Vehicle-to-Infrastructure (V2I) Safety Applications

Performance Requirements, Vol. 2, Curve Speed Warning (CSW)

www.its.dot.gov/index.htm
Final Report — August 2015
FHWA-JPO-16-249

U.S. Department of Transportation

Produced by Battelle Memorial Institute under DTFH61-12-D-00040
U.S. Department of Transportation
Federal Highway Administration Office of Safety Research and Development

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-JPO-16-249		

4. Title and Subtitle	5. Report Date
Vehicle-to-Infrastructure (V2I) Safety Applications Performance Requirements, Vol. 2, Curve Speed Warning	August 2015
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Denny Stephens, Jeremy Schroeder, Rachel Klein	1000025516-0301-2

9. Performing Organization Name And Address	10. Work Unit No. (TRAIS)
Battelle Memorial Institute 505 King Avenue Columbus, OH 43201	11. Contract or Grant No. DTFH61-12-D-00040

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation FHWA Office of Safety Research and Development Turner-Fairbank Highway Research Center 6300 Georgetown Pike McLean, VA 22101	Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Government Technical Monitor; Gregory Davis, FHWA Office of Safety Research and Development

16. Abstract

This document is the second 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 Curve Speed Warning V2I Safety Application. This application is designed to advise drivers of an upcoming curve and to provide an alert and/or warning when the vehicle's current speed may be too high to safely traverse one or more upcoming curves. The safety applications described here integrate 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. 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.

17. Key Words	18. Distribution Statement
Connected vehicles, Vehicle-to-Infrastructure, V2I, V2I Safety Applications, Curve Speed Warning, CSW	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	74	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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Chapter 1 Scope

1.1 Document Identification

This document is the second 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 Curve Speed Warning V2I safety application. This application is designed to advise drivers of an upcoming curve and to provide an alert and/or warning when the vehicle's current speed may be too high to safely traverse one or more upcoming curves.

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 CSW 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 CSW 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 CSW application.

Appendices:

A. CSW 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 Curve Speed Warning (CSW) 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 Curve Speed Warning (CSW) Application Performance Requirements
  - 3.3.1 CSW Application Introduction and Overview
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    - 3.3.1.4 How the Application Works
    - 3.3.1.5 Application Assumptions
    - 3.3.1.6 Application Swim Lane & Sequence Diagrams
    - 3.3.1.7 Messages Exchanged and Used by the Application
  - 3.3.2 CSW Infrastructure Application Component Requirements
  - 3.3.3 CSW 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).

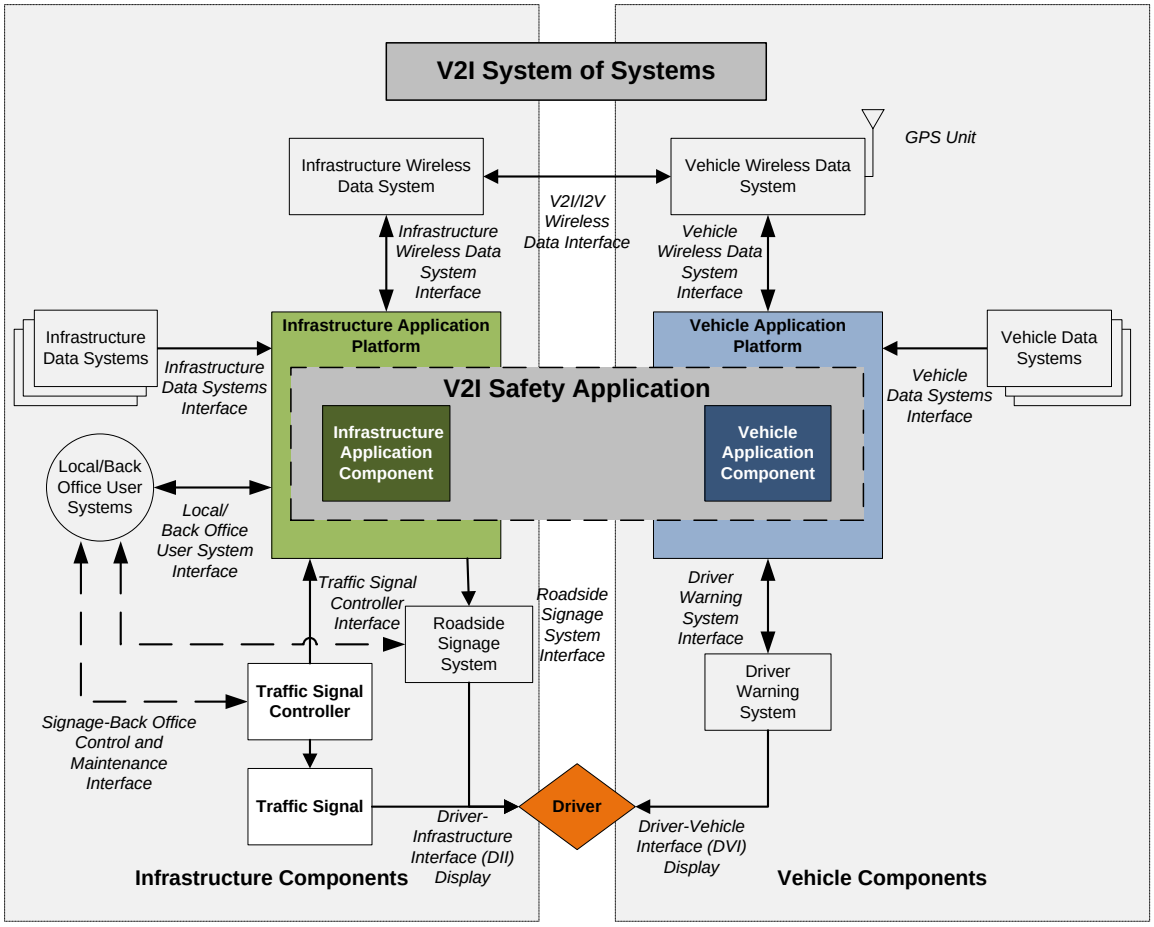
Each of the application components resides and operates on a computing platform that provides the necessary hardware and software data interfaces needed to exchange data with other systems. Each computing platform has an interface for wireless data systems that support with wireless exchange of data 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 Backoffice 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 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 manufacturers' (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 Curve Speed Warning (CSW) Application Performance Requirements

3.3.1 CSW Application Introduction and Overview

Curve Speed Warning – Application designed to advise drivers of an upcoming curve and provide an alert and/or warning to drivers if vehicle's current speed may be too high to safely traverse one or more upcoming curves. The application integrates data from infrastructure- and vehicle-based sensors to determine recommended safe speeds and coordinates roadside and in-vehicle messages to alert and/or warn the driver in time to slow to the recommended safe speed.

3.3.1.1 Application Purpose

The goal of the CSW application is to improve roadway curve safety by reducing run-off-road (ROR) and rollover events in curves by alerting and/or warning drivers in advance if their vehicle speeds exceed a recommended safe threshold for an approaching curve or series of curves. The application uses both infrastructure- and vehicle-based sensor data, to recommend safe curve speeds. Recommendations are based upon available curve geometry, real-time road and weather conditions, and vehicle dynamics and stability telematics data. The application coordinates roadside messages for all vehicles with in-vehicle, vehicle-specific advisories, alerts, and warnings to notify drivers in time for them to slow to the recommended safe speed before entering the curve.

