Project Specific Technical Specification

Transport and Main Roads
PSTS014 TWVR Use Case Specification – Turning Warning Vulnerable Road user

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_PSTS014_021
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	1/10/2020	Updated Table 7.2 to match release 25.2
2.0	Nicholas Brook	28/01/2021	Final updates and adaption for release to external
2.1	Jian Qin	06/10/2021	Overall System Architecture drawing update

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Contents

1 Introduction

The Turning Warning Vulnerable Road user (TWVR) 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
CA	Conflict Area
C-ITS	Cooperative intelligent transport systems
C-ITS-F	Central ITS facility
DWT	Driver Warning Trigger
ETSI	European Telecommunications Standards Institute
EU	European Union
FOT	Field operational test
HMI	Human machine interface
ITS	Intelligent transport systems
MAPEM	MapData extended Message
PDU	Protocol Data Unit
PED	Pedestrian
PSTS	Project Specific Technical Specification
R-ITS-S	Roadside ITS station
RTK	Real Time Kinematic
SCMS	Security credential management system
SPaT	Signal phase and timing (cooperative message)
SPATEM	Signal Phase and Timing Extended Message
TSC	Traffic Signal Controller
TTA	Time to Action
TTE	Time to Event
TWVR	Turning Warning for Vulnerable Road User
UPER	Unaligned Packed Encoding Rules

Acronym	Term
V-ITS-S	Vehicle ITS station
VRU	Vulnerable road user
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
STREAMS	TMR's integrated ITS operating platform

3 Reference documents

Table 3.1 – Referenced documents – External

Document ID	Document Name / Description
ISO/TS 19091:2017	Intelligent transport systems - Cooperative ITS - Using V2I and I2V communications for applications related to signalized intersections
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

Table 3.2 – Referenced documents – Internal

Document ID	Document Name / Description
PSTS002	V-ITS-S Equipment
PSTS003	HMI Equipment
PSTS005	R-ITS-S Equipment
PSTS006	Data Entity Catalogue
PSTS007	C-ITS Station Protocol 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 SPATEM and MAPEM 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 TWVR use case provides a warning to the driver of a cooperative vehicle of a potential conflict with an adjacent vulnerable road user (VRU) crossing during a pedestrian movement at a signalised intersection. The aim is to provide early awareness to the potential conflict allowing drivers to safely slow or stop in advance of the pedestrian crossing and increase awareness of vulnerable road users. For the TWVR application, the awareness of pedestrian movement at an intersection is based on pedestrian phase being displayed (i.e. green walk or red flashing pedestrian light) and displayed by the traffic signals, not the real-time detection of presence at the crossing. This is particularly resonant since COVID19 where many intersections are set to always run pedestrian movements without a demand.

The roadside equipment must broadcast the geometry (MAPEM) and the state and timing (SPATEM) of the intersection[1]. The vehicle must use its own (ego) position with lane level accuracy and confidence to determine which lane it is in relative to the intersection geometry. The vehicle subsequently uses its ego trajectory and its current lane's signal group to calculate the state of the relevant lights when the vehicle is likely to cross the stop bar. The V-ITS-S generates a TWVR HMI warning on the approach to the intersection if it determines the vehicle trajectory may intersect that of an allowed vulnerable road user signal group on the adjacent crossing during the vehicle and pedestrian permitted movement. The TWVR will be triggered if the pedestrian crossing is showing either a green walk or a flashing red stop signal.

[1] SPATEM and MAPEM are ETSI extended SPAT/MAP messages with a specific ETSI header. Thus, except for the ETSI header, the data frames and elements are interchangeable.

