STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR-0003 (REV 04/2024)

1. REPORT NUMBER	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
CA25-4085	N/A	N/A

4. TITLE AND SUBTITLE Caltrans Traffic Operations Data Standards Implementation Recommendations	5. REPORT DATE May 13, 2025
	6. PERFORMING ORGANIZATION CODE PATH, UC Berkeley
7. AUTHOR Anthony D. Patire, Ph.D.	8. PERFORMING ORGANIZATION REPORT NO. N/A
9. PERFORMING ORGANIZATION NAME AND ADDRESS California PATH University of California, Berkeley 1357 South 46th St., Bldg 452 Richmond, CA 94804-4648	10. WORK UNIT NUMBER N/A
	11. CONTRACT OR GRANT NUMBER 65A1019, Task ID 4085
12. SPONSORING AGENCY AND ADDRESS California Department of Transportation P.O. Box 942873, MS #83 Sacramento, CA 94273-0001	13. TYPE OF REPORT AND PERIOD COVERED Final Report 08/23-06/25
	14. SPONSORING AGENCY CODE Caltrans

15. SUPPLEMENTARY NOTES

N/A

16. ABSTRACT

This report investigates the evolving landscape of data standards within the transportation ecosystem, emphasizing their critical role in enabling interoperability, safety, and innovation across Intelligent Transportation Systems (ITS). The report outlines a strategic approach for advancing transportation data interoperability, emphasizing the need for implementation guidance to complement evolving standards. Effective interoperability requires five key components: robust data curation, discoverability, identity management, data exchange, and analytics. The private sector has a vital role to play—competing in analytics and user-facing applications—while resisting vendor lock-in that hampers long-term integration. Emerging standards for Connected Work Zones (CWZ) represent a critical near-term opportunity, with Caltrans positioned to lead by modernizing its Lane Closure System (LCS), engaging stakeholders, and aligning business processes with data needs. The report concludes with actionable next steps for Caltrans, including developing data ontologies, piloting CWZ-compliant workflows, and investing in open, scalable infrastructure to support a safer, more connected transportation ecosystem.

17. KEY WORDS	18. DISTRIBUTION STATEMENT	
Data standards, data exchange, interoperability, digital transportation infrastructure, connected work zones	No restrictions.	
19. SECURITY CLASSIFICATION *(of this report)*	20. NUMBER OF PAGES	21. COST OF REPORT CHARGED
Unclassified	53	N/A

Reproduction of completed page authorized.

DISCLAIMER STATEMENT

PARTNERS FOR ADVANCED TRANSPORTATION TECHNOLOGY
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Traffic Operations Data Standards

Task ID 4085 (65A1019)

Final Report

May 13, 2025

Partners for Advanced Transportation Technology works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

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GLOSSARY

AASHTO — American Association of State Highway and Transportation Officials

API — Application Programming Interface

ARC-IT — Architecture Reference for Cooperative and Intelligent Transportation

ASCII — American Standard Code for Information Interchange

CAV — Connected and Automated Vehicle

CDS — Curb Data Specification

CWZ — Connected Work Zone

CV — Connected Vehicle

FHWA — Federal Highway Administration

GBFS — General Bike Feed Specification

GTFS — General Transit Feed Specification

ITE — Institute of Transportation Engineers

ITIS — International Traveler Information Systems

ITS — Intelligent Transportation Systems

IVI — In-Vehicle Infotainment

LCS — Lane Closure System

MAASTO — Mid America Association of State Transportation Officials

MDS — Mobility Data Specification

NABSA — North American Bikeshare & Scootershare Association

NEMA — National Electrical Manufacturers Association

NTCIP — National Transportation Communications for Intelligent Transportation System (ITS) Protocol

OBU — On Board Unit

OEM — Original Equipment Manufacturer

OMF — Open Mobility Foundation

RSU — Roadside Unit

RTCM — Radio Technical Commission for Maritime Services

TCP — Transmission Control Protocol

TMDD — Traffic Management Data Dictionary

TPIMS — Truck Parking Information Management System

TSP — Transit Signal Priority

URL — Unified Resource Locator

USDOT — United States Department of Transportation

V2X — Vehicle to Everything

WZDx — Work Zone Data eXchange

1. INTRODUCTION

Transportation data standards are an increasingly important and complex topic, as well as a key enabler of Intelligent Transportation Systems (ITS). New data sources, private data providers, and uses for transportation data are exploding. The ability to harness data is at the core of modern efforts to improve the safety of our transportation system and advance mobility for the benefit of all. There is an increasing need for automated data exchange between public agencies and private organizations to improve existing operations and enable new products and services. In addition, the provision of public safety is another overlapping area where first responders require up-to-date and reliable information to succeed in their missions.

If well-defined and implemented widely, data standards can provide significant benefits, including integrating different systems and vendor products, improving and easing data analysis, and enabling Transportation Systems Management and Operations (TSMO) and many cross-jurisdictional and cooperative solutions and strategies. Without data standards, these benefits cannot be realized. However, data standards are not always universal. Standards are constantly evolving with transportation and information technology advances and are not consistently implemented universally and in the same manner across the vendor community. Unfortunately, this results in patchwork solutions that increase costs, undermine integration efforts, and invite opportunities for wasted effort.

California needs a roadmap for data standardization, ensuring that it has a universal set of standards for all its contractual systems integration efforts and that those standards are implemented in the same manner across its vendor community. In addition to data standardization, there are also organizational needs to manage access to data, and security.

This work aims to illuminate some basic structures embedded in the complicated chains of communication that are needed to enable ITS services, or systems to operate. Possible examples are myriad, including statewide transit signal priority, curb and micro-mobility, multi-interoperability of integrated corridor management (ICM), and more. A few examples of possible integration needs include the following:

- The ICM in District Eleven involves Trihydro's SDX application for data exchange. This concept was utilized in the Wyoming Connected Vehicles Pilot in which the Trihydro system can construct Traveler Information Messages (TIM) and broadcast them via SiriusXM. This provides a one-way communications channel that can supplement another channel of communication supported by a deployment of Road Side Units (RSU).
- The ICM in District Twelve uses 188 RSUs installed along freeways and at ramps. Transcore plays a role as a systems integrator. However, the plan involves using Yunex (formerly Siemens) YuTraffic Concert ATMS to manage the RSUs. District 12 is also performing a technology evaluation of video analytics from three vendors. One goal is to determine the feasibility of Connected Vehicle (CV) safety applications.

In part due to complexity and costs, a proposed software integration involving US-50 in District Three was not implemented. This project would have integrated multiple ATMS systems into an ICM system of systems. The products and vendors would have included Transcore's TranSuite ATMS, Econolite's Centracs ATMS, and SwRI's ActiveICM platform.

1.1. PURPOSE

This project aims to guide Caltrans in improving data and system interoperability across California's transportation system. This final report is delivered as part of Caltrans Task ID 4085, Contract Number 65A1019, entitled Caltrans Traffic Operations Data Standards Implementation Recommendations.

This document provides an investigation of the standards landscape in the context of transportation digital infrastructure, and priorities for transportation data exchange use cases. In addition, it proposes both general recommendations as well as specific recommendations pertaining to work zone information and connected work zones (CWZ).

Effective use of work zone data involves multiple systems, and multiple standards to provide a complete service. For example, the location of the work zone must be registered, perhaps in the Lane Closure System (LCS). Work zone activity needs to be updated, perhaps through a smartphone app onsite, or from some centralized system. That data needs to be published to a data exchange system such as 511 or a registered WZDx feed. Finally, that data needs to be served to travelers, perhaps through an RSU, perhaps via SiriusXM radio, or perhaps via routing app from Google, Apple, or Waze. Some of the standards of relevance in this chain of communication could include WZDx, CWZ, J2735, J2945/4, and TMDD. Therefore, data standards overlap is an increasingly important consideration in Caltrans ITS projects that involve data exchange, and these efforts may benefit from heightened awareness of the data standards relevant to their deployment.

1.2. SUMMARY OUTCOME

This report considers a general framework for data sharing that includes data discovery and security in addition to the need for data standards for exchange. Standards provide the syntax for data formatting, which is necessary but not sufficient for effective data exchange. Data quality requires a customer who is actively using the data for a purpose. In general, good data quality does not result from a staff person executing a perfunctory data entry task.

Business processes need to be placed at the front and center of any effort to improve data interoperability. Actionable information is needed to support decisions that drive business processes forward. Therefore, an organization's information needs to be discoverable, secure, and obtainable in a useful format. Discussions of data standards tend to focus on the data exchange and transport functions while neglecting the larger context. This is one limitation of ARC-IT, as elaborated below. While ARC-IT is still extremely useful, it is but one component in a larger context.

This memo clarifies that context and suggests a general set of recommendations. In addition, the challenge of work zones and work zone-related information using the CWZ standard is selected as a particularly important use case for near-term attention. There are a number of organizational challenges that need to be overcome in order to upgrade the existing LCS into a system that can provide a satisfactory CWZ feed. These challenges are a perfect opportunity to align the business processes with the data and the systems used to share that data.

Specific recommendations for CWZ:

- Begin with CWZ and the LCS upgrade effort as a first use case to document the business processes that rely on the data, and to establish a data resources team to create the ontology to describe it
- Engage with external stakeholders who are (or who should be) consumers of CWZ data and determine how to maximize the value of that information
- Identify the key roles and responsibilities of Caltrans staff, contractors, and any external entities that may need to interact with CWZ or LCS data originating from Caltrans
- Document the existing and potential future value chains for CWZ data
- Reach out to the CWZ standards committee to understand emerging goals for the standard
- Begin a pilot project in one district to design user stories around an improved business process for work zone data and implement that process while conforming to relevant standards

1.3. WHAT MAKES FOR SUCCESSFUL STANDARDS AND SPECIFICATIONS?

The traffic and transportation ecosystem involves an enormous variety of stakeholders. Overcoming legacy systems, structures, technologies, and institutional momentum requires intense and focused efforts. The WZDx effort has made excellent progress in a short amount of time. To be precise, WZDx is a specification (not a standard), and it is frozen at version 4.2. Its continued development has become a new standard called Connected Work Zone (CWZ). This pattern of moving from a specification to a standard is a sign of success.

Key ingredients that appear to improve interoperability and standardization include:

- Having a clear value proposition for the underlying data
- Open specifications and standards
- Consortiums for interoperability
- Guidance and support documentation
- Published documentation of lessons learned from pilot deployments

Key factors that make interoperability more complex include:

- Standards with too much flexibility, increasing the likelihood of divergent implementations
- Very different enumerations between the message sets of related standards
- Having a large, heavyweight, monolithic standard that covers too much

For example, GTFS and WZDx started with small, lightweight specifications. They were able to grow and evolve quickly, eventually becoming widely adopted.

Having multiple specifications and standards for similar data is not necessarily bad. The use cases for different message types might require different standards. The key is having focused and clear use cases and compatible object structures.

1.4. DOCUMENT ORGANIZATION

The remainder of this document is organized as follows:

- Section 2 describes a general framework for data sharing that considers data discovery and security in addition to the needs for data standards to enable information exchange
- Section 3 provides an overview of data standards and their usage
- Section 4 describes the need for work zone data and efforts to disseminate it more broadly
- Section 5 presents some examples of national and regional ITS architectures
- Section 6 summarizes a set of implementation guides and resources related to connected vehicles (CVs) and work zone information
- Section 7 compares data fields between lane closure and several work zone data standards
- Section 8 summarizes some MPO perspectives on data exchange and regional ITS
- Section 9 presents key findings from a prior Caltrans effort to create a data collection strategic plan with the idea to "measure once and use many times"
- Section 10 provides a set of recommendations for near-term efforts based on the findings in this report

2. INFORMATION SHARING FRAMEWORK

This section provides a summary of key insights and recommendations from the Information Sharing Framework Task Force (ISFTF) "Approach for Developing an Interoperable Information Sharing Framework" document (1). While the focus of the ISFTF is on public safety, it has substantial overlap with transportation sector challenges, stakeholders, technologies, and more. Specific use cases in the document relate to traffic and weather disturbances that require close collaboration between first responders and public agencies across jurisdictions.

As it is within the transportation ecosystem in the United States, there is also a recognized need to improve communications within the public safety ecosystem. With respect to both transportation and public safety there exists a multitude of platforms and systems used by different stakeholders that are not interoperable. This creates a burden of technical complexity, and limits situational awareness and operational effectiveness in both domains.

The Information Sharing Framework Task Force (ISFTF) aims to achieve an interoperable public safety ecosystem. Stakeholders include police, fire department, 911, emergency medical services, law enforcement dispatch, local hospitals, Emergency Communications Centers (ECCs), Statewide Interoperability Coordinators (SWICs), and more. Regardless of jurisdiction, affiliation, and location, first responders must have need-to-know access to information to succeed in their missions.

2.1. FRAMEWORK FOR INTEROPERABILITY

To achieve interoperability, the ISFTF has put forward a framework (1) and an approach. The framework is roughly segmented into three layers: a presentation layer, an integration layer, and a data layer.

The approach recognizes that underlying data is typically stored in legacy systems and this fact is unlikely to change anytime soon. The presentation layer used by public safety is increasingly a wireless smart device for consuming data via an app. What is needed to connect these two layers is an integration layer that provides four key functions as shown in Figure 2-1, taken from (1).