3.3.1.2 Safety Impacts of the Application

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

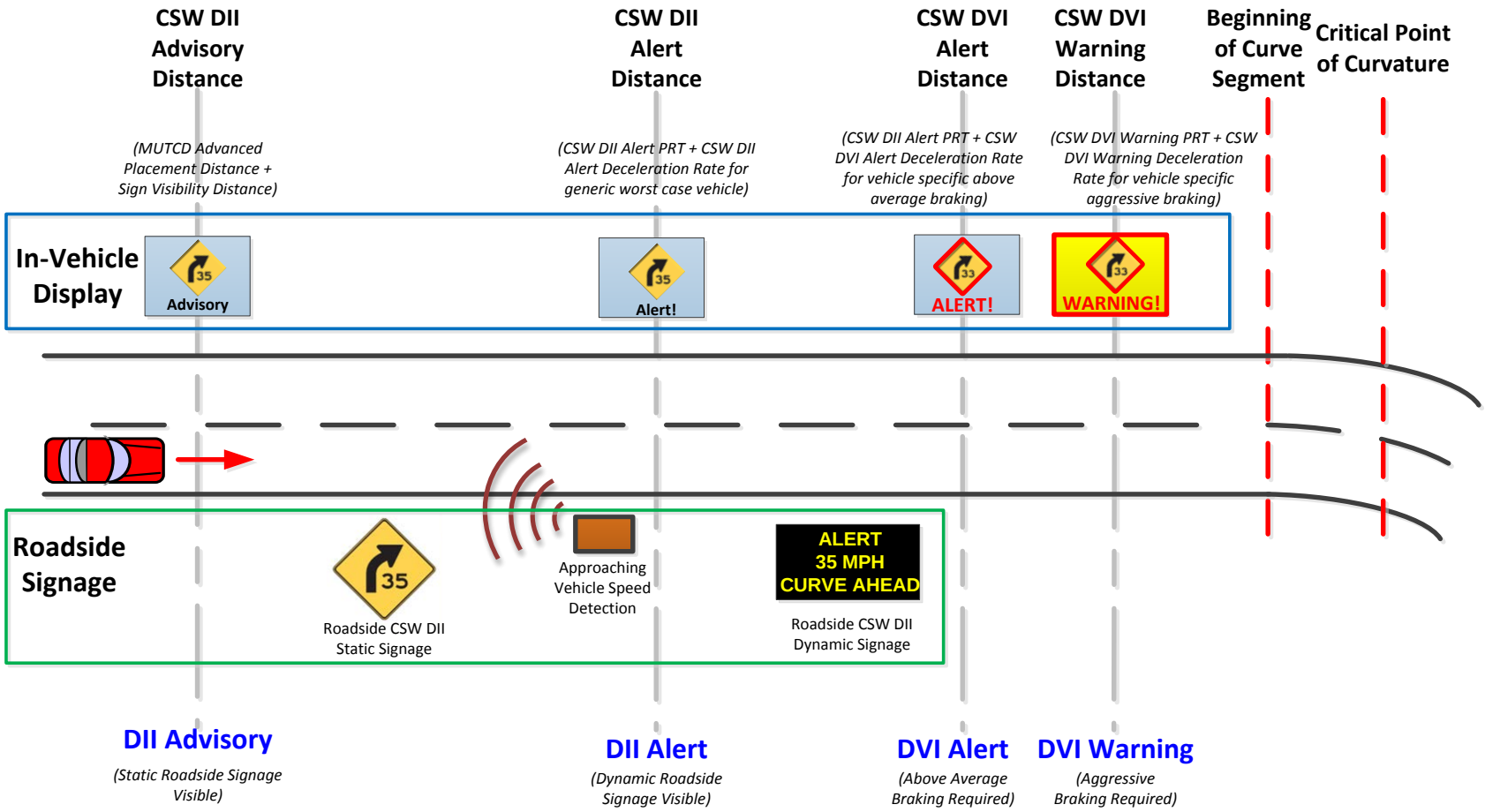
- ***Real-Time Messaging:*** The greatest impact is that drivers will receive real-time alerts and warnings while driving based on their current driving conditions.
- ***Reduction in Curve Speed Related Incidents:*** The CSW application should result in safer trips with fewer incidents on roadway curves.
- ***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 traverse a curve.
- ***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 run-off-road and vehicle roll-over incidents due to excessive curve speed:*** CSW aids drivers by preventing a single vehicle from speeding around a curve and potentially losing vehicle stability. The application will provide messages to the driver regarding safe curve speeds based on current roadway conditions.
- ***Increases driver awareness of approaching curve attributes:*** Unlike current CSW applications, which largely provide a standard static warning based on radar-detected speeds via the roadside infrastructure, the connected vehicle application provides a real-time alert and warning based on the driver's current driving conditions, unique to the driver and his or her vehicle. The application also includes the capability of capturing specific curve geometries and road conditions in real time via roadside equipment. The CSW application is functional for all types of curves, whether the curve is part of the roadway design or whether the road diverges into different paths and the driver selects the curved pathway (e.g., exit ramp).
- ***Provides real-time calculation of safe curve speed based on current conditions:*** CSW allows for the real-time calculation of a safe curve speed, based upon current road and weather conditions along with other vehicle telematics data to calculate a more accurate safe speed (as compared to current CSW applications). The application is also capable of providing a warning within sufficient time for the driver to receive and react to it. The application is designed to provide an advisory message of the upcoming curve if an alert or warning is applicable to assure driver awareness of the curve.

3.3.1.4 How the Application Works

The objective of CSW V2I Application is to deliver coordinated infrastructure- and vehicle-based advisories, alerts, and warnings that notify the driver of potentially unsafe vehicle speeds in sufficient time to slow the vehicle to recommended safe speeds. Figure 3-2 below illustrates the key concepts and integration of roadway and in-vehicle signage. The figure shows the vehicle approaching the entrance to a potentially hazardous curve. The box below the roadway illustrates roadside signage displayed to the driver. The driver first encounters static (or fixed) curve speed signage advising the driver of an impending curve and a recommended safe speed for all vehicles. Driver Infrastructure Interface (DII) signage may include a geometric representation of the curve, a warning message, and/or an advisory speed limit such as that shown in Figure 3-3. The location of this sign in advance of the curve is defined by the MUTCD advanced placement distance in Table 2.5C. Subsequently, the driver encounters a roadside speed detection device and a DII dynamic message sign (DMS). DMS messages are typically text based, as illustrated in Figure 3-4, but may contain graphics. If the speed of the subject or any nearby vehicle exceeds a "DII Alert Speed" (generic safe vehicle speed) threshold for all vehicles, the DMS displays a DII Alert, such as flashing or some other accepted means of capturing the driver's attention. The CSW Infrastructure Application component delivers these roadside advisory and alert messages to the driver, based upon infrastructure-based sensor systems. The DII Alert Speed for all vehicles, defined below, may be conditional based upon available weather or road surface conditions where data are available from the infrastructure. Infrastructure-based signage and messaging is generic, intended for display to all drivers. While intended for all drivers, DII messages may be targeted for specific vehicle classes, such as commercial trucks, and include appropriate language to identify target vehicles.



Not to Scale

Source: Battelle

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

Source: MUTCD 2009 Ed.

Figure 3-3. Example of Horizontal Alignment Signs and Plaques

Source: Caltrans

Figure 3-4. Example of Dynamic Message Sign Alert

The box above the vehicle and road in the Figure 3-2, illustrates the coordinated in-vehicle CSW signage. This illustration assumes the vehicle includes a graphical Driver Vehicle Interface (DVI) display. As the vehicle approaches the curve, the CSW Vehicle Application Component receives a wireless message from the infrastructure containing infrastructure-based sensor data and collects applicable dynamics and stability data from the vehicle. The CSW Vehicle Application Component computes the CSW DVI Alert Speed (or vehicle-specific safe curve speed), using both infrastructure-based sensor data and vehicle-based sensor data. This speed may be above or below the infrastructure-based CSW DII Alert Speed. For example, a truck carrying an unusual load with a high center of gravity and high rollover potential may have a lower vehicle-specific safe curve speed than the generic safe curve speed computed by the infrastructure. In contrast, a sports car under good road surface conditions may have a safe curve speed well above the posted infrastructure based curve speed. The lesser of the (generic) CSW DII Alert Speed or the (vehicle specific) CSW DVI Alert Speed is used as the basis for in-vehicle alerts and warnings.

At approximately the same time that a driver would observe the static roadside advisory sign, the DVI displays a CSW speed advisory, containing the lesser of the CSW DVI Alert Speed or the CSW DII Alert Speed. (The distance at which the CSW Advisory is displayed in the vehicle in advance of the curve is the MUTCD “Sign Visibility Distance” plus the MUTCD Advanced placement Distance in Table 2.5C). If no alerts or warnings are warranted subsequently, the DVI continues to display the CSW speed advisory continuously, until the vehicle exits the curve or series of curves.

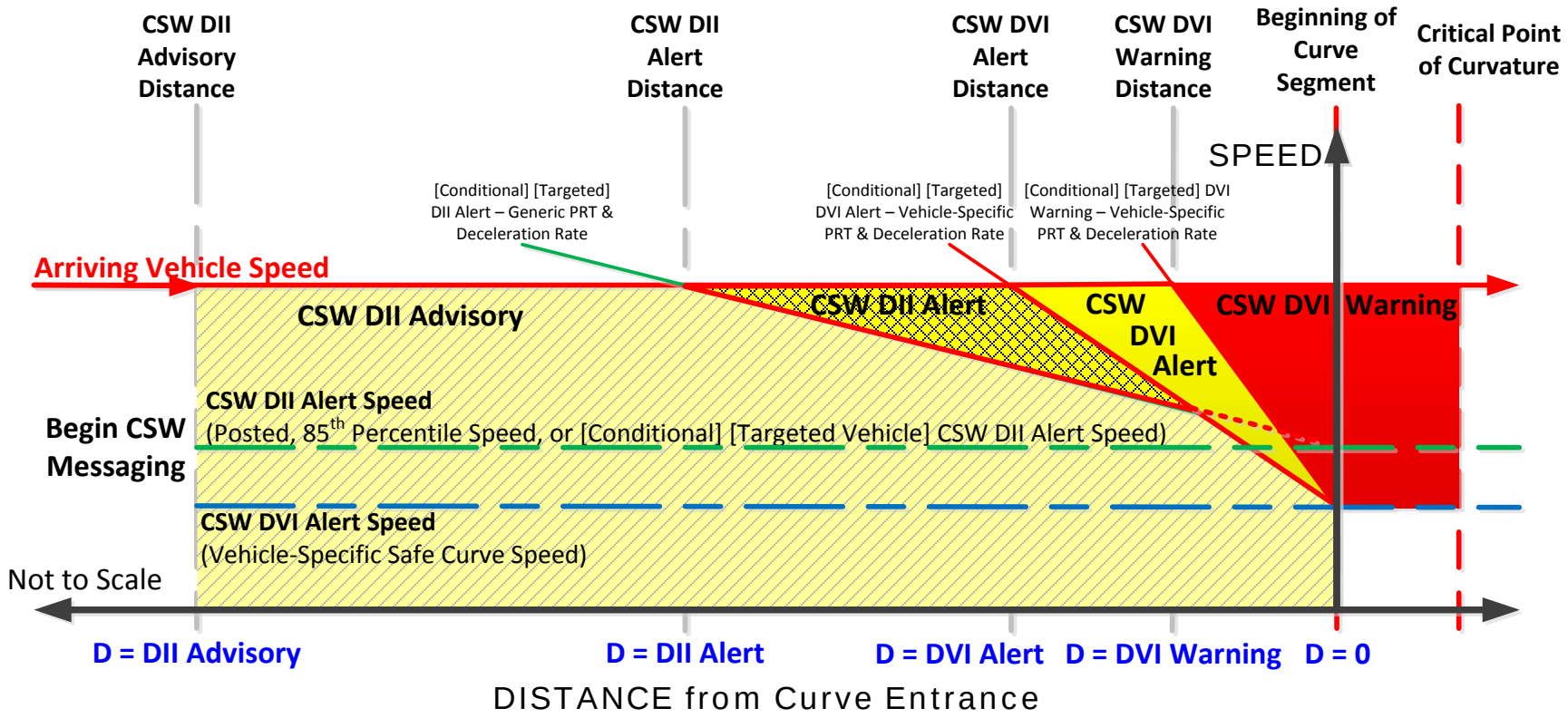
If the vehicle proceeds toward the curve entrance above the advisory speed, the CSW Vehicle Application Component computes and continuously updates the DVI Alert Distance and the DVI Warning Distance for its current speed. The DVI Alert Distance is a distance at which *above average braking* is required to achieve the DVI Alert Speed at the entrance to the curve. The DVI Warning Distance is the distance at which *aggressive braking* is required to achieve the DVI Alert Speed at the entrance to the curve. 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.

