Project Specific Technical Specification

Transport and Main Roads
PSTS015 RWW Use Case Specification – Roadworks Warning

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Queensland
Government

Document control sheet

Contact for enquiries and proposed changes

If you have any questions regarding this document or if you have a suggestion for improvements, please contact:

Contact officer Nicholas Brook

Title Principal Engineer (CAVI)

Phone (07) 3066 8262

Version history

Version no.	Owner	Date	Nature of amendment
1.0	David Alderson	29/06/2018	Tender Issue
1.1	David Alderson	15/3/2019	Removal of speed ahead logic
1.2	David Alderson	06/07/2019	Updates to match learnings from implementation
1.3	Joel Lowe	25/10/2019	Update to DENM definition
1.4	Zinah Tam	27/07/2020	Updated Table 7.2 to match final incorporation of HUET recommendations
1.5	Zinah Tam	28/9/2020	Updated Table 7.2 to reflect release 25.2
2.0	Nicholas Brook	28/01/2021	Updated and adapted for external sharing.
2.1	Jian Qin	07/10/2021	updated the overall system architecture drawing

Contents

1 Introduction

The Road Works Warning use case (RWW) Use Case Specification is intended to provide future use case developers (including V-ITS-S vendors) with details of the Ipswich Connected Vehicle Pilot (ICVP) implementation as a guide. As use cases are expected to fall within the remit of original equipment manufacturers (car, application or device developers) it has been adapted from a prescriptive set of requirements for the pilot, to an example of potential operation within any future Cooperative ITS eco-systems. These are also not to be used directly as a specification for other Transport and Main Roads projects or integration, as they will either be adapted to be project specific or ratified and released as a formal Department Specification.

This specification includes:

- Objectives, general operation and applicable scenarios;

- System components and data flows;

- Life cycles;

- High level HMI requirements;

- Data and message examples; and

- Data definitions.

2 Definition of terms

Table 2.1 – Acronyms

Acronym	Term
ASN.1	Abstract Syntax Notation One
C-ITS	Cooperative intelligent transport systems
C-ITS-F	Central ITS facility
DENM	Decentralised environmental notification message (EU)
eH	event History
eP	event position
ETSI	European Telecommunications Standards Institute
FOT	Field operational test
HMI	Human machine interface
I2V	Infrastructure to Vehicle
ITS	Intelligent transport systems
MUTCD	(Queensland) Manual of Uniform Traffic Control Devices
PDU	Protocol Data Unit
PSTS	Project Specific Technical Specification
R-ITS-S	Roadside ITS station
RTK	Real Time Kinematic
RWW	Road Work Warning
SCMS	Security credential management system
TSC	Traffic Signal Controller
TTA	Time to Action
TTE	Time to Event
UPER	Unaligned Packed Encoding Rules
V-ITS-S	Vehicle ITS station

Acronym	Term
XML	eXtensible Markup Language

Table 2.2 – Definitions

Acronym/Term	Term Description
3G/4G	Cellular wireless network provided through a telecommunications company. 3G is the 3rd generation data network, 4G the fourth and LTE stands for Long Term Evolution.
AUSCORS	Australian Continuously Operating Reference Stations. The Ntrip Broadcaster provided by Geoscience Australia.
FOT	Field Operational Test – the period when the in-vehicle C-ITS systems are operational and logging data
HMI Presentation Manager	Function of the V-ITS-S that arbitrates the information presentation requests to the HMI device
Monitoring system	Sub-system of the C-ITS-F that monitors the operation of the C-ITS Pilot system

3   Reference documents

Table 3.1 – Referenced documents – External

Document ID	Document Name / Description
ETSI TS 101 539 -1 V1.1.1 (2013-08)	Intelligent Transport Systems (ITS); V2X Applications; Road Hazard Signalling (RHS) application requirements specification
ETSI TS 101 539-3 v1.1.1 (2013-11)	Intelligent Transport Systems (ITS); V2X Applications;Longitudinal Collision Warning (LCRW) application requirements specification
ETSI EN 302 637-3 V1.2.2 (2014-11)	Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service

Table 3.2 – Referenced documents – CAVI

Document ID	Document Name / Description
PSTS002	V-ITS-S Equipment
PSTS003	HMI Equipment
PSTS006	Data Entity Catalogue
PSTS007	C-ITS Station Protocol Specification
PSTS018	In-Vehicle Speed (IVS) Use Case Specification

4   Quality system requirements

4.1   Test Acceptance Criteria

For ICVP the V-ITS-S Vendor demonstrated compliance to this specification in accordance with the test acceptance phases defined in the *V-ITS-S Specification PSTS002*.

For each requirement, the selected test plan/s included criteria that clearly defines how each requirement is met to suitably integrate within the ICVP systems. Test plans at a minimum included; consideration of the primary and alternate scenario equivalents identified in this specification. Some circumstances including testing of other scenarios identified by the V-ITS-S Vendor or Principal as appropriate to prove; device, use case or system implementation.

Sample DENMs for RWW are provided in the sample data pack in the following encoding formats:

  a. UPER (encoded)

  b. JSON (decoded)

The data pack also contains the ASN.1 value notation that were used for each use case.