- Discovery: Ability to discover a data resource
- Identity Management: Ability to verify identity and need-to-know
- Data Exchange: Ability to provide data in a usable format
- Analytics: Providing actionable information

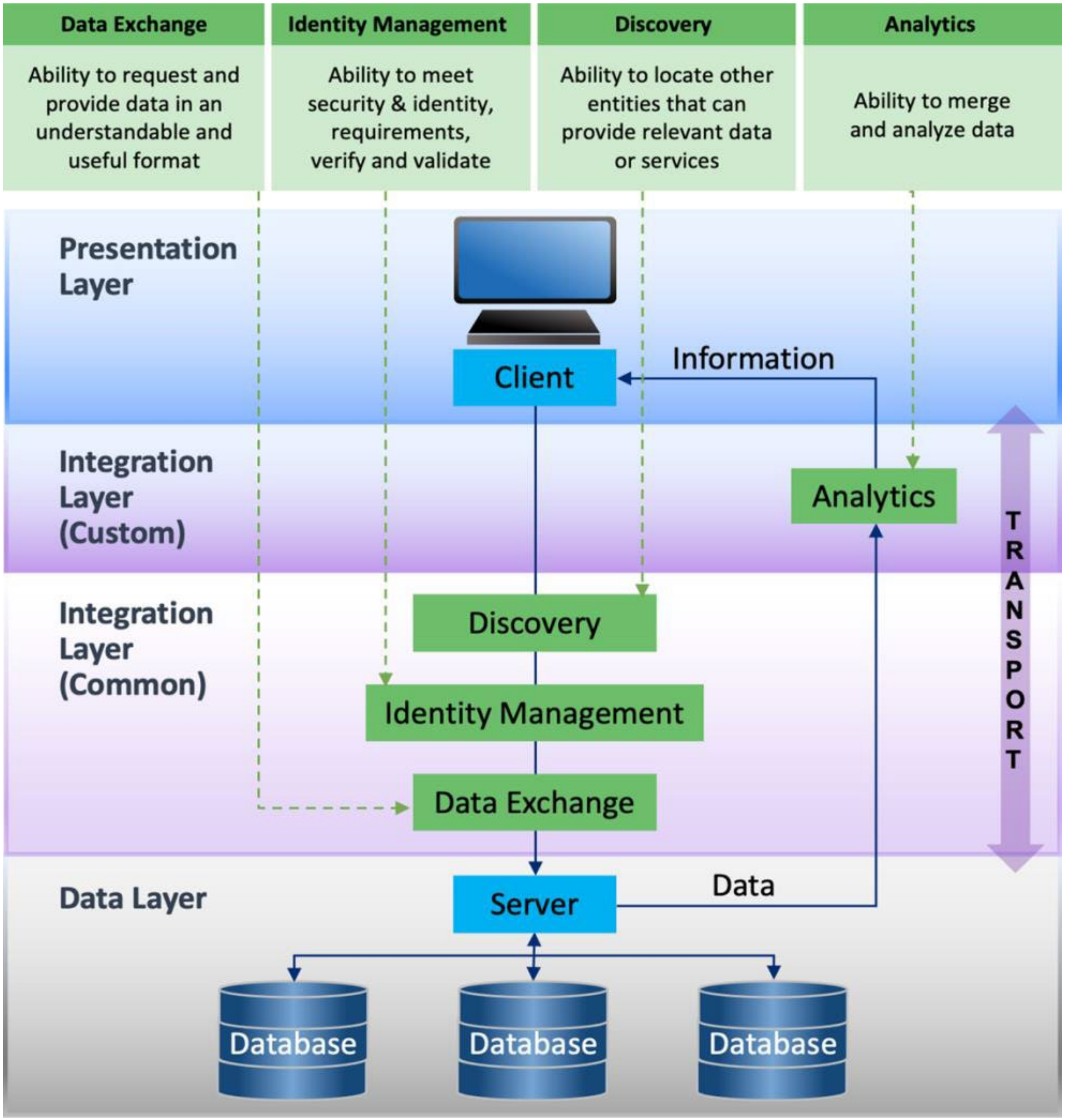

Figure 2-1: General Framework for Information Sharing (1)

The integration layer in Figure 2-1 is divided into two parts. The first part is intended to be common and not proprietary. Fundamentally, there should be nothing proprietary about discovery, access, exchange, and transport. For the benefit of public safety, built-in mechanisms are needed for basic data sharing across systems. This capability should be required in all procurements. Discovery involves the development of data registries and facilitating routine discovery patterns. Having a federated ICAM (Identity, Credential, Access, Management) and SSO (Single Sign On) capability is also fundamental. The integration layer reaches into the data layer to exchange securely any appropriate, timely information. The transport mechanism may add formatting or bandwidth constraints. In general, the underlying data will require reformatting before it can be presented. For this reason, the second part of the integration layer may require custom or proprietary analytics.

This framework very powerful. In addition, it is sufficiently generic and compatible with needs in the transportation ecosystem. As with public safety stakeholders, transportation stakeholders face similar challenges. The transportation data ecosystem is fragmented, and balkanized. Different infrastructure owner-operators (IOOs) at the federal, state, county, regional, and local levels all collect their own data with their own methods, hindering our ability to address transportation issues in holistic, data-driven, and collaborative ways. Underlying data and systems are not compatible. It is not possible to update everything at once. The framework above accepts the reality of past investments and proposes a way forward that leverages those past investments, and builds on top of it.

The layers in Figure 2-1 are well suited to address challenges with transportation data. In general, there will be a need for multiple versions of a client-facing presentation layer. This reflects the fact that there are many different roles for agencies and individuals who work with the data. Some may need to view the data via a smartphone app, while others may need an interface involving multiple screens at a TMC. However, much of the underlying data may reside in the same systems.

The integration layer provides the "glue" between the multitude of agencies and stakeholders with data and the multitude of users who need access. The key to the integration layer is making sure that the functions of discovery, identity management, and data exchange are standardized and open. In general, there will be multiple standards for the range of data that will need to be exchanged, and for the transport mechanisms that will be available to support that exchange. Identity management and security is so important that it will be addressed in more detail below. The main message here is that identity management needs to be standardized and federated using best practices, so that IT departments across multiple, and diverse, stakeholders can agree to allow their systems to be connected.

The private sector has no incentive to build open-architected interoperable systems as illustrated in Figure 2-1. Vendors prefer to build tightly integrated systems that optimize user experience. Their business model often depends on customers relying on them for maintenance and updates. Therefore, a typical vendor solution would feature a vertically integrated package with the presentation layer connected directly to the data layer without the need for an integration layer to communicate or coordinate with components offered by competitors.

The situation can be made much worse when a vendor is asked to integrate their product with a legacy system, or with that of a neighboring stakeholder. In this case, the vendor is not incentivized to build a general integration layer, but rather a custom integration that considers only the scope of the data and collaboration needed for the immediate project to succeed. While efficient in the short term, this myopic, one-off strategy creates a Frankenstein of systems, where each integration is considered separately. The problem is that vendors are incentivized to build precisely what the immediate customer asks for and is willing to pay for, not what the ecosystem actually needs.

The long-term solution is to have a coherent vision for the future of the transportation ecosystem and to build the digital infrastructure necessary to realize that vision. The layers in Figure 2-1 are designed to abstract the key functions into separate, modular blocks that can be defined to have clean and open interfaces. Interoperability requires that product vendors converge towards open standards. Custom integrations are not scalable. Engagement is needed between product vendors and the user ecosystem to identify interoperability gaps, test proofs of concept, and deploy pilot demonstrations.

Comprehensive situational awareness does not arise from any one data source. The ISFTF has identified four distinct data types: video, text, audio, and sensor. Each of these data types has unique characteristics and requirements for interoperability. Furthermore, it is natural that there will be different and evolving standards for each of these data types. There will always be legacy systems, because the scale of the built infrastructure is simply too large to replace all of it at once. What is important for the ecosystem is that it is possible to build common, and reusable, integration blocks to enable data exchange: the ability to request and provide data in an understandable and useful format.

It is crucial to recognize and appreciate the value that private vendors bring to the ecosystem. It is also crucial to create a market within which they are encouraged to compete, and where they can be rewarded with profits. A good place for this competition to take place is in the analytics function of the integration layer. As the variety, quantity, and quality of data sources continue to grow, there will be increasing needs for future innovation to extract useful and actionable information from that data. Therefore, we recommend that incentives be aligned for market competition to be focused on the data analytics, and not on the ecosystem needs for non-propriety and open methods for data discovery, identity management, and data exchange.

2.2. IDENTITY MANAGEMENT

One frequently underappreciated function is that of identity management. The average person in the United States may have 100-200 accounts that require passwords. As a result, password managers and federated login capabilities have become increasingly common. This trend is unlikely to change. Fortunately, this common need for identity management has resulted in well established tools that are increasingly understood and widely used. It is now time for the transportation ecosystem to adopt these tools.

The acronym ICAM stands for Identity, Credential and Access Management. As shown in Figure 2-2, taken from (1), it involves the following:

- Identity: Process to establish a unique representation of a user
- Credentials: Process to establish tokens to enable authentication for an identity
- Authentication: Process to verify the identity using credentials appropriate for the circumstance
- Access: Authenticated user is given data access with appropriate privileges

Federated identity management links a user’s identity across multiple security domains. As the transportation ecosystem evolves, data will increasingly be marshalled across multiple jurisdictions, and from multiple providers. It will be crucial to guarantee that the right individual has access to the right resource at the right time for the right reason in support of a business objective. As a result, technologies that facilitate this federation of identity management should be built into the foundation of any data sharing framework. Equally important, this notion of identity management and security is not something that can be bolted on later. It is an intrinsic part of a safe and secure system for data sharing.

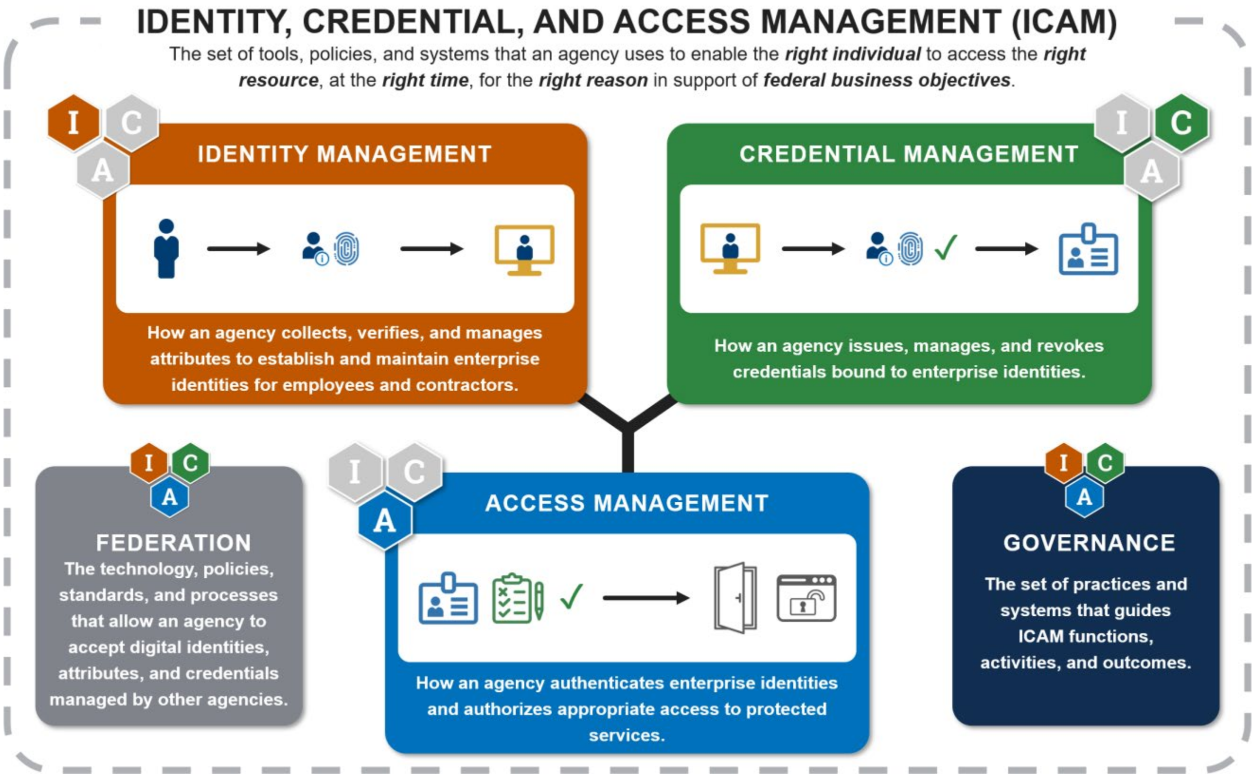

Figure 2-2: Identity Credential and Access Management (ICAM) (1)

3. DATA EXCHANGE STANDARDS AND THEIR USAGE

This section provides a brief overview of selected standards relevant to ITS for the exchange of transportation-related data. Example applications of each standard are provided for context to illustrate their usage. Table 3-1 provides a list with the name of the standard (or family of standards), the name of the organization that owns (or maintains, or has a stake) in the standard, and a website link for further information.

