

# **BASIC INFRASTRUCTURE MESSAGE DEVELOPMENT AND STANDARDS SUPPORT FOR CONNECTED VEHICLES APPLICATIONS**

Task 2  
Infrastructure Information Elements Review

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*Prepared for:*  
Connected Vehicle Pooled Fund Study

*Prepared by:*



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## 1 INTRODUCTION

This review was developed as part of the Connected Vehicle Pooled Fund Study project “Basic Infrastructure Message Development and Standards Support for Connected Vehicles Applications”.

### 1.1 Project Background

In a connected vehicle (CV) environment, vehicles which are equipped with Dedicated Short-Range Communication (DSRC) devices broadcast Basic Safety Messages (BSMs), and a standard such as SAE J2735 has been well defined for what information is in the BSM. On the other hand, from the infrastructure side, which infrastructure information will be or needs to be broadcasted is relatively unknown and has not been well investigated yet.

Current standards include many of the infrastructure related information such as Signal Phase and Timing (SPaT) message and messages that contain intersection geometry (known as MAP messages). Additional infrastructure information could be transmitted that may benefit CVs applications, such as:

- speed limit (particularly where that might be variable)
- standard signage in the area
- presence of school zones
- work zones and lane closures
- messages displayed on variable messages signs or highway advisory radios
- etc.

With this background, it was recently suggested that a corollary message to the BSM from the infrastructure, a Basic Infrastructure Message (BIM), needs to be investigated. Having a standard (or near standard) BIM would help the Original Equipment Manufacturers (OEMs) and third-party application providers to understand that there will be some infrastructure for them to rely on, and will give them some basis for the kind of message they can expect from the infrastructure. At the same time, this will also help the public transportation agencies to know what kind of information to broadcast from their Road Side Equipment (RSE).

Once a standard (or near standard) BIM is developed, the next step would be to work with the appropriate standards development organization and committee to get the BIM standard message under consideration as a standard. Likewise, there is an urgent need for the public agencies (actual operators and maintainers of the infrastructure) to be able to influence the decisions related to the standards for vehicular data, such as BSM, as well. For a variety of reasons (budget, expertise, travel constraints, time availability, etc.), the operating agency personnel have not engaged in these standards development exercises, but have an important interest in their outcomes. Also, many of the states are not even fully aware of what standards exist or what the status of them is. With that being said, it is important to establish a means with which the Connected Vehicle Pooled Fund Study team can track standards related activities and influence the development of these standards.

### 1.2 Project Goals

The goals of this project are:

- Develop a BIM
- Establish a means to collaborate with the relevant standards development organizations

### 1.3 Purpose of this Document

This review paper was developed under Task 2 of the project: “Basic Infrastructure Message Development and Standards Support for Connected Vehicles Applications”. This review is intended to capture the use

cases and information needs pertaining to infrastructure communication. The information in this document will be used in subsequent project tasks to develop the BIM.

## 2 REFERENCES

SAE International. (2016, Mar). *Dedicated Short Range Communications (DSRC) Message Set Dictionary*. Retrieved from SAE International: [https://saemobilus.sae.org/content/j2735\\_201603](https://saemobilus.sae.org/content/j2735_201603)

## 3 TOP LEVEL NEED (USE CASE)

Through efforts represented in Task 4 of this project, the Concept of Operations (section 2) provides context for the infrastructure elements represented below including the user needs. Please reference the Task 4 document for clarification on these items.

## 4 USE CASE INFORMATION

Each use case should be presented with some (or all) of the following information:


- Use Case Name
- Category (typically safety/mobility/environment)
- Short Description (summary)
- Actors (participants)
- Goal (desired result)
- Needs (problem to be addressed)
- Constraints/Presumptions (limitations or assumptions)
- Geographic Scope (range and type)
- Timing Scope (current, predictive, recurring, historical)
- Illustration (graphical representation of actors, events, environment)
- Pre-Conditions (conditions assumed before start of the use case)
- Main Event Flow (primary sequence of events and interactions)
- Alternate Event Flow(s) (alternative sequence given conditions)
- Post-Conditions (anticipated conditions after the interactions are complete)
- Information Requirements (data elements that are exchanged between actors)
- Issues (concerns related to the use case or implementation)
- Source Docs/References (external documents used as reference)

## 5 USE CASES

### 5.1 Static Signage

Use Case Name	Static Signage
Category	Environment
Short Description	Digital representations of physical signs and placards.
Infrastructure Roles	Provide information about static signs to nearby vehicles. Receive static sign information from sign authority or other external source.
Vehicle Roles	Receive information about static signs in the nearby region, display the information to the driver.