5   Overview

The RWW use case provides the driver of a cooperative vehicle a warning relevant to the vehicle's trajectory when approaching and within roadworks environments. The RWW use case provides:

1.   Advanced warning of roadworks to reduce speed to the lowest roadworks speed limit,

2.   Warning when above the lowest roadworks speed limit, and

3.   Information on speed limits on approach to the roadworks and throughout the roadworks area

RWW use case includes roadworks from as short as 3-4hours to long term works of over 6 months, but not rolling (continuously moving) roadworks given the frequency of movement of the site. Roadworks are input through a TMR owned and managed software platform that digitises roadworks information to match the physical on-site signage. The users that input data are trained roadwork staff or team members that both create and verify the activation of the roadworks. The roadworks use case is updated to the vehicles from the C-ITS-F.
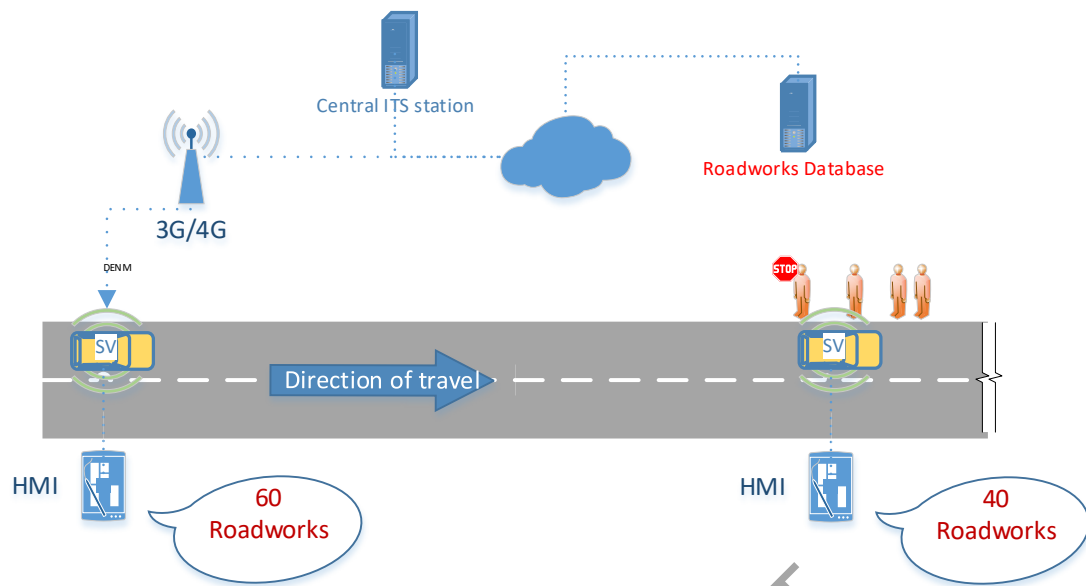
Figure 5.1 – RWW Operation[1]

Requirement: The RWW application shall manage and display speed limit signage and roadwork information to the driver.

Requirement: RWW events shall be as a combination of IVIM and DENM.

Requirement: The RWW is a single DENM set up with its event point set as the lowest speed limit sign within the roadworks, the DENMs trace upstream to be relevant to approaching vehicles and its event history from the event point to the last sign of the site.

Requirement: The RWW application will compare the event history speed in the ala carte container with the vehicle speed and warn the driver if they are over that speed limit.

Requirement: The IVIM matches each speed zone as a relevant zone and operates in alignment with *PSTS018 IVS Use Case Specification.*

Requirement: The RWW application shall store and monitor current geo-tile RWW DENM for up to 50 RWW DENM at a given time.

Requirement: The RWW application shall be capable of handling up to 3 overlapping RWW DENM simultaneously. The current RWW DENM with the lowest speed shall be prioritised.

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[1] HMI content is for illustrative purposes only and may not reflective of final layout

5.1.1   Primary Scenario

In the primary scenario for RWW (refer to Figure 5.2) a vehicle approaches a roadworks site and displays the current road speed (from IVS use case). An advanced warning is also shown if the vehicle is likely to enter the event zone or work area (denoted by the lowest speed zone) above the speed limit. Once in the roadworks event, the current speed limit of the roadworks will always be displayed whilst a reduce speed RWW will be displayed only when the vehicle is over the event history speed limit. The vehicle continues to display the HMI warning until the RWW event is no longer appropriate or the vehicle drops below the speed limit. This RWW given its simplicity for the sake of participants of the pilot does not include any advanced signage, lane advice or any other advanced capabilities of either the IVIM or DENM allow for as per ETSI use case examples for RWW.

The RWW event ceases to be appropriate when:

- Vehicle has passed through the relevant event DENM (trace and event history),
- The vehicle drops below the event history (work area) speed limit, or
- The vehicle departs from the roadworks.

In this scenario, the vehicle:

- Warns the driver about roadworks based on the vehicle's ability to reach the desired speed by the work site.
- Enters the 60km/h event zone over the speed limit
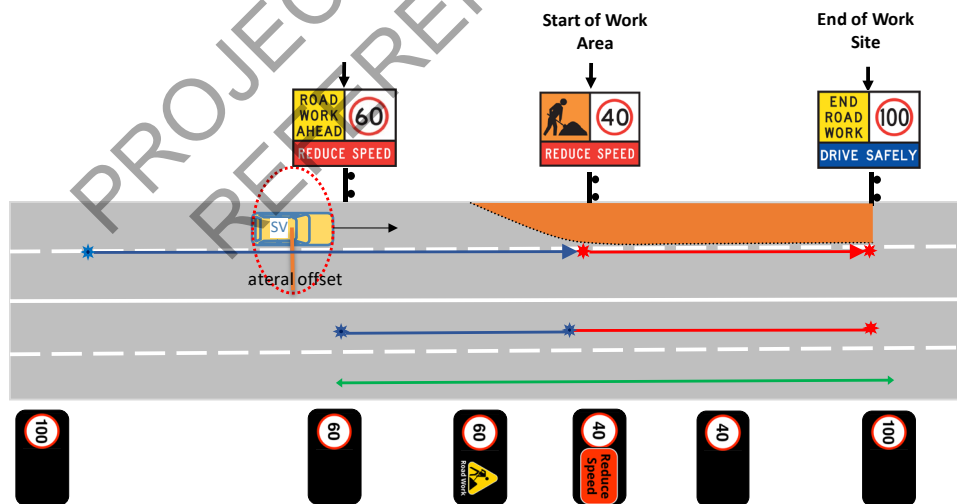- Enters the 40km/h event zone over the speed limit and then adjusts speed to be under the speed limit
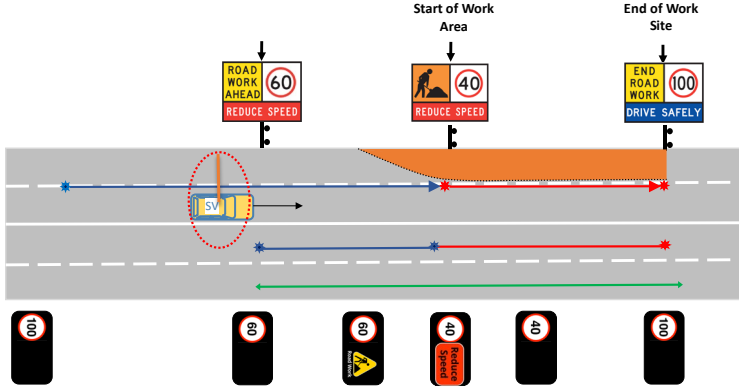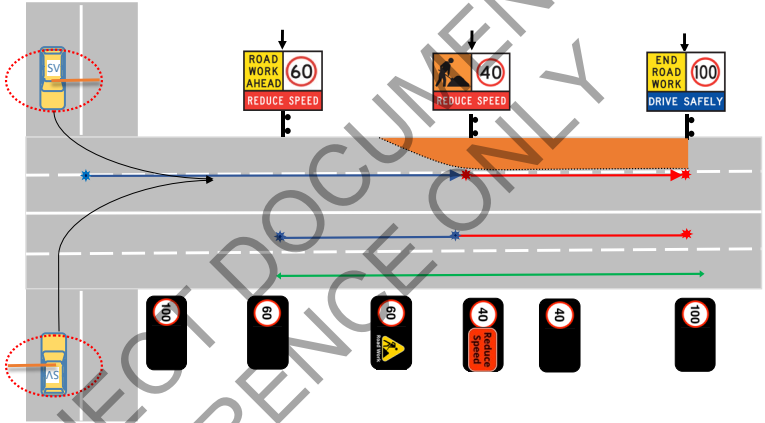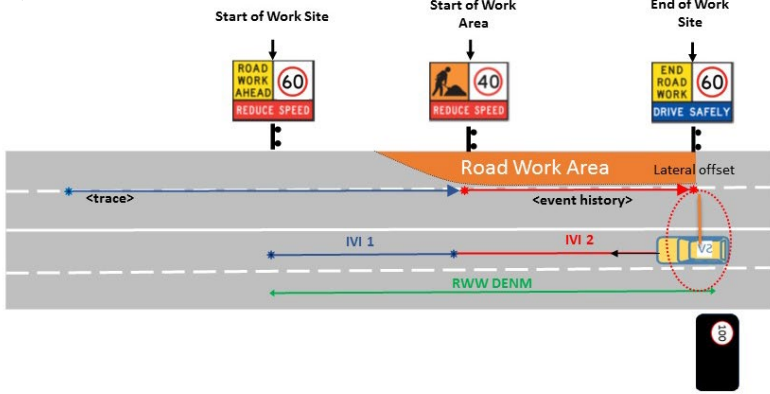- Leaves the roadworks event.
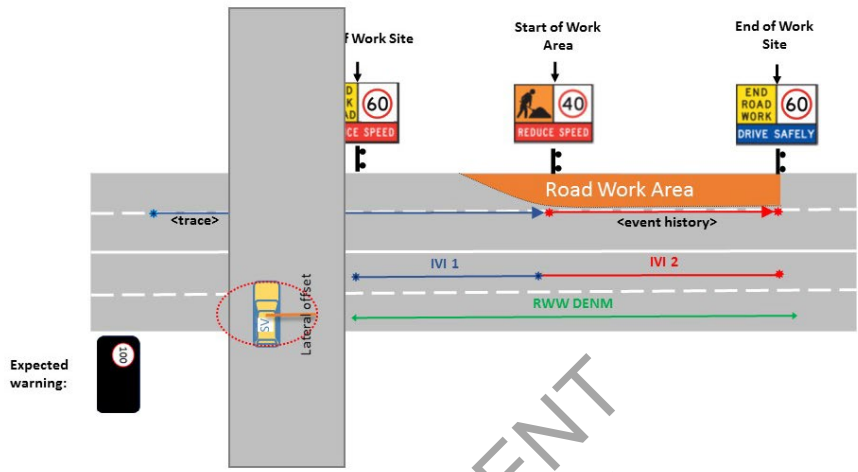

Figure 5.2 - Primary Scenario

5.1.2   Scenario Equivalents

The following table describes the same primary scenario above but with several variants and the expected outcome.

Table 5.1 – Scenario Equivalents

Variant	Visualisation and Comment
Adjacent lanes or wide lanes where lateral offset and trace intersect.	HMI Warning: Yes, this use case isn't lane level so it will be the same as the primary scenario.
Vehicle is entering from side road	HMI Warning: Yes, but only if the vehicle is determined to be on a trace or event history of the roadworks event. Traces can be configured to go around corners and having multiple approaches, in these cases it could warn prior to the corner, whether intending to turn or not.
Vehicle is driving in the opposite direction to roadworks	HMI Warning: No

Variant	Visualisation and Comment
	Comment: Roadworks will often affect both directions of traffic. A second DENM will be created for the opposite direction of travel if roadwork information is required.
Vehicle is driving on a bridge above the roadworks (in a different vertical plane)

HMI Warning: No

Comment: This scenario should not display a HMI warning because the vehicle is not following the same path as the roadworks direction will not match the vehicle heading and the elevation will not match. |

5.1.3 Vehicle Offsets

A lateral offset (distance from the centre of the vehicle) provides additional tolerance in vehicle width to coincide with the trace of the RWW DENM. RWW is intended to be for all vehicles in all lanes of the roadworks event and therefore the lateral offset is large to ensure trace relevance for all lanes.