Table 3-1: List of Standards and Frameworks for Transportation Data Exchange

Standard or Framework	Stakeholders	Website or Online Resource
ARC-IT - Architecture Reference for Cooperative and Intelligent Transportation	USDOT	https://www.arc-it.net/
CDS - Curb Data Specification	Open Mobility Foundation	https://github.com/openmobilityfoundation/curb-data-specification
CWZ - Connected Work Zone	ITE, AASHTO, NEMA, SAE	https://www.ite.org/technical-resources/standards/cwz/
GBFS - General Bike Feed Specification	MobilityData, NABSA	https://gbfs.org/
GTFS - General Transit Feed Specification	MobilityData	https://gtfs.org/
J2540 - ITIS Phrase Lists	SAE - Society of Automobile Engineers	https://www.sae.org/standards/content/j2540/2_202012/
J2735 - V2X Communications Message Set Dictionary	SAE - Society of Automobile Engineers	https://www.sae.org/standards/content/j2735_202309/
J2945/4 - Road Safety Applications	SAE - Society of Automobile Engineers	https://www.sae.org/standards/content/j2945/4_202305/
MDS - Mobility Data Specification	Open Mobility Foundation	https://github.com/openmobilityfoundation/mobility-data-specification
NTCIP - National Transportation Communications for Intelligent Transportation System (ITS) Protocol	NTCIP, NEMA, ITE, AASHTO, USDOT	https://www.ntcip.org/
TMDD - Traffic Management Data Dictionary	ITE	https://www.ite.org/technical-resources/standards/tmdd/
TPIMS - Truck Parking Information Management System	USDOT, MAASTO, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Ohio, Wisconsin	https://trucksparkhere.com/
WZDx - Work Zone Data Exchange	USDOT	https://github.com/usdot-jpo-ode/wzdx

It is worth noting that although ARC-IT is included in the table, it is not actually a standard. ARC-IT began in 1996, when it was known as the National ITS Architecture. It has since been updated and expanded to cover new ITS services over the years. ARC-IT is a framework that provides a common vocabulary for a diverse group of stakeholders to imagine how intelligent transportation systems could be deployed. This information is useful and important when considering the data exchange necessary for an ITS project to succeed. ARC-IT Version 9.2 was released in January, 2024. The latest version supports Multimodal Accessible Travel (MAT), the Management of Electronic Traffic Regulations (METR) and other new concepts and refinements.

3.1. TRADITIONAL INFRASTRUCTURE

Traditional infrastructure consists of equipment typically owned and operated by a city, county, or state department of transportation. The National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) is a constellation of standards that defines protocols and objects for the communication of electronic traffic control and monitoring equipment such as:

- Actuated Traffic Signal Controllers (ASC),
- Dynamic Message Signs (DMS),
- Environmental Sensor Stations (ESS),
- Closed Circuit Televisions (CCTV),
- Data Collection and Monitoring (DCM),
- Ramp Meter Control (RMC),
- Transportation Sensor Systems (TSS),
- Signal Control and Prioritization (SCP), and
- Roadside Units (RSU).

NTCIP is a joint product of industrial and governmental cooperation that includes the efforts of the National Electrical Manufacturers Association (NEMA), the Institute of Transportation Engineers (ITE) and the American Association of State Highway and Transportation Officials (AASHTO). The NTCIP website makes over 40 published standards available.

The Traffic Management Data Dictionary (TMDD) Standard, developed by ITE, is intended to support communications between multiple traffic management centers for cooperative management of freeways, arterials, incidents, and events. TMDD defines dialogs and messages between centers to support shared use and shared management. In addition, TMDD references NTCIP for the communications to field devices. The current TMDD version is 3.1 dated January 2020.

An effort is underway to update TMDD based on lessons learned from previous Integrated Corridor Management (ICM) and other systems integration efforts. According to draft documents for Next Generation TMDD (ngTMDD), the "two primary service packages of ARC-IT addressed by ngTMDD are TM07 Regional Traffic Management, and SU03 Data Distribution."

Key thematic elements for traffic management involve the addition of communication links for:

- sharing information
- sharing control of field devices
- enabling integrated, interjurisdictional traffic management and control

Key thematic elements for data distribution involve:

- maintaining a directory of system users,

- management of connections
- management of data subscriptions

3.2. CONNECTED VEHICLES

Connected vehicles have a finite vocabulary of messages that they can use for communication. First issued in 2006, the V2X Communications Message Set Dictionary is defined by the J2735 standard. It is an SAE standard that specifies a standardized message set, data frames, and data elements for applications that use vehicle-to-everything (V2X) communications systems. The J2735 standard is published on the SAE website, and the current version is dated September 2023.

The J2945/4 standard, first issued in May 2023 by SAE, defines message sets and structures to support roadside safety applications including:

- Curve speed warning (CSW)
- Reduced speed zone warning (RSZW)
- Lane closure warning (LCW)
- Dynamic traveler information (DTI)
- Incident information (INC)

3.3. WORK ZONES

The Work Zone Data Exchange (WZDx) Specification enables infrastructure owners and operators (IOOs) to make work zone data available for third-party use. The intent is to improve safety by providing work zone information that can be consumed by automated driving systems (ADS) and human drivers. The safe navigation of work zones is a substantial challenge for OEMs deploying Connected and Autonomous Vehicles (CAVs). Actionable data that describes work zone geometry, as well as the presence of workers, could be used to generate real-time alerts to improve driver awareness and prevent injury and loss of life. The Work Zone Data Exchange (WZDx) was launched by the US DOT to inspire adoption of a voluntary work zone data specification. Its last update was version 4.2 in January of 2023.

ITE is now transitioning WZDx into a formal standard called Connected Work Zones (CWZ). The Connected Work Zones Implementation Guide and Standard v00.08 was released in August 2023, and it continues to be developed. To be successful, CWZ will need to consider data element definitions and enumerations to facilitate conversions when moving data between formats governed by different standards such as J2735, TMDD and more.

3.4. SAFE TRUCK PARKING

The shortage of safe truck parking has been a consistent concern for decades. Truck parking is important because: (1) Driver fatigue is a factor in accidents; (2) Goods movement enabled by trucking is critical for economic success; (3) Parking shortages strain communities and result in unauthorized parking, idling, noise, emissions, and excessive truck flow on local roads.

TPIMS is a standard for collecting and providing data on truck parking availability and locations. It specifies a static feed, a dynamic feed, and an archive. Version 1.1 was released in December 2018.

3.5. TRANSIT AND BIKESHARE

In 2006, the original Google Transit Feed Specification began as a collaboration between the TriMet transit agency in Portland, Oregon and Google. GTFS became a standard through which transit agencies could publish their schedules in a way that could be read and used by routing applications. At first, it enabled Google to provide directions that involved transit modes in addition to driving.

To encourage adoption, GTFS was renamed to be the General Transit Feed Specification in 2010. Over time, various agencies have used the structures in GTFS, or adapted it to their needs, thus creating additional "flavors" of GTFS. In 2015, efforts were made to realign GTFS, and in 2018 GTFS best practices were published. In 2019, a non-profit organization called MobilityData was established to manage the standard.

Another organization, called NABSA, began as the North American Bikeshare Association in 2014. However, it has grown in scope to include all shared micromobility devices. In 2019, MobilityData was selected by NABSA to manage another standard now called the General Bicycle Feed Specification (GBFS).

GBFS is an open standard for communicating information about shared mobility services for vehicles such as bicycles and scooters as well as stations and pricing. GBFS is intended for findability, and for providing real-time system status (not historical information). GBFS is documented on github.com, and its recommended version is Version 2.3 released in April 2022. GBFS is used by over 30 operators in over 40 countries.

GTFS, also documented on github.com, is an open standard that enables public transit agencies to publish transit service information in a geographic context. GTFS consists of two parts: (1) a somewhat static GTFS Schedule to communicate routes, fares and schedules; and, (2) a dynamic GTFS Realtime to communicate trip updates, vehicle positions, and service alerts. GTFS is used by over 10,000 transit operators in over 100 countries.

3.6. MOBILITY AND CURBSPACE

The Open Mobility Foundation (OMF) maintains two standards and related APIs that connect cities with private mobility providers. In the OMF view, the cities manage the street and can set rules for how, where, and when mobility devices can operate. The private mobility providers then manage the mobility devices. Both standards are documented on github.com.

The Mobility Data Specification (MDS) was initiated in 2018 by the Los Angeles Department of Transportation (LADOT). Ownership of MDS was transferred to the Open Mobility Foundation (OMF) in November 2019. MDS version 2, released in 2023 consists of a set of six Application Programming Interfaces (APIs) to standardize data exchange between cities and mobility providers about the following modes: (1) micromobility e-scooters and bikes, (2) taxis, and TNCs, (3) car share, (4) delivery robots. For micromobilility and car share modes, a public GBFS feed is required for compatibility with MDS.

Demand for urban curb space is growing to accommodate passenger pickup/drop off, delivery services, as well as scooters, bikeshare, and other services. The Curb Data Specification (CDS) Version 1.0, released in April 2022, is a data standard and set of Application Programming Interfaces (APIs) to support effective implementation of curb policies in cities and for curb users.

4. WORK ZONE INFORMATION

This section motivates the need for proactive information about work zones, discusses the growth of the Work Zone Data Initiative, and describes the challenge of modernizing the existing Caltrans Lane Closure System (LCS) to align with WZDx/CWZ standards.

4.1. MOTIVATION

Work zones are associated with elevated risk of collisions and traffic injuries. As shown in Figure 4-1, the overall trend of fatal work zone crashes in the U.S. has increased from 536 to 821 from 2013 to 2022 (2). In addition, distracted driving is found to contribute toward fatal work zone crashes more often than fatal non-work zone crashes.

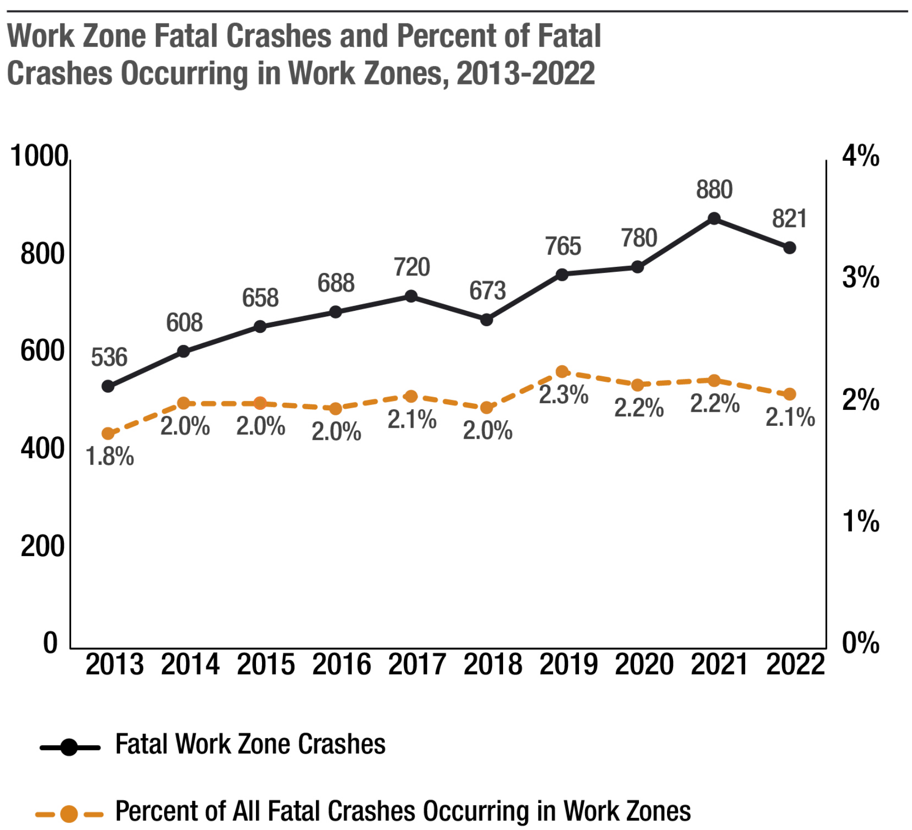

Figure 4-1: Work Zone Fatal Crashes from 2013 to 2022 (2)

Information about work zones, their location, and the presence of workers may be helpful en route as well as during the trip planning process. For this information to be available, the characteristics of the work zone need to be digitized and furnished online in the form of an API that can be accessed automatically.

The safe navigation of work zones is a substantial challenge for OEMs deploying Connected and Autonomous Vehicles (CAVs). Actionable data that describes work zone geometry, as well as the presence of workers, could be used to generate real-time alerts to improve driver awareness and prevent injury and loss of life.

Therefore, the value proposition is clear: work zone data is valuable to multiple stakeholders. The political and economic will exists to standardize, disseminate, and use the data.

4.2. WORK ZONE DATA INITIATIVE

The Work Zone Data Exchange (WZDx) was launched by the US DOT in 2017 to inspire the adoption of a voluntary work zone data specification. Its last update was version 4.2 in January of 2023. The Work Zone Data Exchange (WZDx) Specification (3) enables infrastructure owners and operators (IOOs) to make work zone data available for third-party use. As of December 2024, there are 27 feeds covering more than half of the U.S. (4).

Like GTFS, WZDx is a good example of an early success for digital infrastructure with positive momentum. ITE is now transitioning WZDx into a formal standard called Connected Work Zones (CWZ). The Connected Work Zones Implementation Guide and Standard v00.08 was released in August 2023 and continues to develop. Version v00.23 was released in June 2024.