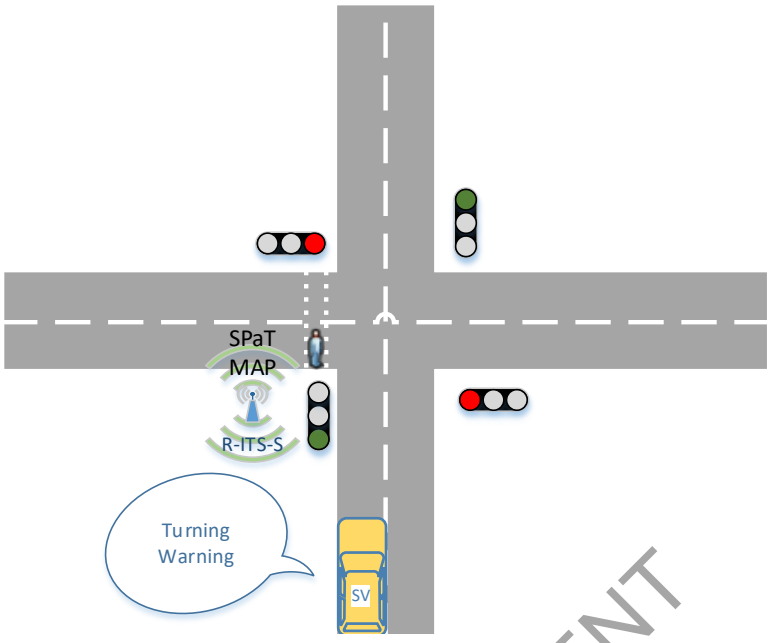


Figure 5.1 TWVR Operation

Requirement: The TWVR application shall identify if its own (ego) vehicle will drive through a traffic intersection whilst the vehicle state is a green light and a pedestrian (vulnerable road user) movement is allowed (green walk or red flashing).

Requirement: The vehicle station facilities used for TWVR shall process SPATEM at 100ms and MAPEM at 500ms for each R-ITS-S in range.

Requirement: The TWVR application shall identify and process SPATEM and MAPEM from up to 3 surrounding intersections at once. The most relevant intersection based on location and direction of travel shall have the highest priority when generating HMI warnings.

5.1.1 Primary Scenario

In the primary scenario for TWVR, the vehicle approaches a signalised intersection with a green light whilst a pedestrian movement is allowed (Green Walk or Flashing Red) on the crosswalk lane.

The V-ITS-S receives intersection information (SPATEM and MAPEM) and the TWVR application determines the time required to stop the vehicle at a predetermined comfortable deceleration rate and the likelihood of exceeding this deceleration rate and entering the conflict area (crossing stop bar) during a conflicting pedestrian phase. If excessive braking is required for the vehicle to stop before the stop bar or the vehicle enters the conflict zone (crossing stop bar) during the conflicting pedestrian phase still being allowed, an HMI warning will be issued to the driver.

The vehicle continues to display the HMI warning until the TWVR event is no longer appropriate. The TWVR event ceases to be appropriate when:

- Vehicle has exited the conflict area (IE passed the relevant conflicting pedestrian crossing or another exit) while the pedestrian is still allowed; or
- Vehicle leaves the lane with a green signal and conflicting pedestrian movement (for example; into straight through lane or side street); or
- Vehicle brakes sufficiently below the clearance threshold; or
- Pedestrian or Vehicle signal group changes is no longer allowed or clearance (therefore in red).

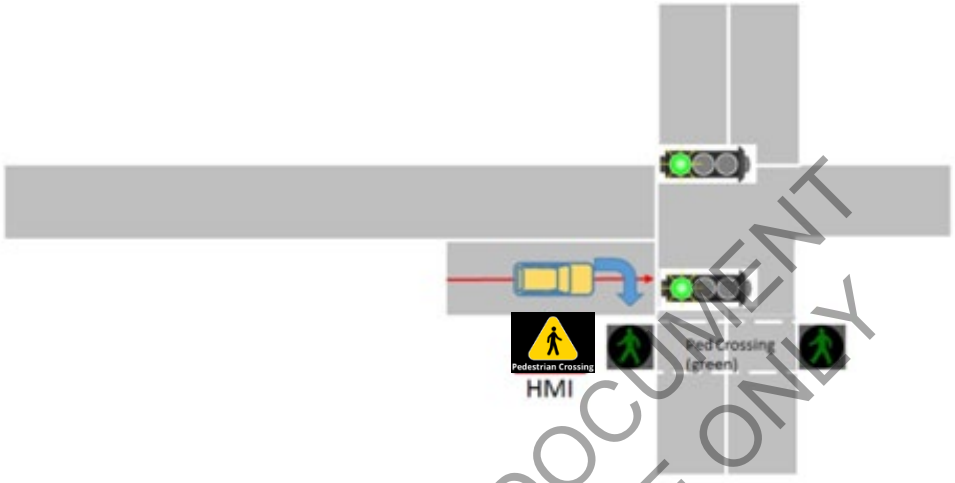
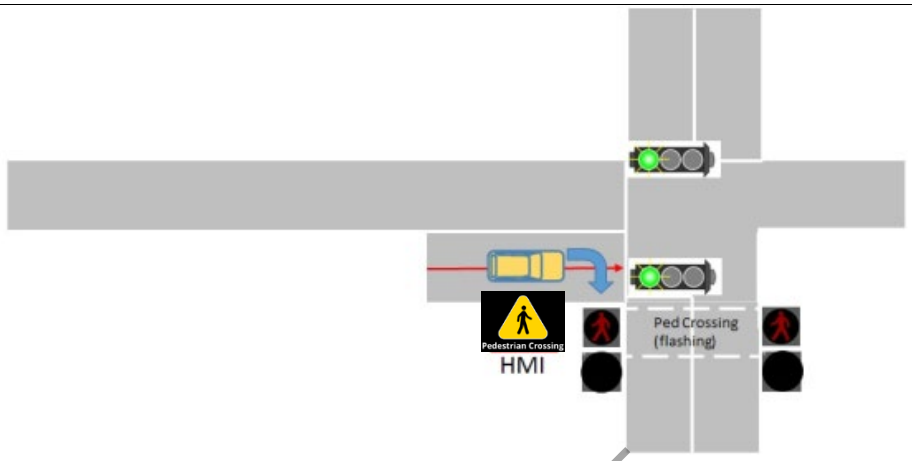


