Safety Application Functionality[1]

Reduced Speed Zone Warning / Lane Closure (RSZW/LC)

The objective of the RSZW/LC application is to leverage V2I communication to inform/warn drivers when they are operating at a speed higher than the posted speed limit and/or by providing information regarding changes in roadway configuration (e.g., lane closures, lane shifts), particularly for a driving scenario requiring a lane change.
When an equipped vehicle approaches a zone that requires reduced speed and/or presents a change in roadway configuration, the application evaluates vehicle speed and position and if appropriate, warns the driver. For example, in the case of a vehicle approaching a work zone, the OBE receives a message from the RSE about the work zone speed limit, geometric configuration and lane closure information for use by the application to inform and warn the driver appropriately. Figure 1 illustrates the RSZW/LC application concept and the application information flow is shown in Figure 2.

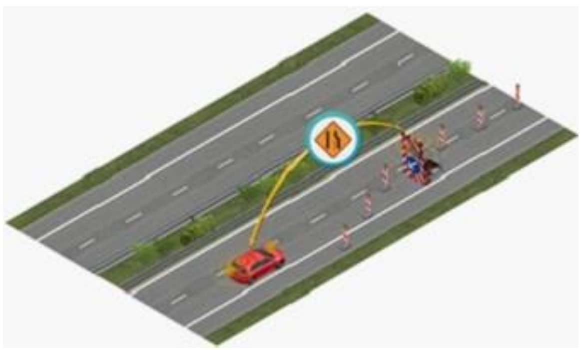

Figure 1: Illustration of RSZW/LC Application Concept

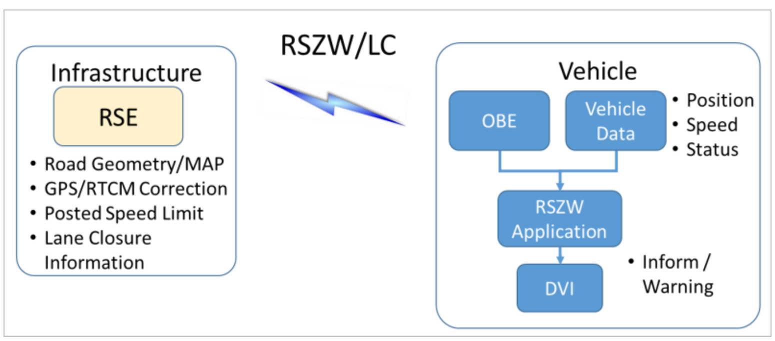

Figure 2: Information Flow for RSZW/LC Application

The RSZW application considers vehicle-centric elements such as vehicle speed in addition to environmental elements such as road work zone geometry, lane closures, presence of workers and speed limits to appropriately provide Inform / Warning

[1] Contents of this section excerpted from "Vehicle-to-Infrastructure (V2I) Safety Applications Project - Task 6, 7 and 8 Combined Interim Report: Application Development, Vehicle Build and Infrastructure Build", CAMP V2I Consortium, as Pre-publication Materials Provided for Comment Only.

messages to the driver. The effectiveness of this application is dependent upon timely updates of the information noted which may require frequent updates for work zones as configuration and presence of workers change.

Red Light Violation Warning (RLVW)

The objective of the RLVW application is to advise drivers of the signal phase of an approaching signalized intersection and, based on data from infrastructure- and vehicle-based sensors, warn them if they are at risk of violating a red signal phase if they do not stop.

The RLVW application receives Signal Phase and Timing (SPaT) and intersection geometry information from the infrastructure RSE and combines it with vehicle kinematic data to determine the potential to violate a red signal phase at an approaching signalized intersection. The RLVW application concept is illustrated in Figure 3. The infrastructure application component provides information to the vehicle application component, which generates a vehicle-specific warning to notify the driver in sufficient time to stop before entering the intersection on a red phase. The information flow for the RLVW application is shown in Figure 4.

Figure 3: Illustration of RLVW Application Concept

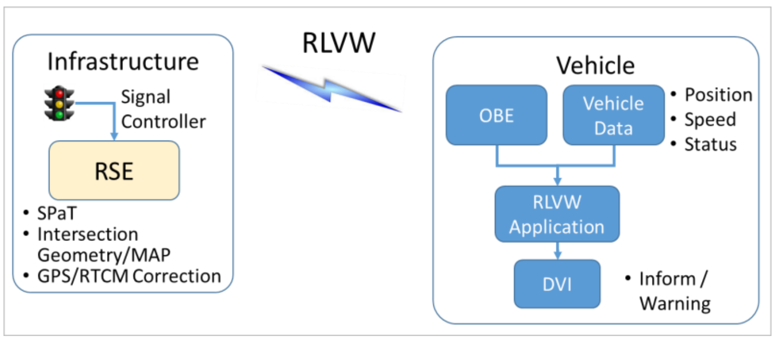

Figure 4: Information Flow for RLVW Application

Wireless Information Exchange

In order to support the operation of vehicle-based and infrastructure-based elements of V2I safety applications, information relevant to each specific application must be exchanged in a common format. As shown, RSZW/LC requires Road Geometry/MAP, GPS/RTCM Corrections, Posted Speed Limit, and Lane Closure information while RLVW uses SPaT, Intersection Geometry/MAP, and GPS/RTCM Corrections. Other V2I safety applications may employ different combinations of information.