4.3. CALTRANS LCS MODERNIZATION EFFORT

The Caltrans Lane Closure System (LCS) is a legacy system used to keep track of all Caltrans-related lane closures in the state. There is recent interest in expanding some capabilities of LCS to provide additional information and to conform with new standards such as CWZ. This effort is in alignment with Caltrans priorities and strategic goals to improve safety.

Traditionally, Caltrans has used Changeable Message Signs (CMS), California Highway Information System (CHIN), and QuickMaps to disseminate messages directly to the traveling public. However, new options are available to disseminate messages without physical signs. One way is to leverage CV2X technology. Another is to provide the information to the media or online routing services (Google, Apple, etc.) and allow that information to be passed on to vehicles and drivers.

The legacy LCS system does not create all the information needed for a satisfactory WZDx/CWZ feed. The Metropolitan Transportation Commission (MTC) created an interim solution that converts LCS data to WZDx. The feed is compliant but not as informative as it could be.

Some limitations include the following:

- LCS lacks a map (road network) that includes the number of lanes in each road segment
- LCS lacks speed information (speed limits) on each road segment

The lack of data in LCS places an extra burden on the user. The system depends on the user submitting the closure to indicate how many regular lanes are in the area that need to be closed and to enter which lanes are being closed. In addition, LCS has no way to validate whether the user input is accurate. There is no automated data-checking ability. This is a major system limitation and can lead to data errors in the feed.

A lane closure operation is a manual and human-centered process. Lane closures go through two levels of review. The contractor request is reviewed by a resident engineer who owns the project. The district traffic manager performs a second level of review to ensure the closure makes sense.

LCS has a limited ability to validate some inputs. It can validate the postmile against the linear reference system (LRS). Along mainline segments, this is easier. However, the LRS generally does not include local roads, ramps, and connectors. So, closures at these places require additional effort on the user's part. The available direction fields and the postmile can be used to indicate which ramp is closed, but this needs to be understood in context. Not all districts necessarily enter information in the same way. In addition, it is a voluntary option to provide geo-coordinates and to put a marker on a connector or ramp.

In theory, adding a speed reduction to LCS would be another data field, but this must be done in context. A process is needed to generate the recommended speed or to have a dynamic speed. This is not a technical issue but a problem with business rules. Who has the authority to set the speed, a Caltrans engineer or a contractor? It is undesirable to build a system that can be easily abused.

All of this suggests a need for investment in business processes and data information systems to improve Caltrans' operational performance in this area.

4.4. MTC 511 WZDX FEED

MTC maintains an Open Data Portal to provide traffic and transit data for the San Francisco Bay Area. Among its services include a Work Zone Data Exchange (WZDx) feed containing road closures and detours for participating San Francisco Bay Area jurisdictions. After obtaining an API key, users can access the data from https://api.511.org/traffic/wzdx?api_key=[API_KEY]

5. ITS ARCHITECTURE

This section provides a limited overview of ARC-IT, or the Architecture Reference for Cooperative and Intelligent Transportation, focusing on work zone information. ARC-IT is a national framework that provides a common vocabulary for diverse stakeholders to imagine how intelligent transportation systems could be deployed. This section provides specific examples of the architecture related to work zone information exchange and the standards supporting it. ARC-IT Version 9.2 was released in January 2024 and is available online. Regional architectures based on ARC-IT are typically intended to be living documents that provide a snapshot of existing ITS assets and future assets planned for future projects. Several examples are described next.

5.1. NATIONAL ITS REFERENCE ARCHITECTURE

Within ARC-IT, concepts and functionalities are organized into service packages to provide context for understanding and implementing intelligent transportation systems. These service packages address specific aspects of transportation systems and promote interoperability among different systems and stakeholders.

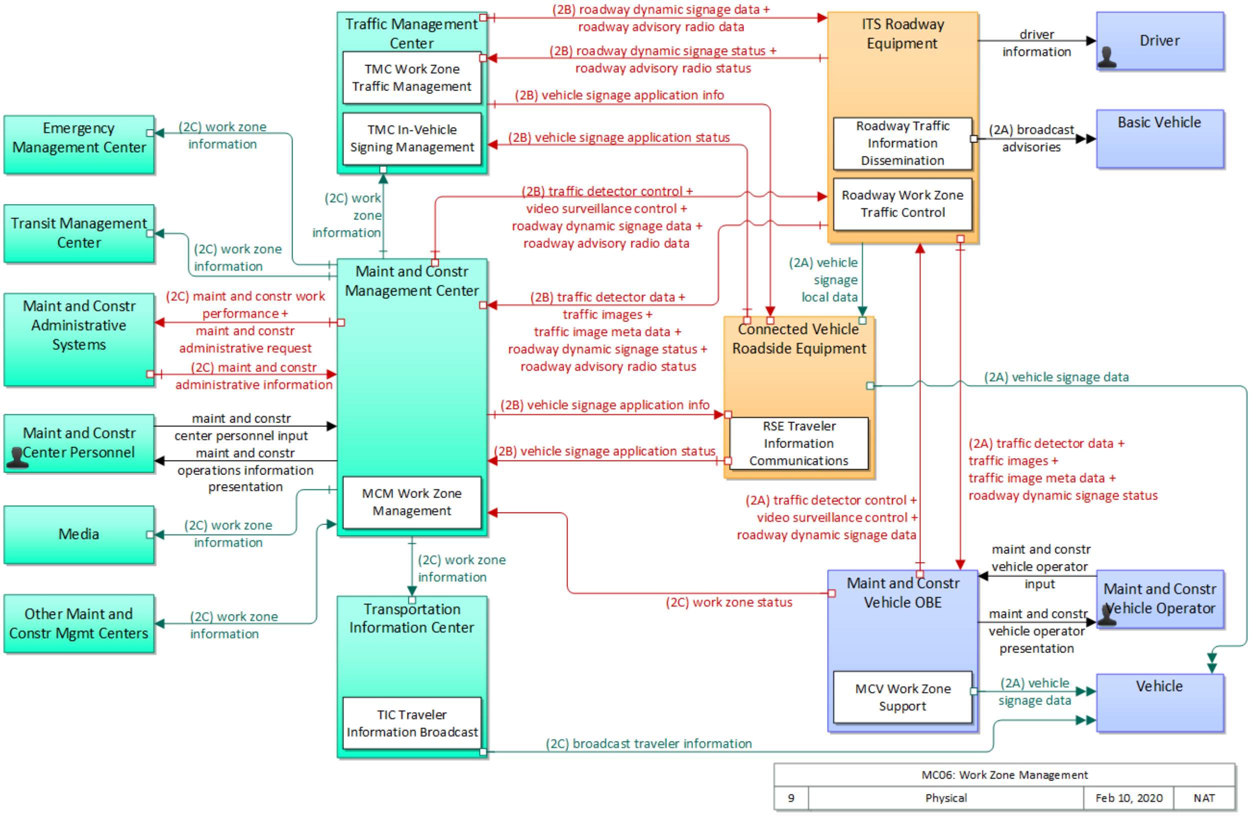

Figure 5-1: ARC-IT Work Zone Management Service Package (5)

For example, the Work Zone Management MC06 service package describes the many ITS components that may play a role in managing road work zones to minimize disruptions and enhance safety for workers and motorists. Work zones are temporary areas where road construction, maintenance, or utility work is being performed, and managing them is vital for maintaining traffic flow and reducing the risk of accidents.

The Work Zone Management physical diagram is illustrated in Figure 5-1. Information flows are shown as arrows between systems. Each information flow is defined as a triple, consisting of three elements: the source, the information, and the destination. In a communications view, each triple is mapped to a selection of communication "solutions" referencing possible standards.

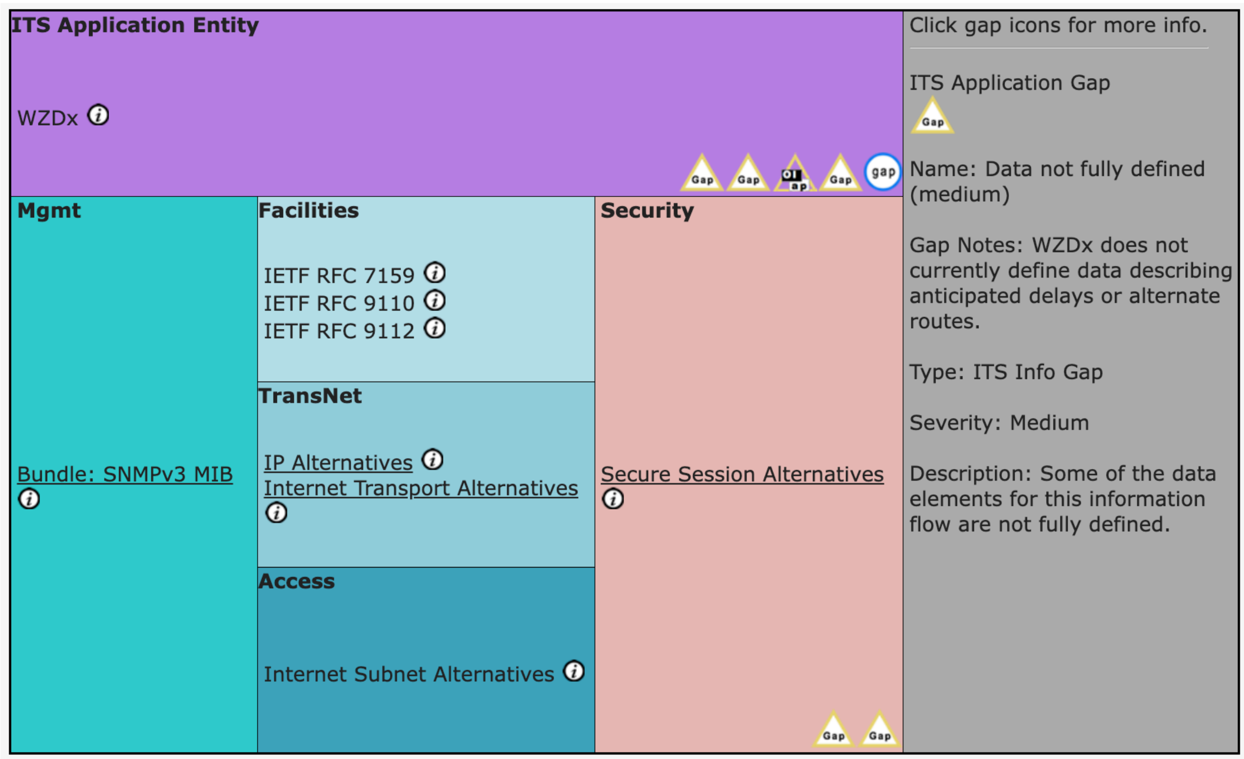

Figure 5-2: ARC-IT Communication Solution view of the WZDx/CWZ Standard (5)

Figure 5-2 shows one example of a communications diagram for work zone-related information flow between a Maintenance and Construction Management Center and a Traffic Management Center. The diagram shows that WZDx/CWZ could be part of the solution. It also displays several icons that identify known issues or gaps for each solution. On the ARC-IT website, the diagrams and arrows contain hyperlinks to other objects within the architecture, which facilitate exploration of the framework. The diagram in Figure 5-2 corresponds to the arrows marked "(2C) work zone information" in Figure 5-1.

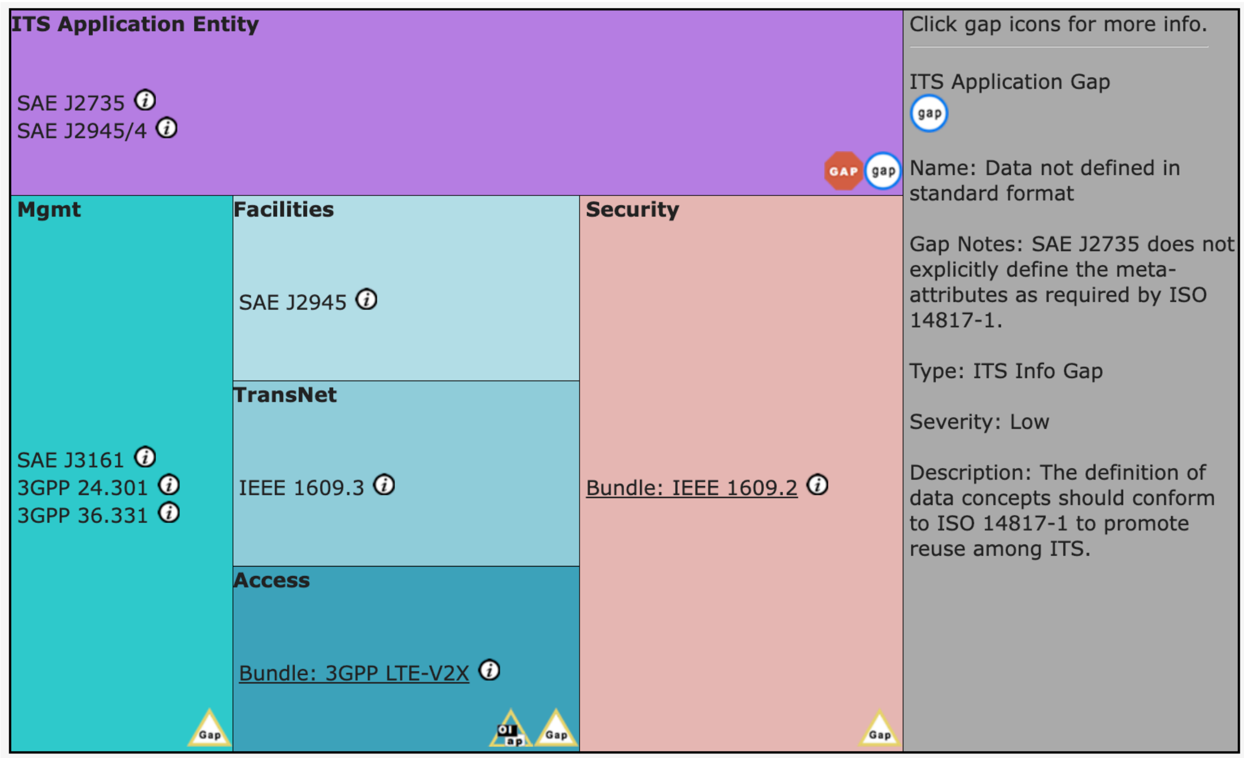

Figure 5-3: ARC-IT Communication solution view of the SAE J2735 and J2945/4 Standards (5)

Figure 5-3 shows one example of a communications diagram for information flow between Connected Vehicle Roadside Equipment and a Vehicle. The diagram shows that SAE J2735 and SAE J2945/4 could be part of the solution. It also displays several icons that identify known issues or gaps for each solution. The diagram in Figure 5-3 corresponds to the arrows marked "(2A) work zone information" in Figure 5-1.