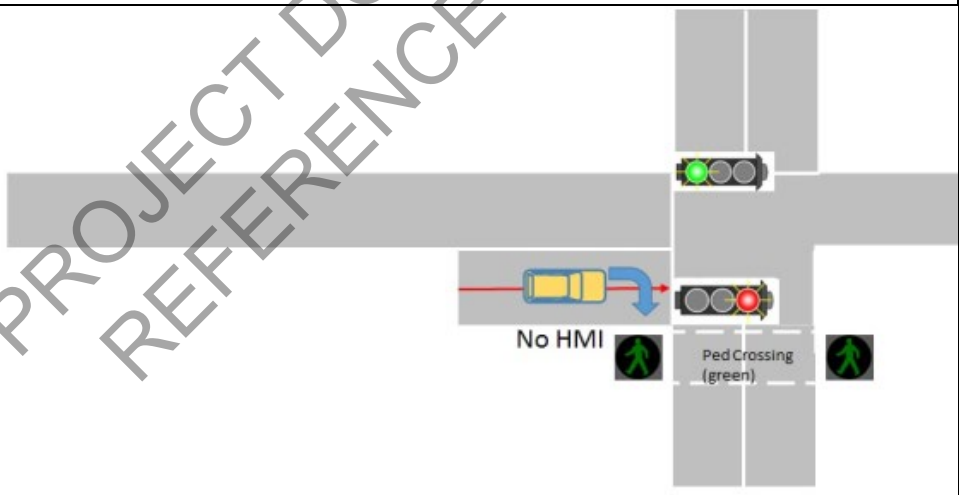
Figure 5.2 – Turning Warning Vulnerable Road user

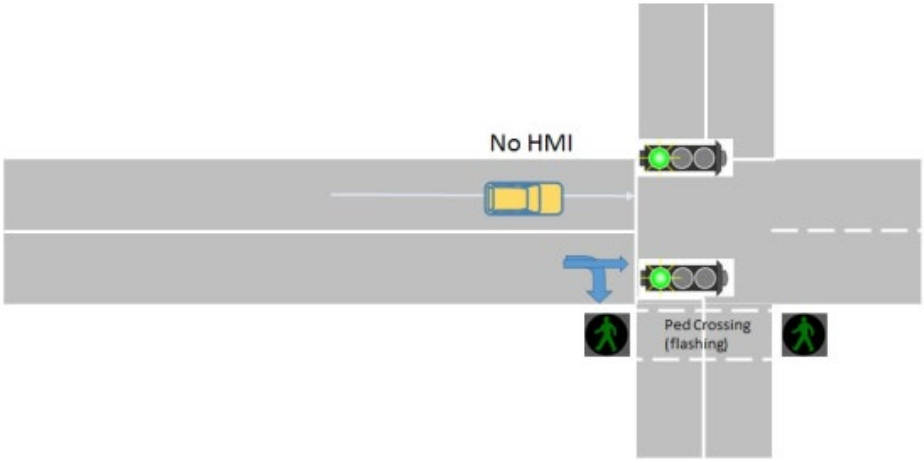
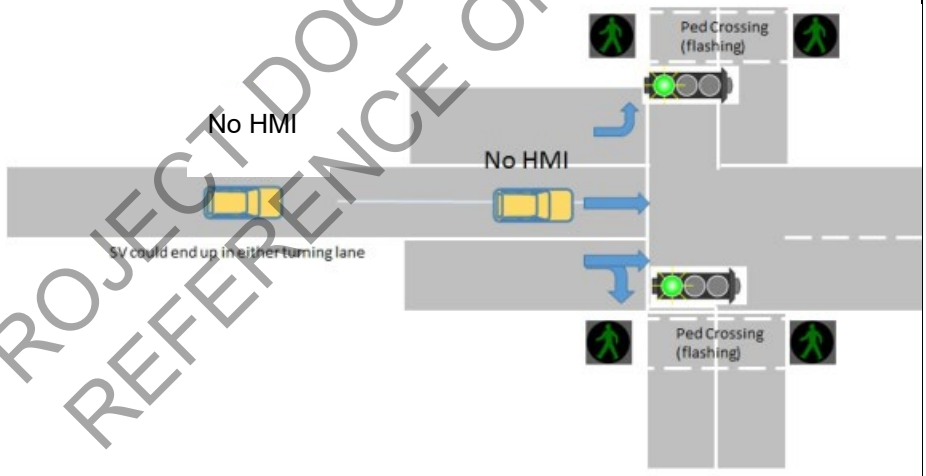
5.1.2 Scenario Equivalents