Use Case Name	Static Signage
Other Roles	Sign authority provides static sign content and location, as well as applicable region information.
Actors	<ul style="list-style-type: none"> <li>• Sign Authority (may be manually entered or sensed)</li> <li>• Infrastructure Equipment</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers retain awareness of the information provided through static signs in the area by leveraging infrastructure-provided information.
Needs	The driver needs to receive information about the location and content of nearby static signs.
Constraints/Presumptions	
Geographic Scope	Local
Timing Scope	Current
Illustration	
Pre-Conditions	Static signs exist in an area and their meaning is unambiguous and relevant to travelers.
Main Event Flow	<ol style="list-style-type: none"> <li>1. Static signage information is provided/updated by roadway authority and sent to RSE.</li> <li>2. RSE provides static signage information to vehicles operating in the region.</li> <li>3. In Vehicle Equipment receives the static signage information and presents relevant information to the operator.</li> </ol>
Alternate Event Flow(s)	<ol style="list-style-type: none"> <li>1. Static signage information is sensed by signage detection and classification equipment.</li> <li>2. Sensed static signage information is provided to RSE.</li> <li>3. RSE provides sensed static signage information to roadway authority for verification.</li> <li>4. Source for presenting information to operator could be sensed static signage data or verified (agreeing) sensed + reported static signage.</li> </ol>
Post-Conditions	Static signage information is available in the vehicle
Information Requirements	<ul style="list-style-type: none"> <li>• Absolute (and optionally contextual) position of signs (angle may be relevant as well)</li> <li>• Type of sign</li> <li>• Content of sign</li> <li>• Applicable region/paths/roadways</li> </ul>

Use Case Name	Static Signage
<p>Issues</p>	<p>Signage can be quite complex and information overload is possible as indicated in the following picture.</p> 
<p>Source Documents/References</p>	<p>Static Sign Definition.docx</p>

### 5.2 Dynamic Traveler Information

Use Case Name	Dynamic Traveler Information
Category	Environment
Short Description	Information that would be displayed dynamically to drivers in a region would be transmitted digitally through BIMs. CVs could then display this information to drivers.
Infrastructure Roles	Provide information about dynamic signs to nearby vehicles. Receive dynamic sign information from sign authority or other external source.
Vehicle Roles	Receive information about dynamic signs in the nearby region, display the information to the driver.
Other Roles	Sign authority provides static sign content and location, as well as applicable region information.
Actors	<ul style="list-style-type: none"> <li>• DTI Source</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers understand and retain the information displayed on dynamic signs along their route.
Needs	The driver needs to receive information about the location and content of nearby dynamic signs.
Constraints/Presumptions	Information from an authorized source is available
Geographic Scope	Regional
Timing Scope	Current, Predictive

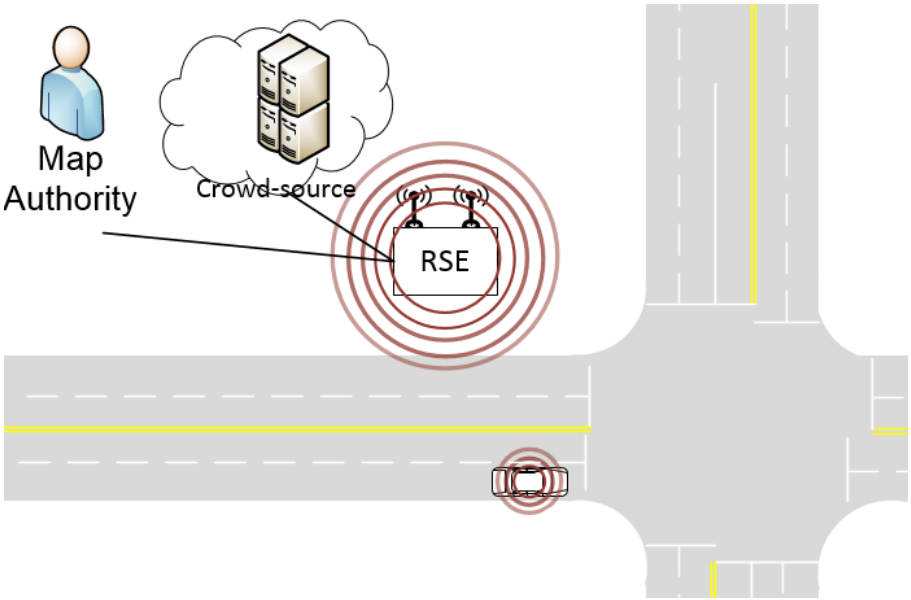
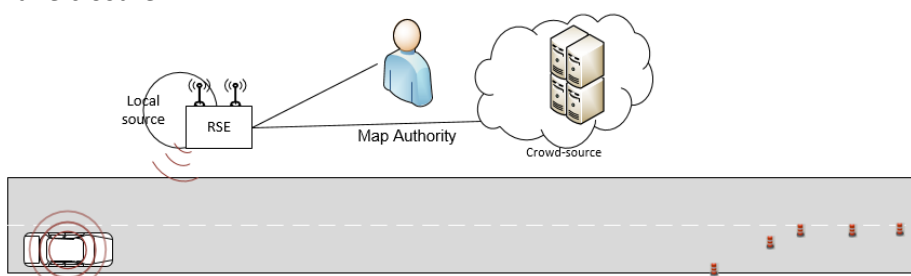
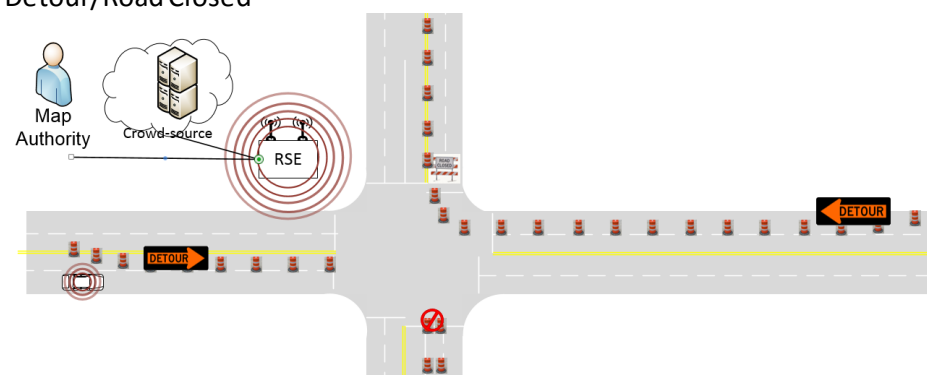
Use Case Name	Dynamic Traveler Information
Illustration	
Pre-Conditions	DTI is available
Main Event Flow	<ol style="list-style-type: none"> <li>1. Authority provides formatted information to RSE.</li> <li>2. RSE provides information to vehicle.</li> <li>3. Vehicle receives information and provides information to occupants.</li> </ol>
Alternate Event Flow(s)	Dynamic information for an entire route is presented to operators prior to departure.
Post-Conditions	Operator has dynamic information available to them .
Information Requirements	<ol style="list-style-type: none"> <li>1. Applicable region/area/path/roadway</li> <li>2. Timeframe</li> <li>3. Content                         <ol style="list-style-type: none"> <li>a. Type of dynamic information</li> <li>b. Priority</li> </ol> </li> </ol>
Issues	Screen real-estate limits the information and text that appears on dynamic signs, but digital presentation would not necessarily be similarly constrained. Should digital dynamic signs be abbreviated in the same way that physical DMS messages are abbreviated?
Source Documents/References	

