Vehicle-to-Infrastructure (V2I) Safety Applications

Performance Requirements, Vol. 3, Red Light Violation Warning (RLVW)

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16. Abstract

This document is the third of a seven volume report that describe the Performance Requirements for the connected vehicle vehicle-to-infrastructure (V2I) safety applications developed for the U.S. Department of Transportation (U.S. DOT). This volume describes the Performance Requirements for the infrastructure and vehicle components of the Red Light Violation Warning V2I Safety Application. This application is designed to advise drivers of an upcoming signalized intersection and provide an alert or warning when the vehicle may violate a red light, based upon their speed and distance to the intersection. The application integrates data from infrastructure- and vehicle-based sensors to determine whether the vehicle will need to stop for a red light and to provide in-vehicle messages to alert and warn the driver in time to stop at the intersection stop bar. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the messages are consistent and coordinated, to best capture the attention of the driver and to avoid conflicting or confusing driver messaging.

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Chapter 1 Scope

1.1 Document Identification

This document is the third of a seven volume report that describes the performance requirements for six connected vehicle vehicle-to-infrastructure (V2I) safety applications developed for the U.S. Department of Transportation (U.S. DOT). This volume describes the Performance Requirements for the infrastructure and vehicle components of the Red Light Violation Warning V2I safety application. This application is designed to advise drivers of an upcoming signalized intersection and provide an alert or warning when the vehicle may violate a red light, based upon their speed and distance to the intersection.

The seven volumes comprising this V2I Safety Applications Performance Requirements report are:

- Vol. 1, V2I Safety Application Overview and Common Requirements
- Vol. 2, Curve Speed Warning (CSW)
- Vol. 3, Red Light Violation Warning (RLVW)
- Vol. 4, Reduced Speed Zone Warning with Lane Closure (RSZW/LC)
- Vol. 5, Spot Weather Information Warning – Reduced Speed (SWIW-RS)
- Vol. 6, Spot Weather Information Warning – Diversion (SWIW-D)
- Vol. 7, Stop Sign Gap Assist (SSGA).

This volume transforms the Concept of Operations (ConOps) and System Requirements previously developed for the RLVW application into a set of performance requirements which specify how the application integrates roadside and in-vehicle advisories, alerts and warnings to make the driver aware of hazards in time to take action to prevent a potential crash. Performance requirements are provided for both infrastructure and vehicle application components of the application to ensure that infrastructure and vehicle messages presented to drivers are consistent and coordinated, to best capture the attention of the driver, and avoid conflicts or confusion.

1.2 Document Overview

The objective of this V2I Safety Application Performance Requirements volume is to provide integrated requirements for the infrastructure and vehicle components of one of a series of V2I safety applications, their wireless messaging and their driver messaging that ensure coordinated and consistent delivery of safety hazard advisories, alerts and warnings to drivers. This volume describes the V2I System of Systems within which the application is expected to function.

The RLVW safety application described here captures relevant data from roadside infrastructure sensors and in-vehicle sensors and processes them to determine if there is a potential crash hazard. If a hazard is detected, the application issues integrated roadside and in-vehicle advisories, alerts and warnings to make the driver aware of the hazards in time to take action to prevent the crash.

The application described here has both an infrastructure-based component and a vehicle-based component, which may be developed by different stakeholders. Infrastructure-based components are expected to be developed by state and local agencies responsible for building and maintaining the roadway infrastructure and their contractors. Vehicle-based components are expected to be developed by vehicle manufacturers, their tier one suppliers, and aftermarket system suppliers. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the data exchange between the two components is synchronized and consistent and that they deliver messages to the driver that are harmonized to best capture the attention of the driver and that avoid confusing the driver.

This document has been written with the assumption that the reader possesses a general knowledge associated with connected vehicles and the associated infrastructure surrounding connected vehicles.

The intended audience of this document includes infrastructure and vehicle application developers, wireless equipment systems manufacturers, intelligent transportation systems (ITS) developers, state and local departments of transportation, and U.S. DOT Connected Vehicle Program Managers.

The remainder of this volume consists of the following sections and content:

Section 2 (Applicable Documents) describes the external documentation utilized and referenced throughout this document.

Section 3 (Requirements) provides the background and requirements for the RLVW application.

Appendices:

A. RLVW Application Message Candidate Data Elements
B. Acronyms and Abbreviations
C. Terms and Definitions

Chapter 2 Referenced Documents

The following sections include documents that are either cited herein or were reviewed for the development of this document. Documents from U.S. DOT are presented first, followed by documents from other government and non-government organizations.

U.S. Department of Transportation

- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-058. (2012).
- Accelerated Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-059. (2012).
- Driver Vehicle Interface (DVI) Design Assistance for Advanced Technology Applications, Campbell, J. L., Brown, J. L., et al, National Highway Traffic Safety Administration, (in press). (Battelle Final Report to Virginia Tech Transportation Institute and National Highway Traffic Safety Administration).
- Highway Functional Classification: Concepts, Criteria and Procedures, Federal Highway Administration, FHWA-PL-13-026, 2013 Edition.
- Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 edition, Federal Highway Administration. http://mutcd.fhwa.dot.gov/.
- Vehicle-to-Infrastructure (V2I) Safety Applications Concept of Operations Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-060. (2013).
- Vehicle-to-Infrastructure (V2I) Safety Applications System Requirements Document. FHWA Office of Safety Research and Development, Turner-Fairbank Highway Research Center. FHWA-JPO-13-061. (2013).

American Association of State Highway and Transportation Officials (AASHTO)

- The Green Book. A Policy on Geometric Design of Highways and Streets, 6th edition. 2011.

International Organization for Standardization (ISO)

- ISO 9141-2. Road vehicles – Diagnostic systems – Part 2: CARB requirements for interchange of digital information (1994).
- ISO 11898, Road vehicles – Controller area network (CAN) – Part 6: High-speed medium access unit with selective wake-up functionality.
- ISO 14230-4, Road vehicles – Diagnostic systems – Keyword Protocol 2000 – Part 4 Requirements for emission-related systems.
- ISO 15765, Road vehicles – Diagnostic communication over Controller Area Network (DoCAN) – Part 4: Requirements for emissions-related systems.

Institute of Transportation Engineers (ITE) Standards

- ITE ATC Transportation Controller (ATC) v5.2b.
- ITE Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications.

National Marine Electronics Association

- NMEA 0183 Interface Standard.

National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) Standards

- NTCIP 1103 Transportation Management Protocols.
- NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.
- NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.
- NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS).

Radio Technical Commission for Maritime Services

- RTCM 10403.2, Differential GNSS (Global Navigation Satellite Systems) Services – Version 3.

Society of Automotive Engineers (SAE) Standards

- SAE J1211. Handbook for Robustness Validation of Automotive Electrical/Electronic Modules.
- SAE J1850 VPW, J1850 PWM. Class B Data Communications Network Interface (June 2006).
- SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary.
- SAE J2178 Class B Data Communication Network Messages-Detailed Header Formats and Physical Address Assignments.

Transportation Research Board (TRB)

- National Cooperative Highway Research Program (NCHRP) Report 600. Human Factors Guidelines for Road Systems, 2nd edition. (2012).

Chapter 3 Performance Requirements

3.1 Introduction and Overview

This section of the document enumerates the Performance Requirements for the Red Light Violation Warning (RLVW) Application. The performance requirements provide requirements for both infrastructure and vehicle application components to ensure the advisories are consistent and coordinated.

3.1.1 Organization of this Chapter

The chapter begins by describing the V2I System, including its functional architecture, components and interfaces. This is followed application performance requirements first for the infrastructure application component, followed by the vehicle application component. This chapter is organized under the following headings.

- 3.1 Introduction and Overview
  - 3.1.1 Organization of this Chapter
  - 3.1.2 Structure and Format of the Performance Requirements
    - 3.1.2.1 Performance Requirements Identifier Structure
    - 3.1.2.2 Verification Methods
- 3.2 V2I System Functional Architecture
  - 3.2.1 System Components and Interfaces
    - 3.2.1.1 Driver
    - 3.2.1.2 Infrastructure Systems Components
    - 3.2.1.3 Vehicle System Components
    - 3.2.1.4 V2I/I2V Wireless Data Interface
    - 3.2.1.5 Infrastructure System Interfaces
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- 3.3 Red Light Violation Warning (RLVW) Application Performance Requirements
  - 3.3.1 RLVW Application Introduction and Overview
    - 3.3.1.1 Application Purpose
    - 3.3.1.2 Safety Impacts of the Application
    - 3.3.1.3 Summary of Improvements
    - 3.3.1.4 How the Application Works
    - 3.3.1.5 Application Assumptions and Considerations
    - 3.3.1.6 Application Swim Lane & Sequence Diagrams
    - 3.3.1.7 Messages Exchanged and Used by the Application
  - 3.3.2 RLVW Infrastructure Application Component Requirements
  - 3.3.3 RLVW Vehicle Application Component Requirements

In developing the performance requirements contained here, the authors developed a framework for coordinating the delivery of roadside and in-vehicle messages to drivers. The framework that sets the stage for subsequent requirements is described in the application introduction and overview and in its assumptions. This is followed by Application Swim Lane and Sequence Diagrams that illustrate the flow of data, data processing and decision trees for hazard assessment and for decisions in whether to issue advisories, alerts and/or warnings to drivers.

As illustrated in the V2I System of Systems description below, the V2I application is implemented in a framework of multiple existing and legacy systems that capture data, process it and issue messages to drivers and other systems. The application description includes a description of the messages that are exchanged between systems that make up the V2I System of Systems.

Following explanation of the rationale and underlying frameworks, requirements are presented, first for the infrastructure application components and then for the vehicle application components. Appendix A provides Application Message Data Tables which suggest data elements that may be needed by the application to perform its required functions.

The authors of these requirements expect that questions will arise during the design and implementation of this application. The rationales, frameworks, and requirements presented here are expected to evolve. Understanding that different components will be developed by different agencies, the purpose here is to provide an underlying structure for discussion between these agencies to support coordination and refinement of the requirements that are necessary to successfully develop and implement the application to achieve its safety objectives.

3.1.2 Structure and Format of the Performance Requirements

Each requirement in the following tables includes the following elements:

- **Unique Identifier** of the form **[A.B.CC.DD]**, described in more detail below.
- **Requirement Title** describes the topic of the requirement. **Requirement Titles** are presented in bold face type for readability.
- **Requirement Statement** provides the specific requirement which is subject to verification and validation, and represents the description of design, development, behavior, operation, performance, etc. of the application. **Requirement Statements** are presented in bold type face to distinguish them from supporting text including the *Requirements Elaboration.*
- *Requirements Elaboration* provides supporting text for the **Requirement Statement** that aids in understanding, interpretation and application of the **Requirement Statement** where needed. *Requirements Elaboration* text is presented in italics type face to distinguish it from the **Requirements Statement**. *Requirements Elaboration* is not necessarily subject to verification and validation, but may be useful in establishing methods and acceptance criteria for verification and validation.
- Verification Method describes how the performance requirements will be verified, whether by Inspection (I), Demonstration (D), Test (T) or Analysis (A). Each of these is described in more detail below.

3.1.2.1 Performance Requirements Identifier Structure

Performance requirements for this V2I application is organized and numbered by the application, the component, and requirement category. For consistency and accessibility the requirements are

uniquely identified by a four element number of the format [A.B.CC.DD] where A designates the application, B designates the application component, CC designates the application category, and DD is the unique requirement number within the category. The [A] designators for each application are

- [1.B.CC.DD] Common Application Requirements
- [2.B.CC.DD] CSW Application Requirements
- [3.B.CC.DD] RLVW Application Requirements
- [4.B.CC.DD] RSZW/LC Application Requirements
- [5.B.CC.DD] SWIW-RS Application Requirements
- [6.B.CC.DD] SWIW-D Application Requirements
- [7.B.CC.DD] SSGA Application Requirements

The [B] designators for the application components are

- [A.1.CC.DD] Infrastructure Application Component Requirements
- [A.2.CC.DD] Vehicle Application Component Requirements
- [A.3.CC.DD] Infrastructure Application Platform Requirements[1]

The [CC] designator for the application categories are

- [A.B.01.DD] Interfaces and Interface Specifications
- [A.B.02.DD] Functional Requirements
- [A.B.03.DD] Data Input Requirements
- [A.B.04.DD] Data Output Requirements

Common Application requirements include the following additional categories:

- [A.B.05.DD] Computation and Communication Performance Requirements
- [A.B.06.DD] Operational Performance Requirements
- [A.B.07.DD] Supportability Requirements
- [A.B.08.DD] Security Requirements
- [A.B.09.DD] Human Factors, Health and Safety Requirements
- [A.B.10.DD] Installation and Setup Requirements
- [A.B.12.DD] Operation, Maintenance and Diagnostic Requirements
- [A.B.12.DD] Documentation Requirements
- [A.B.13.DD] Staffing and Training Requirements
- [A.B.14.DD] Physical and Environmental Performance Requirements

[1] While outside the system of interest, candidate performance requirements are provided in Volume 1 for the Infrastructure Application Platform for reference.