If the vehicle approaches the curve above the CSW DVI Alert Speed, a DVI Alert is issued when the distance to the curve entrance is below the CSW DVI Alert Distance, for its given speed. If the vehicle continues above the CSW DII Alert Speed, a CSW DVI Warning is issued when its distance to the curve entrance is below the DVI Warning Distance for its current speed. The warning continues until the vehicle exits the curve. If the vehicle decelerates to the CSW DII Alert Speed before the Alert or Warning Distance thresholds are crossed, no DVI alerts or warnings are issued. As noted earlier, a CSW Advisory is displayed by default.

Figure 3-2 illustrates advisories, alerts and warnings displayed within the vehicle as a function of vehicle speed and distance from the entrance to the curve. It also illustrates how the DII Alert Distance, the DVI Alert Distance and the DVI Warning Distance are functions of perception reaction time and vehicle deceleration rates. (The CSW DII Alert Distance is the distance at which *above average braking* is required by a *generic worst case vehicle* to achieve the DII Alert Speed at the entrance to the curve.)

The DII Alert Speed, DII Alert PRT and DII Alert Deceleration Rate (for generic worst case vehicles) are supplied to the vehicle application component by the infrastructure. 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 CSW advisories, alerts and warnings. Table 3-2 provides a tabular summary of the DII and DVI display criteria, display signage and their distances from the curve entrance.



Source: Battelle

Figure 3-5. Illustration of In-vehicle Signage as a Function of Vehicle Speed and Distance from Curve Entrance.

Table 3-1. Definition of CSW Terms

CSW DII Alert Speed	Generic, infrastructure-based recommendation for speed at which curve can be traversed safely. May be the posted speed, the 85th Percentile Speed[2], a conditional speed based upon weather or road surface conditions, or may be targeted speed for specific vehicles.
CSW DVI Alert Speed	Vehicle specific recommendation for speed at which the subject vehicle can traverse the curve safely. Based upon both infrastructure and vehicle data. May be conditional, based upon weather or road surface conditions.
CSW DII Advisory	Informative signage indicating a potentially hazardous curve ahead
CSW DII Alert	Dynamic signage indicating the speed of an approaching vehicle is above the CSW DII Alert Speed and a generic worst case vehicle must apply above average braking to achieve the DII Alert speed at the entrance to the curve.
CSW DII Alert Distance	Generic, infrastructure-based recommendation for distance at which to display CSW DII Alert in the vehicle DVI. Distance at which above average braking is required by a generic worst case vehicle to achieve the DII Alert Speed at the entrance to the curve. Dependent upon CSW DII Alert PRT, CSW DII Alert Deceleration Rate, and current environmental conditions.
CSW DII Alert PRT	Generic, infrastructure-based recommendation for Perception Reaction Time used in computing DII Alert Distance.
CSW DII Alert Deceleration Rate	Generic, infrastructure-based recommendation for vehicle deceleration rate used in computing DII Alert Distance.
CSW DVI Alert	In vehicle display indicating the subject vehicle must apply above average braking to achieve the DVI Alert Speed at the entrance to the curve.
CSW DVI Alert Distance	Vehicle specific recommendation for distance at which to display CSW DVI Alert. Distance at which above average braking is required by the subject vehicle to achieve the DVI Alert Speed at the entrance to the curve. Dependent upon vehicle specific CSW DVI Alert PRT, CSW DVI Alert Deceleration Rate, and current environmental conditions.
CSW DVI Alert PRT	Vehicle specific recommendation for Perception Reaction Time used in computing DVI Alert Distance.
CSW DVI Alert Deceleration Rate	Vehicle specific recommendation for vehicle deceleration rate used in computing DVI Alert Distance.
CSW DVI Warning	In vehicle display indicating the subject vehicle must apply above aggressive braking to achieve the DVI Alert Speed at the entrance to the curve.
CSW DVI Warning Distance	Vehicle specific recommendation for distance at which to display CSW DVI Warning. Distance at which aggressive braking is required by the subject vehicle to achieve the DVI Alert Speed at the entrance to the curve. Dependent upon vehicle specific CSW DVI Warning PRT, CSW DVI Warning Deceleration Rate and current environmental conditions.
CSW DVI Warning PRT	Vehicle specific recommendation for Perception Reaction Time used in computing DVI Alert Distance.
CSW DVI Warning Deceleration Rate	Vehicle specific recommendation for vehicle deceleration rate used in computing DVI Alert Distance.

Source: Battelle

[2] Manual on Uniform Traffic Control Devices (MUTCD) for Streets and Highways, 2009 edition, Federal Highway Administration, http://mutcd.fhwa.dot.gov/.

Table 3-2. Summary of CSW Infrastructure and Vehicle Displays

	Driver Infrastructure Interface			Driver Vehicle Interface		
	Display Criterion	**Display Signage**	**Distance from Entrance**	**Display Criterion**	**Display Signage***	**Distance from Entrance**
Stage 1 Advisory	Approaching Curve Reduced Speed Zone	All vehicle Advisory to reduce speed to CSW DII Alert Speed	MUTCD Advanced Placement Distance	Received CSW I2V Wireless Message	If CSW DVI Alert Speed is less than CSW DII Alert Speed then display Vehicle-specific Advisory to reduce speed to CSW DVI Alert Speed; otherwise display all vehicle Advisory to reduce speed to the CSW DII Alert Speed prior to entering the curve.	MUTCD Advanced Placement Distance + Sign Visibility Distance
Stage 2a Infrastructure Alert	Infrastructure detected speed of an approaching vehicle is above the CSW DII Alert Speed and a worst case vehicle must apply above average braking to achieve CSW DII Alert speed prior to entering the curve.	All vehicle Alert to reduce speed to the CSW DII Alert Speed prior to entering the curve.	MUTCD Advanced Placement Distance B	Received CSW I2V Wireless Message indicating infrastructure detected speed of approaching vehicle is above the CSW DII Alert Speed and a worst case vehicle must apply above average braking to achieve CSW DII Alert speed prior to entering the curve.	All vehicle Alert to reduce speed to the CSW DII Alert Speed prior to entering the curve.	Distance at which above average braking is required by a worst case vehicle to achieve the CSW DII Alert Speed prior to entering the curve.
Stage 2b Vehicle Specific Alert	N/A	N/A	N/A	Speed of the subject vehicle is above the CSW DVI Alert Speed and the vehicle must apply above average braking to achieve the CSW DVI Alert speed prior to entering the curve.	Vehicle-specific Alert to reduce speed to CSW DVI Alert Speed prior to entering the curve.	Distance at which above average braking is required by subject vehicle to achieve the CSW DVI Alert Speed prior to entering the curve.
Stage 3 Vehicle Specific Warning	N/A	N/A	N/A	Speed of subject vehicle is above the CSW DVI Alert Speed and the vehicle must apply aggressive braking to achieve the CSW DVI Alert Speed prior to entering the curve.	Vehicle Specific Alert to Reduce Speed to CSW DVI Alert Speed prior to entering the curve	Distance at which above aggressive braking is required by subject vehicle to achieve the CSW DVI Alert Speed prior to entering the curve.

* If applicable, DVI displays Stage 3 Vehicle Specific warning; otherwise if applicable, DVI displays Stage 2b Vehicle-specific Alert; otherwise if applicable DVI displays Stage 2a Infrastructure Alert; otherwise if applicable, DVI displays Vehicle-specific Advisory (DVI Alert Speed); otherwise, DVI displays all vehicle Advisory (DII Alert Speed).