Requirement: The RWW application shall apply a configurable lateral offset (*lateralOffset*) when calculating the vehicle position to the trace for the RWW use case.

6   System Components

The RWW use case is an I2V application and as a result the primary interface is between the C-ITS-F and the V-ITS-S (and HMI). Data is input into the system using the roadworks warning database interface.
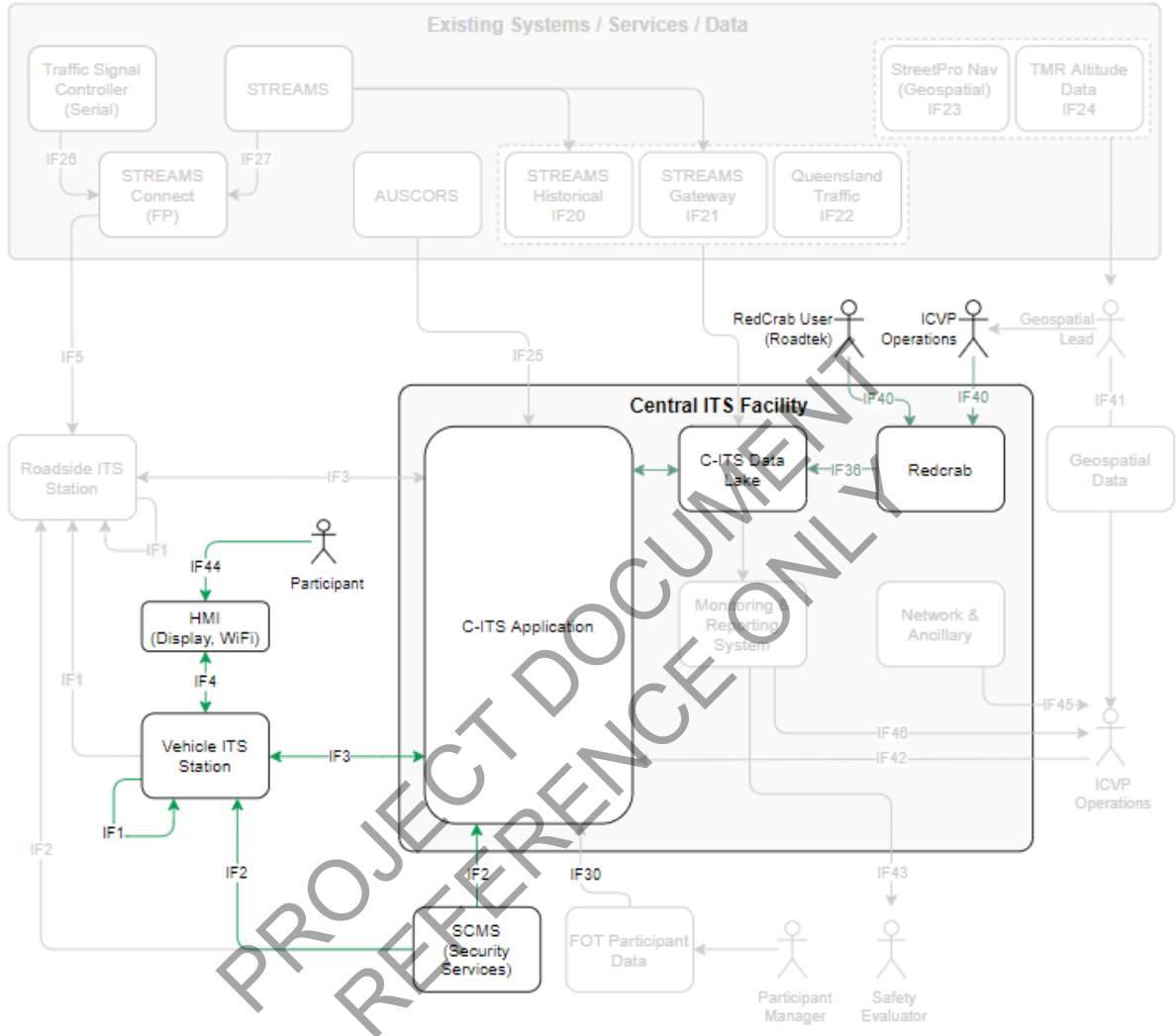
Figure 6.1 – Overall System Architecture

The table below describes the system components that interact for the overall operation of the RWW application.

Table 6.1 – System Component Summary

Component	Role	Requirement	Detailed component lifecycle
V-ITS-S	Event Processor	The RWW use case application is performed in the V-ITS-S.	The process for managing the RWW use case is defined in section 7.1
HMI	Driver Interface	HMI must be on and able to interact with the V-ITS-S for display and status	HMI warnings and speed updates are defined in section 7.1

Component	Role	Requirement	Detailed component lifecycle
RWW Database	Data entry/source	This database is populated through Red Crab, the application tool to be used for configuration of roadworks site data.	Not applicable. Managed by C-ITS-F
C-ITS-F	Messaging and Monitoring	Manages roadworks updates from Red Crab and provides current roadworks to V-ITS-S. Interface for monitoring and use case data logging.	Defined in *C-ITS-S Station Protocol Specification PSTS007*
SCMS	Enabler	Provide secure communications	Defined in *V-ITS-S Specification PSTS002*
AUSCORS	Positioning Augmentation	Provides data to the V-ITS-S through the C-ITS-F that allows greater positioning accuracy for the operation of the use case	Defined in *V-ITS-S Specification PSTS002*
FOT	Evaluation	Evaluation of use case log data.	Not applicable. Managed by C-ITS-F

Requirement: The V-ITS-S shall meet the requirements of *V-ITS-S Specification PSTS002* as a basis for enabling the RWW use case operation. Communications between components using 3G/4G are detailed in *V-ITS-S Specification PSTS002* including communications interface, security management and protocols to enable the data transfers described in Figure 6.2.