3.1.2.2 Verification Methods

The verification method describes how the performance requirements will be verified in order to ascertain that the system of interest conforms to the requirements in this specification. The four potential methods of verification include the following.

Analysis is a verification method that utilizes established technical or mathematical models or simulations, algorithms, charts, graphs, circuit diagrams, or other scientific principles and procedures to provide evidence that stated requirements are met.

Demonstration is a verification method that generally denotes the actual operation, adjustment, or re-configuration of items to provide evidence that the designed functions were accomplished under specific scenarios.

Inspection is a verification method that consists of investigation, without the use of special laboratory appliances or procedures, of items to determine conformance to those specified requirements. Examination is generally nondestructive and typically includes the use of sight, hearing, smell, touch; and/or simple physical manipulation of the system when it is safe to do so. Inspection can also be applied to the project work products. For instance, verifying that software is developed using a certain programming language would be verified by inspection.

Testing is a verification method that generally denotes the determination of properties by instrumentation and measurement. This method includes functional operation, and involves the application of established scientific principles and procedures.

3.2 V2I System Functional Architecture

Figure 3-1 illustrates the V2I System of Systems Functional Architecture upon which the Performance Requirements are based. The figure illustrates a number of key elements concerning the architecture of the V2I safety application described in this volume. First, the V2I safety application has two core components, an Infrastructure Application Component residing and operating on an Infrastructure Application (Computing) Platform and a Vehicle Application Component residing on a Vehicle Application (Computing) Platform. Both components are necessary to achieve the safety application objectives of integrating and processing infrastructure and vehicle data and delivering coordinated messages to the driver. These two application components share data and information by exchanging messages through wireless data interface(s).

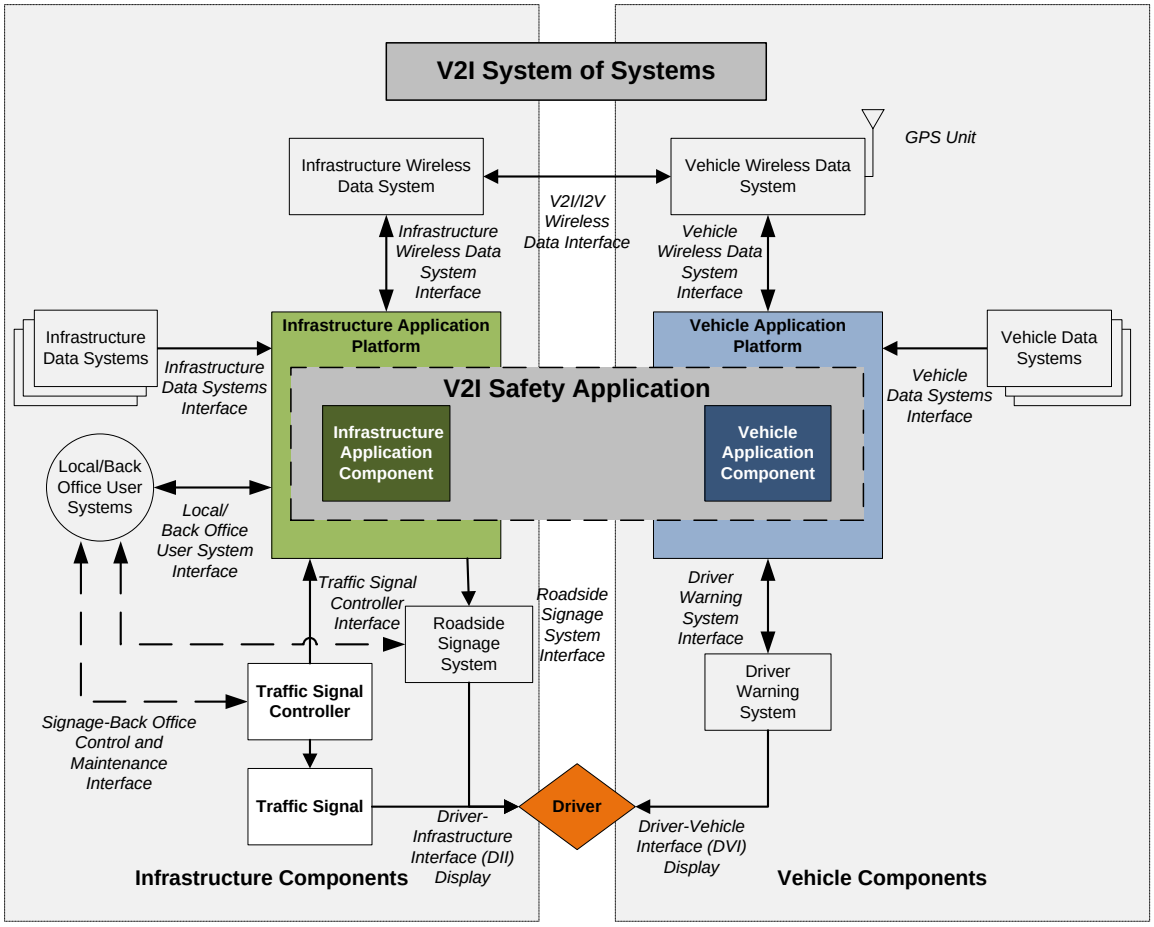
Each of the application components resides and operates on a computing platform that provides the necessary hardware and software data interfaces needed to exchange data with other systems. Each computing platform has an interface for wireless data systems that support with wireless exchange of data between the Infrastructure and Vehicle Application Components. From a requirements standpoint, the Application Components are independent from the form of wireless communication, it is expected that the primary form of communication between the two will be Dedicated Short Range Communication (DSRC).

The Infrastructure Application Platform also provides interfaces for data exchange with Infrastructure Data Systems, Local or Back Office User Systems and user interfaces, Traffic Signal Controllers and Roadside Signage Systems. The Vehicle Application Platform also provides interfaces for capture of data from vehicle systems and a driver warning system with a Driver-Vehicle Interface display.

The infrastructure application component issues messages through dynamic message signs that are visible to and applicable to all approaching vehicles and drivers. The vehicle application component issues messages through a driver warning interface that may be vehicle specific or may be the same as that displayed by dynamic message and static roadside signs. This V2I Safety Application is expected to coordinate and synchronize the display of roadside and in-vehicle messages to the driver.

Vehicle-specific messages for drivers may be equally or more cautious than roadside signs, but must never be less cautious. Vehicle-specific message must never conflict with roadside messages. For example, the vehicle application component in a truck carrying an unusual load with a high center of gravity and high rollover potential may recommend a lower vehicle-specific safe speed in a curve than the infrastructure application component recommends for all vehicles. However, the vehicle application component in a sports car under good road surface conditions must not recommend a higher safe speed in a curve than does the infrastructure signage.

An important concern and rationale for developing these Performance Requirements is that the vehicle and infrastructure components of the applications are likely to be developed and implemented by different entities. Infrastructure components may be developed by public state and local agency infrastructure owners and contractors and vehicle components may be developed by private vehicle manufacturers and suppliers.



Source: Battelle

Figure 3-1. Functional Architecture for Connected Vehicle V2I Safety Applications

3.2.1 System Components and Interfaces

As illustrated in Figure 3-1 there many components which make up the System-of-Interest (SOI) and supporting components. These components include:

- System-Of-Interest Components
  - Infrastructure Application Component
  - Vehicle Application Component
- Supporting Components
  - Infrastructure Application Platform
  - Infrastructure Wireless Data Systems (with GPS)
  - Infrastructure Data Systems
  - Roadside Signage System
  - Traffic Signal Controller
  - Traffic Signal
  - Local/Back Office User Systems

- Vehicle Application Platform
- Vehicle Wireless Data Systems (with GPS)
- Vehicle Data Systems
- Driver Warning System
- Driver

- Interfaces
  - V2I/I2V Wireless Data Interface
  - Infrastructure Wireless Data Systems Interface
  - Vehicle Wireless Data Systems Interface
  - Infrastructure Data Systems Interface
  - Vehicle Data Systems Interface
  - Roadside Signage System Interface
  - Driver Warning System Interface
  - Local/Back Office User Systems Interface
  - Traffic Signal Controller Interface

The function of each of these components and interfaces is described below.

3.2.1.1 Driver

The Driver is the consumer of information delivered by the safety application. Static roadside signage and dynamic Roadside Signage Systems and in-vehicle Driver Warning Systems convey information to drivers such as advisories, alerts, and warnings to make the driver aware of hazards in time to take action to prevent a potential crash.

3.2.1.2 Infrastructure Systems Components

Infrastructure Application Component is the infrastructure component of the V2I safety application. It obtains data from the Vehicle Application Component through the Infrastructure Wireless Data Systems, Infrastructure Data Systems, Traffic Signal Controller and Local/Back Office User Systems, processes the data and issues appropriate message to drivers through Infrastructure Wireless Data Systems and Roadside Signage Systems. The application also issues messages containing relevant data to the Vehicle Application Component through the Infrastructure Wireless Data Systems.

Infrastructure Application Platform is the computational platform which hosts the Infrastructure Application Component and provides the necessary hardware and software interfaces enabling communication with Infrastructure Wireless Data Systems, Infrastructure Data Systems, Roadside Signage System, Traffic Signal Controller, and Local/Back Office User Systems.

Roadside Signage System receives messages from the Infrastructure Application Component and delivers dynamic advisories and alerts to all approaching vehicles from the roadside.

Infrastructure Wireless Data System receives messages from the Infrastructure Application Component through the Infrastructure Application Platform, formats and processes the messages and issues the message via wireless communications to vehicles within wireless communication range. The System also performs the inverse, receiving wireless messages from nearby vehicles, formatting and processing the message and issuing the message to the Infrastructure Application Component through the Infrastructure Application Platform. The system also obtains Universal Time, Coordinated (UTC) time.

Local/Back Office User System provides a technical user interface for the installation, configuration, maintenance, diagnostics, and management of the Infrastructure Application Component. The system may be a computer that is attached locally and temporarily to perform these functions or the system may connect remotely via dedicated lines or the Internet to perform these functions. The system may provide a function for upload or download of configuration and data files to the Infrastructure Application Platform. The system may also provide a connection to obtain GPS differential correction data.

Infrastructure Data Systems provide infrastructure data and information to the Infrastructure Application Component through the Infrastructure Application Platform. Examples of relevant data include weather information, road surface condition data, visibility data, and infrastructure-based vehicle detection and speed data.

Traffic Signal Controller is the external component that provide traffic signal phase and timing data required by some V2I Safety Applications through the Infrastructure Application Platform.

Traffic Signal is the traditional "driver display" component of the Traffic Signal Controller.

3.2.1.3 Vehicle System Components

Vehicle Application Component is the vehicle component of the V2I safety application. It obtains data from the Infrastructure Application Component through Vehicle Wireless Data Systems, Vehicle Data Systems, processes the data and issues appropriate messages to drivers through the Driver Warning System and Driver Vehicle Interface.

Vehicle Application Platform is the computational platform which hosts the Vehicle Application Component and provides the necessary hardware and software interfaces enabling communication with Vehicle Wireless Data Systems, Vehicle Data Systems, and the Driver Warning System.

Driver Warning System is the component which collects and arbitrates messages, advisories, alerts and warnings and delivers them to the driver. These alerts may be visual, aural, haptic, or some other means that captures the driver's attention and conveys the relevant information. When multiple safety applications are hosted on the Vehicle Applications Platform, the Driver Warning System will prioritize and arbitrate alerts and warnings from the multiple safety applications. Note: The placement of the Driver Warning System shown in Figure 3-1 is intended to show representative functionality and is not meant to restrict implementation.

Vehicle Wireless Data System receives messages from the Vehicle Application Component through the Vehicle Application Platform, formats and processes the messages and issues the message via wireless communications to Infrastructure Wireless Data Systems within wireless communication range. This system also performs the inverse, receiving wireless messages from nearby infrastructure, formatting and processing the message and issuing the message to the Vehicle Application Component through the Vehicle Application Platform. This system also obtains GPS location and time. It may include a processor for GPS differential correction.