Source: Battelle

3.3.1.5 Application Assumptions

Assumptions

- The vehicle is driving along a route equipped with a CSW application.
- The vehicle is en route to a destination requiring it to traverse a stretch of roadway with curve(s). This stretch of roadway may be part of the roadway design and unavoidable, or it may be part of a roadway that diverges into different paths, in which the driver selects the non-primary pathway (e.g., an exit ramp, a fork in a two-lane rural road).
- The CSW application might be used in conjunction with other connected vehicle applications.
- In the case of an equipped vehicle, if any data element is unavailable for calculating an appropriate speed, a previously determined default value will be used by the application to compute a safe speed.

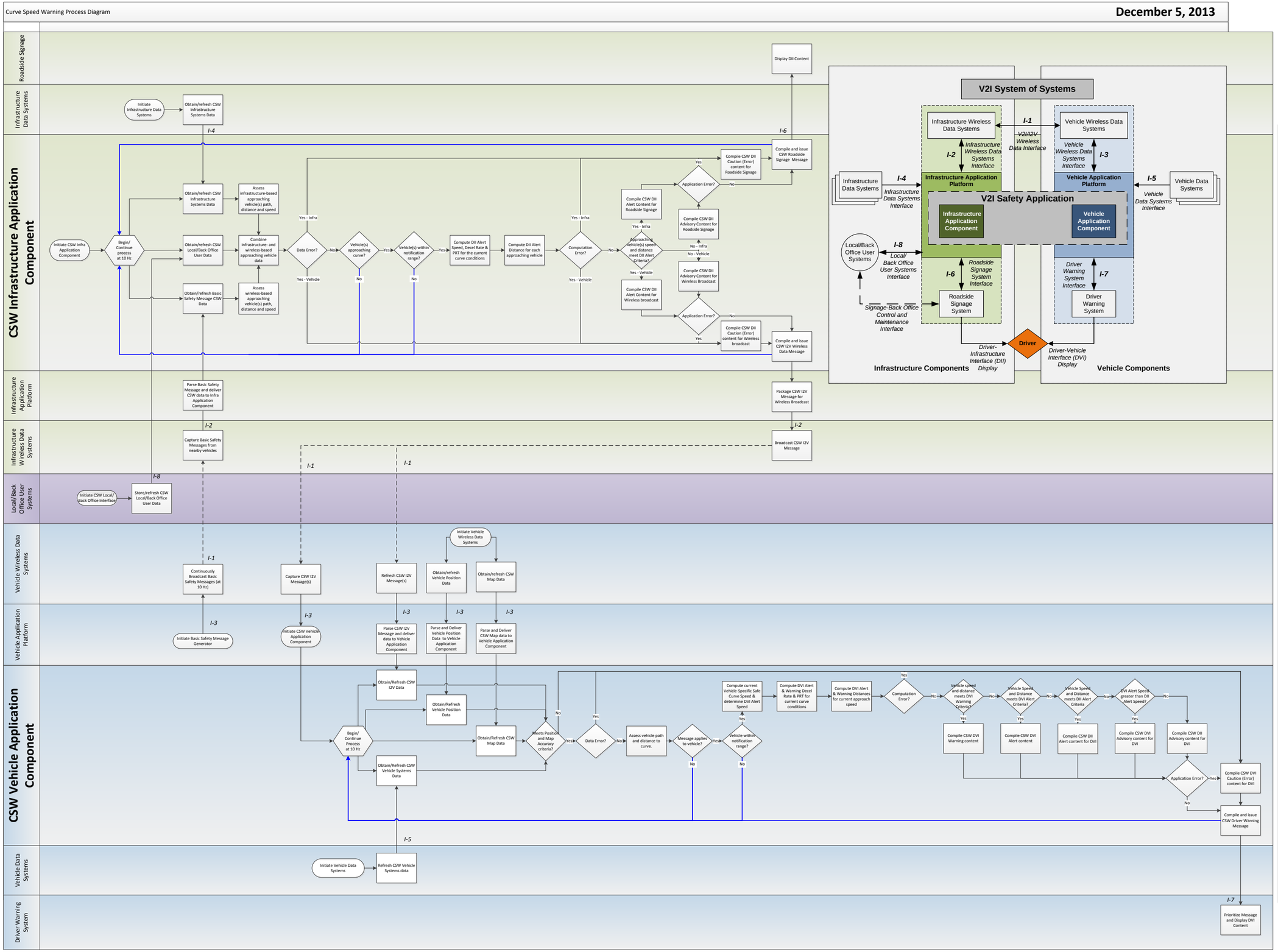
Considerations

The CSW system is intended to warn the equipped vehicle only about imminent curve-related dangers. The system does not account for other drivers on the roadway or their driving behavior.

3.3.1.6 Application Swim Lane & Sequence Diagrams

As the next step in the description of the CSW Application, Figure 3-6 provides a swim-lane process diagram for the curve speed warning application illustrating the sequence of data flows and processing by the CSW Infrastructure Application Component and the CSW Vehicle Application Component. The figure includes the V2I Systems architecture diagram presented earlier for reference.

At a high level, the CSW Infrastructure Application Component obtains infrastructure, local/back office and vehicle data inputs, determines if an advisory, alert or warning is warranted, and, if so, issues a CSW Roadside Signage Message to the Roadside Signage System for display and a CSW I2V Wireless Data Message to the Infrastructure Wireless Data System for broadcast to nearby vehicles. Upon receipt of a CSW I2V Wireless Data Message, the Vehicle Application Platform initiates the CSW Vehicle Application Component. The CSW Vehicle Application Component obtains I2V, position and map data inputs, determines if a driver alert or warning is warranted and, if so, issues a CSW Driver Warning Message to the Driver Warning System. These processes are performed at a rate of 10 Hz to update CSW Roadside Signage Message and the CSW Driver Warning Message to drivers whose vehicles are rapidly approaching the curve and may be rapidly changing speed. This diagram illustrates the concepts that are the basis for CSW application performance requirements.



Source: Battelle

Figure 3-6. CSW Application Swim-lane Process Diagram

3.3.1.7 Messages Exchanged and Used by the Application

For the purposes of these requirements, the data exchanged between system components, across system interfaces are encapsulated in ten 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 CSW 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 CSW Application Components

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
Infrastructure Component Messages					
CSW Infrastructure Systems Message	External Vehicle Detection System, Infra Data System – Road Surface, Infra Data System – Local Weather	Infra Application Component	Detection of approaching vehicles and their speed, road surface conditions, local weather conditions	Table A-2 CSW Infrastructure Systems Message Data Description	Used as input by CSW Infrastructure Application Component to determine if vehicles are approaching the curve and the generic safe curve speed. Road surface and weather data are forwarded to the Vehicle Application Component through the CSW I2V Wireless Message
CSW Roadside Signage Message	Infra Application Component	Roadside Signage System	CSW Roadside Signage message content	Table A-3 CSW Roadside Signage Message Data Description	CSW message content to be displayed on dynamic roadside signage.
CSW Infrastructure Map Message	Local-Back Office Users Systems Interface	Infrastructure Map Message Handler	Detailed Curve Map, Local signage (type and location)	Table A-4 CSW Map Message Data Description	Curve map, type and location of fixed and variable signage. May be uploaded through an externally generated data file.
V2I/I2V Messages					
Basic Safety Message	Vehicle Basic Safety Message Generator	Infrastructure Application Component	Vehicle location, speed and heading	SAE J2735 Basic Safety Message	Data used by Infrastructure Application Component to determine if vehicles are approaching curve and, if so, their speed.
CSW I2V Wireless Message	Infra Application Component	Vehicle Application Component	Curve Geometry, CSW Operational Data, Road Surface Condition, Local Weather Data, CSW Roadside Signage Data	Table A-5 CSW I2V Wireless Message Data Description	Data used by vehicle application component to determine vehicle-specific safe curve speed and content and distance at which to issue advisories, alerts and warnings.

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

Message	Input Source	Output Recipient	Content Utilized	Data Description	Purpose
CSW Wireless Map Message	Infrastructure Map Message Handler	Vehicle Application Component	Detailed map of curve	Table A-4 CSW Map Message Data Description	Used as input by CSW Vehicle Application Component to determine if subject vehicle is approaching the curve and the vehicle-specific safe curve speed.
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 CSW Vehicle Application Component to determine vehicle position, speed and heading to determine if and when to issue advisories, alerts, or warnings.
CSW Vehicle Systems Message	Vehicle Data Systems	Vehicle Application Component	Vehicle Characteristics, Vehicle Functional Status, Vehicle Environmental Data	Table A-6 CSW Vehicle Systems Message Data Description	Used as input by CSW Vehicle Application Component to determine the vehicle-specific safe curve speed.
CSW Driver Warning Message	Vehicle Application Component	Driver Warning System	CSW in-vehicle message content	Table A-7 CSW Driver Warning Message Data Description	CSW message content to be displayed on in-vehicle displays.

