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Project Specific Technical Specification

Transport and Main Roads
PSTS016 RHW Use Case Specification – Road Hazard Warning

October 2021

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:

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Version history

Version no.	Owner	Date	Nature of amendment
1.0	David Alderson	29/06/2018	Tender Issue
1.1	Kathy Mosley/ David Alderson	18/03/2019	Update to REQ_PSTS016_017 and REQ_PSTS016_019
1.2	David Alderson	06/07/2019	Updates to match learnings from implementation
1.3	Zinah Tam	27/07/2020	Updated Table 7.2 to match final incorporation of HUET recommendations
1.4	Zinah Tam	14/09/2020	Added note to Table 7.2 for clarity on release 25.2
2.0	Nicholas Brook	28/01/2021	Final update and adaption for external release
2.1	Jian Qin	07/10/2021	System Architecture drawing update

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1 Introduction

The Road Hazard Warning (RHW) 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.

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Definition of terms

Table 1.1 – Acronyms

Acronym	Term
API	Application programming interface
ASN.1	Abstract Syntax Notation One
C-ITS	Cooperative intelligent transport systems
C-ITS-F	Central ITS facility
DENM	Decentralised environmental notification message (EU)
FOT	Field operational test
HMI	Human machine interface
I2V	Infrastructure to Vehicle
ITS	Intelligent transport systems
PDU	Packet Data Unit
PSTS	Project Specific Technical Specification
RHW	Road hazard warning
R-ITS-S	Roadside ITS station
RTK	Real Time Kinematic
SCMS	Security credential management system
TMC	Traffic management centre
TSC	Traffic Signal Controller
UPER	Unaligned Packed Encoding Rules
V-ITS-S	Vehicle ITS station
XML	eXtensible Markup Language

Table 1.2 – 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 Cross Origin Resource Sharing - the way that the NTRIP data is broadcasted by Geoscience Australia.
FOT	Field Operational Test – the period when the in-vehicle C-ITS systems are operational and logging data
ITS-S	ITS station - includes C-ITS-S, R-ITS-S and V-ITS-S
Monitoring system	Sub-system of the C-ITS-F that monitors the operation of the C-ITS Pilot system

2 Reference documents

Table 2.1 – Referenced documents – External

Document ID	Document Name / Description
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 2.2 – Referenced documents – Internal

Document ID	Document Name / Description
PSTS002	V-ITS-S Equipment
PSTS003	HMI Equipment
PSTS006	Data Entity Catalogue
PSTS007	C-ITS Station Protocol Specification

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3 Quality system requirements

3.1 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 DENM for RHW 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.

4 Overview

The RHW use case provides the driver of a cooperative vehicle a warning of an approaching (or downstream) road hazard early enough to react safely prior to reaching the hazard. The RHW warning is provided as a DENM from the C-ITS-F including relevant hazard data.

The information for the DENM is sourced from *QLDTraffic*, TMR's existing data repository containing authenticated road hazard information. *QLDTraffic* is manually verified and updated (by Traffic Management Centre operators) with details (location, impacted direction) of crashes, flooding, debris on road, congestion and other hazards.

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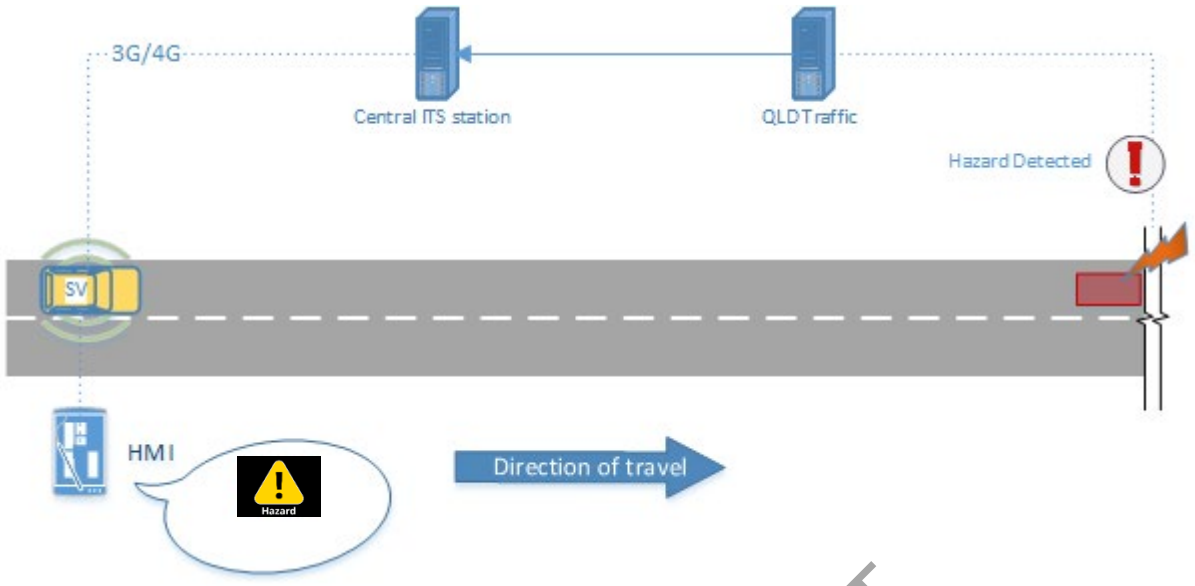