The following table describes the same primary scenario above but with several variants and the expected outcome. In each scenario, the V-ITS-S receives the MAPEM and SPATEM in advance of the intersection approach (as soon as in range of the R-ITS-S).

Table 5.1 – Scenario Equivalents

Variant	Visualisation and Comment
Vehicle Likely to enter the conflict area as the PED signal is at or turning to "Flashing Red"	 HMI Warning: Yes Comment: The application treats red flashing in the same way as a green as it is still a permitted state for VRUs to be present on the crossing.

Variant	Visualisation and Comment
Vehicle in a lane that permits turning movements, however, a conflict with the pedestrian movement is unlikely. For instance, the vehicle has a red light and must stop anyway	 HMI Warning: No Comment: TWVR does not trigger when the ego vehicle's lane's signal group is red. If the vehicle entered was approaching at an unsafe trajectory or entered the conflict area during a red light, the ARLW application would be relevant and may trigger *(PSTS013)*.

Variant	Visualisation and Comment
Vehicle in a non-turning lane but has a green light in a lane which will not conflict with the pedestrian movement.	 HMI Warning: No Comment: A warning doesn't display if the vehicle path is not in a lane that can turn across an active pedestrian state.
Pedestrian state changes to "inactive" solid red whilst vehicle is on approach or in conflict area.	 HMI Warning: No Comment: Vehicle will reassess once it is in a lane that has a potential pedestrian conflict.

5.1.3 Vehicle Location – Lane Association

The TWVR use case is based on the concept of the geometric topography (MAPEM), which details lane specifics including information about the signal groups relevant to each ingress (entry) lane as well as the egress (exit) lane it connects to. The vehicles position is matched to the MAPEM lane that it is most confidently in.

Requirement: The TWVR application assess the lane with most confidence based on the vehicle position relative to the MAPEM node paths.

5.2 MAPEM Logic

As illustrated in Figure 5.3, MAPEM data provides context of the intersection by defining lanes as a series of nodes at the centre of each lane. The space between the stop bars (ingress) and the start of new lanes (egress) is known as the conflict area. The MAPEM links the node at the stop bar with its corresponding exit(s) by defining the *connectsTo* data element. The MAPEM provides the foundation by which V-ITS-S can interpret Signal Phase and Timing (SPaT). SPATEM data provides the real-time status of the intersection including state and persistence of each phase.