### 5.3 Map Information

Use Case Name	Map Information
Category	Environment
Short Description	Information pertaining to the localization and navigation of an area, including any adjustments to the typical driving pattern. This includes highways, intersections, lane adjustments, road closures, and route changes.
Infrastructure Roles	Provide information about localization and navigation to nearby vehicles. Receive dynamic sign information from sign authority or other external source.
Vehicle Roles	Receive information about roadway geometry in the nearby region, display the information to the driver.
Other Roles	Map authority provides content, as well as applicable region information.

Use Case Name	Map Information
Actors	<ul style="list-style-type: none"> <li>• Map Information Source               <ul style="list-style-type: none"> <li>○ Crowd-sourced</li> <li>○ Local map authority</li> <li>○ Global source</li> </ul> </li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Provide drivers with information about the geometry, distances and roadway network.
Needs	The driver needs to receive information about the geometry and roadway network. Additionally, applications running on the OBE can utilize the information.
Constraints/ Presumptions	There is a roadway authority or an authorized information source that can be trusted to provide map information.
Geographic Scope	Range (extended) of RSE and local area
Timing Scope	Current



Use Case Name	Map Information
Illustration	<p data-bbox="451 233 602 260">Intersection</p>  <p data-bbox="451 856 602 884">Lane closure</p>  <p data-bbox="451 1157 699 1184">Detour/Road Closed</p> 
Pre-Conditions	Map information is available –from authorized source or examination of persistent traffic patterns.
Main Event Flow	<ol style="list-style-type: none"> <li data-bbox="451 1640 1230 1667">1. Map information authority provides regional map info to RSE</li> <li data-bbox="451 1667 1105 1694">2. RSE provides regional map info to vehicles in range</li> <li data-bbox="451 1694 1089 1722">3. Vehicle equipment provides map info to operator</li> </ol>
Alternate Event Flow(s)	Given knowledge of anticipated route, updated/changed map information is provided to operator prior to departure.
Post-Conditions	Operator has updated map information.

Use Case Name	Map Information
Information Requirements	<ul style="list-style-type: none"> <li>Map data</li> <li>Route data</li> <li>Timeframe for adjustments (future or current)</li> </ul>
Issues	<ul style="list-style-type: none"> <li>Accuracy between digital information and real-world environment.</li> <li>Registration between localization and global coordinates.</li> <li>Incoming data threshold needs to be reached to provide accurate data (otherwise one errant vehicle could bias the map information).</li> </ul>
Source Documents/References	