Figure 4.1 – RHW operation

Requirement: The RHW application shall manage and display road hazard warnings to the driver.

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

Requirement: The RHW application shall be capable of handling up to 3 overlapping RHW simultaneously.

4.1.1 Primary Scenario

In the primary scenario for RHW (refer to Figure 4.2) the vehicle approaches the road hazard, its position (including lateral offsets) overlap the trace (and within the relevance distance) and in the correct direction. The DENM type could contain lane level information however the data source does not specify to that level and hence was not utilised for ICVP. An informative HMI warning is provided to the driver prior to reaching the road hazard to give the driver enhanced situational awareness.

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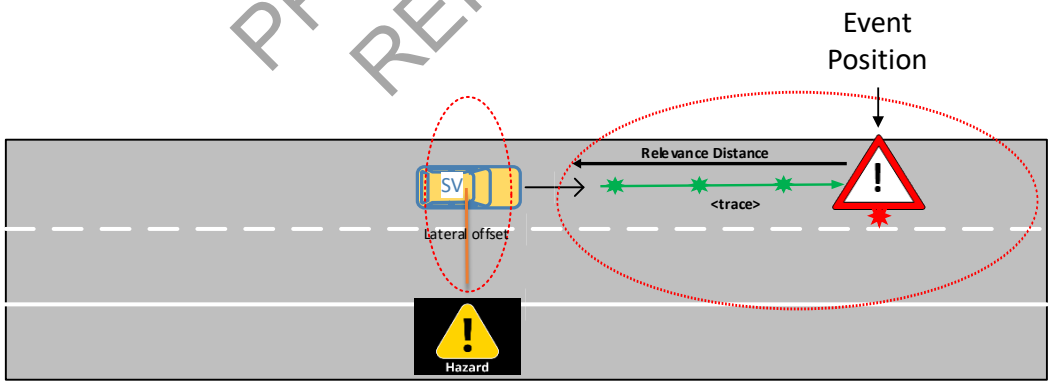
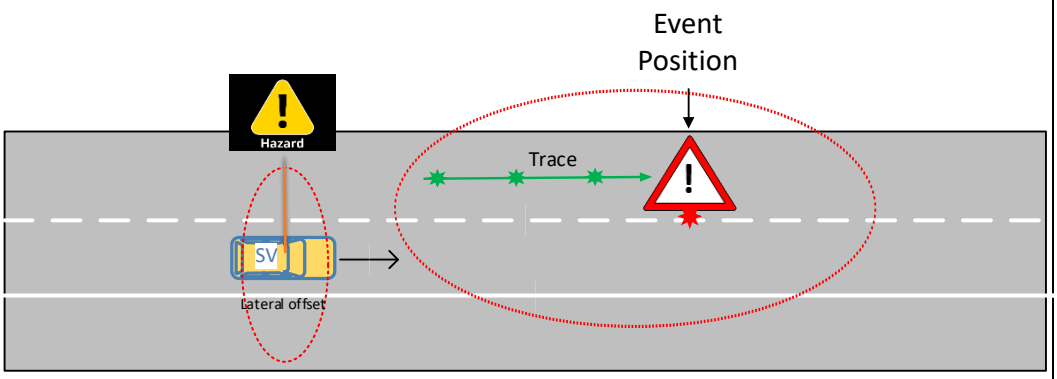
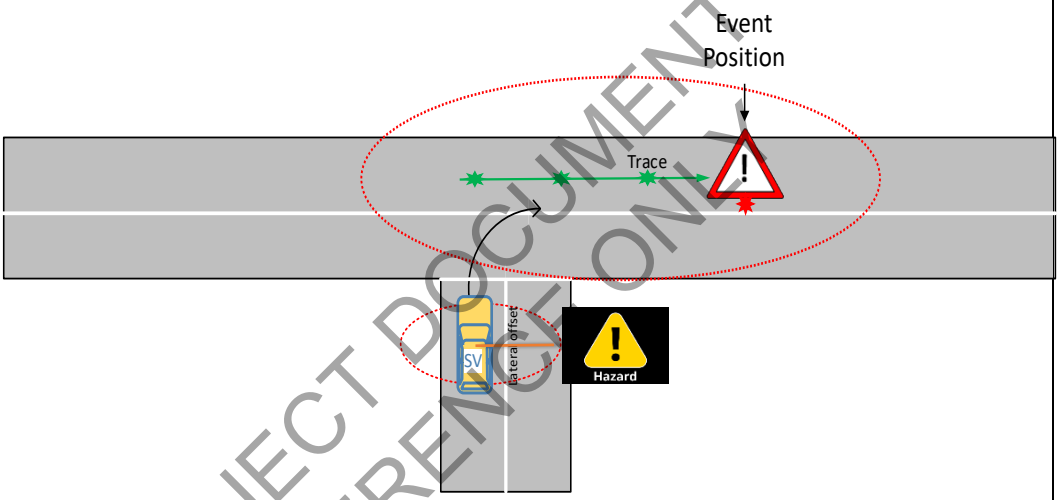
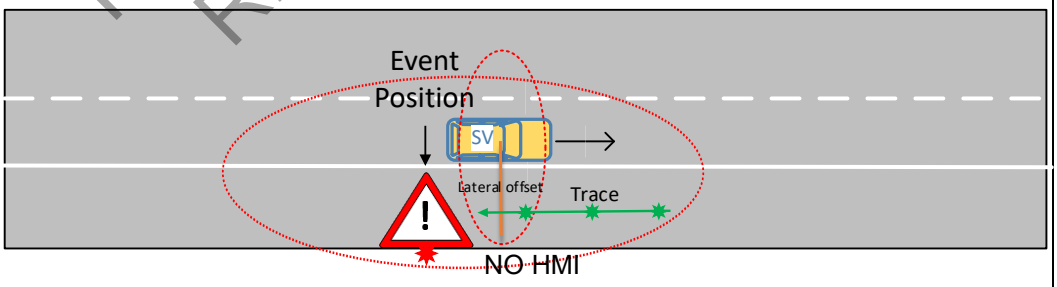