Source: Battelle

3.3.2 CSW Infrastructure Application Component Requirements

Table 3-4 catalogs the performance requirements for the CSW 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. CSW Infrastructure Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
2.01	**CSW Infrastructure Application Component Requirements**			
2.01.01	**CSW Infrastructure Application Component Interfaces and Interface Specifications**			
[2.01.01.01]	**CSW Infrastructure Systems Message Interface**	**The CSW Infrastructure Application Component shall obtain CSW Infrastructure Systems Messages through the Infrastructure Data Systems Interface.**		D
[2.01.01.02]	**Basic Safety Message Interface**	**The CSW Infrastructure Application Component shall obtain Basic Safety Messages through the Infrastructure Wireless Data Systems Interface.**		D
[2.01.01.03]	**CSW Local/Back Office User Data Interface**	**The CSW Infrastructure Application Component shall obtain CSW Local/Back Office User Data through the Local/Back Office User Systems Interface.**		D
[2.01.01.04]	**CSW I2V Wireless Message Interface**	**The CSW Infrastructure Application Component shall issue CSW I2V Wireless Messages through the Infrastructure Wireless Data Systems Interface.**		D
[2.01.01.05]	**CSW Roadside Signage Message Interface**	**The CSW Infrastructure Application Component shall issue CSW Roadside Signage Messages through the Roadside Signage System Interface.**		D
2.01.02	**CSW Infrastructure Application Component Functional Requirements**			
[2.01.02.01]	**Common Infrastructure Application Component Requirements**	**The CSW Infrastructure Application Component shall adhere to Common Infrastructure Application Component Requirements.**		D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.02]	**CSW Infrastructure Systems Message Initiation**	**The CSW Infrastructure Application Component shall obtain CSW Infrastructure Systems Messages upon initiation of the component.**		D
[2.01.02.03]	**CSW Infrastructure Systems Data – Vehicle Speed**	**The CSW Infrastructure Application component shall obtain speed and distance of approaching vehicles from Infrastructure Data Systems before the vehicles are within the CSW DII Advisory Distance of the curve entrance.**	*The CSW DII Advisory Distance is the distance from the beginning of the curve segment defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.* *The CSW Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D
[2.01.02.04]	**CSW Infrastructure Systems Message Refresh Rate**	**The CSW Infrastructure Application Component shall refresh the CSW Infrastructure Systems Message at a configurable frequency.**	*Table A-2, CSW Infrastructure Systems Message Data Description is referenced for guidance.*	D
[2.01.02.05]	**Basic Safety Message Initiation**	**The CSW Infrastructure Application Component shall obtain Basic Safety Messages upon initiation of the component.**	*The CSW Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.06]	**Basic Safety Message Vehicle Speed**	**The CSW Infrastructure Application component shall obtain speed and distance of approaching vehicles from Basic Safety Messages before the vehicles are within the CSW DII Advisory Distance of the curve entrance.**	*The CSW DII Advisory Distance is the distance from the beginning of the curve segment defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.* *The CSW Infrastructure Application component does not correlate connected vehicle and infrastructure data. It processes each independently and issues advisories or alerts if any vehicle meets the relevant criteria.*	D
[2.01.02.07]	**Basic Safety Message Refresh Rate**	**The CSW Infrastructure Application Component shall refresh Basic Safety Messages at a configurable frequency.**		D
[2.01.02.08]	**CSW Local/Back Office User Data Initiation**	**The CSW Infrastructure Application Component shall obtain CSW Local/Back Office User Data upon initiation of the component.**		D
[2.01.02.09]	**GPS Position Accuracy**	**GPS Position data used by the CSW 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
[2.01.02.10]	**CSW Local/Back Office User Data Refresh Rate**	**The CSW Infrastructure Application Component shall refresh CSW Local/Back Office User Data at a configurable frequency.**		D
[2.01.02.11]	**Map Data Accuracy**	**Map data used by CSW 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

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.12]	**Map Data Accuracy**	**Map data used by the CSW 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
[2.01.02.13]	**Approaching Vehicle Characterization**	**The CSW Infrastructure Application Component shall assess CSW Infrastructure Data and CSW Vehicle Data and determine if vehicle(s) are approaching the curve entrance(s), and, if so, the distance and approaching speed of each.**		D
[2.01.02.14]	**Compute [Conditional] [Targeted] CSW DII Alert Speed**	**If the CSW DII advisories and CSW DII alerts are conditional (e.g. based upon weather or road conditions) and/or targeted (e.g. for specific vehicle classes) the CSW Infrastructure Application Component shall compute the [Conditional] [Targeted] CSW DII Alert Speed for the specified class of vehicles using current available CSW Infrastructure Data.**	*The CSW Infrastructure Application Component shall consider other applicable criteria identified in industry standards and local policy such as time of day and weather conditions.* *The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D
[2.01.02.15]	**Compute [Conditional] [Targeted] CSW DII Alert Deceleration Rates**	**If the CSW DII advisories and CSW DII alerts are conditional (e.g. based upon weather or road conditions) and/or targeted (e.g. for specific vehicle classes) the CSW Infrastructure Application Component shall compute the [Conditional] [Targeted] CSW DII Alert Deceleration Rate for the specified class of vehicles using current available CSW Infrastructure Data.**	*The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.16]	**Compute [Conditional] [Targeted] CSW DII Alert Perception Reaction Time**	**If the CSW DII advisories and CSW DII alerts are conditional (e.g. based upon weather or road conditions) and/or targeted (e.g. for specific vehicle classes) the CSW Infrastructure Application Component shall compute the [Conditional] [Targeted] CSW DII Alert Perception Reaction Time for the specified class of vehicles using current available CSW Infrastructure Data.**	*The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D
[2.01.02.17]	**Determine CSW DII Alert Speed**	**The CSW Infrastructure Application Component shall determine the CSW DII Alert Speed based on real-time conditions, (e.g. the posted speed, the 85th percentile speed or the [Conditional] [Targeted] CSW DII Alert Speed) for the specified curve.**	*The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D
[2.01.02.18]	**Determine CSW DII Alert Deceleration Rate**	**The CSW Infrastructure Application Component shall determine the CSW DII Alert Deceleration Rate based on real-time conditions, (e.g. the posted speed, the 85th percentile speed or the [Conditional] [Targeted] CSW DII Alert Speed) for the specified curve.**	*The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D
[2.01.02.19]	**Determine CSW DII Alert Perception Reaction Time**	**The CSW Infrastructure Application Component shall determine the CSW DII Alert Perception Reaction Time based on real-time conditions, (e.g. the posted speed, the 85th percentile speed or the [Conditional] [Targeted] CSW DII Alert Speed) for the specified curve.**	*The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.20]	**CSW DII Advisory Distance Definition**	**The CSW DII Advisory Distance shall be the distance from the beginning of the curve segment defined in the MUTCD Table 2C-4, Guidelines for Advance Placement of Warning Signs plus the sign visibility distance.**	*The DII Advisory Distance is typically static, defined by the MUTCD Table 2C-4.* *The National Cooperative Highway Research Program (NCHRP) Report 600A "Human Factors Guidelines for Road Systems" is referenced for guidance.*	D
[2.01.02.21]	**CSW DII Alert Distance Definition**	**The CSW DII Alert Distance shall be the distance traveled during the CSW DII Alert Perception Reaction Time plus the distance required to slow the detected vehicle from its measured speed to the CSW DII Alert Speed, at a uniform deceleration equal to the CSW DII 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
[2.01.02.22]	**Compute CSW DII Advisory Distance**	**The CSW Infrastructure Application Component shall determine the CSW DII Advisory Distance based upon MUTCD guidelines.**		D
[2.01.02.23]	**Compute CSW DII Alert Distance**	**The CSW Infrastructure Application Component shall compute the CSW DII Alert Distance for each approaching vehicle using the CSW DII Alert Speed, the CSW Alert Deceleration Rate and the CSW DII Alert Perception Reaction Time.**		D
[2.01.02.24]	**CSW DII Content General**	**CSW DII content shall use a prohibitive frame for all driver messages, indicating when conditions may be unsafe.**	*CSW DII content must not indicate that conditions are safe.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.25]	**CSW DII Alert Criterion for Roadside Signage**	**If the distance of any approaching vehicle is less than its CSW DII Alert Distance then the CSW Infrastructure Application Component shall issue a CSW Roadside Signage Message containing a current CSW DII Alert to the Roadside Signage System Interface.**	*The DII Alert Distance is negative when vehicle speeds are below the DII Alert Speed, such that no alert is issued.*	D
[2.01.02.26]	**CSW DII Advisory Criterion for Roadside Signage**	**If the distance of any approaching vehicle is less than the CSW DII Advisory Distance and greater than or equal to its CSW DII Alert Distance then the CSW Infrastructure Application Component shall issue a CSW Roadside Signage Message containing a current CSW DII Advisory to the Roadside Signage System Interface.**	*A DII Advisory message is issued to Roadside Signage Systems and Wireless Data Systems when a vehicle is within sight of an advisory sign (static).* *Assumption: Application includes one static advisory sign and one DMS sign (which, when on, flashes either an advisory or an alert)*	D
[2.01.02.27]	**CSW Roadside Signage Message Output Frequency**	**The CSW Roadside Signage Message shall be issued at a configurable frequency.**		D
[2.01.02.28]	**CSW DII Alert Criterion for I2V Message**	**If the distance of any approaching vehicle is less than its CSW DII Alert Distance then the CSW Infrastructure Application Component shall issue a CSW I2V Message containing a current CSW DII Alert to the Infrastructure Wireless Data Systems Interface.**	*The DII Alert Distance is negative when vehicle speeds are below the DII Alert Speed, such that no alert is issued.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.02.29]	**CSW DII Advisory Criterion for I2V Message**	**If the distance of any approaching vehicle is less than the CSW DII Advisory Distance and greater than or equal to its CSW DII Alert Distance then the CSW Infrastructure Application Component shall issue a CSW I2V Message containing a current CSW DII Advisory and the CSW DII Alert Speed to the Infrastructure Wireless Data Systems Interface.**	*A DII Advisory message is issued to Roadside Signage and Wireless Data when a vehicle is within sight of a caution advisory sign (static).*	D
[2.01.02.30]	**CSW I2V Wireless Message Output Frequency**	**The CSW I2V Wireless Message shall be issued at a configurable frequency.**		D
[2.01.02.31]	**CSW Infrastructure Application Component Caution (Error) Message for Roadside Signage Criterion**	**In the event of an input data, computational or other recoverable CSW Infrastructure Application Component error, preventing issuing of CSW DII advisories, or CSW DII alerts, the CSW Infrastructure Application Component shall issue a CSW Roadside Signage Message containing a CSW DII Caution (Error) and an indication of CSW Infrastructure Application Component Error to the Roadside Signage System Interface.**	*Caution message is displayed when denoting an error.*	D
[2.01.02.32]	**CSW Infrastructure Application Component Caution (Error) Criterion for I2V Message**	**In the event of an input data, computational or other recoverable CSW Infrastructure Application Component error, preventing issuing of CSW DII advisories, or CSW DII alerts, the CSW Infrastructure Application Component shall issue a CSW I2V Message containing a CSW DII Caution (Error) and an indication of CSW Infrastructure Application Component Error to the Infrastructure Wireless Data Systems Interface.**	*Caution message is displayed when denoting an error.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
2.01.03	**CSW Infrastructure Application Component Data Input Requirements**			
[2.01.03.01]	**CSW Infrastructure Systems Message Content**	**The CSW Infrastructure Systems Message shall contain data required to perform the calculations specified under CSW Infrastructure Application Functional Requirements.**	*Table A-2, CSW Infrastructure Systems Message Data Description is referenced for guidance.*	D
[2.01.03.02]	**CSW Infrastructure Systems Message Specification for Vehicle Speed Sensors**	**The CSW Infrastructure Systems Message for capturing data from local Infrastructure-based Vehicle Speed Sensor Systems shall conform to NTCIP 1209 v02 Object Definitions for Transportation Sensor Systems (TSS).**		D
[2.01.03.03]	**CSW Infrastructure Systems Message Specification for Environmental Sensor Stations**	**The CSW Infrastructure Systems Message for capturing data from local ESS Interface shall conform to NTCIP 1204 v03 Object Definitions for Environmental Sensor Stations (ESS) Standard.**		D
[2.01.03.04]	**Basic Safety Message Specification**	**The Basic Safety Message messages shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary**		D
[2.01.03.05]	**CSW Local/Back Office User Data Content**	**The CSW Local/Back Office User Data shall contain data required to perform the calculations specified under CSW Infrastructure Application Functional Requirements.**		D
[2.01.03.06]	**CSW Local/Back Office User Data Specifications**	**The CSW 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