Requirement: The HMI shall meet the requirements of *HMI Specification PSTS003* as a basis for enabling the RWW use case speed updates.

6.1   Typical Process Flow

The process flow for the RWW event is shown in Figure 6.2. This describes the normal process for the event through the relevant system components. The component lifecycles in section 7 describe the detailed creation, management, validation and completion states of the use case (Note: FOT uses an independent process flow to the C-ITS-F and are therefore not included in this use case process flow). The second stage of Figure 6.2 in which the V-ITS-S retrieves speed information from the C-ITS-F returns all RWW for the requested geo-tile.
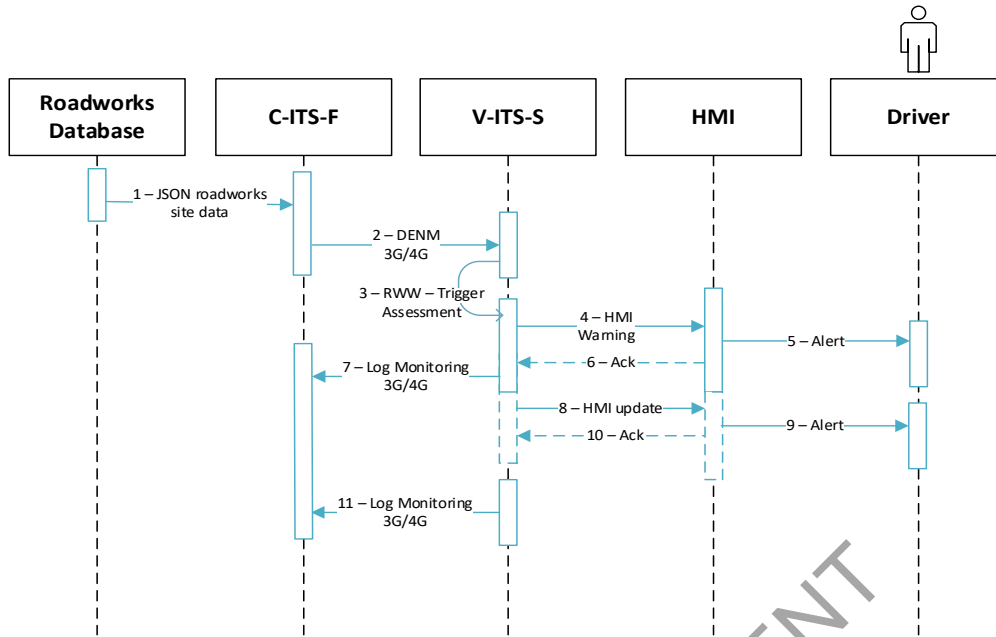
Figure 6.2 – Typical Flow of Data

7   Lifecycles

The RWW event is identified and generated in the V-ITS-S application. Therefore, the event life cycle for this use case matches the V-ITS-S application lifecycle.

7.1   V-ITS-S Application Lifecycle

Figure 7.1 shows a process flow expected from the application within the V-ITS-S to receive RWW DENMs and determine use case behaviour.
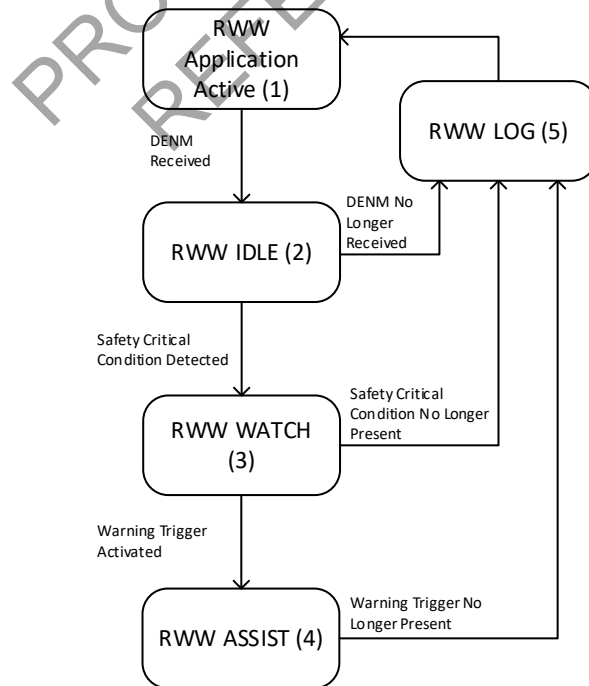

Figure 7.1 – V-ITS-S Lifecycle (modified from ETSI TS 101 539-01:2013)

Requirement: The V-ITS-S shall apply the lifecycle states and transitions in the RWW application (or proven equivalent operation). A critical failure (as defined by the Contractor) in any state or transition shall cause the application to attempt to restart from state (1) to continue normal operation.