Figure 4.2 – Primary Scenario

4.1.2 Scenario Equivalents

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

Table 4.1 – Scenario Equivalents

Variant	Visualisation and Comment
Adjacent lanes or wide lanes where lateral offset and trace intersect.	 HMI Warning: Yes
Vehicle is entering from side road	 HMI Warning: Yes, once the vehicle is determined to be on a trace of the road hazard event.
Vehicle is driving in the opposite direction to road hazard (and road hazard is directional)	 HMI Warning: No, the heading is incorrect by more than a reasonable margin (180°).

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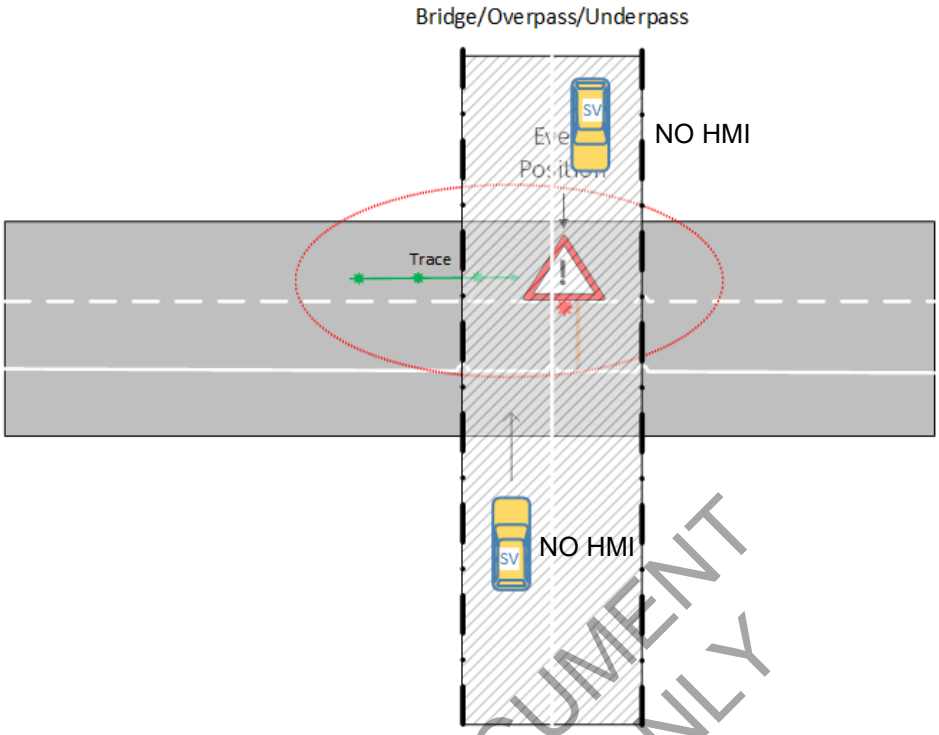
Variant	Visualisation and Comment
Vehicle is driving on a bridge above the road hazard (in a different vertical plane)	 HMI Warning: No Comment: This scenario should not display a HMI warning because the vehicle is not following the same path (direction or elevation) as the road hazard DENM and the elevation does not match. Elevation or heading could be used to discount this scenario when assessing relevance to the trace.