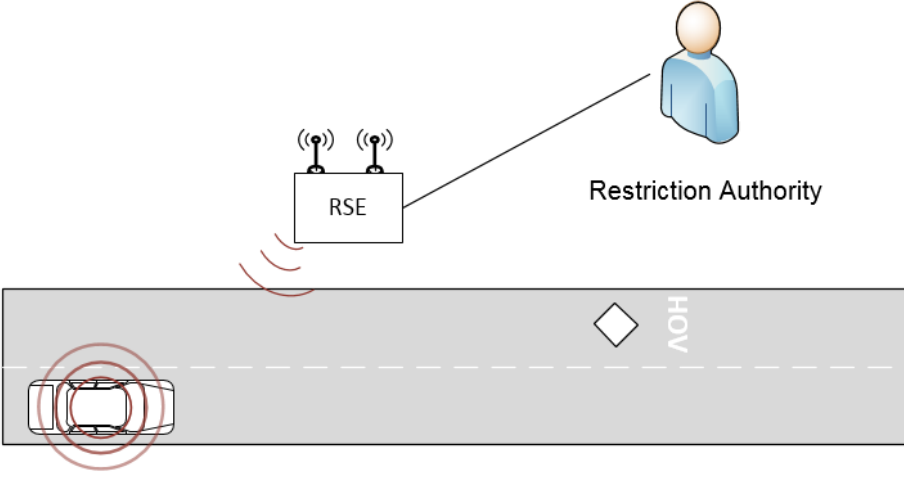
### 5.4 Situational Awareness

Use Case Name	Situational Awareness
Category	Environment
Short Description	Contextual information about the environment and any situational-specific details that would be relevant to safe vehicle operation in an area.
Infrastructure Roles	Provide information about contextual situations in the area. Receive contextual situation information from external sources.
Vehicle Roles	Receive information about situations in the nearby region, display the information to the driver.
Other Roles	Authority provides information about the situation, as well as applicable region information. Roadway users may provide situational awareness information up to a crowd-sourced authority for distribution to other drivers or verification.
Actors	<ul style="list-style-type: none"> <li>Situational awareness authority</li> <li>RSE</li> <li>In Vehicle Equipment</li> </ul>
Goal	Help drivers receive up to date information about situations along their route.
Needs	The driver needs to receive information about situations that may affect their navigation of an area.
Constraints/Presumptions	
Geographic Scope	Local
Timing Scope	Current, Predictive
Illustration	<p>The diagram shows a road scene with several elements. On the left, a car is shown with red concentric circles around it, representing a sensor or communication range. Above the car is a box labeled 'RSE' (Road Side Equipment) with two antenna symbols and red signal waves. To the right of the RSE is a person icon labeled 'Map Authority' and a cloud icon labeled 'Crowd-source' containing server racks. Below the road, there is a wavy blue area labeled 'Water on road' and a white car icon labeled 'Stalled Vehicle'. On the far right, there is a yellow diamond-shaped sign with a black border and a black silhouette of a person holding a flag, labeled 'Flagman'.</p>
Pre-Conditions	Environmental conditions exist

Use Case Name	Situational Awareness
Main Event Flow	<ol style="list-style-type: none"> <li>1. Roadway authority provides situational awareness information to RSE.</li> <li>2. RSE provides information to vehicle equipment.</li> <li>3. Vehicle equipment provides information to operator.</li> </ol>
Alternate Event Flow(s)	<ol style="list-style-type: none"> <li>1. Operator or vehicle provides situational awareness input to In Vehicle Equipment.</li> <li>2. In Vehicle Equipment provides situational awareness input to RSE.</li> <li>3. RSE provides information to roadway authority for verification or statistical analysis and algorithm.</li> </ol> <p>[Main Event Flow can then follow]</p>
Post-Conditions	Operator has updated situational awareness information
Information Requirements	<ul style="list-style-type: none"> <li>• Timeframe</li> <li>• Position/Area</li> <li>• Content <ul style="list-style-type: none"> <li>○ Type of situation</li> <li>○ Specific nature of situation (low speed limit)</li> </ul> </li> </ul>
Issues	This use case does not capture how to represent the difficulties to the operator, everything from oversized vehicles to flagmen to weather. This may be too broad.
Source Documents/References	

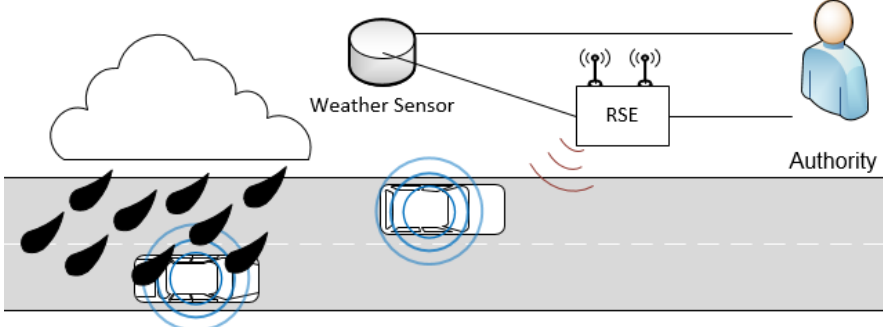
### 5.5 Limited Access

Use Case Name	Limited Access
Category	Safety, Mobility
Short Description	Restrictions for vehicles operating in specific roadway areas.
Infrastructure Roles	Provide information about limited access to nearby vehicles. Receive limited access information from traffic authority or other external source.
Vehicle Roles	Receive information about limited access in the nearby region, display the information to the driver.
Other Roles	Traffic authority provides content and timeframe, as well as applicable region information.
Actors	<ul style="list-style-type: none"> <li>• Limited access source</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers understand and follow the access restrictions along their route.
Needs	The driver needs to receive information about the region and timeframe of relevant limited access areas.
Constraints/Presumptions	
Geographic Scope	Regional, Local, Lane-level
Timing Scope	Current, Predictive, Reoccurring

Use Case Name	Limited Access
Illustration	
Pre-Conditions	Authorized restriction information is available. Vehicle types can be reported/recognized by vehicles.
Main Event Flow	<ol style="list-style-type: none"> <li>1. Authority provides restriction info to RSE.</li> <li>2. RSE provides info to vehicle equipment.</li> <li>3. Vehicle Equipment provides info to operator.</li> </ol>
Alternate Event Flow(s)	
Post-Conditions	In Vehicle Equipment has restriction information for the area.
Information Requirements	<ul style="list-style-type: none"> <li>• Timeframe</li> <li>• Position/Area</li> <li>• Content                             <ul style="list-style-type: none"> <li>○ Type of restriction                                     <ul style="list-style-type: none"> <li>▪ Restriction details (such as direction, vehicle class, price, etc.)</li> </ul> </li> </ul> </li> </ul>
Issues	The “type of vehicle” needs to be reported by the vehicle, but it may require human-interpretation (such as whether a car is eligible for the HOV lane). Human error or intentional misuse may pose a problem.
Source Documents/References	