Vehicle Data Systems represent systems contained within the vehicle that provide vehicle-related information to the Vehicle Application Component. Information provided may come from a positioning system, vehicle data bus, sensors, actuators on the vehicle, or stability systems. Specific interfaces to the original equipment manufacturer's (OEM) vehicle systems are dependent on specific information required to support the safety application.

3.2.1.4 V2I/I2V Wireless Data Interface

V2I/I2V Wireless Data Interface is the wireless communications interface that communicates relevant data between the Infrastructure and Vehicle Application Components through their respective Wireless Data Systems and Application Platforms.

3.2.1.5 Infrastructure System Interfaces

Infrastructure Wireless Data System Interface is the interface between the Infrastructure Application Platform and the Infrastructure Wireless Data Systems Component. This interface is used by the Infrastructure Applications Platform and the Infrastructure Applications Components to send and receive data to nearby vehicles via the V2I/I2V Wireless Data Interface.

Infrastructure Data Systems Interface is the interface between the Infrastructure Application Platform and Infrastructure Data Systems. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to capture data from infrastructure sensor systems such as weather information, road surface condition data, visibility data, and infrastructure-based vehicle detection and speed data.

Roadside Signage System Interface is the interface between the Infrastructure Applications Platform and the Roadside Signage System. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to send advisory and alert messages to local dynamic message signs at the roadside for display to all approaching vehicles.

Local/Back Office User System Interface supports IP communication with a computer that is attached locally or remotely via dedicated lines or the Internet to perform upload and download of data files as well as installation, configuration, maintenance, diagnostics, and management of the Infrastructure Application Component.

Traffic Signal Controller Interface is the interface between the Infrastructure Applications Platform and the local Traffic Signal Controller. The interface is used by Infrastructure Applications Platform to and Infrastructure Applications Components to capture traffic signal phase and timing data required by some V2I Safety Applications.

3.2.1.6 Vehicle System Interfaces

Vehicle Wireless Data System Interface is the interface between the Vehicle Application Platform and the Vehicle Wireless Data Systems component. This interface is used by the Vehicle Applications Platform and the Vehicle Applications Components to send and receive data to nearby infrastructure via the V2I/I2V Wireless Data Interface.

Vehicle Data Systems Interface is the interface between the Vehicle Application Platform and Vehicle Data Systems. The interface is used by Vehicle Applications Platform and Vehicle Applications Components to capture data from vehicle systems such as a positioning system, vehicle data bus, sensors, actuators on the vehicle, or stability systems.

Driver Warning System Interface is the interface between the Vehicle Application Platform and Driver Warning System. The interface is used by Vehicle Applications Platform and Vehicle Applications Components to send messages, advisories, alerts and warnings to the Warning System for arbitration and delivery to the driver.

3.3 Red Light Violation Warning Application Performance Requirements

3.3.1 RLVW Application Introduction and Overview

Red Light Violation Warning – Application designed to advise drivers of an upcoming signalized intersection and provide an alert or warning when the vehicle may violate a red light, based upon their speed and distance to the intersection. The application integrates data from infrastructure- and vehicle-based sensors to determine whether the vehicle will need to stop for a red light and to provide in-vehicle messages to alert and warn the driver in time to stop at the intersection stop bar.

3.3.1.1 Application Purpose

The goal of the RLVW application is to improve roadway safety by reducing red-light running and collisions at signalized intersections. The application will alert and/or warn drivers in advance if their approach to a signalized intersection indicates a potential for violating a red light, given signal phase and timing (SPaT) information from the infrastructure. The application uses both infrastructure- and vehicle-based sensor data to determine the potential for a violation. Driver notifications are based upon available SPaT information, intersection geometry, real-time road and weather conditions, and vehicle dynamics telematics data. The application provides messages for equipped vehicles with in-vehicle, vehicle-specific advisories, alerts, and warnings to notify drivers in time for them to safely decelerate to a complete stop at the stop bar and avoid a red light violation.

3.3.1.2 Safety Impacts of Application

There will be several impacts on drivers in the deployment of V2I safety applications:

- ***Real-Time Messaging:*** The greatest impact is that drivers will receive real-time advisories, alerts and warnings while driving based on their current driving conditions.
- ***Reduction in Red-Light Running Incidents:*** The RLVW application should reduce the number of vehicles exposed to cross-traffic due to intersection violations, resulting in fewer collisions between red-light violators and cross-traffic.
- ***Effective Warning (Format and Timing):*** The safety application is designed to provide drivers with a combination of haptic, visual, and/or audio warnings in an effective format that does not distract or overwhelm them. These warnings are designed to be presented to drivers in a timeframe that provides adequate reaction time to reduce speed and safely stop at the intersection stop bar before illegally entering the intersection.
- ***Modified Driving Behavior:*** It is expected that drivers will modify their driving behaviors in response to the applications' intended purposes, thus creating a safer driving environment. However, as drivers become more accustomed to the safety application, behavior may change as drivers rely more on the application and potentially assume a less active role in driving defensively. Becoming desensitized to and ignoring provided alerts or warnings is an example of a modified behavior that would compromise the safety benefits expected from this application.

3.3.1.3 Summary of Improvements

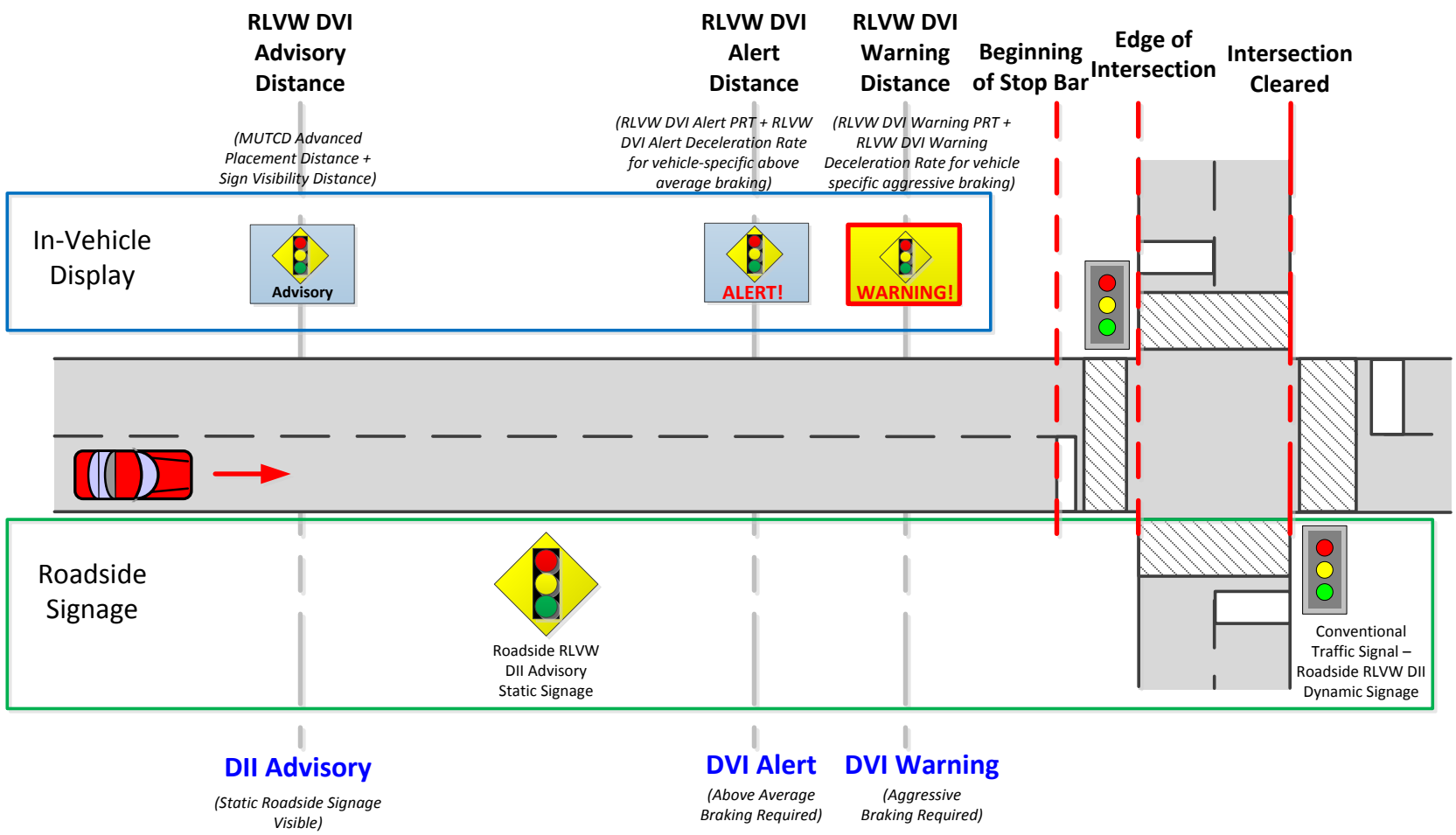
- ***Reduces number of incidents between red-light running violators and cross-traffic:*** RLVW aids drivers by informing a driver if their vehicle is on a trajectory to violate a red light at a signalized intersection, thereby potentially causing a collision with cross-traffic vehicles.
- ***Increases driver awareness of approaching signalized intersection:*** Somewhat like roadside signage warns a driver to "Prepare to Stop When Flashing," RLVW will provide a timely onboard message to the driver to begin braking, based on vehicle operating conditions and roadway conditions.
- ***Provides real-time calculation of safe deceleration and speed based on current conditions:*** The RLVW application includes the capability of capturing detailed maps of intersection geometries in real time via roadside equipment. This, in tandem with lane-level vehicle positioning capabilities, allows for lane-specific system awareness to help determine intended travel through the intersection (i.e., straight, turn left, or turn right). The application can also incorporate current road and weather condition data from the infrastructure along with available vehicle telematics data to calculate the minimum distance necessary to stop under current conditions. The application provides an alert and, if needed, a warning within sufficient time for the driver to react and respond appropriately.

3.3.1.4 How the Application Works

The objective of RLVW V2I Application is to deliver infrastructure data to support the issuance of vehicle-based advisories, alerts, and warnings that notify the driver of an upcoming red signal and the potential of violating the red light.

Figure 3-2 below illustrates the key concepts and integration of in-vehicle signage. The figure shows the vehicle, approaching a signalized intersection that will not be able to clear the intersection legally, due to a red signal. The box below the roadway illustrates existing roadside signage displayed to the driver. The driver first encounters static (or fixed) signage advising the driver of an impending signalized intersection, like those in Figure 3-2. The location of this sign in advance of the signalized intersection is defined by the Manual on Uniform Traffic Control Devices (MUTCD) advanced placement distance in Table 2C-4.

The box above the vehicle and road in Figure 3-2, illustrates the in-vehicle RLVW signage. This illustration assumes the equipped vehicle includes a graphical Driver Vehicle Interface (DVI) display capable of showing text or icon messages such as those shown in Figure 3-3. As the vehicle approaches the signalized intersection, the RLVW Vehicle Application Component receives a wireless message from the infrastructure containing infrastructure-based sensor and Signal Phase and Timing (SPaT) data originating from the Traffic Signal Controller and collects applicable dynamics data from the vehicle. The RLVW Vehicle Application Component computes the vehicle-specific RLVW DVI Alert and RLVW DVI Warning deceleration rates, using both infrastructure-based sensor data and vehicle-based sensor data.



Source: Battelle

Figure 3-2. Illustration of RLVW Roadside and In-Vehicle Signage

Source: MUTCD 2009 Ed.

Figure 3-3. Example of Signs for Vehicles Approaching a Signalized Intersection

At approximately the same time that a driver would observe the static roadside advisory sign, the DVI displays an RLVW Advisory message. (The distance at which the RLVW Advisory is displayed in the vehicle in advance of the signalized intersection is the MUTCD "Sign Visibility Distance" plus the MUTCD Advanced placement Distance in Table 2C-4). If no alerts or warnings are warranted subsequently, the DVI continues to display the RLVW Advisory continuously, until the vehicle exits the signalized intersection.