Requirement: The RWW application shall start up if enabled and request all RWW DENM for the current geo-tile from 3G/4G (see *ucRwwEnabled* in *V-ITS-S Specification PSTS002* for application enabling and disabling). *(State 1)*

Requirement: While the V-ITS-S is powered on the RWW application shall ensure that it receives updates to the RWW DENM by maintaining a subscription to the message topics *(see C-ITS Station Protocol PSTS007).*

Requirement: The RWW application shall receive and maintain the DENM for the current geo-tile and update with new DENM when entering new geo-tiles. DENM received (see *V-ITS-S Specification PSTS002* for requirements of geo-tile and C-ITS-F data transfer) *(Transition 1 to 2)*

Requirement: RWW application shall compare the vehicle metrics (such as speed and location) to the roadworks to determine if the safety critical conditions are met. In order to meet the safety critical conditions, the vehicle shall be: *(State 2)*

1. Travelling between the minimum (*speedMin*) and maximum speed (*speedMax*), and

2. Following the *trace* or *eventHistory* (based on lateral offset defined in section 5.1.3) in the same direction

Requirement: If the *validityDuration* in the DENM has expired or is cancelled by the C-ITS-F, the RWW application shall consider the roadworks as no longer active. *(Transition 2 to 5)*

Requirement: To meet the safety critical conditions, the vehicle shall be: *(Transition 2 to 3)*

1. Travelling between the minimum (*speedMin*) and maximum (*speedMax*) speed; and

2. Within the *RelevanceDistance* defined in the DENMs, and

3. Following the DENM *trace* or *eventHistory* for the RWW event (based on lateral offset defined in section 5.1.3) in the same direction that is currently active

Requirement: If in a *trace*, the RWW application shall assess the time to action between the vehicle and the work area as defined in section 7.2. If in the *eventHistory*, the RWW application shall assess the speed of the vehicle against the speed limit. *(State 3)*

Requirement: RWW application shall determine that the vehicle safety critical conditions are no longer met if: *(Transition 3 to 5)*

1. The vehicle has passed through the relevant event DENM (traces and event histories); or

2. The vehicle departs from the roadworks; or

3. The vehicle reduces speed below the minimum clearance speed which for RWW is the *eventHistory* speed.

Requirement: A collision risk shall be active if action is required within the safety thresholds as defined in section 7.2 *(Transition 3 to 4)*

Requirement: The RWW application shall request a HMI warning (section 7.3) based on the DENM and update speed display (section 0) based on the IVIM (see PSTS018 IVS specification for details) based on the time to action being active as defined in section 7.2 or the vehicle being in the event history. The RWW application shall monitor acknowledgements and the status of the HMI while the display request is active.

(State 4)

Requirement: RWW HMI warning request shall be cleared if the safety critical conditions are no longer met (see transition 3 to 5 above)

(Transition 4 to 5)

Requirement: The RWW application shall log event information in accordance with *V-ITS-S Specification PSTS002* and send to C-ITS-F on 3G/4G.

(State 5)

Requirement: The RWW application shall confirm the event is logged and event completed

(Transition 5 to 1)

7.2 Warning Trigger

When the vehicle enters the relevance distance and the trace of the roadworks, the vehicle must determine whether there is a collision risk based on the Time-To-Event (TTE) between the vehicles and the minimum driver warning triggering time as shown in Figure 7.2. A collision risk for RWW is defined as any speed over the speed limit within the roadworks event.
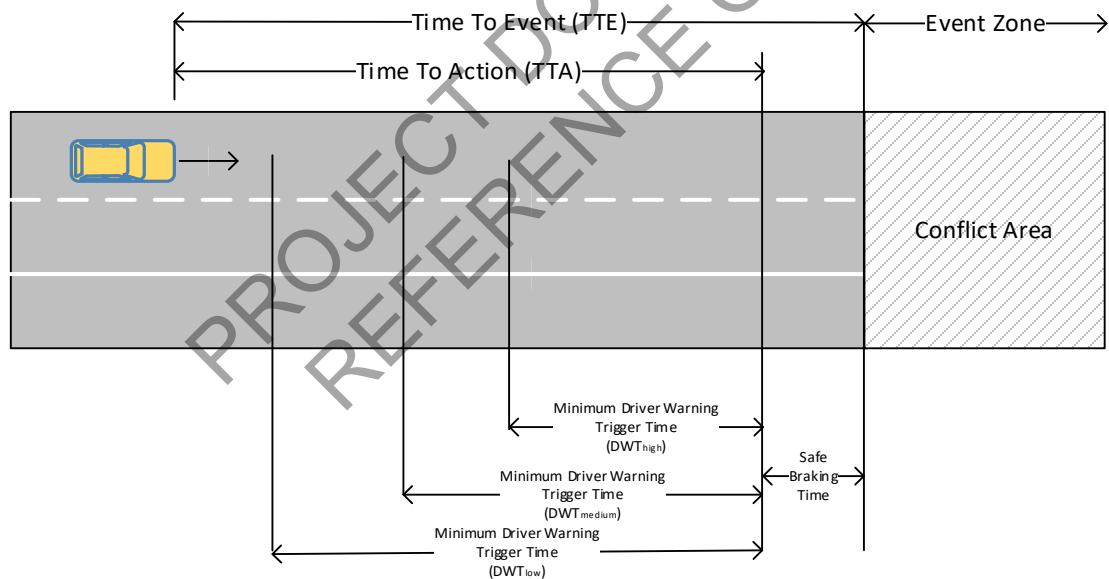
Figure 7.2 – Minimum Warning Trigger Time

Based on the TTA, the trigger is determined based on the graph in Figure 7.3.
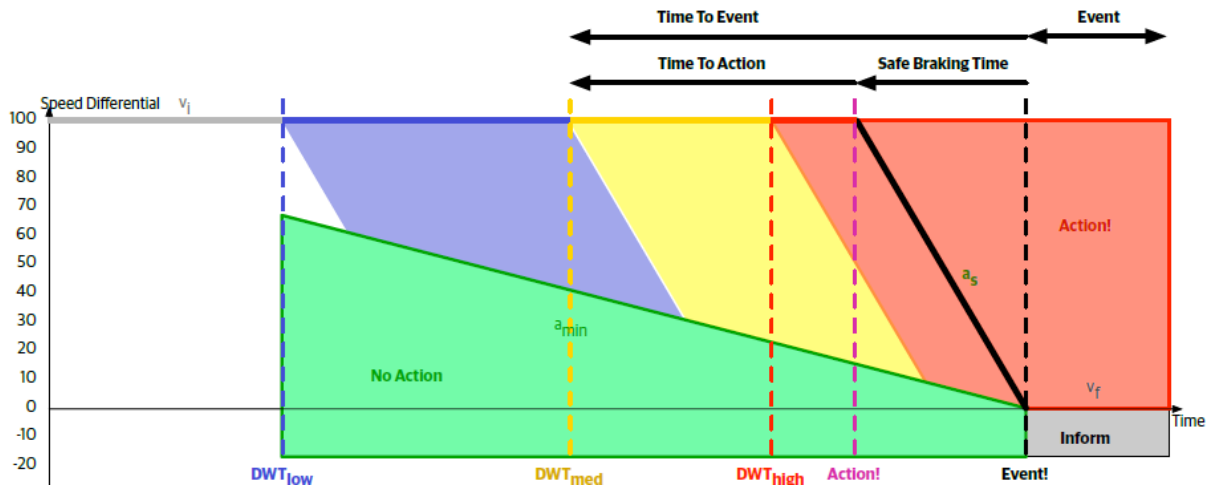
Figure 7.3 – Determining triggers from TTA