It is common for ARC-IT to identify multiple communications solutions for any given triple. Further investigation reveals that a plethora of solutions are possible. In the context of work zones, the European standards appear to have fewer gaps.

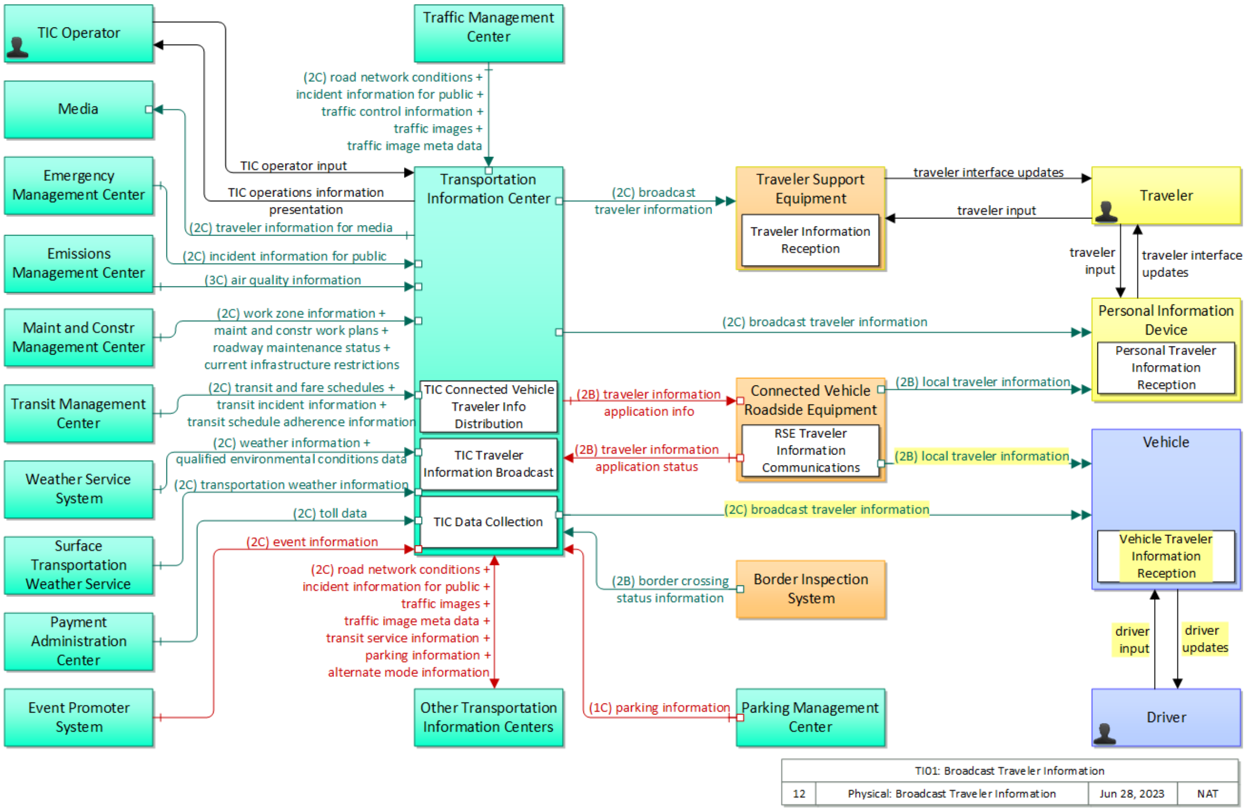

Figure 5-4: ARC-IT Broadcast Travel Information Service Package (5)

Objects are reused among the many different service packages within the architecture. For example, WZDx/CWZ and SAE J2735 appear again in the Broadcast Travel Information Service Package, TI01. This is worth noting because a regional architecture may focus on only a fraction of the possible service packages and only use a fraction of the possible elements in each package.

5.2. REGIONAL ITS ARCHITECTURES

Using ARC-IT as a framework, a regional transportation agency may create a regional ITS architecture to support planning needs and design of new ITS projects that can leverage other ITS assets in the region. This role is filled by RIITS in the LA region and by MTC's regional ITS architecture (RITSA) in the San Francisco Bay Area.

5.2.1. CONNECT-IT

The LA County region's Regional Intelligent Transportation Systems (ITS) architecture is called CONNECT-IT (Connect and Integrate Transportation Technology). It leverages the national architecture to provide a framework and a common vocabulary to describe IT systems, communication channels, and information that flows between systems and across jurisdictional boundaries.

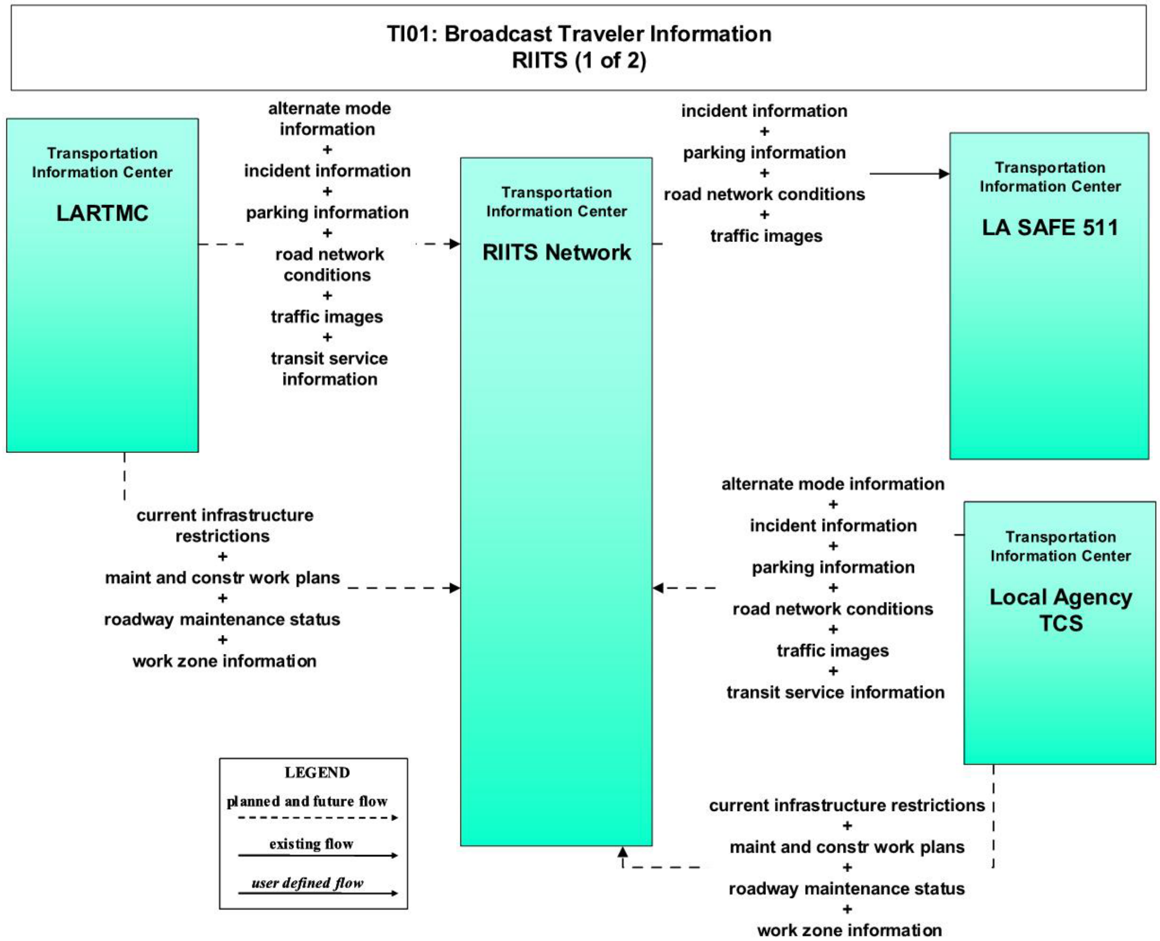

Figure 5-5: CONNECT-IT Diagram of Broadcast Travel Information Service Package (6)

Figure 5-5 illustrates a portion of the Broadcast Travel Information Service Package (existing and planned) in the 2018 version of CONNECT-IT. The regional version names the local centers participating in the architecture, such as the Caltrans LARTMC. Notice that work zone information is planned for but does not currently exist. While CONNECT-IT supports TMDD and J2735, it does not yet include WZDx/CWZ as a solution (6).

5.2.2. MTC RITSA

According to RITSA (7), the current WZDx feed is categorized under the TI01: Broadcast Traveler Information (8) service package, as shown in Figure 5-6. The WZDx feed is provided by MTC's 511 service. According to Figure 5-6, it takes in some maintenance and construction work plans from Caltrans and has ongoing efforts to get additional data from local cities, including San Francisco, Oakland, San Jose, and Alameda County.

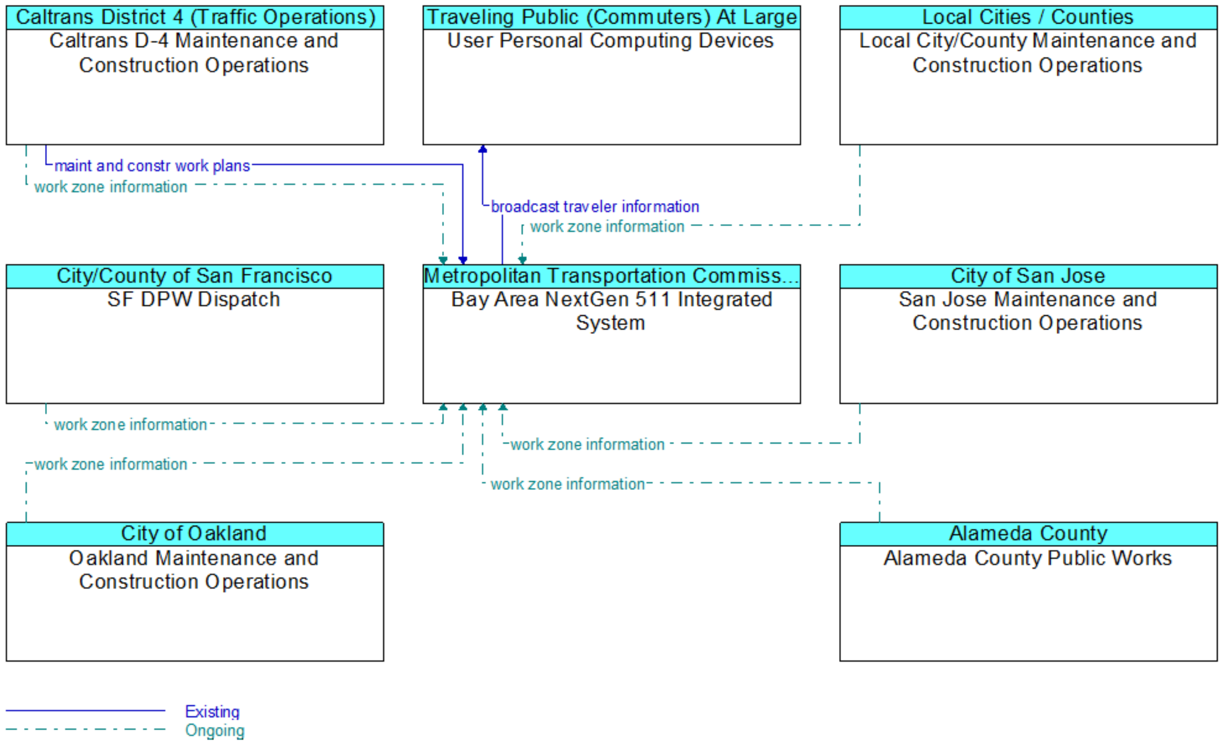

Figure 5-6: RITSA Diagram of Broadcast Traveler Information (8)

6. IMPLEMENTATION GUIDANCE AND RESOURCES

Information about real-world challenges with standards and interoperability was collected. Situations where standards did not match or underlying assumptions about the operational concept of the application, differed across implantations were also of interest. This section summarizes some resources, implementation guidance, and lessons learned.