### 5.6 Data Collection Requests

Use Case Name	Data Collection Request
Category	Environment, Mobility
Short Description	Vehicles have data that can be useful when aggregated, such as traffic conditions and environmental responses (wind-shield wipers, traction control activation, temperature, etc.). This data can be aggregated and anonymized to provide contextual information to a traffic authority.
Infrastructure Roles	Request information from nearby vehicles. Transfer the requested information to authority for storage and processing.
Vehicle Roles	Respond to data requests. Interact with driver/owner to establish permission (or denial) of requested data.
Other Roles	

Use Case Name	Data Collection Request
Actors	<ul style="list-style-type: none"> <li>• Traffic Authority</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help roadway users by gathering and interpreting information gathered from vehicles.
Needs	<p>The driver needs to receive information relevant to the area in order to improve traffic flow.</p> <p>The traffic authority needs to gather and interpret data in order to anticipate problems before they worsen.</p>
Constraints/ Presumptions	
Geographic Scope	Local
Timing Scope	Current, Historical
Illustration	
Pre-Conditions	<ul style="list-style-type: none"> <li>• Data collection agreement has been established.</li> <li>• Collection authority has been authorized and verified.</li> </ul>
Main Event Flow	<ol style="list-style-type: none"> <li>1. Authority indicates desired data.</li> <li>2. Infrastructure requests data from In Vehicle Equipment.</li> <li>3. In Vehicle Equipment provides data.</li> </ol>
Alternate Event Flow(s)	<ul style="list-style-type: none"> <li>• Operator declines to share data.</li> <li>• Authority extracts data from outside sources (such as a weather sensor or report).</li> <li>• RSE utilizes data from outside sources.</li> </ul>
Post-Conditions	Data from vehicles is available for analysis by traffic authority.
Information Requirements	<ul style="list-style-type: none"> <li>• Request for data             <ul style="list-style-type: none"> <li>○ Authorization key</li> <li>○ Type of data desired</li> </ul> </li> </ul>
Issues	<ul style="list-style-type: none"> <li>• Data-rights may reside with the operator, although original owner and operator may be different.</li> <li>• Individual privacy must be protected.</li> <li>• Requesting authority needs to be secure and trusted.</li> </ul>
Source Documents/ References	

### 5.7 Incidents

Use Case Name	Incidents
Category	Environment
Short Description	Occurrences that require authorities to respond.
Infrastructure Roles	Provide information about incidents to nearby vehicles.
Vehicle Roles	Receive information about incidents in the nearby region, display the information to the driver.
Other Roles	Roadway authority provides incident content and timeframe, as well as applicable region information.
Actors	<ul style="list-style-type: none"> <li>• DTI Source</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers understand and respond to incidents along their route.
Needs	The driver needs to receive information about the location and timeframe of nearby incidents.
Constraints/ Presumptions	<ul style="list-style-type: none"> <li>• Information about incidents and enough contextual data is available and will remain persistent long enough to impact traffic.</li> <li>• There are additional options for drivers operating in the region of the incident to mitigate the impact of the incident on their transportation needs.</li> <li>• Incidences are unique from situational awareness in that incidents involve authorities or public service personnel that may impact the traffic flow.</li> </ul>
Geographic Scope	Locale, size will depend on the nature of the incident (traffic accident, sports activity, weather evacuation).
Timing Scope	Current
Illustration	
Pre-Conditions	
Main Event Flow	<ol style="list-style-type: none"> <li>1. Incident information is provided from roadway authority to RSE.</li> <li>2. RSE provides BIM with incident info to vehicles.</li> <li>3. In Vehicle Equipment provides incident information to operators.</li> </ol>
Alternate Event Flow(s)	
Post-Conditions	
Information Requirements	<ul style="list-style-type: none"> <li>• Timeframe</li> <li>• Position/area</li> <li>• Content                             <ul style="list-style-type: none"> <li>○ Incident type                                     <ul style="list-style-type: none"> <li>▪ [Incident details]</li> </ul> </li> </ul> </li> </ul>

Use Case Name	Incidents
Issues	Some incidents or details about them may be sensitive in nature (for privacy or security concerns) and should not be communicated to the public through official channels [examples would include a presidential motorcade, funeral procession, or the cause (or results) of an accident on the road].
Source Documents/References	

### 5.8 Restriction Enforcement

Use Case Name	Restriction Enforcement
Category	Mobility
Short Description	Enforcement of laws or restrictions on specific types of vehicles in a roadway area.
Infrastructure Roles	Receive voluntary information regarding the status of restrictions from operators.
Vehicle Roles	
Other Roles	Operator provides information regarding restrictions or enforcement.
Actors	<ul style="list-style-type: none"> <li>• Enforcement authority</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help roadway authorities enforce restrictions, tolls, etc.
Needs	Enforcement authorities needs to receive information about the vehicles or operators traveling in an area.
Constraints/Presumptions	Authorized and unaltered registration information can be securely stored in the In Vehicle Equipment.
Geographic Scope	Regional
Timing Scope	Current
Illustration	
Pre-Conditions	

