CONNECTED AND AUTONOMOUS VEHICLE (CAV) SITUATIONAL MESSAGE GAP ANALYSIS

Project 14.2: Apply Wyoming DOT Connected Vehicle Pilot Project Results

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1 Background and Need

Connected and autonomous vehicles (CAVs) are poised to transform our streets, communities, and personal lives. As part of this transformation, the USDOT supported the advancement of connected vehicle technology with a pilot deployment program. In 2015, WYDOT, along with Tampa and New York City, were chosen to deploy a real-world pilot project for CV technology. A large portion of this pilot program was dedicated to WYDOT and the I-80 corridor. Trihydro was the technical and application development lead for the WYDOT CV pilot project and worked to develop and deploy various applications to create and deliver Traveler Information Messages (TIMs) depicting events ranging from road conditions, to parking availability, and variable speed limits.

As the world of Connected Vehicle development has evolved so have the CAV message types. The WYDOT CV Pilot project focused on the TIM message type to relay situational information. Since then new standards are emerging and it is important for DOTs to be aware of which message types they should be supporting and what data needs to be collected in order to form the different CAV message sets. As of September 2021, different CAV message types include the TIM, Roadside Safety Message (RSM) currently in final draft from SAE, and WZDx version 3.1 (version 4.0 set to release in the next few months).

2 Document Purpose

This document provides Gap Analysis of the different CAV message sets and will provide a high-level overview of the data set needed in order for a DOT to support the generation of all these CAV message types.

3 The Traveler Information Message (TIM) Data Type

The TIM is defined in detail in the J2735 spec and contains the following data points that a DOT would need to obtain to generate a TIM message.

Data Field	Description/Detail
Anchor Point	This field is needed in order to identify a known point along the geometry of the applicable message. This is typically implemented as a point prior to the start of the valid area for the TIM geometry.
Start Point	This field is the start of the georeferenced area for the TIM message. Please note that all start/end lat./long. points should be as close to the center point of the road as possible.
End Point	This field is identified as the last point in the geofenced area for the applicable TIM.
Path	These are points that identify the line path of the geometry that the TIM will apply to. This can also be expressed as path offsets.
Heading Slices	This is the direction of travel that the TIM applies to. Heading slices are described further in J2735 but are identified as pie slices relating to direction of travel.

Lane Width	This field describes the width of the path that the TIM applies to. For instance if a TIM is ouput for a one lane highway the width would be set such that the TIM only applies to vehicles traveling along that highway and does not impact frontage roads or other areas.
ITIS Code	The message that you which to convey to CAVs
Start Time	The start time for the message
End Time	The end time for the message

4 Work Zone Data Exchange (WZDx) data type

The WZDx message is defined in detail on the WZDx github website (https://github.com/usdot-jpo-ode/wzdx/tree/main/create-feed). The spec contains the following data points that a DOT would need to obtain in order to generate a WZDx message.

Data Field	Description/Detail
Location Method	Describes the means with which the work zone start and end points are defined.
Update Date	Date that the feed was last modified
Update Frequency	The frequency with which the data for the WZDx feed is published
Geometry	A GeoJSON object of LineString or Multipoint (note that this is similar to the path object in the TIM)
Event Type	This value can either be Detour or Work-zone
Start Date	The Start Date for the event
End Date	The End Date for the event
Start Date Accuracy	The estimated and verified accuracy of the Start Date
End Date Accuracy	The estimated and verified accuracy of the End Date
Beginning Accuracy	The Estimated and Verified accuracy of the beginning coordinate
Ending Accuracy	The Estimated and Verified accuracy of the ending coordinate
Road Names	The Names of the roads on which the event occurs
Direction	Direction of Traffic flow regardless of the real heading angle (northbound, westbound, etc.)
Vehicle Impact	Impact to Vehicular lanes along a single road in a single direction
Relationship *(Optional)*	Identifies related WZDx road events (sequential or hierarchical)
Lanes *(Optional)*	List of individual lanes within a road event
Beginning Cross Street *(Optional)*	Name or number of the nearest cross street where the road event begins
Ending Cross Street *(Optional)*	Name of number of the nearest cross street where the road event ends
Beginning Milepost *(Optional)*	The linear distance measured against a milepost marker along the roadway where the event begins
Ending Milepost *(Optional)*	The linear distance measured against a milepost marker along the roadway where the event ends