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4.1.3 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 RHW DENM. This allowance is required for RHW as the accuracy of input data does not allow the DENM to be lane level specific.

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

5 System Components

The RHW 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 hazard warning database.

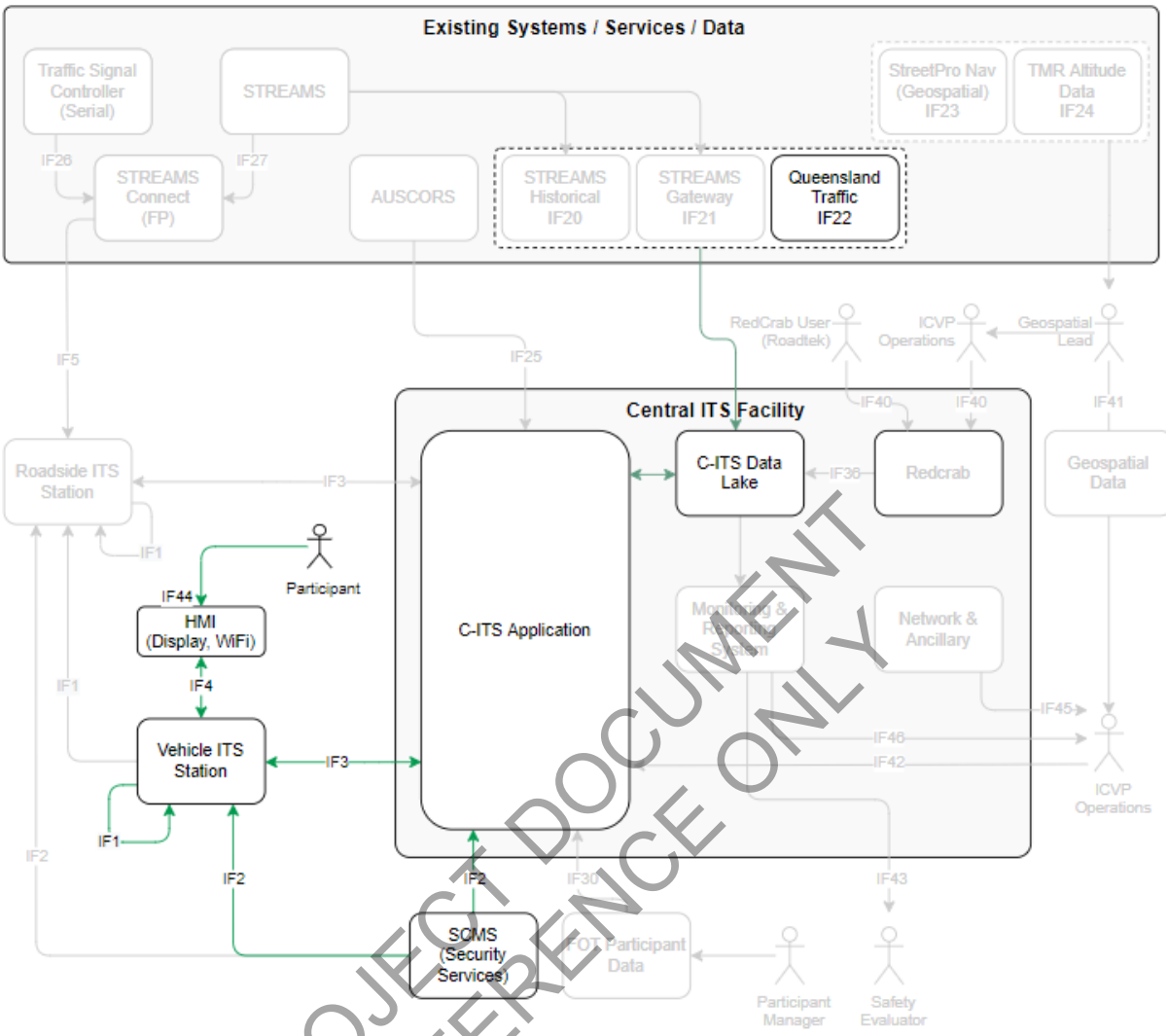

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Figure 5.1 – System Architecture