Requirement: Distance (d_{V_RW} in metres) to the first speed limit drop location shall be calculated based on the first DENM event point and the vehicle location.

Requirement: While the application is in RWW WATCH, it shall assess safe braking time, safe braking distance and TTA based on the following calculations:

$$\text{Safe Braking Time} = t_{safe} = (v_f - v_i) / a_{safe}$$

$$\text{Safe Braking Distance} = d_{safe} = v_i * t_{safe} + \tfrac{1}{2} * a_{safe} * t_{safe} * t_{safe}$$

$$\text{Time-To-Action} = TTA = (d_{V\_RW} - d_{safe}) / v_i$$

Where:

v_i = Current Speed

v_f = Speed Limit for first speed drop (*speedLimit* in DENM)

a_{safe} = Safe braking deceleration speed (*decelerationSafe*)

Requirement: The RWW application shall consider the TTA as not applicable (no warning required) if:

1. a significant amount of time for braking is available; and

2. a significant distance for braking is available; and

3. A TTA based on the following calculations:

$$\text{No Action Time} = t_{no\_action} = (v_f - v_i) / a_{min}$$

$$\text{No Action Distance} = d_{no\_action} = v_i * t_{no\_action} + \tfrac{1}{2} * a_{min} * t_{no\_action} * t_{no\_action}$$

$$\text{Time-To-Action at minimum braking} = TTA_{min} = (d_{V\_RW} - d_{no\_action}) / v_i$$

Where:

v_i = Current Speed

v_f = Speed Limit for first speed drop (*speedLimit* in DENM)

a_{min} = Minimal braking deceleration speed (*decelerationMin*)

Requirement: Based on the TTA and TTA$_{min}$ calculations, the RWW application shall associate a HMI warning identifier.

Requirement: The RWW application shall apply the following rules while the vehicle is in the event History (conflict area):

1. A high level HMI warning shall occur while the vehicle is above the speed limit identified in the roadworks; or

2. A low level HMI warning shall occur while the vehicle is below the speed limit identified in the roadworks

Requirement: Based on the vehicle location, DWT min calculation and TTE, the V-ITS-S application shall associate a HMI warning identifier.

Table 7.1 – Driver Warning Trigger Time to HMI Warning

DENM zone	Collision Risk	Description	HMI Warning ID
trace	TTA < *thresholdHigh*	Critical collision risk	RWW_HIGH
	thresholdHigh < TTA < *thresholdMedium*	Safety awareness required	RWW_MEDIUM
	thresholdMedium < TTA < *thresholdLow*	Comfort warning required	RWW_LOW
	TTA > *thresholdLow*	No action required	No HMI change
	TTA$_{min}$ > 0	No action required	No HMI change
eventHistory	Vehicle Speed > current speed limit in RWW DENM	Critical collision risk	RWW_HIGH_EVENT
	Vehicle Speed < current speed limit in RWW DENM	Comfort warning required	RWW_LOW_EVENT

7.3 HMI Warning

The HMI warning provides information in the vehicle that allows the driver to take suitable evasive action. The HMI warning is based on the trigger calculations and the resulting collision risk. The library of RWW use case HMI warnings includes the collision risk stages and an associated image/sound.

Requirement: The HMI shall display the image and play the audio sound based on the HMI warning requested from the V-ITS-S and information presented in Table 7.2. The HMI warning shall display in accordance with *HMI Specification PSTS003*. The V-ITS-S and HMI shall provide image and audio sound configuration updates based on the HMI Warning ID.

Table 7.2 – HMI Warning Lookup

HMI Warning ID	Description	Image	Audible Sound
RWW_LOW	Comfort warning	None[1]	None
RWW_MEDIUM	Safety warning	None[1]	None
RWW_HIGH	Critical warning	Road Work	RWW_HIGH.wav
RWW_LOW_EVENT	Comfort warning	None	None
RWW_MEDIUM_EVENT	Safety warning	None	None
RWW_HIGH_EVENT	Critical warning	Reduce Speed	RWW_HIGH_EVENT.wav

Notes:

[1] The final HMI display for ICVP was optimised for simplicity of participants as such not all possible warning escalations were used. However, this does not form a recommendation for future use or TMR expectations of industry. It would be expected future developers would consider integration into existing systems to best suit users' expectations and understanding.

7.4   HMI Speed Display

The HMI speed display for RWW will follow the details and requirements that are in PSTS018 IVS Use Case Specifications.

7.5   Continuity

Requirement: The HMI warning and speed display shall remain valid while the V-ITS-S preconditions and trigger conditions remain valid for the last RWW DENM received. If the vehicle receives a new RWW DENM with the same identifier, the trigger and display conditions shall be reassessed against the new parameters in the DENM in accordance with the V-ITS-S application lifecycle.