6.1. ITS JPO CV PILOT PROGRAM

One resource for information about Connected Vehicle (CV) standards, such as J2735, J2945/1, and J2945/4, is available through the ITS JPO CV Pilot Program website (9). A sample of interoperability challenges, negative impacts, and resolutions are listed in Table 6-1.

Table 6-1: Sample of Interoperability Challenges Noted in CV Pilots

Type of Challenge	Standard Name	Summary	Negative Impact	Resolution
Inappropriate criteria for privacy mechanism	SAE J2945/1	SAE J2945/1 Standard's Certificate Change (CERTCHG) requirement	Privacy is not protected because CERTCHG is too infrequent in dense urban grid networks such as NYC	Proposal: Adjust criteria from absolute distance to distance traveled
Standards gap in definition	SAE J2735	Lack of clarity in the definition of a crosswalk to be communicated in the MAP message	Standards compatible messages but with underlying differences in semantics	A crosswalk is defined as an area between curbs, not including a safe waiting area at sidewalk entry/exit
Update to use new technology	TMDD	TMDD specifies the use of communication layer technology	The message layer is linked to the communication layer; therefore, it cannot be compliant and update the communication layer independently from the message layer	Suggest using JSON and REST instead of XML and SOAP

The first two challenges in Table 6-1 appear difficult to foresee. For this reason, the value of pilot projects and demonstrations cannot be overstated. Such activities are necessary to refine a standard or requirement set.

The third challenge has to do with the architecture of the standard itself. The technology of data exchange and communication is changing rapidly, and it is crucial to distinguish among what should be independent layers in a framework. TMDD is perceived to be heavyweight, monolithic, and needing updates.

6.2. CTI GUIDE

A Connected Intersections (CI) Implementation Guide (10) was released in September 2021 and updated in June 2022. The guide is most relevant to J2735 and the applications related to connected vehicles (CVs). Its purpose is to

- Standardize key capabilities and interfaces for a connected intersection
- Address ambiguities and gaps
- Provide guidance to realize truly interoperable systems

It is envisioned that automated transportation systems may be essential users of CI.

The CTI Guide (10) offers insight based on experiences gleaned from early deployments and open dialogue between various ecosystem stakeholders, including IOOs, OEMs, and the traffic signal controller industry.

The CTI Guide reports that early deployments of CV technologies were not truly interoperable. A connected intersection (CI) committee was assembled with five task forces to develop further guidance on what data and messages a connected intersection needs to provide, with an initial focus on the Red Light Violation Warning (RLVW) application. Aspects of this work involved:

- Positioning and RTCM messages
- Security
- Harmonizing messages (SPaT), (MAP)
- Testing and Conformity
- Traffic Controller Issues

The RLVW application is intended to work by calculating a deterministic end of green warning. This deterministic end time is then communicated to the CV and used to calculate whether the CV is at risk of entering the intersection after the green time has elapsed. However, many actuated traffic signals (commonly deployed in cities across the U.S.) are configured using a gap-based green extension, whereby a vehicle detection upstream (by a loop detector) can cause the traffic signal to extend the green to accommodate the extra demand. This vehicle detection is inherently non-deterministic. As a result, the traffic controller itself does not have the capability to unilaterally decree when the end of green time will occur.

Different vendors may have different approaches to handling this challenge. However, the ultimate goal is to have truly interoperable systems so that the RLVW application can work exactly the same way and have the same safety performance across the U.S. Herein lies the challenge, where a desirable improvement to the status quo now requires standardization of something that until now has not been standardized but has instead been a range of individualized habits (that previously served society fairly well) widely deployed, used, and understood by a large existing workforce of city, county, and state traffic engineers in their respective jurisdictions.

The CTI Guide provides example test cases to verify a subset of requirements. It also provides illustrative examples of operational scenarios:

- Texas Diamond Intersection
- Florida T-intersection
- High-Intensity Activated Crosswalk Beacon (HAWK signal)

These examples explain how system components in an application can interconnect and work together.

6.3. DRIVE OHIO

The Drive Ohio program (11) maintains an excellent database of documents pertaining to the deployment of CV applications. In December 2023, Standard Operating Principles (SOP) were developed for Curve Speed Warning (CSW), Lane Closure Warning (LCW), and Reduced Speed Zone Warnings (RSZW) (12).

Similar to the CTI Guide above, the purpose of the SOP document is to address the lack of a consistent approach for CV applications. In contrast, the CTI guide focuses on RLVW, whereas the SOP focuses on CSW, LCW, and RSZW. The SOP acknowledges SAE J2735 and J2945/4 for providing uniform message elements and structure. However, there remains a substantial range of practical details needed for deployments of CV applications to be consistent and interoperable across IOO boundaries. Inconsistency exists among OEM/suppliers and their products.

The SOP provides considerations for the specific advantages of each of the applications and how they provide value beyond what is possible with the legacy approach:

- Curve Speed Warning (CSW)
  - Legacy Approach: Static signage controlled by MUTCD
  - Value and advantage of the CV application: integrate additional data such as weather, road surface conditions, and specifics of the target vehicle dynamics
- Lane Closure Warning (LCW)
  - Legacy Approach: Temporary traffic control through signage, DMS, arrow boards, and combinations
  - Value and advantage of the CV application: Providing information even when visibility is low and considering specifics of the target vehicle dynamics
- Reduced Speed Zone Warnings (RSZW)
  - Legacy approach: Static or changeable signage, flashing beacons dictated by MUTCD
  - Value and advantage of the CV application: Multiple methods to alert a driver and consider specifics of the target vehicle dynamics

The SOP considers the application level and how to create a consistent approach regardless of the technology (radio, CV2X, 5G, etc.) used to deliver the messages. It aims to clarify how IOOs want V2X applications to function. From there, it determines data needs and suggests the semantic content for application-supporting messages. The SOP uses the Manual on Uniform Traffic Control Devices (MUTCD) as a guiding document. In addition, it references ARC-IT and recommends ITIS phrases to communicate succinctly and unambiguously. The SOP remarks that the roadway geometry data included in the RSM-supporting messages is not explicitly intended for but could be utilized by vehicles equipped with ADS technology.

Although SAE 2945 RSM messages are not yet supported by OBU manufacturers, they are recommended in the future (12):

> "Based on the SAE message set standards that were published at the time that these recommendations were developed, CSW recommendations were originally written to utilize the Traveler Information Message (TIM) defined in SAE J2735. After the publication of SAE J2945/4 in May of 2023, the CSW recommendations were rewritten to utilize the Roadside Safety Message (RSM) defined in SAE J2945/4. LCW and RSZW recommendations were also written to utilize the RSM."

The SOP comments on the relative information content between WZDx and RSM messages (12):

> "A Work Zone Data Exchange (WZDx) Work Zone feed may be used for some of the data required to construct an LCW RSM10. The WorkZoneRoadEvent object describes a work zone road event, including where, when, and what activities are taking place within a work zone on a roadway. A full "work zone" is represented by one or more WorkZoneRoadEvents. Note that additional data beyond what is contained in a Work Zone feed is required to construct an RSM."

The SOP provides specific recommendations for all three applications along the following lines:

- Roles and expectations defined for IOO and OEM with respect to the CSW application
- Recommends minimum requirements
- Recommends use of ITIS codes
- Recommends having a process for data quality checks
- Recommends authentication: Security Credentials Management System (SCMS)
- Recommends event information includes a cancellation field as mandatory

6.4. OMNIAIR CONSORTIUM

The OmniAir Consortium (13) is an industry association promoting interoperability and certification for connected vehicles, ITS, and transportation payment systems. The consortium has several working groups focused on certification, cybersecurity, test specifications for V2X, device-level testing, and Road Usage Charge (RUC).

OmniAir organizes so-called Plugfest events to ensure C-V2X equipment (RSUs, OBUs, and modules) are interoperable, conform to industry standards, and meet security requirements in laboratory and field environments.

OminAir also has an accreditation process to certify a range of vendor products and to certify laboratories qualified to perform certification tests.

6.5. CAMP V2I CONSORTIUM

The Crash Avoidance Metrics Partners (CAMP) V2I Consortium includes Honda, Hyundai, Mazda, Ford, GM, Nissan, Subaru, Volkswagen, and Volvo. CAMP released a toolchain (14) meant to incorporate geospatial data into a map for use with Road Safety Messages (RSM). This is potentially useful for any applications where real-world road geometry needs to be digitized.

The toolchain contains several modules (tools) to acquire vehicle path data, build a map that describes work zone geometry, visualize and verify the built map, and build Road Safety Messages (RSM) for Reduced Speed Zone Warning with Lane Closures (RSZW/LC) Safety Application for over-the-air transmission. The toolchain references the SAE J2735 and J2945/4 documents.

The CAMP Toolchain assumes that a vehicle with a GPS device is used to record a trajectory through an open lane of a work zone. A user then enters supplementary information. This supplementary information includes the geometrical details, such as the start/end of lane closure, worker presence, etc. Additional configuration information includes start/end time, speed limits, etc. This information is then combined to form an XML description that can be viewed in a map visualizer. Another module in the toolchain can create an RSM.

6.6. ASAM STANDARDS

The Association for Standardization of Automation and Measuring Systems (ASAM) (15) is a "non-profit organization that promotes standardization of toolchains in automotive development and testing." These standards have applications for modeling, simulation, and developing CV, AV, and ADAS capabilities.

Although focused on the automobile industry, ASAM owns several standards related to vehicle simulation applications and the representation of mobility infrastructure. Three core standards include OpenSCENARIO, OpenDRIVE, and OpenCRG. OpenSCENARIO is intended for use with road network descriptions from OpenDRIVE and can use road surface profiles from OpenCRG.

- OpenSCENARIO: defines a format to describe dynamic driving content such as maneuvers involving vehicles, pedestrians, and other traffic participants.
- OpenDRIVE: defines a format to describe the static geometry of road lanes, such as road markings, signals, etc., and can be exchanged between different simulators. It is also intended to help develop and validate ADAS and AD features.
- OpenCRG: defines a format for the description of road surfaces (curved regular grid)

In addition to these relatively established standards, ASAM members develop additional concepts (that may mature into future standards) meant to foster collaboration and accelerate the development of ADAS and AD technologies. Among these items include:

- OpenODD: a concept project to create a format to represent the operational design domain of a city or an AV's capabilities. This will enable automated processes to check if a given AV with a given ODD is allowed to operate in a given city. In addition, it would help to design vehicle test cases
- OpenLABEL: an annotation format for labeling objects in a driving environment. It is intended as a building block of an Autonomous Driving System's (ADS) perception stack.

- OpenTestSpecification: a test methodology blueprint for autonomous driving functions
- OpenXOntology: an effort to define knowledge representations (ontologies) with standard definitions, properties, and relationships for main concepts among the ASAM OpenX standards, with applications for automated driving

7. COMPARISON OF WORK ZONE-RELATED STANDARDS

This section compares data fields among various formats used in California to express the location and time of a lane closure or work zone event. The comparison is not exhaustive, but it includes many data fields that focus on location and time. The comparisons are made between the WZDx/CWZ family of standards, the SAE J2735 and J2945/4 family (16), and the legacy California Lane Closure System (LCS) (17).

WZDx is a data format designed to contain information about a work zone and make it usable for third parties. There are multiple versions of this standard in use:

- Version 4.1
- Version 4.2

The Connected Work Zones Implementation Guide and Standard (CWZ) is an emerging Connected Work Zone information standard. It is based on WZDx Version 4.2 and is mostly compatible with WZDx. A few exceptions (18) prevent full backward compatibility with WZDx version 4.2.

- Previously deprecated elements have been removed
- Some optional elements have been made mandatory
- Some elements were renamed
- Some elements within enumerations were renamed

Table 7-1 provides a comparison of the different data fields used to describe work zone and lane closure information among a variety of different formats, including:

- CWZ: Connected Work Zone Implementation Guide and Standard v00.23
- WZDx version 4.2
- WZDx version 4.1
- Caltrans Lane Closure System (LCS)
- Road Safety Message (RSM)

The current MTC feed provides data in WZDx version 4.1. LCS does not appear to have fields to express whether a zone is active or when workers are present.

The leftmost column in Table 7-1 provides the parameters in CWZ. Note that event_status is no longer present in CWZ. In WZDx version 4.1, the EventStatus enumerated type was still present but deprecated. Its possible values were planned, pending, active, canceled, and completed. The RoadEventCoreDetails object has a field called update_date that indicates when any information in the RoadEventFeature (including child objects) is updated.