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

Table 5.1 – System Component Summary

Component	Role	Requirement	Detailed component lifecycle
V-ITS-S	Event Processor	The RHW use case application is performed in the V-ITS-S.	The process for managing the RHW use case is defined in section 6.1
HMI	Driver Interface	HMI must be on and able to interact with the V-ITS-S for display and status	HMI warnings are defined in section 6.2
RHW database	Data entry/source	This database is populated through the QLDTraffic API which manages road hazards state-wide	Not applicable. Managed by C-ITS-F

Component	Role	Requirement	Detailed component lifecycle
C-ITS-F	Messaging and Monitoring	Manages hazard updates from QLDTraffic and provides current hazard events 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 RHW use case operation.

Requirement: Communications between components using cellular connection (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 5.2.

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

5.1 Typical Process Flow

The process flow for the RHW event is shown in Figure 5.2. This describes the normal process for the event through the relevant system components. The component lifecycles in section 6 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 5.2 in which the V-ITS-S retrieves hazard information from the C-ITS-F returns all RHW DENM for the relevant geo-tile.

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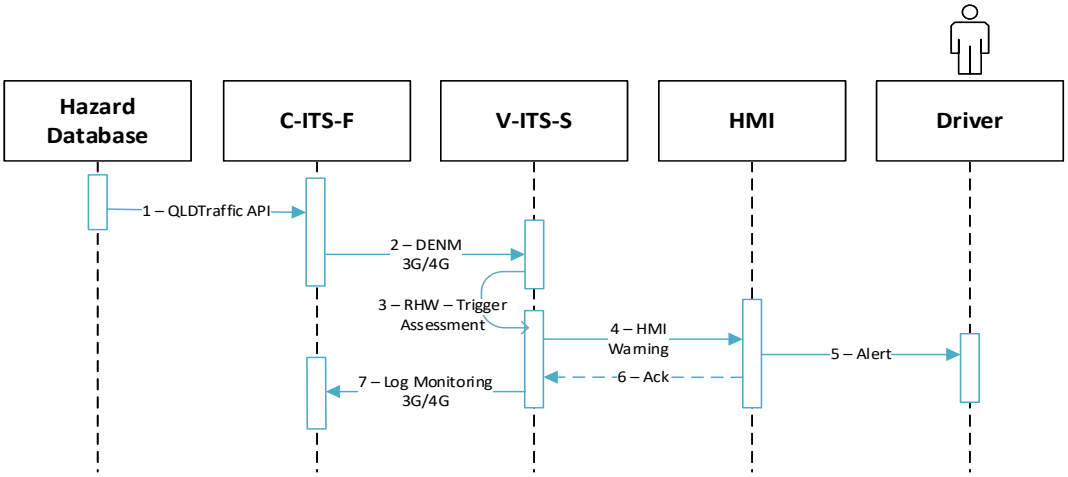

Figure 5.2 – Typical Flow of Data

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6 Lifecycles

The RHW 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.

6.1 V-ITS-S Application Lifecycle

Figure 6.1 shows a process flow expected from the application within the V-ITS-S to receive RHW DENMs and determine use case behaviour.

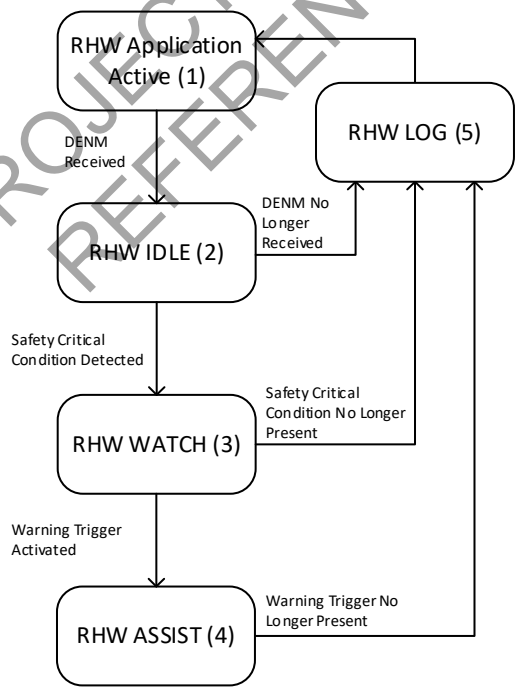

Figure 6.1 – V-ITS-S Lifecycle (modified from ETSI 101 539-03:2013)