The Basic Information Message (BIM) is a proposed new message format that enables the transmission of all required data elements for V2I safety applications in a single message and is extensible to support future event based applications. The BIM structure is based on the European Telecommunications Standards Institute (ETSI) standard for the Decentralized Environmental Notification Message (DENM). This concept of message structure uses existing SAE J2735 data elements. As shown in Figure 5, the BIM structure is made of a container concept consisting of a common container that provides basic information elements about an event such as event location, type, time and duration. The event-specific container provides data elements relevant to the event (e.g., speed limits, event MAP, associated flags) for use by on-board applications. Such a concept provides flexibility to extend the message structure by adding containers for future event types (use cases) yet maintaining backward compatibility.

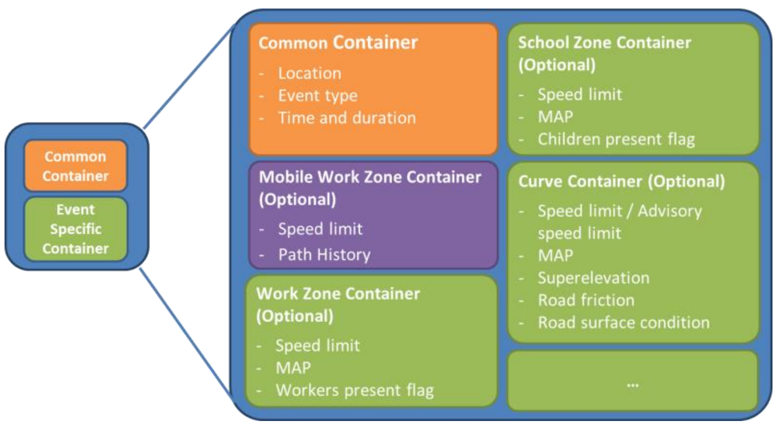

Figure 5: Basic Information Message Structure

Potential Safety Benefit(s)

Reduced Speed Zones

The Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E) Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) application was based on the functionality and design that was defined for the Reduced Speed Zone Warning Application.[2] The R.E.S.C.U.M.E. INC-ZONE application was developed, prototyped and tested in a controlled environment as part of the Dynamic Mobility Applications program.[3,4] The corridor modeling and simulation conducted by Booz Allen Hamilton of the INC-ZONE application as part of these activities revealed important conclusions regarding the effectiveness of the applications under test conditions. The following are the major conclusions.

<u>Network-Wide Performance</u>

- The average network-wide reduction in delay and increase in speed was higher for dry conditions than rainy conditions. The percent benefit was greater for average delay than for average speed.
- The reduction in network delay was between 1 percent and 14 percent, and the increase in average speed was between 1 percent and 8 percent for dry conditions. These benefits were more for long incident than short incident scenarios.
- The reduction in network delay was between 1 percent and 7 percent, and the increase in average speed was between 0.25 percent and 3 percent for rainy conditions. These benefits were more for short incident than long incident scenarios.[5]

<u>Incident-Zone Level Performance</u>

- In terms of mobility, the increase in section throughput increases with market penetration, with values ranging between 1 percent and 14 percent.
- Mobility improvement at the incident zone, as reflected by the increase in section throughput, was found to be higher under dry conditions than rainy conditions for all levels of market

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[2] Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) is a communication approach that will improve protection of incident sites where there have been crashes, accidents, or other events impacting traffic such as stalled vehicles or vehicles pulled over for moving violations.

[3] The R.E.S.C.U.M.E application bundle aims to advance vehicle to vehicle safety messaging over dedicated short-range communications (DSRC) to improve the safety of emergency responders and travelers. Three applications, Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG), Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE), and Emergency Communications and Evacuation (EVAC) are included in the R.E.S.C.U.M.E. application bundle.

[4] The Dynamic Mobility Applications program was initiated to create applications that fully leverage frequently collected and rapidly disseminated multi-source data gathered from connected travelers, vehicles and infrastructure to increase efficiency and improve individual mobility while reducing negative environmental impacts and safety risks.

[5] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203

penetration. The average improvement under dry conditions was around 2 percent higher than under rainy conditions.