The following conditional fields are deprecated in WZDx version 4.1 and removed from CWZ:

- start_date_accuracy
- end_date_accuracy
- beginning_accuracy
- ending_accuracy

They are replaced by the following fields and intended to be reported by a person or GPS-equipped field device:

- is_start_date_verified
- is_end_date_verified
- is_start_position_verified
- is_end_position_verified

Table 7-1: Comparison of Parameters in Different Formats for Work Zone Information

CWZ	WZDx v.4.2	WZDx 4.1	LCS	RSM
id	id	id	index	eventID
type	type	type		
geometry_type	geometry_type	geometry_type		referencePointType
geometry	geometry_coordinates	geometry_coordinates	beginLongitude, beginLatitude, endLongitude, endLatitude	referencePoint
data_source_id	data_source_id	data_source_id		Data Source Authenticity, Data Source Authorization
event_type	types_of_work	event_type		Event Type
road_names	road_names	road_names	beginRoute, endRoute	Event Location
direction	direction	direction	beginDirection, endDirection, travelFlowDirection	Event Location Applicable Heading
related_road_events	related_road_events			
project_id				
description	description	description		Common Message Header

CWZ	WZDx v.4.2	WZDx 4.1	LCS	RSM
creation_date	creation_date	creation_date	recordDate, recordTime	Event Time (Event Start Time)
update_date	update_date	update_date		Event Updates
start_date	start_date	start_date	closureStartDate	Event Time (Event Start Time)
end_date	end_date	end_date	closureEndDate	Event Time (Event End Time)
work_zone_type			typeOfClosure	
	event_status	event_status	isClosureEndIndefinite	Event Updates, Event Cancellation
is_start_date_verified	is_start_date_verified	start_date_accuracy		
is_end_date_verified	is_end_date_verified	end_date_accuracy		
is_start_position_verified	is_start_position_verified	beginning_accuracy		Event Location Uncertainty
is_end_position_verified	is_end_position_verified	ending_accuracy		Event Location Uncertainty
location_method	location_method	location_method		Event Location Definition
vehicle_impact	vehicle_impact	vehicle_impact	facility	Affected Vehicles
beginning_cross_street	beginning_cross_street	beginning_cross_street	beginLocationName	Event Location
ending_cross_street	ending_cross_street	ending_cross_street	endLocationName	Event Location
beginning_reference_post			beginMilepost	

CWZ	WZDx v.4.2	WZDx 4.1	LCS	RSM
ending_reference_post			endMilepost	
reference_post_unit				
types_of_work	type_name	type_name	typeOfWork	Event Type
are_workers_present	are_workers_present	are_workers_present		Provide Indication of People Present
worker_presence_method	worker_presence_method	worker_presence_method		Provide Obstacle Indication
worker_presence_definition	worker_presence_definition	worker_presence_definition		Provide Obstacle Indication
worker_presence_confidence	worker_presence_confidence	worker_presence_confidence		Provide Obstacle Indication
worker_presence_last_confirmed_date	worker_presence_last_confirmed_date	worker_presence_last_confirmed_date		Provide Obstacle Indication
impacted_cds_curb_zones	impacted_cds_curb_zones			
lanes_order	lanes_order			Lane Closure Warning Needs
lanes_type	lanes_type			Lane Closure Warning Needs
lanes_status	lanes_status			Lane Closure Warning Needs
lanes_restrictions	lanes_restrictions			Lane Closure Warning Needs
reduced_speed_limit_kph	reduced_speed_limit_kph			Reduced Speed Zone Event

CWZ	WZDx v.4.2	WZDx 4.1	LCS	RSM
restrictions	restrictions			Lane Closure Warning Needs, Dynamic Traveler Information Needs

8. MPO PERSPECTIVES

8.1. RIITS

The Regional Integration of Intelligent Transportation Systems (RIITS) (19) exists to "...support the exchange of transportation information and resources between and within government organizations for regional operational mobility improvements." Key focus areas are all intelligent transportation systems and speed and reliability for public transportation in Los Angeles County with extended support for transportation throughout Southern California via Southern California 511. Programs supported by RIITS include signal priority for buses and trains, bikeshare, express lanes, Metro FSP, integrated corridor management, events, and video data sharing. Key standards of importance for RIITS include TMDD, GTFS, GTFS-RT, and WZDx/CWZ and their associated standards.

RIITS is a multi-jurisdictional membership organization within the Los Angeles region. The Los Angeles County Metropolitan Transportation Authority (LACMTA) serves as the RIITS Administrator, regional transportation planning authority, and owner/operator of the regional public transportation system. This is similar to an MPO but is a unique state-chartered agency responsible for transportation in Los Angeles County.

When Caltrans provides a new CATMS system that districts will adopt, RIITS envisions it as a management system that should enable a user to see and interact with whatever it is connected to as a central manager of regional transportation.

RIITS emphasizes collaboration and coordination, with consolidation being adopted as a central focus around the administration of agreements through RIITS. Prior iterations of RIITS focused on the center-to-center communication between agencies without consideration for the needs of programs under development. The idea was that RIITS would be available when a program needed or wanted to use RIITS. This approach did not lead to a lot of participation, so the approach was changed to partner with transportation programs and complete portions of projects associated with RIITS operations. A priority example is helping buses to have signal priority. Signal priority requires updated agreements between stakeholders, handled by having a baseline existing agreement for the region and adding project-specific attachments as needed.

RIITS faces various challenges regarding information and data exchange:

- Upgrading video data interfaces from analog to digital. It is expensive and time-consuming. As technology advances, it is important to have smooth transfers.
- Authentication and access: Determining and enforcing who has access to view and modify data. TMDD 3.1 has limited capabilities regarding security.
- Dissatisfaction with TMDD 3.1. Anxious for an update.
- Having truly up-to-date data with a timestamp. TMDD is from center to center. There are latency delays between systems that add up. RIITS currently uses NTCIP for county-wide TSP, not TMDD.

It is a challenge to coordinate alterations of bus routes due to major construction activities by other agencies such as Caltrans. It is not common for all jurisdictions and agencies to scan LCS for closures that will impact their operations. There are hundreds of projects in Los Angeles at any one time. LCS does not send targeted notifications to personnel in local jurisdictions who might be affected by a closure. As a result, emergencies arising from a closure need to be handled after the fact rather than proactively mitigated.

Within LAMetro's system, there is now a process that connects issues with chat conversations instead of email. The system authenticates users and keeps the conversation in one place.

8.2. MTC

The Metropolitan Transportation Commission (MTC) owns and operates the '511 SF Bay' brand name. MTC collects data from various government agencies in the Bay Area and disseminates that data with some additional regional value added. MTC is always looking for new ways to provide more open data for everyone.

MTC provides transit data using GTFS and GTFS-RT. In addition, MTC uses APIs and European standards for communicating small data packets such as NetEx and SIRI. NetEx is a European specification comparable but broader in scope than GTFS; SIRI is analogous to GTFS-RT.

GTFS is a bulk data standard that provides a firehose of data that includes the entire schedule and service configuration for the agency. It provides everything all at once: routes, stops, trips, schedules, fares, etc. It is the same firehose with real-time data using GTFS-RT. GTFS-RT provides real-time arrival/departure predictions, vehicle locations, and service alerts for the entire system. The consumer must filter it on the client side to find what is needed for a particular application. NetEx and SIRI based APIs allow MTC to provide limited and specific information for a single stop or route.

MTC provides road closure and traffic event data in the WZDx format. MTC also owns a custom traffic event API, supported for internal applications and 511.org website.

For toll rate information, MTC provides a toll rate data API. It provides real-time toll rate information on express lanes operated by MTC. It also includes bridge tolls.

MTC is also working on a regional mapping data services (RMDS) platform for government agencies in the Bay Area. The concept is to enable authorized agencies to integrate live transit and traffic maps on digital dissemination channels for public consumption. Open Street Maps (OSM) will be the base map. It will be possible to add business data, transit routes, etc. One goal is to help cities look at their inventory of transportation elements and manage that information for their needs. This will likely reduce transportation project cost and time for data collection and analysis, and provide more content control for participating agencies.

For GTFS, MTC creates a consolidated regional feed for more than 35 participating transit operators. MTC adds value that individual operators may not provide, such as fare discount information for transfers. The regional feed also provides navigational pathways within transit station/hub areas. Pathways help transit journey planning apps help customers navigate through complex stations.

In order to improve the quality of transit information, additional data standardization such as the Transit Operational Data Standard (TODS) and the Transit ITS Data Exchange Specification (TIDES) and their adoption are important. MTC actively participates in TODS and TIDES efforts.

9. DATA COLLECTION STRATEGIC PLAN

This section provides a summary of key insights and recommendations from the Caltrans 2022 Statewide Data Collection Strategic Plan (20). Many of the ideas in the strategic plan overlap directly with the goals of the present project. Of particular importance is a core business process that, if adopted, would facilitate improved integration, data standardization, and exchange.

The strategic plan identifies the main data-related challenges, and proposes a continual process to develop data resource ***ontologies*** to support all other Caltrans business practices. This process is iterative, and can be implemented in stages. An ***ontology*** describes core informational concepts that drive business processes and relationships among the concepts. An ontology is not to be confused with a data exchange format or a taxonomy. These things are different and serve different purposes. A taxonomy is a knowledge classification system that organizes concepts into hierarchical categories. An ontology may contain several taxonomies. A data exchange format is simply a format for data; it is not intended to describe all the relationships between the objects, or to connect to business processes. If adopted and maintained, what an ontology will do is to ensure a consistent meaning and naming across disparate disciplines.

9.1. SUMMARY OF THE DATA STRATEGIC PLAN

Caltrans should have a unified and coordinated approach to data collection and management of both field asset and mobility data. Digital assets and physical assets should be linked and maintained together. Figure 9-1, taken from (20), presents a strategy toward these goals.

Core data-related challenges include:

- Siloed data procurement, and siloed systems for measurement
- Lack of ontologies to support business processes
- Siloed analytics (eg., PeMS vs WIM data)

The proposed solution involves the following:

- Increase awareness of data resources through the creation of data registries and catalogs
- Establish processes to create data resource ontologies that support business processes
- Identify data integration opportunities

A permanent, continual process as depicted by the arrows in Figure 9-1 is needed to:

- Document domain-specific business processes and associated data use
- Build domain ontologies and data dictionaries
- Establish a Caltrans data registry with links to catalogs

Key recommendations:

- Establish a registry listing key data catalogs and repositories; consider the selection of a metadata standard such as DublinCore, ISO 19115, FGDC, etc.
- Establish repositories tied to business areas or units
- Build teams to document business processes, and consider how emerging data can inform business processes

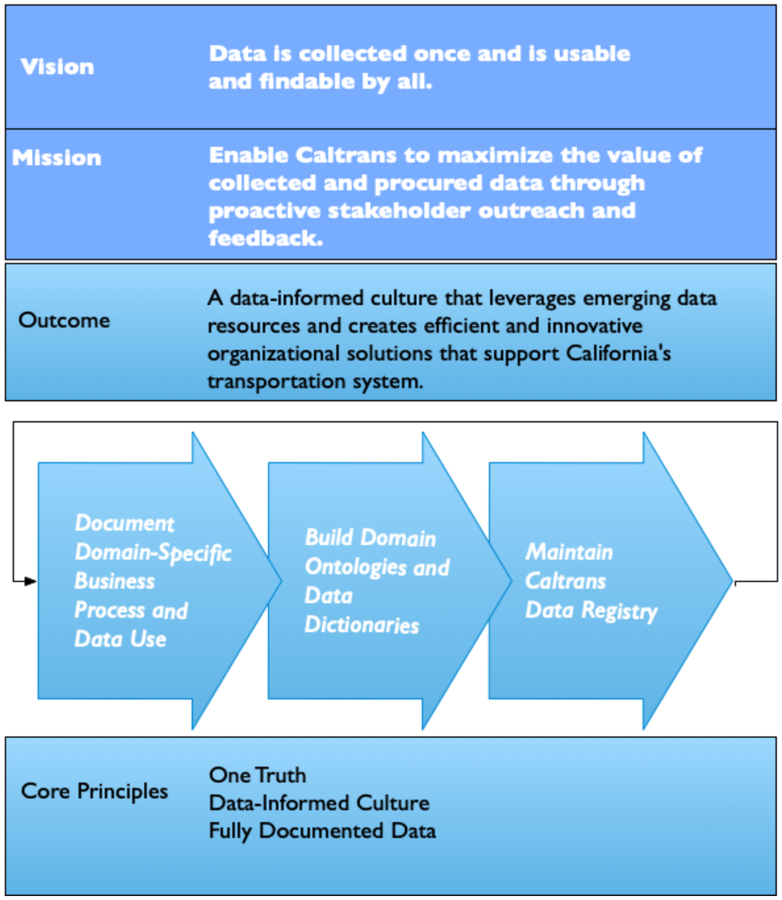

Figure 9-1: High-level Data Strategy (20)

9.2. REFLECTIONS ON THE DATA STRATEGIC PLAN

Over time, one would aim to develop a comprehensive ontology. The ontology provides a foundation for interoperability across the organization. The ontology is used to ensure consistent meaning and naming across disparate disciplines. In addition, it can provide needed guidance to communicate data semantics across organizations.

One great example of this is the interoperability challenge involving the definition of a "crosswalk" as discussed in the previous Technical Memo: Standards Analysis. In the two CV pilots, the notion of what it meant to be a "crosswalk" was different. Although the data syntax was the same, and the data could be exchanged in a standards-compatible way, the underlying semantics were different. This is just one example in which the value of an ontology can be illustrated.

Actually implementing a process like that illustrated in Figure 9-1 is not easy. One way to begin would be to identify business processes that lack information. Start with one domain-specific topic area. Form a data resource team around that topic. Define the ontology and work with the enterprise data steward to define the metadata. Then add this to the data catalog.