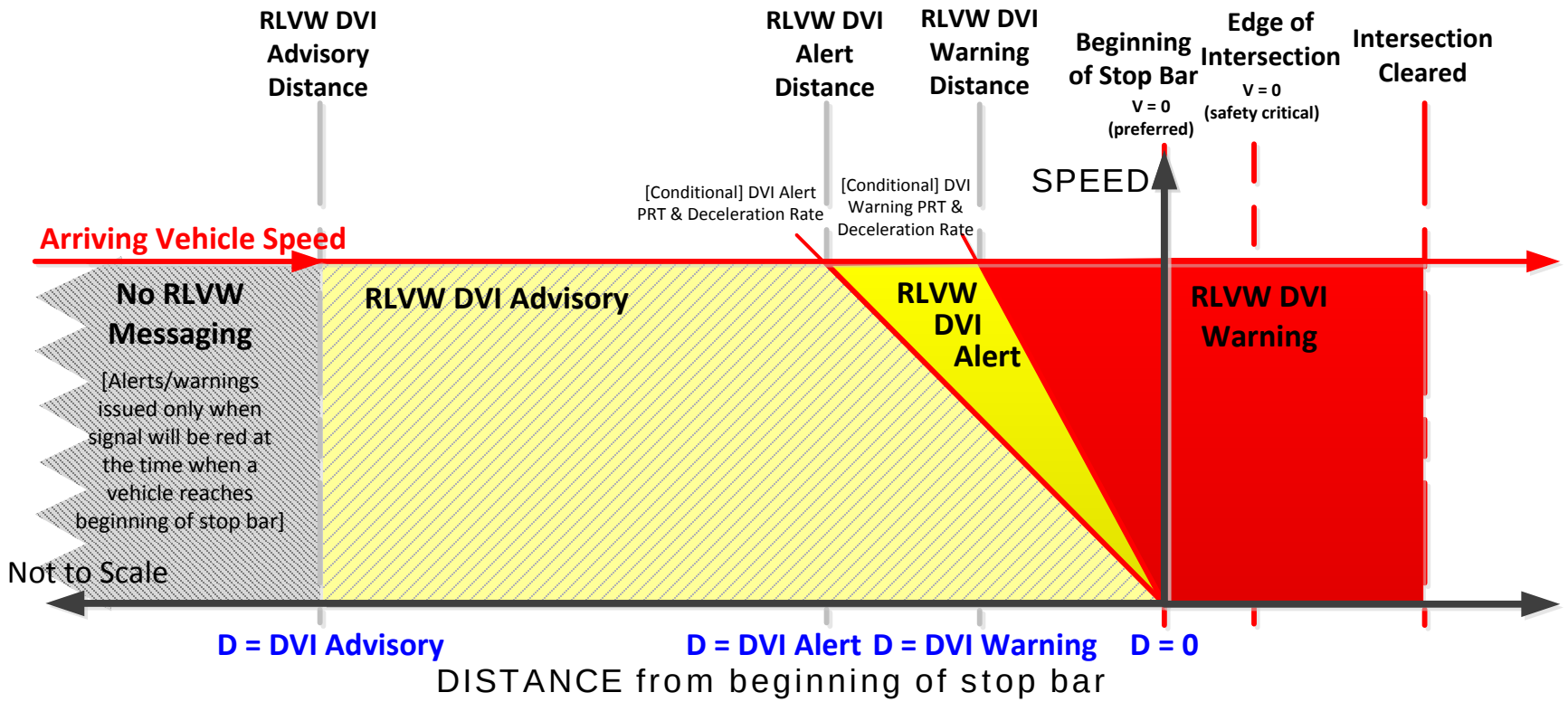
The RLVW Vehicle Application Component computes and continuously updates the DVI Alert Distance and the DVI Warning Distance for the vehicle's current trajectory and current SPaT information. The DVI Alert Distance is a distance at which *above average braking* is required for the vehicle to stop at the stop bar. The DVI Warning Distance is the distance at which *aggressive braking* is required for the vehicle to stop at the stop bar for a red light. The Alert and Warning Distances are vehicle specific, dependent upon the DVI Alert Perception Reaction Time (PRT), DVI Alert Deceleration Rate, DVI Warning PRT, and DVI Warning Deceleration Rate. They may also be conditional, based upon infrastructure weather or road surface conditions where data are available.

Alerts and warnings will only be issued to vehicles that do not have sufficient time to legally clear the intersection, i.e., the signal will be red before the vehicle can enter the intersection. Current positioning information is used when available to modify alerts and warnings for a turning vehicle (e.g., use of SPaT information for a left-turn traffic signal phase versus a through traffic signal, legal turn on red without stopping). Given this, when applicable, a DVI Alert is issued when the distance to the stop bar is less than the DVI Alert Distance for its current speed, i.e. when above average braking is required for the vehicle to stop at the stop bar. If the vehicle does not decelerate adequately, a DVI Warning is issued when the distance to the stop bar is less than the DVI Warning Distance for its current speed, i.e. when aggressive braking is required for the vehicle to stop at the stop bar. The warning continues until the vehicle exits the signalized intersection or comes to a complete stop at the stop bar. As noted earlier, an RLVW Advisory is displayed by default.

After a vehicle has made a complete stop at the signalized intersection for a red light, the RLVW Vehicle Application Component will issue a warning if the vehicle begins to move prior to a green signal, unless local policy allows turns on red.

Figure 3-4 illustrates the advisory, alert and warning displayed within the vehicle as a function of vehicle speed and distance from the stop bar at the signalized intersection. It also illustrates how the DVI Alert Distance and the DVI Warning Distance are functions of PRT and vehicle deceleration rates. The vehicle-specific PRT and Deceleration Rates are computed by the vehicle. They may be conditional based upon infrastructure weather or road surface conditions where data are available.

Table 3-1 provides a definition of the terms used here for the RLVW advisories, alerts and warnings. Table 3-2 provides a tabular summary of the driver-infrastructure interface (DII) and DVI display criteria, display signage and their distances from the stop bar at the signalized intersection.



Source: Battelle

Figure 3-4. Illustration of In-vehicle signage as a function of vehicle speed and distance from stop bar at signalized intersection

Table 3-1. Definition of RLVW Terms

RLVW DVI Advisory	Informative message indicating a signalized intersection ahead
RLVW DVI Alert	In-vehicle display indicating the subject vehicle must apply above average braking to come to a complete stop at the stop bar prior to the signalized intersection; the vehicle will be unable to legally traverse the intersection.
RLVW DVI Alert Distance	Vehicle-specific recommendation for distance at which to display RLVW DVI Alert. Distance at which above average braking is required by the subject vehicle to come to a complete stop at the stop bar prior to the signalized intersection, as the vehicle will be unable to legally traverse the intersection. Dependent upon vehicle-specific RLVW DVI Alert PRT, RLVW DVI Alert Deceleration Rate, and current environmental conditions.
RLVW DVI Alert PRT	Vehicle-specific recommendation for Perception Reaction Time used in computing DVI Alert Distance.
RLVW DVI Alert Deceleration Rate	Vehicle-specific recommendation for vehicle deceleration rate used in computing DVI Alert Distance.
RLVW DVI Warning	In-vehicle display indicating the subject vehicle must apply above aggressive braking to come to a complete stop at the stop bar prior to the signalized intersection; the vehicle will be unable to legally traverse the intersection.
RLVW DVI Warning Distance	Vehicle-specific recommendation for distance at which to display RLVW DVI Warning. Distance at which aggressive braking is required by the subject vehicle to come to a complete stop at the stop bar prior to the signalized intersection, as the vehicle will be unable to legally traverse the intersection. Dependent upon vehicle-specific RLVW DVI Warning PRT, RLVW DVI Warning Deceleration Rate and current environmental conditions.
RLVW DVI Warning PRT	Vehicle-specific recommendation for Perception Reaction Time used in computing DVI Warning Distance.
RLVW DVI Warning Deceleration Rate	Vehicle-specific recommendation for vehicle deceleration rate used in computing DVI Alert Distance.

Source: Battelle

Table 3-2. Summary of RLVW Vehicle Displays

	Driver Vehicle Interface		
	Display Criterion	**Display Signage***	**Distance from Stop Bar**
Stage 1 Advisory	Received RLVW I2V Wireless Message. Displayed until vehicle clears intersection, unless an alert or warning is warranted.	In-vehicle Advisory to inform driver of an upcoming signalized intersection.	MUTCD Advanced Placement Distance + Sign Visibility Distance
Stage 2 Vehicle-Specific Alert	Vehicle must apply above average braking to come to a complete stop at the intersection stop bar, prior to the signal turning red.	Vehicle-Specific Alert to come to a complete stop at the at the intersection stop bar, prior to the signal turning red.	Distance at which above average braking is required by subject vehicle to come to a complete stop at the intersection stop bar, prior to the signal turning red.
Stage 3 Vehicle-Specific Warning	Vehicle must apply aggressive braking to come to a complete stop at the intersection stop bar, prior to the signal turning red.	Vehicle-Specific Warning to come to a complete stop at the intersection stop bar, prior to the signal turning red.	Distance at which aggressive braking is required by subject vehicle to come to a complete stop at the intersection stop bar, prior to the signal turning red.
	Speed of the vehicle exceeds zero during a red light and the vehicle has crossed the stop bar. A vehicle determined to be making a legal turn on red is exempt from this warning.	Vehicle-Specific Warning that the traffic signal is red and the vehicle is unable to legally enter the intersection.	Any distance past the stop bar when the vehicle speed is greater than 0 during a red signal, unless the vehicle is attempting a legal turn on red.

* If applicable, DVI displays Stage 3 Vehicle-Specific warning; otherwise if applicable, DVI displays Stage 2 Vehicle-Specific Alert; otherwise, DVI displays vehicle Advisory.

Source: Battelle

3.3.1.5 Application Assumptions and Considerations

Assumptions

- The vehicle is approaching a signalized intersection equipped with a RLVW application.
- Only drivers of equipped vehicles receive notifications.
- The RLVW application may be used in conjunction with other connected vehicle applications.
- Information is processed in the vehicle.
- The application requires local policy to define what constitutes a legal stop at an intersection, i.e., turns on red after rolling or complete stops. Further, it is not unusual for vehicles to advance beyond the stop bar before coming to a complete stop. Application design and human factors research will balance the need for issuing warnings to vehicles in imminent danger of coming into conflict with cross-traffic, versus causing excessive nuisance alarms for vehicles that are attempting to make a legal turn on red.

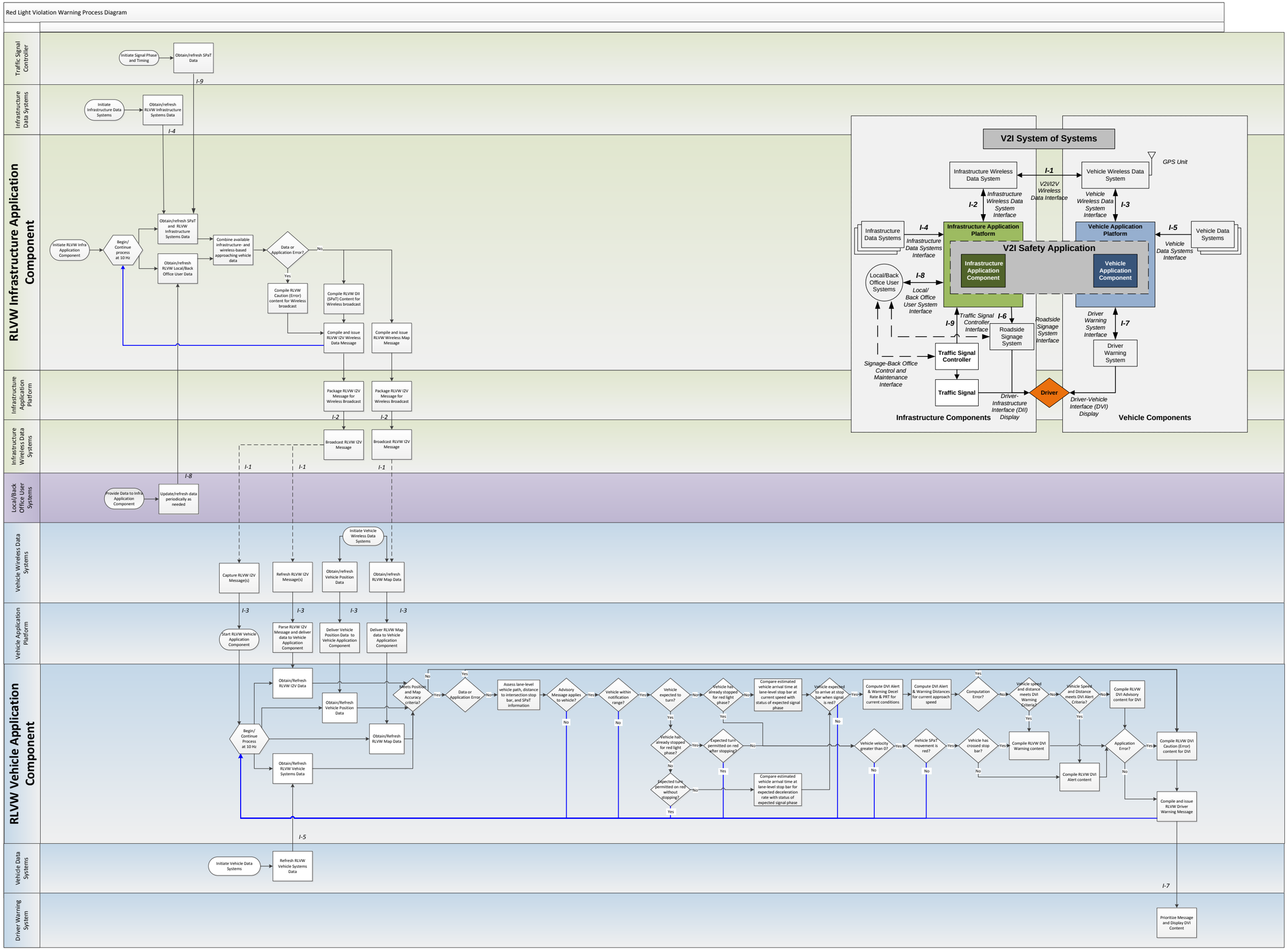
Considerations

The RLVW system is intended to warn the equipped vehicle against entering a signalized intersection illegally on a red signal. The system does not account for other drivers on the roadway or their driving behavior.