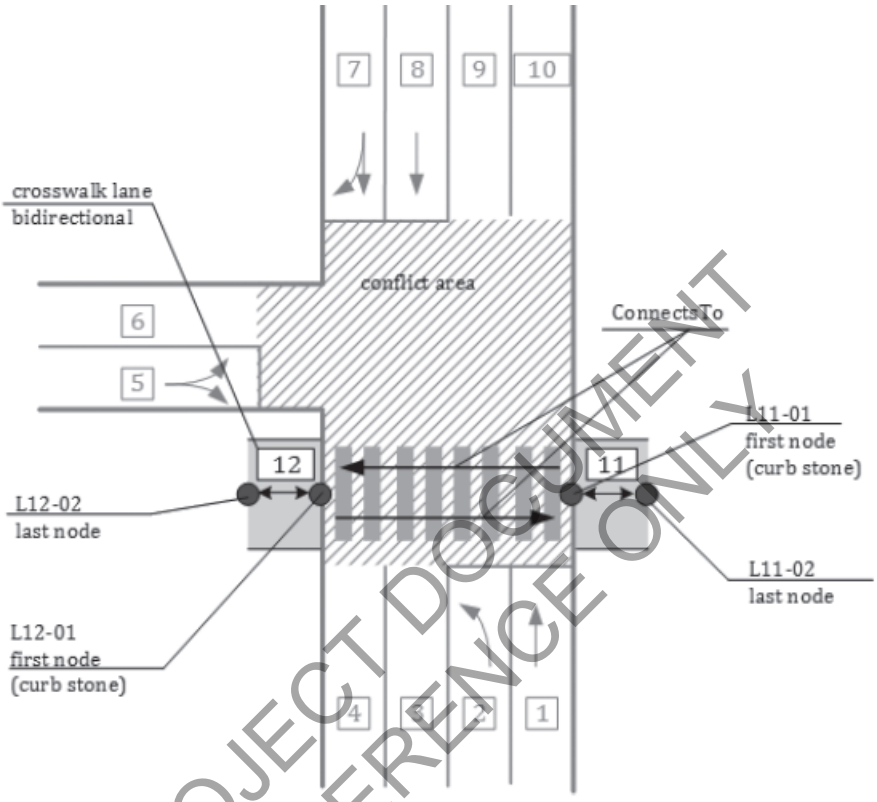


Figure 5.3 - Intersection MAPEM Layout (ISO/TS 19091:2017)

Requirement: The TWVR application shall use received MAPEM to determine the vehicle location against a lane and subsequently; *ingress*, *connectsTo, signal group* and *egress* paths.

5.3 SPATEM Logic

The list of available *eventState* options are listed in Table 5.2 along with their commonly used description. It is indicated if they are not expected to be applicable (NA) to the pilot.

Table 5.2 – SPAT Event States

***eventState* (enumerated value)**	**Common description**
unavailable (0)	Unknown or error
dark (1)	Traffic signal is unlit
stop-Then-Proceed (2)	Left turn on red **(NA)**
stop-And-Remain (3)	Red
pre-Movement (4)	Red+Yellow EU **(NA)**

***eventState* (enumerated value)**	**Common description**
permissive-Movement-Allowed (5)	Green (Filtered)
protected-Movement-Allowed (6)	Green (Controlled)
permissive-clearance (7)	Yellow (Filtered)
protected-clearance (8)	Yellow (Controlled)
caution-Conflicting-Traffic (9)	Flashing Yellow

The pedestrian lanes are treated in the same way as vehicular lanes in terms of linking between lane, signal group and state describes the traditional naming against SPATEM naming, of note is that SPATEM for pedestrians is used as protected (controlled) and permitted as the intention is that a V-ITS-S shall not expect a pedestrian to yield for it whilst the pedestrian group is in a green or flashing phase.

Table 5.3 – Pedestrian States

Traditional	**SPATEM (Controlled)**
Green Walk	*permissive-Movement-Allowed* (5)
Flashing Red	*permissive-clearance* (7)
Red	*stop-And-Remain* (3)

The STREAMS Connect provides the timing information for the relevant phase as shown in Table 5.4.

Table 5.4 – SPATEM Timing (Traffic Signals and Pedestrian Signals)

SPAT Parameter	**Description**	**Green**	**Active (pedestrian)**	**Yellow / Flashing Red**	**Red**
startTime	Determined as soon as the next *eventState* is known then revised at the start of the relevant *eventState* and does not change during the event state	Yes	Yes	Yes	Yes
minEndTime	For *stop-And-Remain eventState* represents the all-red parameter	Yes	Yes	Yes	Yes
maxEndTime	Determined at the start of the Flashing Red for the Flashing Red event state. The next active signal group *startTime*, *minEndTime* and *maxEndTime* are also provided at the start of the Yellow event state. Hence - there is no predictive SPATEM data - the next phase change is		Yes	Yes	

SPAT Parameter	Description	Green	Active (pedestrian)	Yellow / Flashing Red	Red
	only known at the beginning of Flashing Red. Pedestrian timing is fixed by the traffic controller and therefore is known for Green and Flashing Red, active states. For the Flashing Red and pedestrian active event state, the *maxEndTime* is equal to the *minEndTime*				
likelyTime	Optional, and not populated for pedestrian signals or if the phase is in dwell (no demand for other phases) and the time exceeds the plan time.		Yes	Yes	

Requirement: The TWVR application can determine the current SPATEM signal state and timings of conflicting movements for the relevant vehicle position as linked by the MAPEM lane ingress and egress compared to other lanes.