One particularly timely and relevant example is that of the Caltrans Lane Closure System (LCS). As discussed in the previous Technical Memo: Standards Analysis, the existing LCS lacks a map, lanes information, and speed limit information. This places an additional burden on users of the system when they need to enter details pertaining to planned work. These limitations in turn become roadblocks when it comes to generating a CWZ (or WZDx) feed that can be published online, and shared with stakeholders.

This CWZ example is a perfect domain area in which to assemble a team to map out the business processes, the data that is needed, and to define that ontology. While the CWZ standard may provide inspiration about data elements that may belong in the ontology, it should not be confused with the ontology. The ontology needs to support and to drive the business processes within Caltrans.

There is one other crucial point about this CWZ example that relates to identity management and security. The business processes required to maintain roads are complex, and they involve many roles, including engineers, contractors, management, etc. One role may need to define the scope of the work zone, another role may need to define safety countermeasures, another may need to update planned work for the day. It might not be appropriate for one role to override the reduced speed limit imposed by another role. This fact reinforces the notion that federated systems are needed to handle identity management and security as the needs for data sharing and collaboration continue to grow.

Additional thoughts:

- There are a variety of data catalog solutions available in the marketplace today. Some proprietary examples are Snowflake and DataBricks. A non-propriety example is the Comprehensive Knowledge Active Network (CKAN)
- Competing standards for data and data exchange will always exist. ARC-IT is an excellent resource; have a product evolution plan to guide development and deployment
- Guidance is always informed by experience. This is the role of prototyping and pilot deployments. What is crucial is that lessons learned are documented and distributed widely
- Business processes change over time. Therefore, ontologies will change as well. Some level of versioning is important so that ontologies, dictionaries, etc. can evolve.

10. RECOMMENDATIONS

This section collects key recommendations and organizes them in one place. The recommendations are intended to be generally applicable. One example is provided for how these recommendations could be carried forward in the context of Connected Work Zone Data. These recommendations are intended to improve interoperability across platforms and jurisdictions, and to encourage the creation of scalable, extensible, and shareable integration components.

10.1. GENERAL RECOMMENDATIONS

The general recommendations here echo major themes in the Caltrans 2022 Statewide Data Collection Strategic Plan (20). The reader is encouraged to access it for additional details:

- Data Discovery: Establish a plan to evaluate and select data cataloging tools that can provide the functions of data discovery.
- Establish a data registry to improve organizational access to existing data. Consider selection of metadata standards such as DublinCore, ISO 19115, FGDC, etc.
- Establish data repositories connected to business areas or units.
- Build teams to document business processes and to consider how existing and emerging data can inform business processes.
- Collect and document use cases for data discovery and sharing that support core business processes. The goal is to create a list and prioritize.
- Make it an organizational goal to procure non-proprietary and open methods for data discovery, identity management, and data exchange.
- Identity Management: Establish a plan to evaluate and select an identity management system. Reach out to regional stakeholders in California to connect IT professionals across jurisdictions.
- Establish a roadmap to facilitate the continual evolution of systems and technology; enable versioning of ontologies, standards, and applications.
- Engage with consortiums and stakeholders who actively promote interoperability in the transportation ecosystem, such as the OmniAir Consortium, Crash Avoidance Metrics Partners (CAMP), etc.
- Promote and participate in pilot projects to gain experience with new data-driven technologies; document findings and lessons learned to contribute toward improved guidance and shared understanding of standards implementation issues.
- Document the existing business processes for the collection and standardization of data for traffic events and incidents.

10.2. FOCUSED CWZ RECOMMENDATIONS

This section discusses recommendations in contest of a specific example focused on work zone information and data exchange formats such as CWZ, TIM, and RSM that are relevant to this data:

- Begin with CWZ and the LCS upgrade effort as a first use case to document the business processes that rely on the data, and to establish a data resources team to create the ontology to describe it.

- Engage with external stakeholders who are (or who should be) consumers of CWZ data and determine how to maximize the value of that information
- Identify the key roles and responsibilities of Caltrans staff, contractors, and any external entities that may need to interact with CWZ or LCS data originating from Caltrans
- Document the existing and potential future value chains for CWZ data
- Reach out to the CWZ standards committee to understand emerging goals for the standard
- Begin a pilot project in one district to design user stories around an improved business process for work zones data and implement that process while conforming to relevant standards

Digital and physical infrastructure that can generate and deliver timely and actionable information about work zones is valuable. It has the potential to save lives and improve safety for both human and automated drivers. Work zones are useful edge cases for ADAS and automated driving systems, and detailed data about these cases are sorely needed for training new AI.

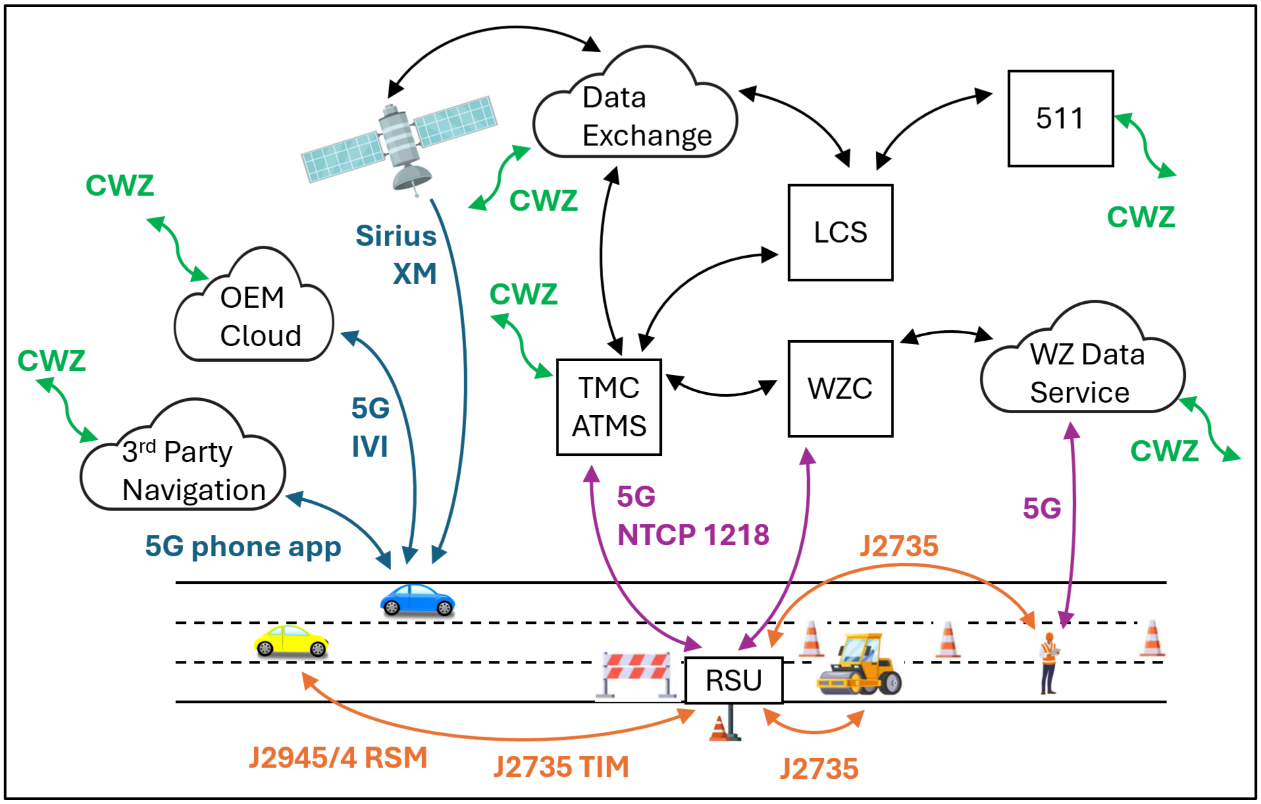

Figure 10-1: Data Pathways for Work Zone Data

There is an emerging ecosystem for work zone-related data and multiple pathways for data to be sourced and distributed, as illustrated in Figure 10-1. This information may include the location of the work zone, timing of work zone activity, lane closures, reduced speed zones, etc. Some of the primary sources of data may include:

- Crowd-sourced data: provided to a 3rd party data aggregator
- Legacy Lane Closure System (LCS) that may feed into ATMS, 511, or other data exchanges
- Road Side Unit (RSU) local to the work zone
- Contractor on site providing status updates

In addition, there are multiple providers of data, and possible alerts related to the work zone, such as:

- 3rd party navigation apps providing data over cellular networks
- In-Vehicle Infotainment (IVI) system receiving updates from an OEM cloud
- Sirius XZM radio via data exchange
- 511 system that provides its own CWZ or WZDx feed
- RSU that may provide TIM or RSM messages

As more WZDx and CWZ feeds are deployed, it is important to be sure that they support underlying business processes. It is increasingly likely that work zone information will be collected from multiple sources, filtered through multiple public and private stakeholders, and delivered through multiple channels. It may not be obvious which source is the most up-to-date, or authoritative. It will be crucial to have data registries that keep track of the existing data sources.

More importantly, it is crucial to understand the value chain for work zone data. While public safety is a major priority, private stakeholders have an interest in monetizing the value they can add to the data. Future work should develop the ecosystem including public and private partnerships that can realize a sustainable value chain through the recommendations outlined above.

11. REFERENCES

1. **Cybersecurity and Infrastructure Security Agency.** Approach for Developing an Interoperable Information Sharing Framework. [Online] August 2021. https://www.cisa.gov/sites/default/files/video/21_0929_cisa_approachfordeveloping_isf_v3_508_0.pdf .

2. **American Road & Transportation Builders Association (ARTBA).** Work Zone Safety Information Clearinghouse. [Online] 2025. https://workzonesafety.org/work-zone-data/.

3. **ITS JPO.** Work Zone Data Exchange (WZDx) Specification. [Online] 2023. https://github.com/usdot-jpo-ode/wzdx.

4. **U.S. Department of Transportation.** Work Zone Data Exchange (WZDX) Feed Registry. [Online] 2025. https://data.transportation.gov/Roadways-and-Bridges/Work-Zone-Data-Exchange-WZDx-Feed-Registry/69qe-yiui/about_data.

5. —. ARC-IT - Architecture Reference for Cooperative and Intelligent Transportation. [Online] https://www.arc-it.net/.

6. **Regional Integration of Intelligent Transportation Systems.** LA County Regional ITS Architecture. [Online] [Cited: 4 24, 2025.] https://laconnect-it.com/standards/.

7. **Metropolitan Transportation Commission.** ITS Architecture. [Online] 2023. [Cited: 12 11, 2024.] https://mtc.ca.gov/operations/programs-projects/intelligent-transportation-systems/its-architecture .

8. —. MTC Work Zone Data Exchange (WZDx) System. [Online] [Cited: 12 11, 2024.] https://itsbayarea.mtc.ca.gov/project-details/288.

9. **U.S. Department of Transportation.** USDOT ITS Research - Connected Vehicle Pilot Deployment Program. [Online] 2020. [Cited: 12 11, 2024.] https://www.its.dot.gov/pilots/success.htm.

10. **Connected Intersections (CI) Committee.** Connected Intersections Implementation Guide: Guidance to Setting Up and Operating a Connected Intersection. [Online] 2021. https://www.ite.org/ITEORG/assets/File/Standards/CTI%204501v0101-tracked.pdf.

11. **DriveOhio.** Ohio CV/AV Systems Engineering Guidebook. [Online] [Cited: 12 11, 2024.] https://drive.ohio.gov/programs/av-cv/cv-av-systems/welcome.

12. —. CV Applications: Standard Operating Principles (SOP) For Curve Speed, Lane Closure, and Reduced Speed Zone Warnings. *V2X Standard Operating Principles.* [Online] 12 6, 2023. https://drive.ohio.gov/programs/av-cv/app-standards.

13. **OmniAir Consortium.** OmniAir Consortium. [Online] 12 11, 2024. https://omniair.org/.

14. **Crash Avoidance Metrics Partners LLC.** V2I Safety Applications: Connected Work Zone Software Toolchain User Guide. [Online] 9 3, 2019. https://www.campllc.org/software-tools/.

15. **Association for Standardization of Automation and Measuring Systems.** *https://www.asam.net/.* [Online] [Cited: 12 11, 2024.] https://www.asam.net/.

16. **SAE International.** Road Safety Applications. [Online] 5 10, 2023. https://www.sae.org/standards/content/j2945/4_202305/.

17. **Caltrans.** Lane Closure System. *Caltrans Commercial Wholesale Web Portal (CWWP).* [Online] 12 11, 2024. https://cwwp2.dot.ca.gov/documentation/lcs/lcs.htm.

18. **Institute of Transportation Engineers.** Connected Work Zones Implementation Guide and Standard v00.23. [Online] 6 2024. https://www.ite.org/technical-resources/standards/cwz/.

19. **LA County Metro.** Regional Integration of Intelligent Tranportation Systems. [Online] [Cited: 12 11, 2024.] https://www.riits.net/about/.

20. **J Macfarlane, A Patire, R Wagner, V Nandigam.** Caltrans Strategic Plan for Data Collection. [Online] June 16, 2022. https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca22-task3834-dor-guidance.pdf.