Requirement: The V-ITS-S shall apply the lifecycle states and transitions in the RHW application (or tested 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 RHW application shall start up if enabled and request all RHW DENM for the current geo-tile from cellular 3G/4G (see *ucRhwEnabled* in *V-ITS-S Specification PSTS002* for application enabling and disabling). *(State 1)*

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

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

Requirement: The RHW application shall compare the vehicle trajectory (heading, speed and location) to the hazard 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 and maximum speed, and
2. Within the *relevanceDistance* defined in the DENM, and
3. Following the *trace* (based on lateral offset defined in section 4.1.3) in the same direction, and
4. DENM is current and active.

Requirement: If the *validityDuration* in the DENM has expired or is received as a DENM cancel from the C-ITS-F, the RHW application shall consider the hazard as no longer present. *(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 DENM, and
3. Following any DENM *trace* for the RHW event (based on lateral offset defined in section 4.1.3) in the same direction

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Requirement: The RHW application shall assess the collision risk as defined in section 6.2. *(State 3)*

Requirement: The RHW application shall request an HMI warning based on the RHW_LOW image in Table 6.2. The RHW application shall monitor acknowledgements and the status of the HMI while the display request is active.

Requirement: RHW 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 event DENM (*trace*); or
2. The vehicle departs from the *relevanceDistance*; or
3. The vehicle reduces speed below the minimum clearance speed (*speedClear*)

Requirement: A collision risk shall be active if action is required within the safety thresholds as defined in section 6.2. *(Transition 3 to 4)*

Requirement: The RHW application shall request the appropriate HMI warning as defined in section 6.3 to the HMI Presentation Manager detailed in *V-ITS-S Specification PSTS002*[1]. The RHW application shall monitor acknowledgements and the status of the HMI while the display request is active. *(State 4)*

Requirement: RHW HMI warning request shall be cleared if: *(Transition 4 to 5)*

1. The vehicle safety critical conditions are no longer met (see transition 3 to 5 above)

Requirement: The RHW 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 RHW application shall confirm the event is logged and event completed *(Transition 5 to 1)*

6.2 Warning Trigger

When the vehicle enters the relevance distance and the trace of the RHW event, 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 6.2.

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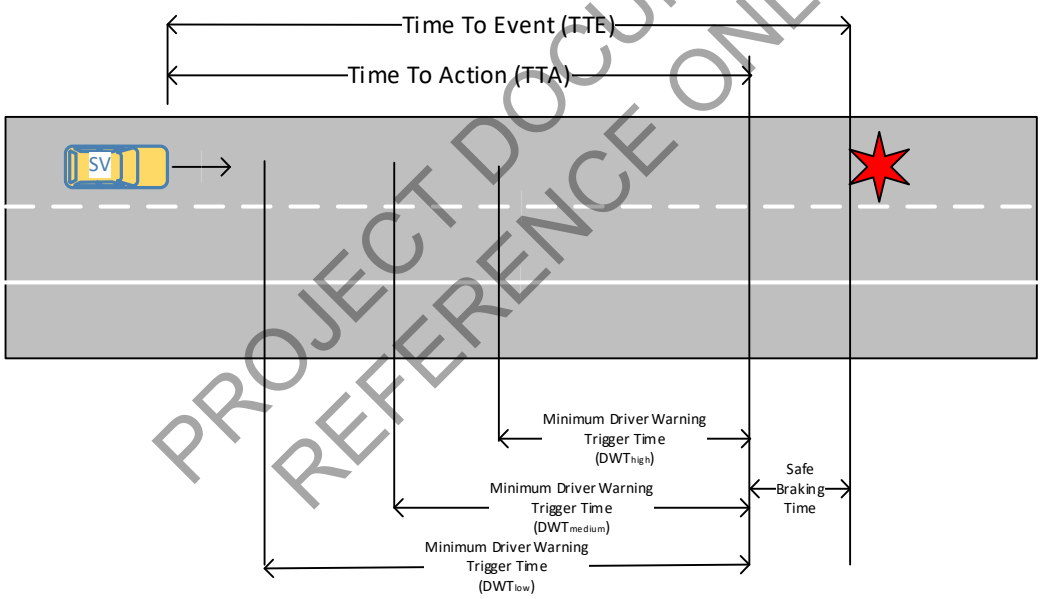

Figure 6.2 – Minimum Warning Trigger Time

Based on the TTA, the trigger is determined based on the graph in Figure 6.3.