5.3.1 Usage of maneuverAssistList in SPATEM

The *connectionID* data element is an integer value index used to relate any clearance information with a target conflicting movement. The target movement is described in MAPEM in the *connectTo* data frame. As such, the *connectionID* used in *maneuverAssistList* dataframe in the SPATEM must match the corresponding *connectionID* value used in the *connectTo* data frame in MAPEM.

The *pedBicycleDetect* data element is a Boolean type value which is set to TRUE (1) if any pedestrians or bicycle movement signals are detected in an active (green walk or red flashing) state which conflict with the target lane or lanes associated with *connectionID*. If no active pedestrian signals detected for that connection ID, the *pedBicycleDetect* is set to FALSE.

Requirement: In order to implement the TWVR application, the V-ITS-S can use the information provided in the *maneuverAssistList* data frame. Specifically, two data elements are required:

1. spat.intersections.maneuverAssistList.connectionID, and
2. *spat.intersections.maneuverAssistList.pedBicycleDetect*

Note: ICVP use of the *pedBicycleDetect* flag was determined as the simplest method for the V-ITS-S vendor. Whilst when correctly provided aligns with the standards, the method to generate this field from current TMR traffic signal control systems it is not a true representation of the "detect" intent rather a flag suggesting the movement is "active". As such future enhancements to TMR SPATEM output should include reappropriating this field to its true ETSI standard meaning.

6 System Components

The TWVR use case is an I2V application and as a result the primary path is through the intersection equipment (Traffic Signal Controller (TSC), STREAMS Connect and R-ITS-S) and the V-ITS-S (and HMI).