3.3.1.6 RLVW Application Swim Lane & Sequence Diagrams

As the next step in the description of the RLVW Application, Figure 3-5 provides a swim-lane process diagram for the RLVW application illustrating the sequence of data flows and processing by the RLVW Infrastructure Application Component and the RLVW Vehicle Application Component. The figure includes the V2I Systems architecture diagram presented earlier for reference.

At a high level, the RLVW Infrastructure Application Component obtains infrastructure, local/back office, and vehicle data inputs, and provides a RLVW I2V Wireless Message to the Infrastructure Wireless Data System for broadcast to nearby vehicles. Upon receipt of a RLVW I2V Wireless Message, the Vehicle Application Platform initiates the RLVW Vehicle Application Component. The RLVW Vehicle Application Component obtains I2V, position and map data inputs, determines if a driver alert or warning is warranted and, if so, issues an RLVW Alert or Warning to the Driver Warning System. These processes are performed at a rate of 10 Hz to update RLVW Roadside Signage Message and the RLVW Driver Warning Message to drivers whose vehicles may be rapidly changing speed and are rapidly approaching a signalized intersection that either does or will have a red signal indication before the vehicle can legally cross the stop bar. This diagram illustrates the concepts that are the basis for RLVW application requirements enumerated in sections 3.4.2 and 3.4.3.



Source: Battelle

Figure 3-5. RLVW Application Swim-lane Process Diagram

3.3.1.7 Messages Exchanged and Used by RLVW Application

For the purposes of these requirements, the data exchanged between system components, across system interfaces are encapsulated in nine messages summarized in Table 3-3 below. The table summarizes the message name, the source and recipient of the message, general description of the message content, location for description of data elements, and purpose of the message. In some cases such as the Basic Safety Message, the message is defined in an existing standard, such as SAE J2735. For further reference and background information, Appendix A suggests candidate data elements which may be included in these messages to support the RLVW safety application algorithms. Table A-1 provides an explanation of the headers in candidate data tables. As noted in Table 3-3, Table A-2 through Table A-7 describe the candidate data elements for each of the messages. This information is provided for guidance when implementing the performance requirements specified in this document.

Table 3-3. Summary of Messages used by RLVW Application Components

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
Infrastructure Component Messages					
RLVW Infrastructure Systems Message	External Vehicle Detection System, Infra Data System – Road Surface, Infra Data System – Local Weather	Infra Application Component	Detection of road surface conditions, local weather conditions	Table A-2 RLVW Infrastructure Systems Message Data Description	Road surface and weather data are forwarded to the Vehicle Application Component through the RLVW I2V Wireless Message
RLVW Traffic Signal Controller Message	Traffic Signal Controller	Infra Application Component	SPaT information	Table A-3 RLVW Traffic Signal Controller Message Data Description	Data are forwarded to the Vehicle Application Component through the RLVW I2V Wireless Message.
RLVW Infrastructure Map Message	Local-Back Office Users Systems Interface	Infrastructure Map Message Handler	Detailed map of intersection	Table A-4 RLVW Map Message Data Description	Used as input by RLVW Vehicle Application Component to determine if subject vehicle is approaching the signalized intersection.
V2I/I2V Messages					
RLVW I2V Wireless Message	Infra Application Component	Vehicle Application Component	SPaT Data, Road Surface Condition Data, Local Weather Data, DII and DVI Advisory, Alert, Warning Data	Table A-5 RLVW I2V Wireless Message Data Description	Data used by vehicle application component to determine vehicle-specific deceleration rates and the need and distance for issuing advisories, alerts and warnings.
RLVW Wireless Map Message	Infrastructure Map Message Handler	Vehicle Application Component	Detailed map of intersection	Table A-4 RLVW Map Message Data Description	Used as input by RLVW Vehicle Application Component to determine if subject vehicle is approaching the signalized intersection.

Table 3-3. Summary of Messages used by RLVW Application Components (Continued)

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
Wireless Position Correction Message	Infrastructure Position Correction Message Handler	Vehicle GPS Message Handler	Differential GPS Correction Data	SAE J2735 RTCM Corrections Message	Used as input by vehicle application component to determine if advisories, alerts and warnings are warranted.
Vehicle Component Messages					
GPS Position Message	Vehicle GPS Position Message Handler	Vehicle Application Component	Location, speed, heading of subject vehicle	SAE J2735 Full Position Vector	Use by the RLVW Vehicle Application Component to determine vehicle position, speed and heading to determine if and when to issue advisories, alerts, or warnings.
RLVW Vehicle Systems Message	Vehicle Data Systems	Vehicle Application Component	Vehicle Characteristics, Vehicle Functional Status, Vehicle Environmental Data	Table A-6 RLVW Vehicle Systems Message Data Description	Used as input by RLVW Vehicle Application Component to determine vehicle braking capabilities and whether the vehicle will be turning.
RLVW Driver Warning Message	Vehicle Application Component	Driver Warning System	RLVW in-vehicle message content	Table A-7 RLVW Driver Warning Message Data Description	RLVW message content to be displayed on in-vehicle displays.

Source: Battelle

3.3.2 RLVW Infrastructure Application Component Requirements

Table 3-4 catalogs the performance requirements for the RLVW Infrastructure Application Component. These were developed based upon the integration strategy described in Section 3.3.1.4 above. It is expected that, as connected vehicle technology evolves and vehicle and infrastructure application component owners develop this and other V2I Safety Applications, the rationales, frameworks, and performance requirements presented here will evolve. Accordingly, before embarking upon design and development, application owners should update and refine the requirements to reflect current standards and policies. It is the responsibility of the designer to ensure that the resulting applications do not conflict with applicable published state and national regulations, policies, and guidelines.

Table 3-4. RLVW Infrastructure Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.01	**RLVW Infrastructure Application Component Requirements**			
3.01.01	**RLVW Infrastructure Application Component Interfaces and Interface Specifications**			
[3.01.01.01]	**RLVW Infrastructure Systems Message Interface**	**The RLVW Infrastructure Application Component shall obtain RLVW Infrastructure Systems Messages through the Infrastructure Data Systems Interface.**		D
[3.01.01.08]	**Basic Safety Message Interface**	**The RLVW Infrastructure Application Component shall obtain Basic Safety Messages received through the Infrastructure Wireless Data Systems Interface.**		D
[3.01.01.01]	**RLVW Local/Back Office User Data Interface**	**The RLVW Infrastructure Application Component shall obtain RLVW Local/Back Office User Data through the Local/Back Office User Systems Interface.**		D
[3.01.01.02]	**RLVW Traffic Signal Controller Data Interface**	**The RLVW Infrastructure Application Component shall obtain RLVW Traffic Signal Controller SPaT Data through the Traffic Signal Controller Interface.**		D
[3.01.01.03]	**RLVW I2V Wireless Message Interface**	**The RLVW Infrastructure Application Component shall issue RLVW I2V Wireless Messages through the Infrastructure Wireless Data Systems Interface.**		D
3.01.02	**RLVW Infrastructure Application Component Functional Requirements**			
[3.01.02.01]	**Common Infrastructure Application Component Requirements**	**The RLVW Infrastructure Application Component shall adhere to Common Infrastructure Application Component Requirements.**		D
[3.01.02.02]	**RLVW Infrastructure Systems Message**	**The RLVW Infrastructure Application Component shall obtain RLVW Infrastructure Systems Data upon initiation of the**		D

Table 3-4. RLVW Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
	Initiation	**component.**		
[3.01.02.03]	**RLVW Infrastructure Systems Message Refresh Rate**	**The RLVW Infrastructure Application Component shall refresh the RLVW Infrastructure Systems Message at a configurable frequency.**		D
[3.01.02.04]	**Basic Safety Message Initiation**	**The RLVW Infrastructure Application Component shall obtain Basic Safety Messages upon initiation of the component.**		D
[3.01.02.05]	**Basic Safety Message Refresh Rate**	**The RLVW Infrastructure Application Component shall refresh Basic Safety Messages at a configurable frequency.**		D
[3.01.02.06]	**Local/Back Office User Data Initiation**	**The RLVW Infrastructure Application Component shall obtain RLVW Local/Back Office User Data upon initiation of the component.**		D
[3.01.02.07]	**Local/Back Office User Data Refresh Rate**	**The RLVW Infrastructure Application component shall refresh RLVW Local/Back Office User Data at a configurable frequency.**		D
[3.01.02.08]	**RLVW Traffic Signal Controller SPaT Data Initiation**	**The RLVW Infrastructure Application Component shall obtain RLVW Traffic Signal Controller SPaT Data upon initiation of the RLVW infrastructure application component.**		D
[3.01.02.09]	**GPS Position Accuracy**	**GPS Position data used by the RLVW Vehicle Application Component shall be of at least Road Level Position Accuracy.**	*Road Level Position Accuracy is defined under Common Infrastructure Application Component Requirements.*	D
[3.01.02.10]	**RLVW Traffic Signal Controller SPaT Data Refresh Rate**	**The RLVW Infrastructure Application component shall refresh RLVW Traffic Signal Controller SPaT Data at a configurable frequency.**		D
[3.01.02.11]	**Map Data Accuracy**	**Map data used by RLVW Vehicle Application Component shall be of at least Road Level Position Accuracy.**	*Road Level Position Accuracy is defined under Common*	D

Table 3-4. RLVW Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
			Infrastructure Application Component Requirements.	
[3.01.02.12]	**Map Data Accuracy**	**Map data used by the RLVW Infrastructure Application Component shall be of at least Road Level Position Accuracy.**	*Road Level Position Accuracy is defined under Common Infrastructure Application Component Requirements.*	D
[3.01.02.13]	**RLVW I2V Wireless Message Content**	**The RLVW Infrastructure Application Component shall compile and issue an RLVW I2V Wireless Message containing RLVW Traffic Signal Controller SPaT Data to the Infrastructure Wireless Data Systems Interface.**		D
[3.01.02.14]	**RLVW I2V Wireless Message Initiation**	**The RLVW Infrastructure Application Component shall issue RLVW I2V Wireless Messages upon initiation of the component.**		D
[3.01.02.15]	**RLVW I2V Wireless Message Issuance**	**The RLVW Infrastructure Application Component shall issue RLVW I2V Wireless Messages at a configurable frequency.**		D
[3.01.02.16]	**RLVW Infrastructure Application Component Caution (Error) Criterion for I2V Message**	**In the event of an input data, computational or other recoverable RLVW Infrastructure Application Component error, preventing issuance of RLVW advisory message, the Infrastructure Application Component shall issue a RLVW I2V Message containing a RLVW DII Caution (Error) and an indication of RLVW Infrastructure Application Component Error to the Infrastructure Wireless Data Systems Interface.**	*Caution message is displayed when denoting an error.*	D

Table 3-4. RLVW Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.01.03	**RLVW Infrastructure Application Component Data Input Requirements**			
[3.01.03.01]	**RLVW Infrastructure Systems Message Content**	**The RLVW Infrastructure Systems Message shall contain the data needed to perform the calculations specified under RLVW Infrastructure Application Functional Requirements.**		D
[3.01.03.02]	**RLVW Local/Back Office User Data Content**	**The RLVW Local/Back Office User Data shall contain the data needed to perform the calculations specified under RLVW Infrastructure Application Functional Requirements.**		D
[3.01.03.03]	**RLVW Local/Back Office User Data Specifications**	**The RLVW Local/Back Office User Data and all Local/Back Office User System messages shall conform to Traffic Management Data Dictionary (TMDD) Standard v3.03 for the Center-to-Center Communications.**		D
[3.01.03.04]	**RLVW Traffic Signal Controller Message Content**	**The RLVW Traffic Signal Controller Message shall contain the data needed to perform the calculations specified under RLVW Infrastructure Application Functional Requirements.**		D
[3.01.03.05]	**RLVW Traffic Signal Controller Message Specification**	**The RLVW Traffic Signal Controller Message shall conform to NTCIP 1211:2008 V01.38 Object Definitions for Signal Control and Prioritization (SCP) Standard.**		D

Table 3-4. RLVW Infrastructure Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.01.04	**RLVW Infrastructure Application Component Data Output Requirements**			
[3.01.04.01]	**RLVW I2V Wireless Message Content**	**The RLVW I2V Wireless Message shall contain the data needed to perform the calculations specified under RLVW Vehicle Application Functional Requirements.**		D
[3.01.04.02]	**RLVW I2V Wireless Message Specifications**	**The RLVW I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary.**		D
[3.01.04.03]	**RLVW I2V Wireless Message Content Text**	**The RLVW I2V Wireless Message shall contain RLVW Traffic Signal Controller SPaT Data.**	*The DII for this application is the traffic signal display.*	D

Source: Battelle

3.3.3 RLVW Vehicle Application Component Requirements

Table 3-5 catalogs the performance requirements for the RLVW Vehicle Application Component. These were developed based upon the integration strategy described in Section 3.3.1.4 above. It is expected that, as connected vehicle technology evolves and vehicle and infrastructure application component owners develop this and other V2I Safety Applications, the rationales, frameworks, and performance requirements presented here will evolve. Accordingly, before embarking upon design and development, application owners should update and refine the requirements to reflect current standards and policies. It is the responsibility of the designer to ensure that the resulting applications do not conflict with applicable published state and national regulations, policies, and guidelines.