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.03.07]	**CSW Local/Back Office User Data Content Text**	**The CSW Local/Back Office User Data shall contain text used in CSW DII Advisory and CSW DII Alert roadway signage.**		D
[2.01.03.08]	**CSW Local/Back Office User Data Content Prohibitive Frame**	**CSW DII advisory and CSW DII alert text shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and DII alert messages shall not indicate that conditions may be safe.*	D
[2.01.03.09]	**CSW Local/Back Office User Data Content Graphics**	**The CSW Local/Back Office User Data shall contain shapes and graphics used in CSW DII Advisory and CSW DII Alert roadway signage.**		D
2.01.04	**CSW Infrastructure Application Component Data Output Requirements**			
[2.01.04.01]	**CSW I2V Wireless Message Content**	**The CSW I2V Wireless Message shall contain data required to perform the calculations specified under CSW Vehicle Application Functional Requirements.**	*Table A-5, CSW I2V Wireless Message Data Description is referenced for guidance.*	D
[2.01.04.02]	**CSW I2V Wireless Message Specification**	**The CSW I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary.**		D
[2.01.04.03]	**CSW I2V Wireless Message Content Text**	**The CSW I2V Wireless Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution (Error) text used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[2.01.04.04]	**CSW I2V Wireless Message Prohibitive Frame**	**The CSW I2V Wireless Message content (CSW DII advisory, CSW DII alert, and CSW DII Caution (Error) messages) shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and alert messages shall not indicate that conditions may be safe.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.01.04.05]	**CSW I2V Wireless Message Graphics**	**The CSW I2V Wireless Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution (Error) shapes and graphics used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[2.01.04.06]	**CSW Roadside Signage Message Content**	**The CSW Roadside Signage Message shall contain the content to be displayed on dynamic roadside signage.**	*The CSW Roadside Signage Message shall contain one of three types of DII contents, a CSW DII Advisory, a CSW DII Alert, or a CSW DII Caution.* *Table A-3, CSW Roadside Signage Message Data Description is referenced for guidance.*	D
[2.01.04.07]	**CSW Roadside Signage Message Specifications**	**The CSW Roadside Signage Message shall conform to NTCIP 1203 v02 Object Definitions for Dynamic Message Signs (DMS) Standard.**		D
[2.01.04.08]	**CSW Roadside Signage Message Text**	**The CSW Roadside Signage Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution text.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[2.01.04.09]	**CSW Roadside Signage Message Prohibitive Frame**	**The CSW Roadside Signage Message (CSW DII advisory and CSW DII alert messages) shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DII advisory and alert messages shall not indicate that conditions may be safe.*	D
[2.01.04.10]	**CSW Roadside Signage Message Graphics**	**The CSW Roadside Signage Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution shapes and graphics.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D

Source: Battelle

3.3.3 CSW Vehicle Application Component Requirements

Table 3-5 catalogs the performance requirements for the CSW 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. CSW Vehicle Application Component Performance Requirements

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
2.02	**CSW Vehicle Application Component Requirements**			
2.02.01	**CSW Vehicle Application Component Interfaces and Interface Specifications**			
[2.02.01.01]	**CSW I2V Wireless Message Interface**	**The CSW Vehicle Application Component shall obtain CSW I2V Wireless Messages through the Vehicle Wireless Data Systems Interface.**		D
[2.02.01.02]	**CSW Vehicle Data Interface**	**The CSW Vehicle Application Component shall obtain CSW Vehicle Data through the Vehicle Data Systems Interface.**		D
[2.02.01.03]	**CSW Driver Message Interface**	**The CSW Vehicle Application Component shall issue CSW Driver Messages through the Driver Warning System Interface.**		D
2.02.02	**CSW Vehicle Application Component Functional Requirements**			
[2.02.02.01]	**Common Vehicle Application Component Requirements**	**The CSW Vehicle Application Component shall adhere to Common Vehicle Application Component Requirements.**		D
[2.02.02.02]	**CSW Vehicle Application Component Initiation**	**The CSW Vehicle Application Component shall be initiated upon receipt of a CSW I2V Wireless Message by the Vehicle Wireless Data Systems.**		D
[2.02.02.03]	**CSW I2V Wireless Message Initiation**	**The CSW Vehicle Application Component shall obtain CSW I2V Wireless Messages upon initiation of the component.**		D
[2.02.02.04]	**CSW I2V Wireless**	**The CSW Vehicle Application Component shall refresh**		D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
	Message Refresh Rate	**the CSW I2V Wireless Message Input at a configurable frequency.**		
[2.02.02.05]	**CSW Vehicle Data Initiation**	**The CSW Vehicle Application Component shall obtain CSW Vehicle Data upon initiation of the component.**		D
[2.02.02.06]	**Vehicle Data Systems Refresh Rate**	**The CSW Vehicle Application Component shall refresh CSW Vehicle Data at a configurable frequency.**		D
[2.02.02.07]	**CSW Infrastructure Data**	**Upon receipt of a CSW I2V Wireless Message, the CSW Vehicle Application Component shall open the message and parse it for relevant CSW data.**		D
[2.02.02.08]	**CSW Positioning Accuracy Determination**	**The CSW Vehicle Application Component shall determine if the received Position Data and the Map Data meet the position accuracy requirements for the received CSW I2V Wireless Message.**		D
[2.02.02.09]	**CSW Positioning Accuracy Assessment**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the CSW I2V Wireless Message, the CSW 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 CSW application position accuracy requirements are satisfied for the CSW I2V Wireless Message.*	D
[2.02.02.10]	**CSW Positioning Accuracy Message – Advisory**	**If the received Position Data and Map Data do not meet the position accuracy requirements for the received CSW I2V Wireless Message, the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DII Advisory to the Driver Warning System.**	*The CSW Application issues only advisory messages if position and map accuracy are not sufficient to support alert and warning calculations.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.11]	**CSW I2V Message Applicability Determination**	**The CSW Vehicle Application Component shall determine if the received CSW I2V Wireless Message is applicable, based upon the subject vehicle's apparent path, its distance to the specified curve entrance, the specified class of vehicles to which the message applies and other message criteria.**		D
[2.02.02.12]	**CSW I2V Message Applicability Assessment**	**If the received CSW I2V Wireless Message is not applicable, the CSW Vehicle Application Component shall refresh the CSW I2V Wireless Message and continue processing.**	*The application should continue iteratively obtaining CSW I2V Wireless Messages until a message applicable to current vehicle conditions is received.*	D
[2.02.02.13]	**Compute Vehicle-Specific Safe Curve Speed**	**The CSW Vehicle Application Component shall compute the Vehicle-Specific Safe Curve Speed based upon available CSW infrastructure and CSW vehicle data.**		D
[2.02.02.14]	**Compute [Conditional] CSW DVI Alert Deceleration Rates**	**The CSW Vehicle Application Component shall compute the CSW DVI Alert Deceleration Rate for the subject vehicle based upon available CSW infrastructure and CSW vehicle data.**		D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.15]	**Compute [Conditional] CSW DVI Alert Perception Reaction Time**	**The CSW Vehicle Application Component shall compute the CSW DVI Alert Perception Reaction Time for the subject vehicle based upon available CSW infrastructure and CSW vehicle data.**	*The following is referenced for guidance: 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
[2.02.02.16]	**Compute CSW DVI Warning Deceleration Rate**	**The CSW Vehicle Application Component shall compute the CSW DVI Warning Deceleration Rate for the subject vehicle based upon available CSW infrastructure and CSW vehicle data.**		D
[2.02.02.17]	**Compute CSW DVI Warning Perception Reaction Time**	**The CSW Vehicle Application Component shall compute the CSW DVI Warning Perception Reaction Time for the subject vehicle based upon available CSW infrastructure and CSW vehicle data.**	*The following is referenced for guidance: 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