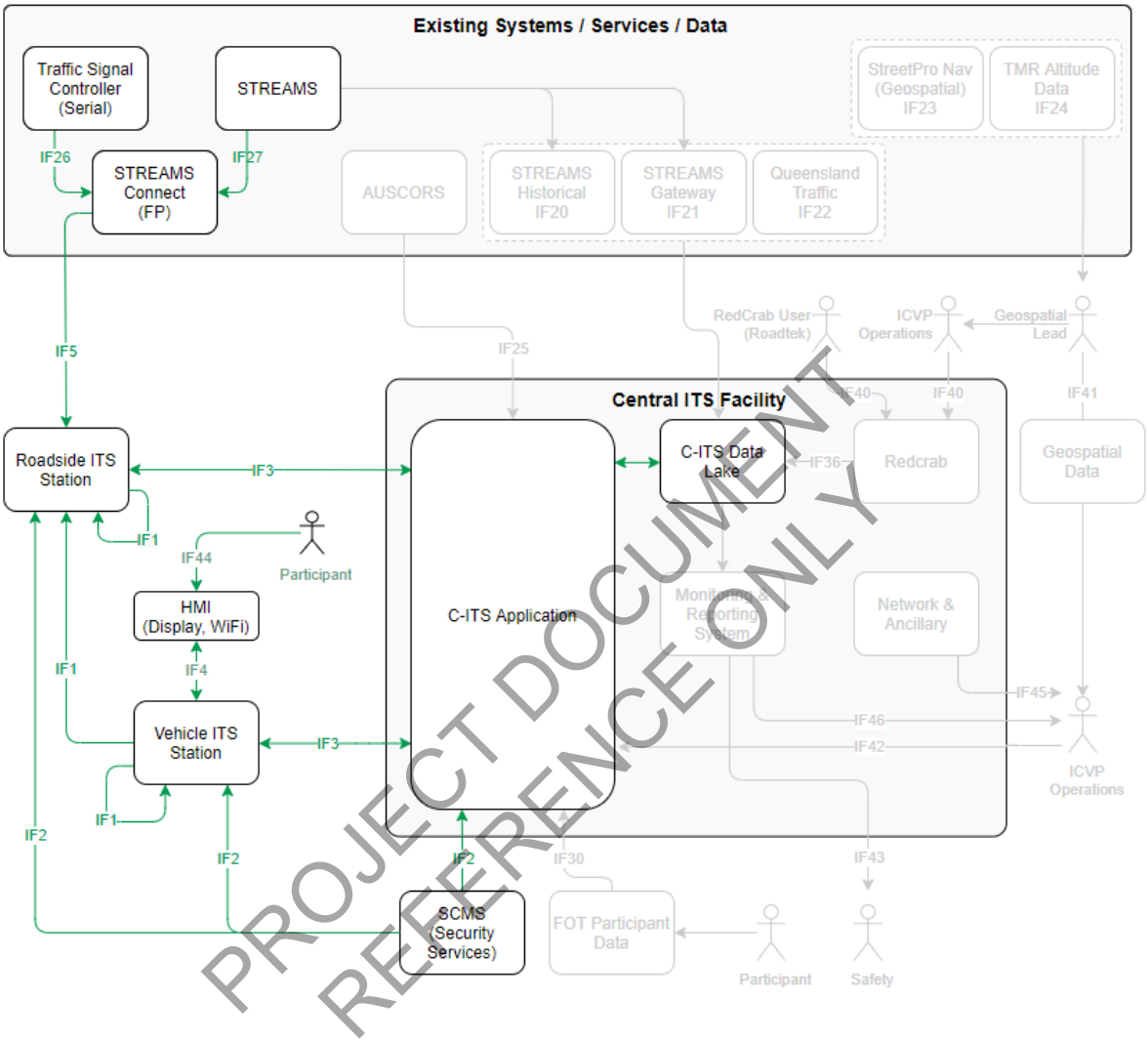


Figure 6.1 - Overall System Architecture

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

Table 6.1 - System Component Summary

Component	Role	Requirement	Detailed component lifecycle
V-ITS-S	Event Creator and Processor	An TWVR use case application must be enabled in the vehicle components. The conflict assessment off intersection information must be performed in the V-ITS-S.	The process for managing the TWVR use case is defined in section 7.1

Component	Role	Requirement	Detailed component lifecycle
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 7.3
R-ITS-S	Enabler	Broadcast intersection status including real-time SPATEM information and geometry MAPEM	Update repeat. Sends broadcasts based on inputs from STREAMS Connect and C-ITS-F
STREAMS Connect	Enabler	Generates C-ITS appropriate SPATEM from TSC and sends to the R-ITS-S	Repeated updates of SPATEM at 100ms and MAPEM at 500ms
TSC	Data Source	Provides traffic signal state and timing	Repeated update of signal status to STREAMS Connect
SCMS	Enabler	Provide secure communications	Defined in *C-ITS-S Station Protocol Specification PSTS007*
C-ITS-F	Monitoring and updates	Interface for monitoring and use case logging MAPEM updates are sent through C-ITS-F Configuration tool	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 events 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 TWVR use case operation. Communications between components using 3G/4G and ITS-G5 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 TWVR use case HMI warnings.

Requirement: The R-ITS-S shall meet the requirements of *R-ITS-S Specification PSTS005* as a basis for enabling the TWVR use case operation.

6.1 Typical Process Flow

The process flow for the TWVR 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 use an independent process flow to the C-ITS-F and are therefore not included in this use case process flow).