Table 3-5. RLVW Vehicle Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.02	**RLVW Vehicle Application Component Requirements**			
3.02.01	**RLVW Vehicle Application Component Interfaces and Interface Specifications**			
[3.02.01.01]	**RLVW I2V Wireless Message Interface**	**The RLVW Vehicle Application Component shall obtain RLVW I2V Wireless Messages through the Vehicle Wireless Data Systems Interface.**		D
[3.02.01.02]	**Vehicle Data Systems Interface**	**The RLVW Vehicle Application Component shall obtain applicable RLVW Vehicle Data through the Vehicle Data Systems Interface.**		D
[3.02.01.03]	**RLVW Driver Message Interface**	**The RLVW Vehicle Application Component shall issue RLVW Driver Messages through the Driver Warning System Interface.**		D
3.02.02	**RLVW Vehicle Application Component Functional Requirements**			
[3.02.02.01]	**Common Vehicle Application Component Requirements**	**The RLVW Vehicle Application Component shall adhere to Common Vehicle Application Component Requirements.**		D
[3.02.02.02]	**RLVW Vehicle Application Component Initiation**	**The RLVW Vehicle Application Component shall be initiated upon receipt of an RLVW I2V Wireless Message by the Vehicle Wireless Data Systems.**		D
[3.02.02.03]	**RLVW I2V Wireless Message Initiation**	**The RLVW Vehicle Application Component shall obtain RLVW I2V Wireless Messages upon initiation of the component.**		D
[3.02.02.04]	**RLVW I2V Wireless Message Refresh Rate**	**The RLVW Vehicle Application Component shall refresh the RLVW I2V Wireless Message Input at a configurable frequency.**		D
[3.02.02.05]	**RLVW Vehicle Data Initiation**	**The RLVW Vehicle Application Component shall obtain RLVW Vehicle Data upon initiation of the component.**		D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[3.02.02.06]	**Vehicle Data Systems Refresh Rate**	**The RLVW Vehicle Application Component shall refresh RLVW Vehicle Data at a configurable frequency.**		D
[3.02.02.07]	**RLVW Infrastructure Data**	**Upon receipt of a RLVW I2V Wireless Message, the RLVW Vehicle Application Component shall open the message and parse it for relevant RLVW data.**		D
[3.02.02.08]	**RLVW Positioning Accuracy Determination**	**The RLVW Vehicle Application Component shall determine if the received Position Data and the Map Data meet the position accuracy requirements for the received RLVW I2V Wireless Message.**		D
[3.02.02.09]	**RLVW Positioning Accuracy Assessment**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the RLVW I2V Wireless Message, the RLVW Vehicle Application Component shall refresh the Position Data and Map Data and continue processing.**	*The application should continue iteratively obtaining position and map data until RLVW application position accuracy requirements are satisfied for the RLVW I2V Wireless Message.*	D
[3.02.02.10]	**RLVW Positioning Accuracy Message – Advisory**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the received RLVW I2V Wireless Message, the RLVW Vehicle Application Component shall issue a RLVW Driver Message containing a RLVW DII Advisory to the Driver Warning System.**	*The RLVW Application issues only advisory messages if position and map accuracy are not sufficient to support alert and warning calculations.*	D
[3.02.02.11]	**RLVW I2V Message Applicability Determination**	**The RLVW Vehicle Application Component shall determine if the received RLVW I2V Wireless Message is applicable, based upon the subject vehicle's apparent path, the specified class of vehicles to which the message applies and other message criteria.**		D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[3.02.02.12]	**RLVW I2V Message Applicability Assessment**	**If the received RLVW I2V Wireless Message is not applicable, the RLVW Vehicle Application Component shall refresh the RLVW I2V Wireless Message and continue processing.**	*The application should continue iteratively obtaining RLVW I2V Wireless Messages until a message applicable to current vehicle conditions is received.*	D
[3.02.02.04]	**Determine Signal Phase on Intersection Approach**	**The RLVW Vehicle Application Component shall determine if the vehicle is expected to arrive at the beginning of the stop bar within the red signal phase.**		D
[3.02.02.05]	**Determine Legality of Right Turn on Red**	**The RLVW Vehicle Application Component shall assess whether vehicles are permitted to turn right on red after stopping per local policy.**		D
[3.02.02.06]	**Compute [Conditional] RLVW DVI Alert Deceleration Rate**	**The RLVW Vehicle Application Component shall compute the RLVW DVI Alert Deceleration Rate for the subject vehicle based upon available RLVW infrastructure and RLVW vehicle data.**		D
[3.02.02.07]	**Compute [Conditional]RLVW DVI Alert Perception Reaction Time**	**The RLVW Vehicle Application Component shall compute the RLVW DVI Alert Perception Reaction Time for the subject vehicle based upon available RLVW infrastructure and RLVW vehicle data.**		D
[3.02.02.08]	**Compute RLVW DVI Warning Deceleration Rate**	**The RLVW Vehicle Application Component shall compute the RLVW DVI Warning Deceleration Rate for the subject vehicle based upon available RLVW infrastructure and RLVW vehicle data.**		D
[3.02.02.09]	**Compute RLVW DVI Warning Perception Reaction Time**	**The RLVW Vehicle Application Component shall compute the RLVW DVI Warning Perception Reaction Time for the subject vehicle based upon available RLVW infrastructure and RLVW vehicle data.**		D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[3.02.02.10]	**Determine RLVW DVI Advisory Distance**	**The RLVW DVI Advisory Distance shall be (from the beginning of the stop bar), the sign visibility distance plus the distance defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Sign.**		D
[3.02.02.11]	**Determine RLVW DVI Alert and Warning Distances**	**The RLVW Vehicle Application Component shall compute the RLVW DVI Alert Distance and the RLVW DVI Warning Distance for the subject vehicle corresponding to its current speed and available RLVW Infrastructure and RLVW Vehicle Data.**		D
[3.02.02.12]	**RLVW DVI Alert Distance Equation**	**The RLVW DVI Alert Distance shall be the distance traveled during the RLVW DVI Alert Perception Reaction Time plus the distance required to slow the subject vehicle from its current speed to a speed of zero, at a uniform deceleration equal to the RLVW DVI Alert Deceleration Rate.**	*The following information is referenced for guidance: 0.34g is the uniform deceleration rate required to safely stop a fully loaded (new) tractor trailer as defined in NHTSA FMVSS 121. 0.56g is the uniform deceleration rate required to safely stop a fully passenger vehicle as defined in NHTSA FMVSS 135. Industry guidelines and/or local policy should provide guidance on deceleration rates for specific circumstances.*	D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[3.02.02.13]	**RLVW DVI Warning Distance Equation**	**The RLVW DVI Warning Distance shall be the distance traveled during the RLVW DVI Warning Perception Reaction Time plus the distance required to slow the subject vehicle from its current speed to a speed of zero, at a uniform deceleration equal to the RLVW DVI Warning Deceleration Rate.**	*The following information is referenced for guidance: 0.34g is the uniform deceleration rate required to safely stop a fully loaded (new) tractor trailer as defined in NHTSA FMVSS 121. 0.56g is the uniform deceleration rate required to safely stop a fully passenger vehicle as defined in NHTSA FMVSS 135. Industry guidelines and/or local policy should provide guidance on deceleration rates for specific circumstances.*	D
[3.02.02.14]	**RLVW DVI Warning Criterion**	**If the vehicle is expected to approach the intersection during the red phase, and if local policies require stopping on red, and if either the distance of the subject vehicle is less than the RLVW DVI Warning Distance for its current speed or the vehicle has crossed the stop bar, then the RLVW Vehicle Application Component shall issue a RLVW Driver Message containing a RLVW DVI Warning to the Driver Warning System.**		D
[3.02.02.15]	**RLVW DVI Alert Criterion**	**If the vehicle is expected to approach the intersection during the red phase, and if local policies require stopping on red, and if the distance of the subject vehicle is less than the RLVW DVI Alert Distance for its current speed and greater than or equal to the RLVW DVI Warning Distance for its current speed, then the RLVW Vehicle Application Component shall issue a RLVW Driver Message containing a RLVW DVI Alert to the Driver Warning System.**		D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[3.02.02.16]	**RLVW DVI Advisory Criterion**	**If the vehicle is expected to approach the intersection during the red phase, and if local policies require stopping on red, and if the distance of the subject vehicle is less than the RLVW DVI Advisory Distance and greater than or equal to the RLVW DVI Alert Distance, the RLVW Vehicle Application Component shall issue a RLVW Driver Message containing a RLVW DVI Advisory to the Driver Warning System.**		D
[3.02.02.05]	**RLVW Input Data and Message Issuance Refresh Frequency**	**The RLVW Vehicle Application Component shall repeat its assessment and message issuance functions at a configurable frequency.**	*Message issuance functions include: RLVW DVI Advisory, RLVW DVI alert, RLVW DVI warning, and RLVW DVI Caution (Error).*	D
[3.02.02.06]	**RLVW Advisory and RLVW Alert Termination**	**The RLVW Vehicle Application Component shall cease issuing RLVW DVI advisory and RLVW DVI alerts when the vehicle passes the beginning of the stop bar.**		D
[3.02.02.07]	**RLVW Warning Termination**	**The RLVW Vehicle Application Component shall cease issuing RLVW DVI warnings when the vehicle has cleared the intersection.**		D
[3.02.02.08]	**RLVW Vehicle Application Component Error**	**In the event of an input data error, a computational error or other non recoverable RLVW Vehicle Application Component Error preventing issuing of RLVW DVI advisories, RLVW DVI alerts, or RLVW DVI warnings, or position and map accuracy requirements not being met, the RLVW Vehicle Application Component shall issue a RLVW Driver Message containing a RLVW DVI Caution (Error) to the Driver Warning System.**		D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.02.03	**RLVW Vehicle Application Component Data Input Requirements**			
[3.02.03.01]	**RLVW I2V Wireless Message Content**	**The RLVW I2V Wireless Message shall contain the data required to perform the calculations specified under RLVW Vehicle Application Functional Requirements**	*Table (RLVW Wireless) RLVW I2V Wireless Message Data Description is referenced for guidance.*	D
[3.02.03.02]	**RLVW I2V Wireless Message Specification**	**The RLVW I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary**		I
[3.02.03.03]	**RLVW I2V Wireless Message Content Text**	**The RLVW I2V Wireless Message shall contain RLVW Traffic Signal Controller SPaT Data.**		D
[3.02.03.01]	**RLVW Vehicle Systems Message Content**	**The RLVW Vehicle Systems Message shall contain data required to perform the calculations specified under RLVW Vehicle Application Functional Requirements.**	*Table (RLVW Vehicle) RLVW Vehicle Systems Message Data Description is referenced for guidance.*	D
[3.02.03.02]	**Vehicle Data Systems Message Specifications**	**The RLVW Vehicle Systems Message shall conform to the standards and guidelines specified by the vehicle Original Equipment Manufacturer.**	*Specific interfaces to the OEM vehicle systems will be dependent on specific information required to support the safety application. Examples of vehicle data communication system specifications include: ISO 14230-4, ISO 9141-2, SAE J1850 VPW, SAE J1850 PWM, ISO 15765, ISO 11898, and SAE J2178*	D

Table 3-5. RLVW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
3.02.04	**RLVW Vehicle Application Component Data Output Requirements**			
[3.02.04.01]	**RLVW Driver Message Content**	**The RLVW Driver Message shall contain the RLVW DII Advisory, RLVW DII Alert, RLVW DII Caution, RLVW DVI Alert, RLVW DVI Warning, or RLVW DVI Caution content to be displayed on the Driver Warning Interface.**		D
[3.02.04.02]	**RLVW Driver Message Specifications**	**The following is referenced for guidance pertaining to RLVW Driver Message Specifications: Campbell, J. L., Brown, J. L., Graving, J. S., Richard, C. M., Lichty, M. G., Sanquist, T., Bacon, L. P., … Morgan, J. F. (in press). Driver Vehicle Interface (DVI) Design Assistance for Advanced Technology Applications. (Final report to Virginia Tech Transportation Institute and National Highway Traffic Safety Administration). Seattle, WA: Battelle.**		D

Source: Battelle

APPENDIX A. RLVW Application Message Candidate Data Elements

Appendix A suggests candidate data elements which may be included in these messages to support the RLVW safety application algorithms. Table A-1 provides an explanation of the headers in candidate data tables. As noted in Table 3-3, Table A-2 through Table A-7 describe the candidate data elements for each of the messages. This information is provided for guidance when implementing the performance requirements specified in this document.