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.18]	**Determine CSW DVI Alert Speed**	**The CSW Vehicle Application Component shall determine the CSW DVI Alert Speed using the CSW DII Alert Speed and the Vehicle-Specific Safe Curve Speed.**	*It is expected that the DVI Alert Speed will be the lesser of the DII Alert Speed and the Vehicle-Specific Safe Curve Speed, but may be subject to published industry or OEM guidelines.*	D
[2.02.02.19]	**Determine CSW DVI Alert and Warning Distances**	**The CSW Vehicle Application Component shall compute the CSW DVI Alert Distance and the CSW DVI Warning Distance for the subject vehicle corresponding to its current speed and available CSW Infrastructure and CSW Vehicle Data.**		D
[2.02.02.20]	**CSW DVI Alert Distance Equation**	**The CSW DVI Alert Distance shall be the distance traveled during the CSW DVI Alert Perception Reaction Time plus the distance required to slow the subject vehicle from its current speed to the CSW DVI Alert Speed, at a uniform deceleration equal to the CSW 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. CSW Vehicle Application Component Performance Requirements (Continued)

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.21]	**CSW DVI Warning Distance Equation**	**The CSW DVI Warning Distance shall be the distance traveled during the CSW DVI Warning Perception Reaction Time plus the distance required to slow the subject vehicle from its current speed to the CSW DVI Alert Speed, at a uniform deceleration equal to the CSW DVI Warning Deceleration Rate.**		D
[2.02.02.22]	**CSW DVI Warning Criterion**	**If the distance of the subject vehicle is less than the CSW DVI Warning Distance for its current speed, then the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DVI Warning to the Driver Warning System.**		D
[2.02.02.23]	**CSW DVI Alert Criterion**	**If the distance of the subject vehicle is less than the CSW DVI Alert Distance for its current speed and greater than or equal to the CSW DVI Warning Distance for its current speed, then the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DVI Alert to the Driver Warning System.**		D
[2.02.02.24]	**CSW DII Alert Criterion**	**If the DVI Alert Distance is not positive and if the distance of the subject vehicle is less than CSW DII Alert Distance, the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DII Alert to the Driver Warning System.**	*The Vehicle component should issue a DII Alert or a DVI Alert, but not both.*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.25]	**CSW DII Advisory Criterion**	**If the distance of the subject vehicle is less than the CSW DII Advisory Distance and greater than or equal to the lesser of the CSW DII Alert Distance and the CSW DVI Alert Distance, the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DII Advisory and CSW In-Vehicle Advisory Alert Speed to the Driver Warning System.**		D
[2.02.02.26]	**CSW Advisory, CSW Alert and CSW Warning Termination**	**The CSW Vehicle Application Component shall cease issuing CSW DII advisory, CSW DVI alert and CSW DVI warnings when the vehicle passes the end of the subject curve segment.**		D
[2.02.02.27]	**CSW DVI and CSW DII Message Consistency**	**The CSW Vehicle Application Component shall not issue a less safe CSW DII advisory, CSW DVI alert, or CSW DVI warning than the CSW Infrastructure Application components.**	*For example, vehicle applications may recommend slower speeds than the infrastructure applications, but not higher.*	D
[2.02.02.28]	**CSW DVI Message Precedence**	**The CSW Vehicle Application Component shall govern the message to be delivered to the Driver Warning System, based upon available CSW infrastructure and CSW vehicle data.**		D
[2.02.02.29]	**CSW Caution (Error) Message Definition**	**The CSW DVI Caution (Error) Message shall contain a blank or generic caution and an indication that the system is not operational.**		D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.02.30]	**CSW Vehicle Application Component Error**	**In the event of an input data error, a computational error or other nonrecoverable CSW Vehicle Application Component Error preventing issuing of CSW DVI advisories, CSW DVI alerts, or CSW DVI warnings, or position and map accuracy requirements not being met, the CSW Vehicle Application Component shall issue a CSW Driver Message containing a CSW DVI Caution (Error) to the Driver Warning System.**		D
2.02.03	**CSW Vehicle Application Component Data Input Requirements**			
[2.02.03.01]	**CSW I2V Wireless Message Content**	**The CSW I2V Wireless Message shall contain the data required to perform the calculations specified under CSW Vehicle Application Functional Requirements.**	*Table A-5, CSW I2V Wireless Message Data Description is referenced for guidance.*	D
[2.02.03.02]	**CSW I2V Wireless Message Specification**	**The CSW I2V Wireless Message shall conform to SAE J2735:2009-11 Dedicated Short Range Communications (DSRC) Message Set Dictionary**		I
[2.02.03.03]	**CSW I2V Wireless Message Content Text**	**The CSW I2V Wireless Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution (Error) text used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[2.02.03.04]	**CSW I2V Wireless Message Graphics**	**The CSW I2V Wireless Message shall contain CSW DII Advisory, CSW DII Alert, and CSW DII Caution (Error) shapes and graphics used in roadway signage.**	*The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) is referenced for guidance.*	D
[2.02.03.05]	**CSW Vehicle Systems Message Content**	**The CSW Vehicle Systems Message shall contain data required to perform the calculations specified under**	*Table A-6, CSW Vehicle Systems Message Data Description is*	D

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
		CSW Vehicle Application Functional Requirements.	*referenced for guidance.*	
[2.02.03.06]	**Vehicle Data Systems Message Specifications**	**The CSW 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
2.02.04	**CSW Vehicle Application Component Data Output Requirements**			
[2.02.04.01]	**CSW Driver Message Content**	**The CSW Driver Message shall contain the CSW DII Advisory, CSW DII Alert, CSW DII Caution, CSW DVI Alert, CSW DVI Warning, or CSW DVI Caution content to be displayed on the Driver Warning Interface.**	*Table A-7, CSW Driver Message Data Description is referenced for guidance.*	D
[2.02.04.02]	**CSW Driver Message Specifications**	**The following is referenced for guidance pertaining to CSW 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

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

Rqmt. No.	Requirement Title	Performance Requirement	Elaboration	Verif. Method (I,D,T,A)
[2.02.04.03]	**CSW Driver Message Text**	**The CSW Driver Message shall contain CSW DII Advisory, CSW DII Alert, CSW DII Caution, CSW DVI Alert, CSW DVI Warning, CSW DVI Caution text.**		D
[2.02.04.04]	**CSW Driver Message Graphics**	**The CSW Driver Message shall contain CSW DII Advisory, CSW DII Alert, CSW DII Caution, CSW DVI Alert, CSW DVI Warning, CSW DVI Caution shapes and graphics.**		D
[2.02.04.05]	**CSW Driver Message Prohibitive Frame**	**CSW DVI alert and CSW DVI warning messages shall use a prohibitive frame indicating when unsafe conditions may exist.**	*Prohibitive frame means that DVI alert and DVI warning messages shall not indicate that conditions may be safe.*	D
[2.02.04.06]	**CSW Driver Message – DVI and DII Message Consistency**	**The CSW Vehicle Application Component shall not issue less safe CSW DII advisory, CSW DVI alert, or CSW DVI warnings than the CSW Infrastructure Application components.**		D
[2.02.04.07]	**CSW Driver Message – DVI Message Precedence**	**The CSW Vehicle Application Component shall govern the message to be delivered to the Driver Warning System, based upon available CSW infrastructure and CSW vehicle data.**		D

