliability, uptime, frequency of updates, and other quality factors.

Data owners seek to monetize their data IP and can optimize and recoup their investment in value-added features, by limiting the usage and redistribution right of the data.

Data ownership may also apply when addressing the source of the data, i.e., the equipment used that generates the data. For example, contractors may feel that they are the owners of data, since the data is generated and collected from their vehicles, devices they own, and workers they employ.

Data owners have to deal with a number of legal issues—for example, the liability they absorb as contractors—that extends to sourcing data to the public sector or third parties, such as navigation and transportation service providers. It is important to note for an IOO whether to absorb the liability risk of CWZ data, since most IOOs pass on the general risk of work zones onto contractors.

Guidance Needs – Licensing [B.2.2.2]
One concern data owners have is determining who has rights to the data when it is aggregated. Limiting a data consumer's rights to redistribution of data protects data owners. Licensing the data provides clarification on restrictions related to the data's usage and may include limited rights to re-distribute the data or to save the data for historical analysis purposes.

It is important for licensees, especially IOOs, to understand the constraints stated in a data license. CWZ deployers will need to think about their long-term goals to identify the impacts of the limitations and constraints that are enacted in a license. It is noteworthy that while accepting a license limits usage, it also limits exposure to liability risk.

Rationale: CWZ WG Discussion.

- There were questions about why this section is in a standard.
- This is about contracting. Keep contracting out of this document.
- This section should not be contracting guidance.
- Perhaps re-characterize that what IOOs need is to establish a “pre-qualification” process.
- There was a suggestion to separate the discussion on Contracting from the discussion on Data Ownership and Licensing
- There was a question as to whether this would only apply to pilot projects.
- There was a suggestion that maybe a discussion about qualified products lists is better.
- There is a lot of equipment out there and is being tested. Recommend that agencies accept testing done in other States.
- One issue is that if IOOs do not require (emphasis on the term require) the CWZ equipment, then this equipment is less likely to be deployed in a WZ.
- One person suggested broadening the discussion to include all those that will benefit.
- There was a question as to why it is necessary to 'single out' IOOs in this section.
- Some IOOs are requiring the use of electronic work zone equipment.
- There was clarification that this section is not intending to mandate anything.
- One benefit is assisting with the inspection process. The equipment manufacturers can facilitate the process to verify the equipment is in fact working.
- It is important to show the value – e.g., to consumers, to OEMs – and that that value comes at an additional cost when you deploy electronic equipment.
- Many will shrug at the guidance and 'recommendations'. The goal should be for deployers to figure out how to make their data fit the requirements in the standard.
- We have to remember that each IOO is different, and they should not be lumped together.
- What's important is to focus not on the equipment, but rather on the work zone features required and data you need to collect and share. Let the features drive the equipment choices.
- There was some concern about why we are discussing Data Ownership and Licensing?

- One person offered an example: For DeviceFeed information, we (equipment vendor) need to specify ownership of the data, and the limitations of sharing the data with others. Typically, for IOOs, if the device feed matches a planned project, then that becomes part of the agency's WZFeed, and that is the only data that the agency can distribute. For a navigation company, the agreement may be completely different.
- There was clarification that an agency's WZFeed is a public resource and should be freely available. All agreed.
- There was more concern about whether this topic should be included in this guidance.
- There was additional support for the statement that the WZFeed shall be freely available – and that this should be stated in an agreement.
- The WG collectively agreed to remove this section after much discussion.

Annex F
Listing of Differences between the CWZ Standard and the WZDX v4.2 Specification JSON Schemas [Informative]

This annex lists differences between the JSON Schemas contained in Section 5 of this standard and the WZDX v4.2 Specification JSON Schemas.

F.1 Differences Affecting Both the WorkZoneFeed and DeviceFeed

1. Replaced the use of GeoJSON ‘MultiPoint’ type with ‘Point’ as follows: The Geometry object's 'type' property MUST be LineString (RFC 7946 Section 3.1.4) or Point (RFC 7946 Section 3.1.2).
2. Changed ‘feed_info’ to required because ‘road_event_feed_info’ was deprecated.
3. Changed ‘update_frequency’ to required.
4. Changed ‘update_frequency’ minimum value ‘1’ to ‘-1’.
5. Changed ‘update_date’ to required.
6. Removed deprecated element ‘lrs_type’.
7. Removed deprecated element ‘lrs_url’.
8. Removed deprecated element ‘location_verify_method’.
9. Corrected typographical error of “verfied” to “verified” throughout.
10. Removed ‘restriction’ as an enumerated value of ‘EventType’.
11. Changed ‘milepost’ to ‘reference_post’ throughout.
12. Added ‘reference_post_unit’ element.
13. Updated the ‘reference_post_unit’ element to include ‘miles’.
14. Added Operational Policy and Constraint that states that the assignment of UUIDs is governed by the regulatory guidelines and policies of the data provider. For example, the assignment of uniform resource identifiers may be governed by policies to guarantee privacy. As a result, UUIDs may need to change over time.
15. Added Business Rule that states that all universally unique identifiers must comply with the UUID standard (RFC4122) reference.
16. Added ‘project_id’ element.

F.2 WorkZoneFeed Differences

1. Changed ‘is_start_position_verified’ to required.
2. Changed ‘is_end_position_verified’ to required.
3. Changed ‘is_start_date_verified’ to required.
4. Changed ‘is_end_date_verified’ to required.
5. Removed deprecated element ‘relationship’.
6. Removed deprecated element ‘lane_number’.
7. Removed deprecated enumeration ‘SpatialVerification’.
8. Removed deprecated enumeration ‘TimeVerification’.
9. Removed deprecated enumeration ‘EventStatus’.
10. Changed WorkTypeName enumeration text “maintenance” to “non-encroachment”.
11. Removed deprecated enumerated item ‘center-left-turn-lane’ from ‘LaneType’.

F.3 DeviceFeed Differences

1. Removed deprecated element ‘is_moving’.
2. Removed enumerated item ‘road-event-start’ from ‘MarkedLocationType’
3. Removed enumerated item ‘road-event-end’ from ‘MarkedLocationType’.
4. Removed deprecated enumerated item ‘temporary-traffic-signal’ from ‘MarkedLocationType’.
5. Added new enumerated items for vehicle types and ‘other’ to ‘MarkedLocationType’.

6. Added enumerated item ‘pavement-marking-vehicle’ to ‘MarkedLocationType’.
7. Added ‘is_in_transport_position’ to FieldDeviceCoreDetails to reflect that other devices (in addition to the ArrowBoard device) may have the characteristic of being in transport position.
8. Removed ‘is_in_transport_position’ from ArrowBoard device.
9. Added ‘is_image_url_public’ to contents of the Camera device.
10. Added ‘video_url’ to contents of the Camera device.
11. Added ‘is_video_url_public’ to contents of the Camera device.
12. Added ‘video_update_frequency’ element to contents of Camera device to reflect how often video is updated.
13. Added ‘travel_time_sec’ element to contents of TrafficSensor device.
14. Added ‘travel_time_sec’ to contents of TrafficSensorLaneData.
15. Added ‘RoadsideUnit’ as a new device.
16. Added ‘roadside-unit’ enumerated item to ‘FieldDeviceType’.
17. Added element ‘message_types’ to identify message being broadcast by an RSU (e.g., RSM, TIM, SPaT, MAP). Added enumerated list of potential RSU messages that could be broadcast.

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