Table A-1. Explanation of Candidate Data Table Headers

Data Element Descriptor	Explanation	Example
Data Item Description	Name of obtainable measure or item,	Posted speed limit, number of lanes
Application	V2I Safety Application that the data element pertains to	RLVW, RLVW
Type of Data	Identifies a general classification of the data element	Location data, speed data
Static/ Dynamic	Distinguishes the frequency by which the data element is subject to changes	Static, Dynamic
Need	Identifies whether the data element is critical to the application function, versus those that can enhance it	Required, optional
Input Source	Identifies the component that supplies the data element	Vehicle Application Component, infrastructure data system
Output Recipient	Identifies the component that receives the data element	Vehicle Application Component, infrastructure application component
Unit of Measure (English)	Metric used to quantify the data element, English system of measurement	Feet, °F
Valid Range (English)	Span of values from minimum to maximum that are acceptable inputs, English system of measurement	5-20, (-30)-120
Accuracy/ Tolerance (English)	Degree of variance between actual and measured value that will be acceptable, English system of measurement	+/-5, +/-0.01
Unit of Measure (Metric)"	Metric used to quantify the data element, international system of measurement	Meter, °C
Valid Range (Metric)	Span of values from minimum to maximum that are acceptable inputs, international system of measurement	5-20, (-30)-120
Accuracy/Tolerance(Metric)"	Degree of variance between actual and measured value that will be acceptable, international system of measurement	+/-5, +/-0.01
Refresh Rate	Frequency that the data element is updated with a new external value	10 Hz, Annually
References	Source documents that contain supporting information	MUTCD
Notes	Supplemental explanation	Determined by MUTCD or Local Policy

Source: Battelle

Table A-2. Description of Candidate Data Elements for the RLVW Infrastructure Data Systems Message

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Local Spot Weather Data (optional)															
Air Temperature	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		Temperature may be measured locally or estimated from nearby sensors
Temperature tolerance (if estimated)	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	°F	(-30)-120	+/-5	°C	(-35)-49	+/-9	5 min		Temperature may be measured locally or estimated from nearby sensors
Current precipitation condition	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	1 min		Precipitation may be measured locally or estimated from nearby sensors
Precipitation tolerance (if estimated)	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	5 min		Precipitation may be measured locally or estimated from nearby sensors
Visibility	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Visibility tolerance	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Wind Speed	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	mph	0-100	+/- 5	km/h	0-160	+/-9	1 min		
Precipitation rate	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in./hr	0-20	+/- 0.5	cm/hr	0-51	+/-1.3	1 min		
Precipitation accumulation	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	1 min		
Water depth	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Snow depth	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System – Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		

Table A-2. Description of Candidate Data Elements for the RLVW Infrastructure Data Systems Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Local Weather Data Applicable Road Map Segments	RLVW	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Local Weather Data Applicable Date and Time - Begin	RLVW	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Weather Data Applicable Date and Time - End	RLVW	Local Weather Data	Dynamic	Required	Infra Data System – Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Road Surface Data (optional)															
Road surface temperature	RLVW	Road Surface Condition	Dynamic	One required from group	Infra Data System – Road Surface	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	RLVW	Road Surface Condition	Dynamic	One required from group	Infra Data System – Road Surface	Infra Application Component	n/a	-	-	n/a	-	-	5 min		
Road surface friction coefficient	RLVW	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road Condition Data Applicable Road Map Segments	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time - Begin	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Road Condition Data Applicable Date and Time - End	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System – Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		

Source: Battelle

Table A-3. Description of Candidate Data Elements for the RLVW Traffic Signal Controller Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	Standards/ References	Notes
Date and Time (required)															
UTC Time	RLVW	Date/Time	Dynamic	Required	GPS Device	Infra Application Component				Date/Time		TBD	1 Minute	NMEA	
Traffic Signal Timing Data (required)															
Phase Pedestrian Clear	RLVW	Traffic Signal Timing Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer (seconds)		TBD	Integer (seconds)		TBD	Daily	NTCIP 1202	
Phase Yellow Change	RLVW	Traffic Signal Timing Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer (seconds)		TBD	Integer (seconds)		TBD	Daily	NTCIP 1202	
Phase Red Clearance	RLVW	Traffic Signal Timing Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer (seconds)		TBD	Integer (seconds)		TBD	Daily	NTCIP 1202	
Traffic Signal Status Data (required)															
Phase Status Reds	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Phase Status Yellows	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Phase Status Greens	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Phase Flashing Status	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Phase Status DontWalks	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Phase StatusPedClears	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	

Table A-3. Description of Candidate Data Elements for the RLVW Traffic Signal Controller Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	Standards/ References	Notes
Phase Status Walks	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Overlap Status Reds	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Overlap Status Yellows	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Overlap Status Greens	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Timebase Action Number	RLVW	Traffic Signal Control Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 - 256	TBD	Integer	0 - 256	TBD	10 Hz	NTCIP 1202	
Overlap Flashing Status	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Discontinuous Change Flag	RLVW	Traffic Signal Status Data	Dynamic	Optional	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	Extended NTCIP 1202	
Vehicle Minimum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	
Vehicle Maximum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	
Ped Minimum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	
Ped Maximum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	

Table A-3. Description of Candidate Data Elements for the RLVW Traffic Signal Controller Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	Standards/ References	Notes
Overlap Minimum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	
Overlap Maximum Time to Change	RLVW	Traffic Signal Timing Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer (1/10th Second)	0-12001	TBD	Integer (1/10th Second)	0-12001	TBD	10 Hz	Extended NTCIP 1202	
Intersection Status - Manual Control Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	+/- 1 min	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Stop Time Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	+/- 1 min	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Fault Flash Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	+/- 1 min	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Preempt Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	+/- 1 min	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - TSP Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	+/- 1 min	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Coordination Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1		Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Coordination in Transition	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
Intersection Status - Programmed Flash Active	RLVW	Traffic Signal Status Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0 or 1	TBD	Integer	0 or 1	TBD	10 Hz	NTCIP 1202	
SPaT Message Sequence Counter	RLVW	Control/Verification Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	Integer	0-256	TBD	Integer	0-256	TBD	10 Hz	Extended NTCIP 1202	

Table A-3. Description of Candidate Data Elements for the RLVW Traffic Signal Controller Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	Standards/ References	Notes
Traffic Signal System Configuration Data (required)															
Intersection ID	RLVW	Traffic Signal System Configuration Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Approach ID	RLVW	Traffic Signal System Configuration Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Lane ID	RLVW	Traffic Signal System Configuration Data	Static	Required	Traffic Signal Controller	Infra Application Component	Integer	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Lane Movement	RLVW	Traffic Signal System Configuration Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Lane Movement Type	RLVW	Traffic Signal System Configuration Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Lane Movement Phase	RLVW	Traffic Signal System Configuration Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Intersection Lane Movement Phase Type	RLVW	Traffic Signal System Configuration Data	Dynamic	Required	Traffic Signal Controller	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		

Source: Battelle

Table A-4. Description of Candidate Data Elements for the RLVW Infrastructure Map Message and RLVW Wireless Map Message

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Geometric Intersection Design (GID)	RLVW	Geometric information for the lanes and attributes for the intersection	Geometric information is Static, Attributes can be Dynamic	Required	Local/Back Office User	Infra Application Component	NA	NA	NA	NA	NA	NA	1 Hz	SAE J2735 ICD for SPaT	
GID Message Data Items (required)															
Intersection Identifier	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Unsigned 32-bit Integer	NA	NA	Unsigned 32-bit Integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Unique within a specified region
Reference Latitude	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Signed 32-bit Integer	NA	NA	Signed 32-bit Integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		
Reference Longitude	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Signed 32-bit Integer	NA	NA	Signed 32-bit Integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		
Reference Elevation	RLVW	RLVW Map Data	Static	Optional	Local/Back Office User	Infra Application Component	Signed 16-bit Integer	NA	NA	Signed 16-bit Integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Above or below the reference ellipsoid
Lane Number	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Unsigned 8-bit integer	NA	NA	Unsigned 8-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Provide for each approach lane
Lane Type	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Unsigned 8-bit integer	NA	NA	Unsigned 8-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Motorized, Computed, Pedestrian, Special
Lane Attributes	RLVW	RLVW Map Data	Dynamic	Required	Local/Back Office User	Infra Application Component	Unsigned 16-bit integer	NA	NA	Unsigned 16-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Permitted maneuvers, turns and travel restrictions

Table A-4. Description of Candidate Data Elements for the RLVW Infrastructure Map Message and RLVW Wireless Map Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Lane Width	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Unsigned 16-bit integer	NA	NA	Unsigned 16-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Can be provided and various levels of granularity
Lane Node Eastern Offset	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Signed 16-bit integer	NA	NA	Signed 16-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Offset from previous lane node
Lane Node Northern Offset	RLVW	RLVW Map Data	Static	Required	Local/Back Office User	Infra Application Component	Signed 16-bit integer	NA	NA	Signed 16-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Offset from previous lane node
Lane Node Elevation Offset	RLVW	RLVW Map Data	Static	Optional	Local/Back Office User	Infra Application Component	Signed 16-bit integer	NA	NA	Signed 16-bit integer	NA	NA	Upon reconstruction, repaving, restriping or signal change		Offset from previous lane node
Roadside Signage Data Items															
MUTCD Sign Number options for consideration to be used as DII Advisory Message	RLVW	RLVW Roadside Signage Data	Static	At Least One Required from Group	Local/Back Office User	Infra Application Component	Integer	NA	NA	Integer	NA	NA	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
Graphic options for consideration to be used as DII Advisory Message	RLVW	RLVW Roadside Signage Data	Static	At Least One Required from Group	Local/Back Office User	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
Advisory Text options for consideration to be used as DII Advisory Message	RLVW	RLVW Roadside Signage Data	Static	At Least One Required from Group	Local/Back Office User	Infra Application Component	Latin Alphabet	A-Z	NA	Latin Alphabet	A-Z	NA	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
DII Advisory Sign Distance	RLVW	RLVW Roadside Signage Data	Static	Required	Local/Back Office User	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.

Table A-4. Description of Candidate Data Elements for the RLVW Infrastructure Map Message and RLVW Wireless Map Message (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
DII Advisory Visibility Distance	RLVW	RLVW Roadside Signage Data	Static	Required	Local/Back Office User	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
MUTCD Sign Number options for consideration to be used as DII Alert Message	RLVW	RLVW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local/Back Office User	Infra Application Component	Integer	NA	NA	Integer	NA	NA	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
Graphic options for consideration to be used as DII Alert Message	RLVW	RLVW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local/Back Office User	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
Alert Text options for consideration to be used as DII Alert Message	RLVW	RLVW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local/Back Office User	Infra Application Component	Latin Alphabet	A-Z	NA	Latin Alphabet	A-Z	NA	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
DII Alert Sign Distance	RLVW	RLVW Roadside Signage Data	Static	Optional	Local/Back Office User	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.
DII Alert Visibility Distance	RLVW	RLVW Roadside Signage Data	Static	Optional	Local/Back Office User	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	Roadside Signage Revision		Determined by MUTCD and Local Policy. Static Data may be loaded through an externally generated data file.