Use Case Name	Restriction Enforcement
Main Event Flow	<ol style="list-style-type: none"> <li>1. Infrastructure device requests enforceable information, provides authentication identity.</li> <li>2. In Vehicle Equipment verifies the authentication and replies with information regarding enforcement.</li> </ol>
Alternate Event Flow(s)	<ul style="list-style-type: none"> <li>• Restriction Enforcement request is refused by the In Vehicle Equipment or operator, alternate inspection is still necessary.</li> <li>• Enforcement information indicates a deficit, appropriate information is displayed to operator/enforcement authority.</li> </ul>
Post-Conditions	Enforcement information has been gathered from nearby vehicles
Information Requirements	<ul style="list-style-type: none"> <li>• Timing</li> <li>• Validity</li> <li>• Content <ul style="list-style-type: none"> <li>○ Type of enforcement</li> </ul> </li> </ul>
Issues	Privacy, authentication of enforcement authority, enforcement actions.
Source Documents/References	

### 5.9 Driver Safety/Assistance/Support

Use Case Name	Driver Support
Category	Safety
Short Description	Vehicles that must stop along a roadway can rapidly and accurately provide information regarding a loss of safety or capability to an authorized authority.
Infrastructure Roles	Receive information from vehicles that need support. Provide information to roadway authority.
Vehicle Roles	Gather information from the driver regarding necessary assistance or support. Transmit support requests to Infrastructure.
Other Roles	Roadway authority provides support and coordinates response, optionally with indications about the time to response or assistance provided.
Actors	<ul style="list-style-type: none"> <li>• Roadway Authority</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> <li>• Emergency Call Box</li> </ul>
Goal	Provide additional channels of communication between roadway authority and vehicle operators.
Needs	The driver needs to be able to request support from the roadway authority without walking to the nearest emergency call box (if available). The roadway authority needs to have a mechanism of providing more detailed information to the driver with regards to the availability and timeliness of support.
Constraints/Presumptions	An operator is capable of accurately entering specific assistance needs. Additional/multiple assistance is not needed or can be indicated.
Geographic Scope	Region
Timing Scope	Current



Use Case Name	Driver Support
Illustration	
Pre-Conditions	A vehicle needs assistance.
Main Event Flow	<ol style="list-style-type: none"> <li>1. A vehicle must stop along a roadway, and the operator interacts with the In Vehicle Equipment to provide the nature of the support need.</li> <li>2. The In Vehicle Equipment transmits this information to infrastructure and to the roadway authority.</li> <li>3. The roadway authority dispatches assistance and provides feedback to the support vehicle.</li> </ol>
Alternate Event Flow(s)	<ul style="list-style-type: none"> <li>• Another vehicle near the support vehicle relays the support request (either immediately or after some delay) to an infrastructure device or another vehicle.</li> <li>• An incident may also be generated to relevant vehicles to allow them to respond appropriately to the stopped vehicle.</li> <li>• Existing infrastructure devices such as emergency call boxes may be integrated into the system and provide the support information or generate Incident information.</li> <li>• Emergency vehicles may respond and initiate emergency vehicle alerts.</li> </ul>
Post-Conditions	Information about the existence and nature of a vehicle that requires support is provided to an authority that can then respond.
Information Requirements	<ul style="list-style-type: none"> <li>• Location</li> <li>• Type of support needed</li> <li>• Anticipated response time/location of assistance</li> </ul>
Issues	Security and privacy concerns about a disabled vehicle and any individuals that are distressed needs to be maintained.
Source Documents/References	