Event Status *(Optional)*	The status of the Event (planned, pending, active, cancelled, completed)
Types of Work *(Optional)*	List of the types of work being done in a road event
Workers Present *(Optional)*	A flag indicating if there are workers present in the event space
Reduced Speed Limit *(Optional)*	The reduces speed limit within the event space
Restrictions *(Optional)*	A list of restrictions that apply to the given road segment associated with the work zone. Examples include (no trucks, hov-3, etc)

5 ROADSIDE SAFETY MESSAGE (RSM) DATA TYPE

The RSM is defined in the J2945/4 standard but is not yet finalized and published. It is expected to be published and finalized before the end of the 2021. In general, the RSM is the most detailed of all these CAV message sets. The RSM typically requires detailed path data from a vehicle navigating a particular road segment in order the generate an RSM with Work Zone information. Since this Gap analysis focuses on comparing the TIM, WZDx, and RSM the below information focuses on data needed to generate an RSM for a Work Zone area.

Data Field	Description/Detail
startDateTime	The start of the event
endDateTime	The end of the event
eventRecurrence	This object defines the recurrence of the event (if this is a recurring event) and details how frequently and which days the recurrence takes place.
causeCode	This code describes the cause of the event
subCauseCode	Additional information on the cause of the event or subsequent event
Heading	Part of the Region object. Describes the applicable heading for the approaching vehicle to the event.
Approach Region	Describes the lat/long of all path points for which the event applies.
Path Width	Describes the width (in meters) that the event applies to.
CrossLinking	Allows the RSM to link to other RSM events.
Lane Information	This includes the following lane information: - Number of Lanes - Vehicle Path Data Lane (the lane for which the vehicle path data was collected) - Average Lane width (in Meters) - Approach Lane Padding (in Meters) – this represents the variation in the average lane width by the padding value - Work Zone Lane Padding (in Meters) – represents the variation in average lane width by the padding value
Speed Limits (for work zone message)	Contains the following information: - Normal Speed - Speed Limit at a reference point (ex. Start of a work zone) - Speed Limit when workers are present.

Work Zone Map	Contains detailed path and mapping information for a work zone. Please note that lane level detail is needed to generate this from a instrumented vehicle equipped with a high resolution GNSS receiver.

6 Analysis

Below is a high-level review and analysis of the different CAV message sets, what data is needed in order to generate the message set, and finally a state-by-state analysis of what additional data would be required by each state in order to generate each of the different types of data feeds. Please note, that this is only based on the previous analysis of state data feeds that were completed.

6.1 Roadside Safety Message

Of the CAV message sets reviewed (TIM, WZDx, and RSM), the message set with the most detailed information and data gathering requirements is the RSM. As seen in Appendix A the RSM not only contains the most detailed message set but the data requires having a high resolution GNSS instrumented vehicle to gather path points to accurately map work zone and lane level data. Other information that State DOTs may find difficult to acquire include lane width and lane width buffers, workers or people present, and accurate times for work zones being active.

Implementing and managing RSM messages may require significant effort from state DOTs but also provides detailed lane level information for Connected and Autonomous vehicles to be able to safely navigate roads as well as work zones.

6.2 Work Zone Data Exchange

The next most detailed message type was the WZDx message. This message type contained a subset of data from the RSM and does not require all lane level mapping information to be detailed in the WZDx message, though it does require detailed path information for any lane closures that may exist. Even though it requires less data points than the RSM the WZDx message does require significantly more data points as well as accuracy requirements than a TIM message does though the majority of that additional data is optional within the current 3.1 WZDx specification.

Implementing and managing basic WZDx feeds will require more effort to maintain and keep accurate than just a basic TIM feed. This is due to the additional lane level information and the frequency with which information in the WZDx is needed to stay accurate. Also note that the WZDx standard is an evolving standard that will most likely grow in the number of required fields over the years with at least two minor releases and one major release forecast for the next several years.

6.3 Traveler Information Message

While still offering a rich set of data for CAV consumption the TIM message also doesn't require a significant amount of data for State DOTs to collect and report on. Typically, the data required still involves geographic path data as well as lane width information and heading information data outside of that is not necessary for the message set to be built and distributed.