Source: Battelle

Table A-5. Description of Candidate Data Elements for the RLVW I2V Wireless Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Operational Data (required)															
RLVW Applicable Date and Time – Begin	RLVW	RLVW Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
RLVW Applicable Date and Time – End	RLVW	RLVW Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
RLVW Applicable Road Map Segments	RLVW	RLVW Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Data format is based upon segments in RLVW Road Map
Intersection Identifier Data															
Intersection Identifier	RLVW	RLVW Map Data	Static	Required	Infra Application Component	Vehicle Application Component	Unsigned 32-bit Integer	NA	NA	NA	NA	NA	Upon reconstruction, repaving, restriping or signal change		Unique within a specified region
Local Spot Weather Data (optional)															
Air Temperature	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		Temperature may be measured locally or estimated from nearby sensors
Temperature tolerance (if estimated)	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	°F	(-30)-120	+/-5	°C	(-35)-49	+/-9	5 min		Temperature may be measured locally or estimated from nearby sensors
Current precipitation condition	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	1 min		Precipitation may be measured locally or estimated from nearby sensors

Table A-5. Description of Candidate Data Elements for the RLVW I2V Wireless Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Precipitation tolerance (if estimated)	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	n/a	-	-	n/a	-	-	5 min		Precipitation may be measured locally or estimated from nearby sensors
Visibility	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Visibility tolerance	RLVW	Local Weather Data	Dynamic	Optional	Infra Data System - Local Weather	Infra Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Wind Speed	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System - Local Weather	Infra Application Component	mph	0-100	+/- 5	km/h	0-160	+/-9	1 min		
Precipitation rate	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System - Local Weather	Infra Application Component	in./hr	0-20	+/- 0.5	cm/hr	0-51	+/-1.3	1 min		
Precipitation accumulation	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System - Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	1 min		
Water depth	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System - Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Snow depth	RLVW	Local Weather Data	Dynamic	One required from group	Infra Data System - Local Weather	Infra Application Component	in.	0-20	+/- 0.5	cm	0-51	+/-1.3	10 min		
Local Weather Data Applicable Road Map Segments	RLVW	Local Weather Data	Dynamic	Required	Infra Data System - Local Weather	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		
Local Weather Data Applicable Date and Time - Begin	RLVW	Local Weather Data	Dynamic	Required	Infra Data System - Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Weather Data Applicable Date and Time - End	RLVW	Local Weather Data	Dynamic	Required	Infra Data System - Local Weather	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		

Table A-5. Description of Candidate Data Elements for the RLVW I2V Wireless Message Data Description (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Local Road Surface Data (optional)															
Road surface temperature	RLVW	Road Surface Condition	Dynamic	One required from group	Infra Data System - Road Surface	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	RLVW	Road Surface Condition	Dynamic	One required from group	Infra Data System - Road Surface	Infra Application Component	n/a	-	-	n/a	-	-	5 min		
Road surface friction coefficient	RLVW	Road Surface Condition	Dynamic	Optional	Infra Data System - Road Surface	Infra Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road Condition Data Applicable Road Map Segments	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System - Road Surface	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time - Begin	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System - Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Road Condition Data Applicable Date and Time - End	RLVW	Road Surface Condition	Dynamic	Required	Infra Data System - Road Surface	Infra Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		

Source: Battelle

Table A-6. Description of Candidate Data Elements for the RLVW Vehicle Systems Message Data Descriptions

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
Vehicle Characteristics															
Vehicle mass	RLVW	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	lb.	100-100000	+/- 25	kg	45-45360	+/- 11.3	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle length	RLVW	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft	0-200	+/- 2	m	0-61	+/-0.6	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle CG Height	RLVW	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	in	0-300	+/- 2	cm	0-7620	+/- 50.8	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Average Deceleration Rate	RLVW	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-32.2	+/- 1	m/s^2	0-9.81	+/- 0.304	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Maximum Deceleration Rate	RLVW	Vehicle Characteristics	Quasi-Static (per vehicle trip)	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-32.2	+/- 1	m/s^2	0-9.81	+/- 0.304	Upon Power On		Assumes Mass, Length and Height are constant during trip, defined as vehicle start up/shut down cycle.
Vehicle Functional Status															
Vehicle Speed Current	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	mph	0-120	+/- 2	km/h	0-194	+/-3.2	10 Hz		
Vehicle acceleration Current	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	ft/s^2	0-50	+/- 2	m/s^2	0-15	+/-0.6	10 Hz		
Brake activation	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Steering wheel angle	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	degrees	(-70)-70	+/- 2	degrees	(-70)-70	+/- 2	10 Hz		
Vehicle traction control	RLVW	Vehicle	Dynamic	Optional	Vehicle Data	Vehicle	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		

Table A-6. Description of Candidate Data Elements for the RLVW Vehicle Systems Message Data Descriptions (Continued)

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
activation		Functional Status			Systems	Application Component									
Antilock brake system activation	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Electronic stability control activation	RLVW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	on/off	n/a	n/a	on/off	n/a	n/a	10 Hz		
Vehicle Environmental Data															
Temperature (Air)	RLVW	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 Hz		Potential for Ice
Rain Sensor Status	RLVW	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4?	n/a	n/a	0,1,2,3,4?	n/a	n/a	1 Hz		Potential for Slippery Roads/Low Visibility
Windshield Wiper Status	RLVW	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4?	n/a	n/a	0,1,2,3,4?	n/a	n/a	1 Hz		Potential for Slippery Roads/Low Visibility
Headlight Status	RLVW	Vehicle Environmental Data	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	0,1,2,3,4?	n/a	n/a	0,1,2,3,4?	n/a	n/a	1 Hz		Potential for Low Visibility

Source: Battelle

Table A-7. Description of Candidate Data Elements for the RLVW Driver Warning Message Data Description

Data Item Description	Application	Type of Data	Static/ Dynamic	Need	Input Source	Output Recipient	Unit of Measure (English)	Valid Range (English)	Accuracy/ Tolerance (English)	Unit of Measure (Metric)	Valid Range (Metric)	Accuracy/ Tolerance (Metric)	Refresh Rate	References	Notes
DVI MUTCD Sign Number	RLVW	RLVW Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	Integer	TBD	NA	Integer	TBD	NA	10 Hz		Determined by MUTCD, Local Policy, and Driver Warning System manufacturer specifications
DVI Graphic	RLVW	RLVW Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	TBD	TBD	NA	TBD	TBD	NA	10 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DVI Text	RLVW	RLVW Driver Warning Message Data	Dynamic	At Least One Required From Group	Vehicle Application Component	Driver Warning System	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	Alpha numeric, upper and lower case	A-Z, a-z, 0-9	NA	10 Hz		Determined by Roadside Signage System manufacturer specifications
DVI Message Valid Time	RLVW	RLVW Driver Warning Message Data	Dynamic	Required	Vehicle Application Component	Driver Warning System	min	0.01 to 1440	+/- 0.01	min	0.01 to 1440	+/- 0.01	10 Hz		Determined by Roadside Signage System manufacturer specifications
DVI Message Priority	RLVW	RLVW Driver Warning Message Data	Dynamic	Required	Vehicle Application Component	Driver Warning System	Integer	TBD	NA	Integer	TBD	NA	10 Hz		Determined by Roadside Signage System manufacturer specifications

Source: Battelle

APPENDIX B. Acronyms and Abbreviations

AAHSTO	American Associated of State Highway and Transportation Officials
CAN	Controller Area Network
ConOps	Concept of Operations
CSW	Curve Speed Warning
DII	Driver-Infrastructure Interface
DMS	Dynamic Message Signs
DoCAN	Diagnostic Communication Over Controller Area Network
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
DVI	Driver-Vehicle Interface
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
GNSS	Global Navigation Satellite Systems
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
MUTCD	Manual on Uniform Traffic Control Devices
NCHRP	National Cooperative Highway Research Program
NTCIP	National Transportation Communications for Intelligent Transportation System Protocol
OEMs	Original Equipment Manufacturers
PRT	Perception Reaction Time
RLVW	Red Light Violation Warning
RSZW/LC	Reduced Speed Zone Warning with Lane Closure
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers
SCP	Signal Control and Prioritization
SOI	System-of-Interest
SPaT	Signal Phase and Timing
SSGA	Stop Sign Gap Assist

SWIW-D	Spot Weather Information Warning – Diversion
SWIW-RS	Spot Weather Information Warning – Reduced Speed
TBD	To Be Determined
TMDD	Traffic Management Data Dictionary
TRB	Transportation Research Board
TSS	Transportation Sensor Systems
U.S. DOT	United States Department of Transportation
UTC	Universal Time, Coordinated
V2I	Vehicle-to-Infrastructure

APPENDIX C. Terms and Definitions

Advisory Message – An informative message to the driver regarding current roadway conditions; less urgent, i.e., not necessarily crash-imminent, than an alert or warning.

Alert – A cautionary message about an anticipated crash scenario and/or vehicle conflict; more urgent than an advisory message, less urgent than a warning.

Connected Vehicle – In the context of this document, refers to the methods, data and technologies used in the bi-directional exchange of information between infrastructure and vehicles for purposes of improving safety, mobility and environmental conditions.

Degraded – Mode of the safety application where it is capable of providing a subset of its intended function(s).

Failure – Mode of the safety application where the safety application is incapable of providing any of its intended function(s).

False Alarm – Situation where the safety application provides an alert/warning to the driver when the conditions to not warrant an alert/warning.

Functional Class of Roadway – The functional class of roadways are defined in FHWA "Functional Classification Guidelines". Revised 1989.

Missed Alarm – Situation where the safety application does not provide an alert/warning to a driver when the conditions warrant an alert/warning.

Non-volatile Storage – Type of storage that remains intact even when there is no power.

Offline – State of the safety application where the safety application is not processing data or providing advisories, alerts and/or warnings.

Online – State of the safety application where the safety application is functioning and providing advisories, alerts and/or warnings.

Operational – Mode of the safety application where the safety application is capable of providing all of its intended function(s).

Perform – To work in a manner to achieve the desired outcome.

Physical Security – Describes measures that are designed to deny access to unauthorized personnel (including attackers or even accidental intruders) from physically accessing a building, facility, resource, or stored information; and guidance on how to design structures to resist potentially hostile acts.[2] Physical security can be as simple as a locked door on a roadside cabinet.

Prohibitive Reference Frame – Indicates when *unsafe* conditions are present, as opposed to "safe" conditions; "unsafe" is much easier to quantify than "safe," indicates the requirement that users also apply their own judgment, and can lessen liability issues as compared to indicating a more definitive 'permissive' notification of when conditions are "safe".

[2] Task Committee; Structural Engineering Institute (1999). *Structural Design for Physical Security*. ASCE. ISBN 978-0-7844-0457-7.

Roadside Configuration Data – Data provided from the infrastructure data equipment or back office that details the lane(s), roadway geometry, and/or map of the area needed by a safety application

Road Weather Information – Data on road and weather conditions that may impact vehicle safety including visibility, wind speed, precipitation, air and road surface temperature, road surface condition, etc.

Roadway Work Zone Configuration Information – Data on work zone configuration elements that may impact vehicle safety including lane shifts, lane reductions, etc.

Roadway Work Zone Operations Information – Data on work zone operational elements that may impact vehicle safety including buffer zones, traffic control setup, temporary pavement markings, temporary traffic barriers, road closures, changed lighting conditions (during night work),etc.

Threshold – A point in both time and/or location, depending on the specific application, that the application would reach a decision point resulting in an action being taken. This action would typically be expected to include alerts and/or warnings issued to the driver, but could also include additional actions.

Vehicle Type – Identification of vehicle role (e.g., ambulance, police cruiser, maintenance vehicle, etc.) as specific class of vehicle satisfies in the surface transportation system. A specific, standardized nomenclature does not exist.

Vehicle Class – One of 13 FHWA designations of motorized vehicles ranging in size from a Class 1 Motorcycle through a Class 13 – Seven or more axle truck.[3]

Vehicle Telematics Data – Data made available from vehicle electronic systems that could be utilized by the connected vehicle in-vehicle application. Examples include vehicle operating speed; operational status of windshield wipers, headlights, etc.; driver application of brakes or accelerator; etc.

Warning – An urgent message for a more immediate, potentially crash imminent scenario and/or vehicle conflict; more urgent than both an advisory message and alert.

[3] Traffic Monitoring Guide, U.S. DOT, May 2001, http://www.fhwa.dot.gov/ohim/tmguide/tmg4.htm#app4c

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