[1] The HMI Presentation Manager provides a single point of control for managing, prioritizing and logging all driver alerts including all use case warnings, speed limits and system status.

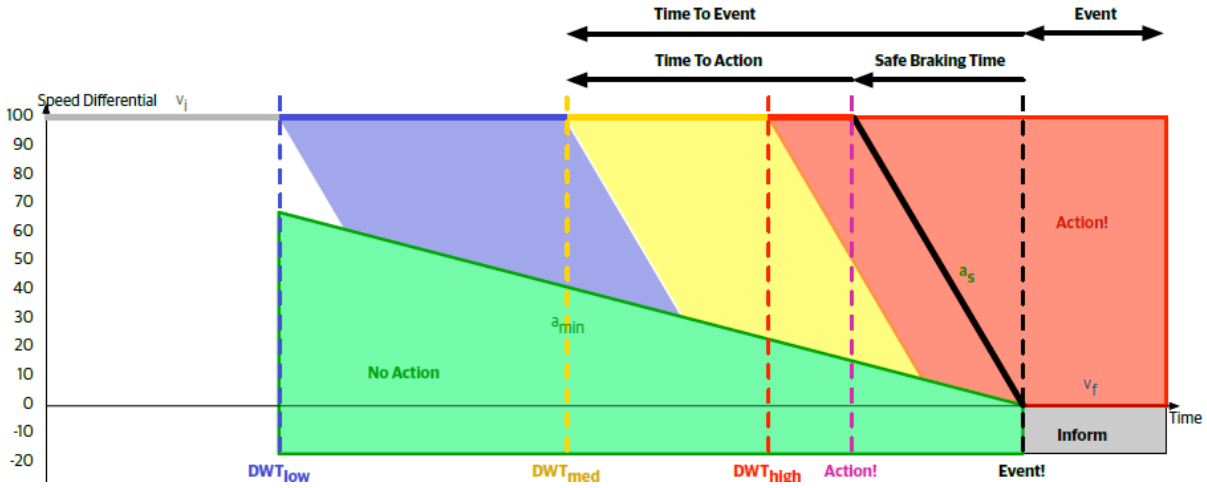

Figure 6.3 – Determining triggers from TTA

Requirement: Distance (d_{V_H} in metres) to the hazard shall be calculated based on the DENM event point and vehicle location.

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

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

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

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

Where:

v_i = Current Speed

v_f = Speed required to reach for an RHW event (*eventSpeed* in DENM)

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

Requirement: The RHW 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:

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

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

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

Where:

v_i = Current Speed

v_f = Speed required to reach for an RHW event (*eventSpeed* in DENM)

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

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Requirement: Based on the TTA and TTA_{min} calculations, the V-ITS-S application shall associate a HMI warning identifier.

Table 6.1 – Driver Warning Trigger Time to HMI Warning

Collision Risk	Description	HMI Warning ID
TTA < *thresholdLow*	Comfort warning required	RHW_LOW
TTA_{min} > 0	No action required	No HMI change

Note: Medium and high warning levels may be required if accuracy of the use case input is improved.

6.3 HMI Warning

The HMI warning provides information in the vehicle that allows the driver to take suitable evasive action.

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 6.2. 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 6.2 – HMI Warning Lookup

HMI Warning ID[1]	Description	Image	Audible Sound
RHW_LOW	Comfort warning		None

Notes:

[1] Medium and high warning levels may be required if accuracy of the use case input is improved.

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6.4 Continuity

Requirement: The HMI warning shall remain valid while the V-ITS-S preconditions and trigger conditions remain valid for the RHW DENM. If the vehicle receives a new RHW 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 RHW 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*).

7 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 7.1 – Key Configurable Parameters

Reference Clause	Description	Unit	Factory Default	Min	Max	Device(s), systems affected
4.1.3	*lateralOffset*	cm	600	0	1000	V-ITS-S
6.1	*speedMin*	km/h	20	0	200	V-ITS-S
6.1	*speedMax*	km/h	130	0	200	V-ITS-S
6.1	*speedClear*	km/h	0	0	200	V-ITS-S
6.2	*thresholdLow*	ds	200	0	250	V-ITS-S
6.3	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.