Requirement: On completion of the RWW HMI warning, the HMI shall return to any lower priority use case HMI warning currently active (if no other HMI warnings are active, the HMI shall return to the default state as defined in *HMI Specification PSTS003*).

8   Key Configurable Parameters

Requirement: The following key configurable parameters shall be configurable from the C-ITS-F in accordance with *V-ITS-S Specification PSTS002.* These parameters shall be used through the use case to allow adjustments to the operation and timing.
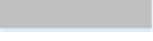
Table 8.1 - RWW Configurable Parameters

Reference Clause	Description	Unit	Factory Default	Min	Max	Device(s), systems affected
5.1.3	*lateralOffset*	cm	600	0	1000	V-ITS-S
7.1	*speedMin*	km/h	20	0	200	V-ITS-S
7.1	*speedmax*	km/h	130	0	200	V-ITS-S
7.1	*speedClear*	km/h	eventHistory defined	0	200	V-ITS-S
7.2	*decelerationSafe*	0.1m/s/s	48	0	100	V-ITS-S
7.2	*decelerationMin*	0.1m/s/s	8	0	100	V-ITS-S
7.2	*thresholdHigh*	ds	100	0	250	V-ITS-S
7.2	thresholdMedium	ds	100	0	250	V-ITS-S
7.2	thresholdLow	ds	100	0	250	V-ITS-S
7.3	Images and Audio per HMI Warning ID		N/A			V-ITS-S and HMI

Note: a value of 0 disables the function associated with the parameter.

9 Data Definition

The DENM structure in Figure *9.1* describes the overview of the RWW message which is subsequently detailed in data element level in the *Data Entity Catalogue PSTS006*. The message structure identifies the following data components:

1. ITS PDU container
2. Message set
3. Data frame
4. Sequence of data frame
5. Data element
6. Short listed CAVI DENM data entity but not applicable to RWW UC

Requirement: The RWW application shall use DENM data elements in accordance with the *Data Entity Catalogue PSTS006*.
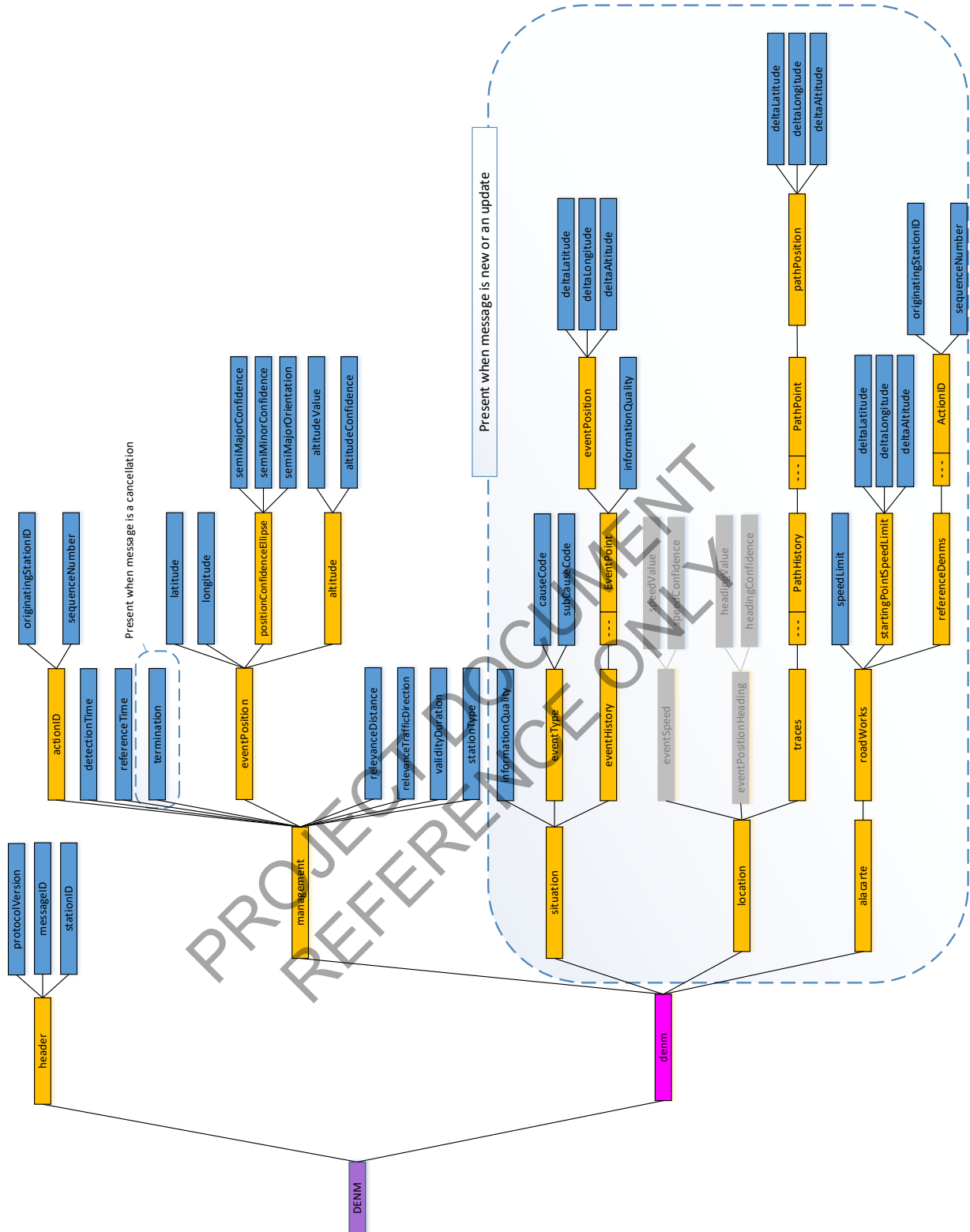
Figure 9.1 *- RWW DENM Message Structure*

PROJECT DOCUMENT
REFERENCE ONLY