### 5.10 Emergency Vehicle Operations

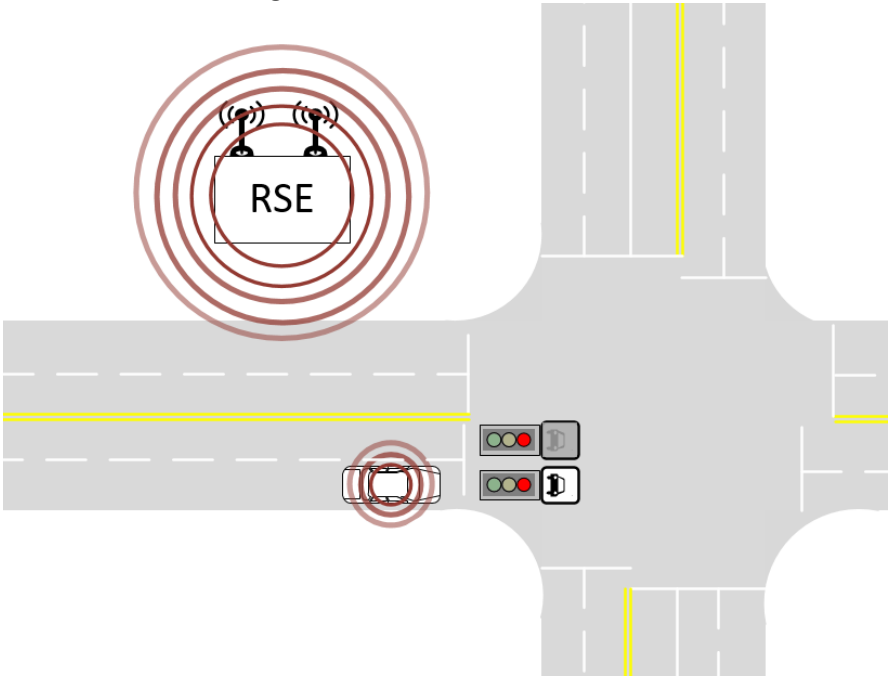
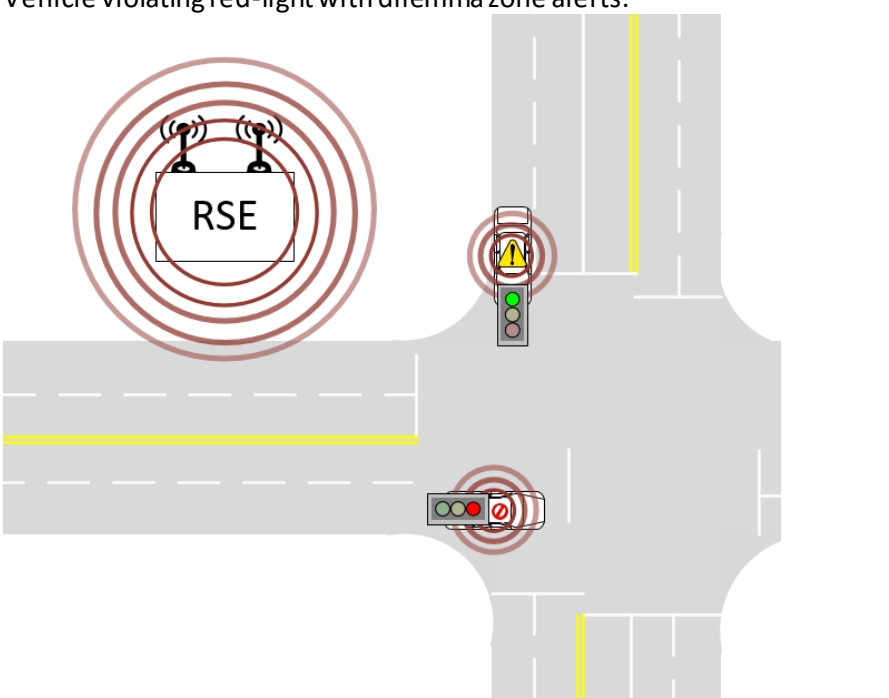
Use Case Name	Emergency Vehicle Operations
Category	Safety
Short Description	Information about emergency response vehicles that are operating on a roadway are provided to vehicles.
Infrastructure Roles	Provide information about emergency vehicle operations to nearby vehicles.
Vehicle Roles	Receive information about emergency vehicle operations in the nearby region, display the information to the driver.
Other Roles	Emergency dispatch provides content and timeframe, as well as applicable region information.

Use Case Name	Emergency Vehicle Operations
Actors	<ul style="list-style-type: none"> <li>• Emergency Dispatch</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers understand and respond to the presence of emergency vehicles and any approaching emergency vehicles in their vicinity.
Needs	The driver needs to receive information about the location and nature of nearby emergency vehicles.
Constraints/ Presumptions	Privacy surrounding the emergency response can be adhered to.
Geographic Scope	
Timing Scope	Current, Predictive
Illustration	<p>Emergency vehicles approaching a CV/region and a CV approaching an emergency vehicle.</p>
Pre-Conditions	
Main Event Flow	<ul style="list-style-type: none"> <li>• An emergency vehicle is dispatched to respond to an incident, and the infrastructure reports information to vehicles in effect that allows a CV operator to respond safely to the presence or future location of emergency vehicles.</li> <li>• This may be available prior to the Vehicle-to-Vehicle (V2V) information directly from the emergency vehicle.</li> </ul>
Alternate Event Flow(s)	The infrastructure is aware of the planned route for the emergency vehicle, and this information is reported to the operators of CVs, who choose to alter their route to avoid causing additional congestion.
Post-Conditions	CV operators are informed about the existence, type, location and possibly destination of emergency vehicles.
Information Requirements	<ul style="list-style-type: none"> <li>• Timeframe</li> <li>• Location</li> <li>• Content                             <ul style="list-style-type: none"> <li>○ Type of emergency vehicle</li> <li>○ [Planned route segments]</li> </ul> </li> </ul>
Issues	Privacy, security of emergency responders
Source Documents/ References	

### 5.11 Intersection

Use Case Name	Intersection
Category	Safety

Use Case Name	Intersection
Short Description	Potential vehicle interaction between vehicles and between infrastructure and vehicle at cross-roads and intersections including indications of dilemma zones are communicated to vehicles through a BIM.
Infrastructure Roles	Provide information about intersections to nearby vehicles. Information may include: <ul style="list-style-type: none"> <li>• Interactions between vehicles (potential collisions, violations, presence and type of vehicles).</li> <li>• Interactions with infrastructure (traffic signals, position reports, geometry).</li> </ul>
Vehicle Roles	Receive information about intersections in the nearby region, display the information to the driver.
Other Roles	Roadway authority could provide content and timeframe, as well as applicable region information.
Actors	<ul style="list-style-type: none"> <li>• Intersection geometry provider</li> <li>• RSE</li> <li>• In Vehicle Equipment</li> </ul>
Goal	Help drivers gain additional insight about intersections along their route.
Needs	<ul style="list-style-type: none"> <li>• The driver needs to receive information about the geometry, status and potential interactions with other vehicles at roadway intersections.</li> </ul>
Constraints/ Presumptions	<ul style="list-style-type: none"> <li>• Vehicle paths or intentions can be correctly calculated.</li> <li>• Timely alerts can be generated.</li> <li>• Operators can respond in a safe manner.</li> <li>• False negatives are kept to a minimum to prevent operator overload or frustration.</li> </ul>
Geographic Scope	Regional
Timing Scope	Current