8 Data Definitions

The DENM structure in Figure 8.1 describes the overview of the RHW 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 attribute but not applicable to RHW UC

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Requirement: The RHW application shall use DENM data elements in accordance with the *Data Entity Catalogue PSTS006*.

Requirement: The cause codes and sub-cause codes utilised from the DENM for this use case are in Table 10. In the future this use case could be supported by more warning types and relevant codes.

Table 2: RHW DENM Cause Codes

Type of warning	CauseCode	SubCauseCode
Debris on Road	10	0
Road Damage	9	0
Stationary Vehicle	94	0
Flash Flooding	17	0
Long Term Flooding	17	0
Crash - Multi-Vehicle	2	1
Crash - Single-Vehicle	2	0

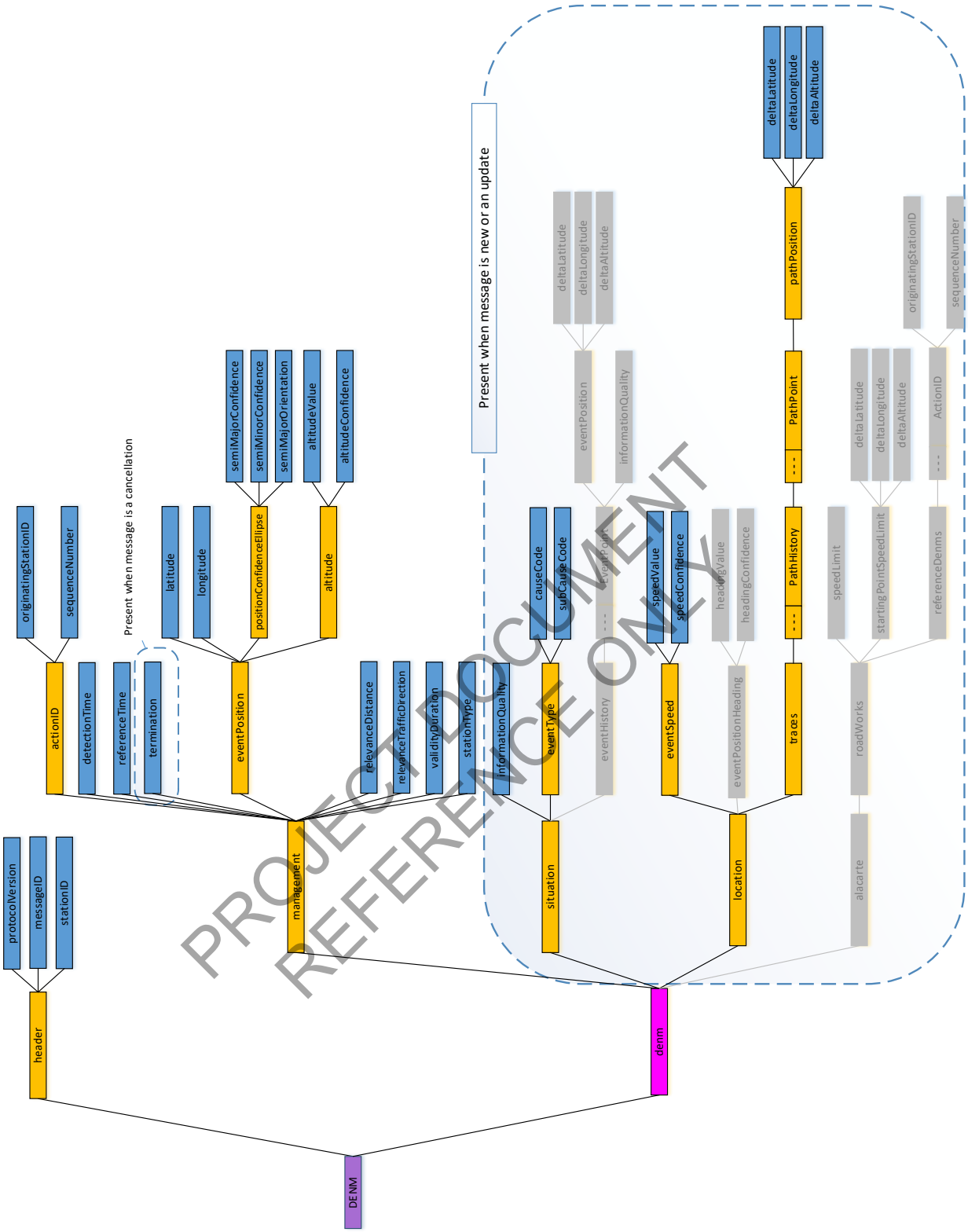

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Figure 8.1 – RHW DENM Message Structure

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