Source: Battelle

APPENDIX A. CSW Application Message Candidate Data Elements

Appendix A suggests candidate data elements which may be included in these messages to support the CSW 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, CSW
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 CSW 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
Approaching Vehicle Data (required)															
Target (#)	CSW	Approaching Vehicle	Dynamic	Required	External Vehicle Detecti on System	Infra Application Component	Integer	1-15	NA	Integer	1-15	NA	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range	CSW	Approaching Vehicle	Dynamic	Required	External Vehicle Detection System	Infra Application Component	ft	1-5000	+/- 2	m	0.3-1524	+/-0.6	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Target (#) Range Rate	CSW	Approaching Vehicle	Dynamic	Required	External Vehicle Detection System	Infra Application Component	ft/s	1-200	+/- 1	m/s	0.3-61	0.3	10 Hz		The Application shall be capable of processing up to 15 simultaneous targets identified by Infrastructure Data Systems
Road Surface Condition Data (optional)															
Road surface friction coefficient	CSW	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road surface temperature	CSW	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	CSW	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time – Begin	CSW	Road Surface Condition	Dynamic	Optional	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	CSW	Road Surface Condition	Dynamic	Optional	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 Road Map Segments	CSW	Road Surface Condition	Dynamic	Optional	Infra Data System – Road Surface	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Road Condition Data format is based upon segments in Curve Road Map

Table A-2. Description of Candidate Data Elements for the CSW 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 (optional)															
Visibility	CSW	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		
Estimated precipitation condition	CSW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Air Temperature	CSW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Local Weather Data Applicable Date and Time – Begin	CSW	Local Weather Data	Dynamic	Optional	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	CSW	Local Weather Data	Dynamic	Optional	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 Road Map Segments	CSW	Local Weather Data	Dynamic	Optional	Infra Data System – Local Weather	Infra Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Weather Data format is based upon segments in Curve Road Map

Source: Battelle

Table A-3. Description of Candidate Data Elements for the CSW Roadside Signage 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
DII MUTCD Sign Number	CSW	CSW Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage System	Integer	TBD	NA	Integer	TBD	NA	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DII Graphic	CSW	CSW Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage System	TBD	TBD	NA	TBD	TBD	NA	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications
DII Text	CSW	CSW Roadside Signage Data	Dynamic	MUTCD Sign Number or Graphic and Text	Infra Application Component	Roadside Signage 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	1 Hz		Max 3 Lines, 20 Characters each is typical for Roadside Dynamic Message Signs
DII Advisory Valid Time	CSW	CSW Roadside Signage Data	Dynamic	Required	Infra Application Component	Roadside Signage System	min	0.01-1440	+/- 0.01	min	0.01-1440	+/- 0.01	1 Hz		Determined by MUTCD, Local Policy, and Roadside Signage System manufacturer specifications

Source: Battelle

Table A-4. Description of Candidate Data Elements for the CSW Infrastructure Map Message and CSW 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
Curve Geometry Data (required															
Minimum Curve Radius	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	20-2000	+/- 2	m	6-610	+/-0.6	Reconstruction, Repaving, or Restriping		Minimum radius of curvature found somewhere within the curve. Static Data may be loaded through an externally generated data file.
Maximum Curve Superelevation	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft/ft	0-0.2	+/- 0.01	m/m	0-0.2	+/- 0.01	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 1 – Latitude	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 1 – Longitude	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 1 – Elevation	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	(-150)-12,000	+/- 2	m	(-46)-3658	+/-0.6	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 1 – Road Grade	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	percent	0-20	+/- 0.05	percent	0-20	+/- 0.05	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 2 – Latitude	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-90)-90	+/- 0.000001	degrees	(-90)-90	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 2 – Longitude	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	degrees	(-180)-180	+/- 0.000001	degrees	(-180)-180	+/- 0.000001	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 2 – Elevation	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	ft	(-150)-12,000	+/- 2	m	(-46)-3658	+/-0.6	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.
Curve Entrance 2 – Road Grade	CSW	Curve Geometry	Static	Required	Local User/Data Infrastructure	Infra Application Component	percent	0-20	+/- 0.05	percent	0-20	+/- 0.05	Reconstruction, Repaving, or Restriping		Static Data may be loaded through an externally generated data file.

Table A-4. Description of Candidate Data Elements for the CSW Infrastructure Map Message and CSW 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
Operational Data (required)															
Posted Speed Limit	CSW	CSW Operational Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	mph	25-90	+/- 2	km/h	40-145	+/-3.2	Speed Limit Revision		Static Data may be loaded through an externally generated data file.
Advisory Speed Limit	CSW	CSW Operational Data	Static	Required	Local User/Data Infrastructure	Infra Application Component	mph	5-65	+/- 2	km/h	8-105	+/-3.2	Speed Limit Revision		Static Data may be loaded through an externally generated data file.
Roadside Signage Data															
Curve Entrance 1 – MUTCD Sign Number options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	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.
Curve Entrance 1 – Graphic options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	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.
Curve Entrance 1 – Advisory Text options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	At Least One Required from Group	Local User/Data Infrastructure	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.
Curve Entrance 1 – DII Advisory Sign Distance	CSW	CSW Roadside Signage Data	Static	Required	Local User/Data Infrastructure	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.
Curve Entrance 1 – DII Advisory Visibility Distance	CSW	CSW Roadside Signage Data	Static	Required	Local User/Data Infrastructure	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 CSW Infrastructure Map Message and CSW 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
Curve Entrance 1 – MUTCD Sign Number options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local User/Data Infrastructure	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.
Curve Entrance 1 – Graphic options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local User/Data Infrastructure	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.

Table A-4. Description of Candidate Data Elements for the CSW Infrastructure Map Message and CSW 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
Curve Entrance 1 – Alert Text options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	MUTCD Sign Number or Graphic and Text	Local User/Data Infrastructure	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.
Curve Entrance 1 – DII Alert Sign Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 1 – DII Alert Visibility Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – MUTCD Sign Number options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – Graphic options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – Advisory Text options for consideration to be used as DII Advisory Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	Latin Alphabet	A-Z		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.
Curve Entrance 2 – DII Advisory Sign Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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 CSW Infrastructure Map Message and CSW 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
Curve Entrance 2 – DII Advisory Visibility Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – MUTCD Sign Number options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – Graphic options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – Alert Text options for consideration to be used as DII Alert Message	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	Infra Application Component	Latin Alphabet	A-Z		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.
Curve Entrance 2 – DII Alert Sign Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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.
Curve Entrance 2 – DII Alert Visibility Distance	CSW	CSW Roadside Signage Data	Static	Optional	Local User/Data Infrastructure	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 CSW 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)															
CSW Applicable Date and Time – Begin	CSW	CSW 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		
CSW Applicable Date and Time – End	CSW	CSW 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		
CSW Applicable Road Map Segments	CSW	CSW Operational Data	Dynamic	Required	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Data format is based upon segments in CSW Road Map
Road Surface Condition Data (optional)															
Road surface friction coefficient	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	coefficient	-	+/- 0.01	coefficient	-	+/- 0.01	1 min		
Road surface temperature	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Road surface wetness	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		
Road Condition Data Applicable Date and Time – Begin	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle 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	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Road Condition Data Applicable Road Map Segments	CSW	Road Surface Condition	Dynamic	Optional	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Road Condition Data format is based upon segments in Curve Road Map
Local Weather Data (optional)															
Visibility	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	ft	1-1000	+/- 2	m	0.3-305	+/-0.6	1 min		
Estimated precipitation condition	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	1 min		

Table A-5. Description of Candidate Data Elements for the CSW 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
Air Temperature	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	°F	(-30)-120	+/- 2	°C	(-35)-49	+/-3.6	1 min		
Local Weather Data Applicable Date and Time – Begin	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle 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	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	Date & Time	Current + 30 days	+/- 1 min	Date & Time	Current + 30 days	+/- 1 min	1 min		
Local Weather Data Applicable Road Map Segments	CSW	Local Weather Data	Dynamic	Optional	Infra Application Component	Vehicle Application Component	TBD	TBD	TBD	TBD	TBD	TBD	TBD		Weather Data format is based upon segments in Curve Road Map

Source: Battelle

Table A-6. Description of Candidate Data Elements for the CSW 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 (optional)															
Vehicle mass	CSW	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	CSW	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	CSW	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	CSW	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	CSW	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 (optional)															
Vehicle Speed Current	CSW	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	CSW	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	CSW	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	CSW	Vehicle Functional Status	Dynamic	Optional	Vehicle Data Systems	Vehicle Application Component	degrees	(-70)-70	+/- 2	degrees	(-70)-70	+/- 2	10 Hz		
Vehicle traction control	CSW	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 CSW 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	CSW	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	CSW	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 (optional)															
Temperature (Air)	CSW	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	CSW	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	CSW	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	CSW	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 CSW 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	CSW	CSW 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	CSW	CSW 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	CSW	CSW 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	CSW	CSW 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	CSW	CSW 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
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	Reduced Speed Zone Warning
RSZW/LC	Reduced Speed Zone Warning with Lane Closure
SAE	Society of Automotive Engineers
SOI	System-of-Interest
SSGA	Stop Sign Gap Assist
SWIW	Spot Weather Information Warning
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
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.[3] 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".

[3] 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.[4]

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.

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

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FHWA-JPO-16-249

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