Use Case Name	Intersection
<p>Illustration</p>	<p>Vehicle detection at signalized intersection:</p>  <p>Vehicle violating red-light with dilemma zone alerts:</p> 
<p>Pre-Conditions</p>	
<p>Main Event Flow</p>	<ol style="list-style-type: none"> <li>1. [Optional, may be always broadcast regardless of detection] A vehicle waiting for a red light is detected by the infrastructure.</li> <li>2. The vehicle is provided with a status indication that the infrastructure recognizes their presence and proper position.</li> </ol>

Use Case Name	Intersection
Alternate Event Flow(s)	<ul style="list-style-type: none"> <li>• Vehicle enters an intersection while their lane has a red light, infrastructure calculates an interaction between that vehicle and another vehicle, infrastructure provides warnings and alerts as appropriate to each vehicle.</li> </ul>
Post-Conditions	Drivers are informed of infrastructure status and warned of detected collisions due to interactions with the infrastructure.
Information Requirements	<ul style="list-style-type: none"> <li>• Position</li> <li>• Content <ul style="list-style-type: none"> <li>○ Type of interaction</li> <li>○ Time until interaction</li> </ul> </li> </ul>
Issues	<p>Operators need to respond properly to the detected danger; intersection interactions have a variety of causes and proper responses that need to be executed quickly. Enabling operators to respond properly without giving them direct instructions would be difficult.</p> <p>Also, if a collision was predicted, would the traffic authority be partially responsible if the accident does occur?</p>
Source Documents/References	

## 6 CONCLUSION

This review paper was developed under Task 2 of the project: “Basic Infrastructure Message Development and Standards Support for Connected Vehicles Applications”. This review is intended to capture the use cases and information needs pertaining to infrastructure communication. The information in this document will be used in subsequent project tasks to develop the BIM.

The goal of this task is to develop a comprehensive list of infrastructure information elements that are available and desirable to be broadcasted under a CV environment. Table 1 provides a list of elements that represent applicable data elements identified during this task (SAE International, 2016).

**Table 1. Identified Infrastructure Information Elements**

Information Data Frame	Type	Specific Type	Standard	Description
<b>StaticSignage</b>	<b>Message</b>	<b>Message</b>		<b>(compare to TravelerDataFrame)</b>
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
timestamp	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
position	Position3D	Object		
		Latitude	SAE J2735	
		Longitude	SAE J2735	
		Elevation	SAE J2735	
		Sequence of RegionalExtension	SAE J2735	Optional
content	CHOICE	Object	SAE J2735	Possibly also use EnabledLaneList and RevocableLane.
		item CHOICE { itis ITIS.ITIScodes,	SAE J2735	This element describes a category and an item from that category all ITS standards use the same types here to explain the type of the alert / danger / hazard involved.
		text ITIS textPhrase		provide message/information
<b>Dynamic Traveler Information</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width

Information Data Frame	Type	Specific Type	Standard	Description
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for MAP
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
dynamicContent	Choice	Object		Message specific details
<b>Map Information</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
mapContent	Choice	Object		Map Context (construction, typical, etc.) message specific details.
<b>Situational Awareness</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
situationalAwarenessContent	Choice	Object		Message specific details

Information Data Frame	Type	Specific Type	Standard	Description
<b>Limited Access</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
limitedAccessContent	Choice	Object		Message specific details
<b>Data Collection Request</b>				
id	dataCollectionID	Integer	SAE J2735	-- the unique value
packet	dataCollectionPacket	Object		
<b>Incidents</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
incidentContext	Choice	Object		Message specific details
<b>Vehicle Enforcement</b>				
id	vehicleEnforcementID	Integer	SAE J2735	-- the unique value
packet	vehicleEnforcementPacket	Object		



Information Data Frame	Type	Specific Type	Standard	Description
<b>Driver Support</b>				
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
position	Position3D	Object	SAE J2735	
driverSupportContext	DriverSupportContext	Object		
<b>Emergency Vehicle Operations</b>				
msgCnt	MsgCount	Integer	SAE J2735	The MsgCount data element is used to provide a sequence number within a stream of messages with the same DSRCmsgID and from the same sender.
startTime	MinuteOfTheYear	Integer	SAE J2735	The MinuteOfTheYear data element expresses the number of elapsed minutes of the current year in the time system being used (typically UTC time).
durationTime	MinutesDuration	Integer	SAE J2735	Can figure end time from duration
path	OffsetSystem	Object	SAE J2735	Lat/Long offsets with lane width
geometry	GeometricProjection	Object	SAE J2735	Circle (point and radius)
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
regionPointSet	Polygon/RegionPointSet	Object	SAE J2735	Ordered set of closed convex points
emergencyVehicleContext	Choice	Object		Message specific details
<b>Intersection</b>				
id	IntersectionReferenceID	Object	SAE J2735	Reference object for a map
intersectionContext	IntersectionContext	Object		Railroad Crossings (Not provided for in standard), School Crossings, etc.