- Reduction in maximum deceleration was found to be between 1 and 89 percent for different operational conditions, with the highest improvement being for the dry conditions with long incident case.
- Reduction in sublink speed ranged between 0 and 14 percent with the highest reduction for the dry conditions with long incident case.[6]

User Level Value

- The increase in average speed and average following distances for equipped users versus non-equipped users were studied. Use of INC-ZONE in rainy conditions with short incidents showed more user benefits than for other operational conditions.
- The increase in average speed for INC-ZONE users was between 13 percent and 40 percent over non-users.
- The increase in average following distance for INC-ZONE users was between 2.5 percent to 19 percent over non-users.
- The difference between average speed and average following distance of users and non-users of INC-ZONE increased with rising market penetration.[7]

Signalized Intersections

The following excerpt from AASHTO's series of Connected Vehicle (CV) deployment analyses[8] highlights the potential for RLVW to improve safety.

> "Improving safety is a primary objective, and estimates of the potential for safety improvement with V2I systems could provide insight.
>
> - The 2010 NHTSA report on *Frequency of Target Crashes for IntelliDrive Safety Systems* asserts that V2I systems as the primary countermeasure would "potentially address about 25% of all crashes involving all vehicle types," including crashes at intersections.[9] The report does not specifically address the fraction of crashes occurring at intersections.
> - A 2010 NHTSA report on *Crash Factors in Intersection-Related Crashes* determined that 36% of crashes in the U.S. in 2008 were intersection-related, and 52.5% of vehicles involved in those crashes were traveling on signal-controlled roadways.[10]
> - A 2009 Noblis document, *Footprint Analysis for IntelliDrive[SM] V2V Applications, Intersection Safety Applications, and Tolled Facilities*, found in a study of intersections and collision frequency in three large metro areas that 20% of

[6] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203

[7] Impact Assessment of Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) and Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) - Final Report. May 8, 2015. FHWA-JPO-15-203

[8] National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014

[9] National Highway Transportation Safety Administration; *Frequency of Target Crashes for IntelliDrive Safety Systems* Report Number DOT HS 811 381; October 2010.

[10] National Highway Transportation Safety Administration; *Crash Factors in Intersection-Related Crashes: An On-Scene Perspective*; Report Number DOT HS 811 366; September 2010.

intersections account for 50% of collisions, and that 50% of intersections account for 80% of collisions.[11]

- An earlier 2005 study, *Intersection Crash Summary Statistics for Wisconsin*, found in a state-wide study that crashes at signal-controlled intersections represented 68.8% of crashes at controlled intersections, although only 48.5% of intersections studied were signalized. Crashes at intersections with greater than 25,000 vehicles per day entering the intersection represented 48.3% of crashes at controlled intersections, although those represented only 28.1% of controlled intersections.[12]

Although none of these studies directly address warrants for V2I-enabling signalized intersections, it can be inferred that there are likely safety benefits, that deployment at signalized intersections would address a greater fraction of potential crashes than at non-signalized intersections, and that deployment at high-volume intersections would address the greatest likelihood of crashes. Any consideration for mobility and environmental benefits would further increase deployment incentives and would likely reinforce the safety warrants."

Deployment Cost Estimates

Infrastructure Side

The following excerpt from AASHTO's series of deployment analyses[13] summarizes the range of infrastructure costs to be expected when implementing CV technology.

"Based on preliminary designs and the limited experience with pilot deployments, with all estimates in constant 2013 dollars:

- The average direct (Dedicated Short Range Communications) DSRC roadside unit (RSU) deployment cost per site is estimated to be $17,600.
- The cost to upgrade backhaul to a DSRC RSU site is estimated to vary between $3,000 and $40,000, at an estimated national average of $30,800.
- The typical cost of signal controller upgrade for interfacing with a DSRC RSU is estimated to be $3,200.
- The annual operations and maintenance cost for a DSRC RSU site are estimated to be $3,050."

Vehicle Side

The following excerpts from NHTSA's report entitled "Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application[14]" provide initial insight into anticipated vehicle side costs to deploy CV technology.

Summary of Likely Costs in Year 1 for New Vehicles (2012 dollars)

[11] Noblis, Inc.; *Footprint Analysis for IntelliDrive[SM] V2V Applications, Intersection Safety Applications, and Tolled Facilities*; prepared for the U.S. DOT / RITA / ITS JPO; March 2009; Accessed February 2014 at http://www.its.dot.gov/research_docs/pdf/12Footprint.pdf.

[12] Traffic Operations and Safety Laboratory, University of Wisconsin-Madison; *Intersection Crash Summary Statistics for Wisconsin*; June 2005.

[13] National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Footprint, Timelines and Cost Estimation, Draft Report v1, February 21, 2014

[14] DOT HS 812 014, August 2014

(Excerpt from Table XI-2)

	Consumer Costs
Supplier Costs	$327.13
Installation Costs	$15.67
Minus Current GPS Installation	$13.89
Total	**$329.14**

Aftermarket Consumer Cost Estimates for Year 1 (2012 dollars)
(Excerpt from Table XI-12)

	Equipment	Installation	**Total**
Retrofit	252.20	135	**387.20**
Self-contained	213.20	112.5	**325.70**