7 STATE GAP ANALYSIS

This section details the State Gap analysis for each of the given states who participated in the TIM/data feed as well as Wyoming. The table below indicates which fields were present in the state's data feed and which fields were missing from the given data feeds.

Message Type	Field	Minnesota	North Dakota	South Dakota	Washington	Wyoming
TIM	Lane Width	--	--	--	--	X
TIM	ITIS Codes	--	--	--	--	X
TIM	Lat/Lon Path points	--	X	--	--	X
TIM	Duration	X	X	X	X	X
TIM	ITIS Code Specific meta data	--	--	--	--	X
WZDx	Location Method	--	--	--	--	--
WZDx	Update Date	X	X	X	--	--
WZDx	Update Frequency	--	--	--	--	--
WZDx	Geometry	--	X	--	--	X
WZDx	Event Type	X	X	X	X	X
WZDx	Start Date	X	--	X	X	X
WZDx	End Date	--	--	X	X	X
WZDx	Start Date Accuracy	--	--	--	--	--
WZDx	End Date Accuracy	--	--	--	--	--
WZDx	Beginning Accuracy	--	--	--	--	--
WZDx	Ending Accuracy	--	--	--	--	--
WZDx	Road Names	X	X	X	X	--
WZDx	Direction	X	X	X	X	X
WZDx	Vehicle Impact	X	X	--	X	X
WZDx	Relationship *(Optional)*	--	--	--	--	--
WZDx	Lanes *(Optional)*	--	--	--	--	--
WZDx	Beginning Cross Street *(Optional)*	--	--	--	--	--
WZDx	Ending Cross Street *(Optional)*	--	--	--	--	--
WZDx	Beginning Milepost *(Optional)*	--	X	X	X	--
WZDx	Ending Milepost *(Optional)*	--	X	X	X	--
WZDx	Event Status *(Optional)*	--	--	--	X	X
WZDx	Types of Work *(Optional)*	X	X	X	X	X
WZDx	Workers Present *(Optional)*	--	--	--	--	--
WZDx	Reduced Speed Limit *(Optional)*	--	X	--	X	X
WZDx	Restrictions *(Optional)*	X	X	X	X	X
RSM	startDateTime	X	--	X	X	X
RSM	endDateTime	X	--	X	X	X
RSM	eventRecurrence	--	--	--	--	--
RSM	causeCode	--	--	--	--	--
RSM	subCauseCode	--	--	--	--	--

RSM	Heading	X	X	X	X	X
RSM	Approach Region	--	--	--	--	X
RSM	Path Width	--	--	--	--	X
RSM	CrossLinking	--	--	--	--	--
RSM	Lane Information	--	--	--	--	--
RSM	Speed Limits (for work zone message)	--	X	--	X	X

Table 7-1: State Gap Analysis. X indicates existing feed includes field, -- indicates existing feed does not include field

8 CONCLUSIONS

Connected Vehicles are just beginning to be deployed in production environments in places like the CV Pilot projects in New York, Tampa, and Minnesota with many other state and federal pilots also in the works. Getting messages to CAVs on the roadway does have high potential to feed information to drivers about situational data. This information may be invaluable to reducing congestion, warning drivers of road conditions, and saving lives of drivers already on our roadways. As the message sets evolve and are adopted by CAVs the standards may also be updated. So far, the TIM message standard is the most mature and stable standard of the existing CAV message sets. This message set is required to be supported by OBU manufacturers that are building out J2735 compliant on board units. Though the TIM message set is recommended as the quickest way to support the J2735 traveler message set it doesn't provide detailed GPS lane level information that AVs use for navigating work zones. For State DOTs to support enhanced message sets such as the RSM it will require significant effort to gather, build and deploy rich RSM and WZDx message sets.

9 APPENDIX A

Below is a table of the data gathering requirements for all of the CAV message sets listed in this document.

Table 9-1Message Gap Analysis, X - Required, O - Optional

Data Description	RSM	WZDx	TIM
Message Cause (Event Type)	X		X
Basic Path Geometry	X	X	X
Lane Level Geometry	X	X	
GNSS Lane Level Geometry	X	O	
Lane Width	X		X
People Present	X	O	
Relationships	X	O	
Number of Lanes	X	O	
Cross Streets		O	
Speed Limits	X	O	
Heading	X		X
Recurring Events	O		
Start Date	X	X	X
End Date	X	X	X
ITIS Meta Data	X		X