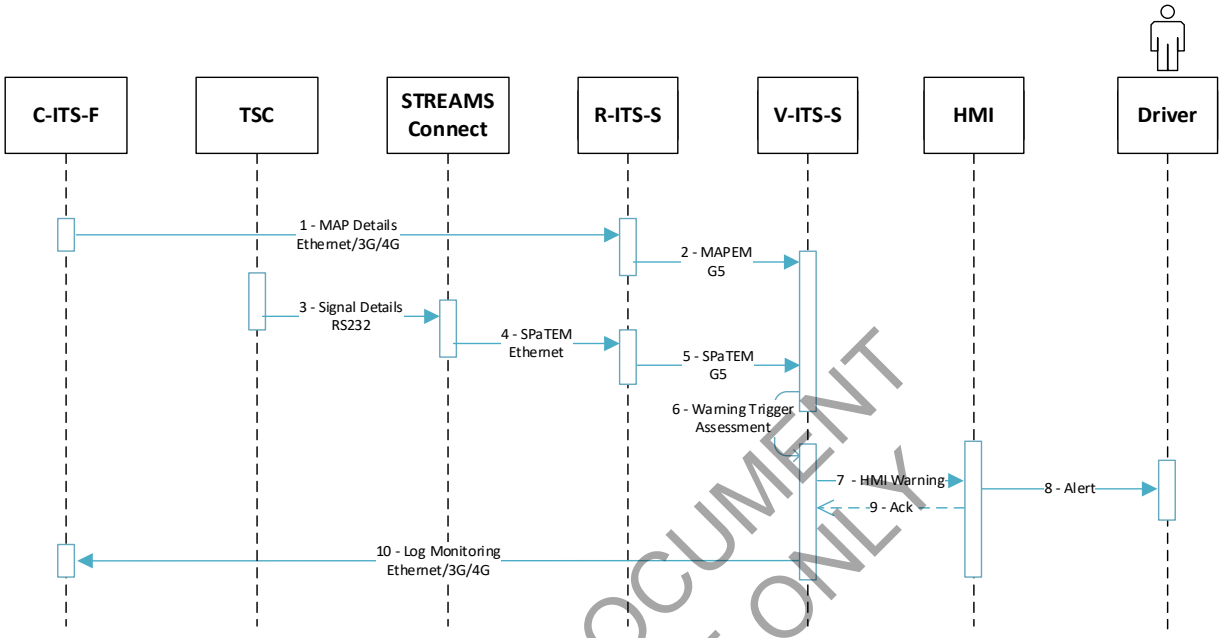


Figure 6.2 - Typical Data Flow

7 Lifecycles

The TWVR 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

The following diagram shows a process flow expected from the V-ITS-S to receive SPATEM and MAPEM and determine use case behaviour.

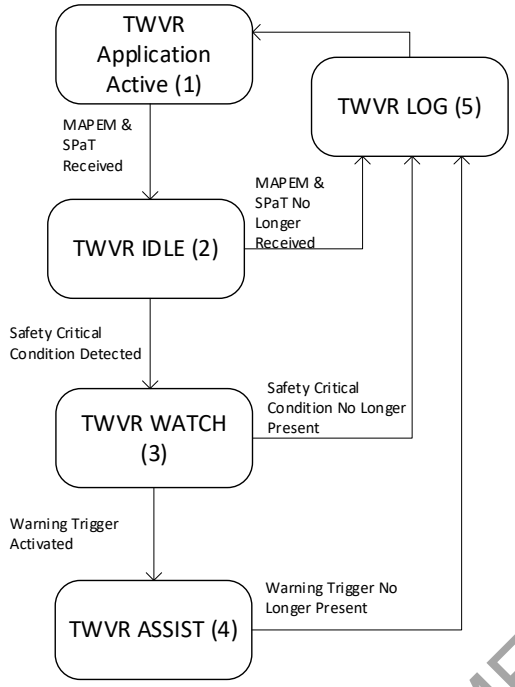


Figure 7.1 - V-ITS-S Lifecycle (modified from ETSI TS 101 539-03:2013)

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

Requirement: TWVR application shall start up if enabled and monitor for MAPEM and SPATEM on ITS-G5 while the V-ITS-S is powered on (see *ucTwvrEabled* in *V-ITS-S Specification PSTS002* for application enabling and disabling). *(State 1)*

Requirement: The TWVR application shall receive MAPEM and SPATEM for the creation of a TWVR event. *(Transition 1 to 2)*

Requirement: TWVR application shall compare the vehicle metrics (such as speed and location) to the intersection information (MAPEM) 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 (*speedMax*) speed, and
2. Within a lane node path defined in the MAPEM (based on lane width provided in MAPEM)

Requirement: If the SPATEM is considered old (nominally 1s since last update), the TWVR application shall consider the intersection as no longer relevant and return to waiting for a new MAPEM and new SPaT. *(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. Following the node path (based on vehicle offset defined in section 5.1.3) in the same direction

Requirement: TWVR application shall assess the state of the signals and pedestrian movement and the likelihood of entering the intersection while both overlap as defined in section 7.2. *(State 3)*

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

1. The vehicle stops; or
2. The vehicle departs from the node path of the MAPEM; or
3. The vehicle departs from the conflict zone; or
4. The traffic signal state is expected to be red for the signal group of the vehicle's lane; or
5. The relevant conflicting pedestrian state is red or expected to be red before the stop bar.

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

Requirement: The TWVR application shall request a HMI warning display based on pedestrian risk being active as defined in section 7.3.The TWVR application shall monitor acknowledgements and the status of the HMI while the display request is active. *(State 4)*

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

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

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

7.2 Warning Trigger

When the vehicle enters any lane (node path) of the intersection, the vehicle must determine the current state of the traffic signal relevant to that lane is aligned. If the signal state is green and the pedestrian signal is in green walk or flashing red, the vehicle must determine whether there is a conflict risk based on the Time-To-Event area (TTE) and the minimum driver warning triggering time as shown in Figure 7.2. If the signal state is green, the pedestrian signal is in green walk or flashing red and the vehicle is in the event zone (conflict area), the HMI warning must alert the driver.

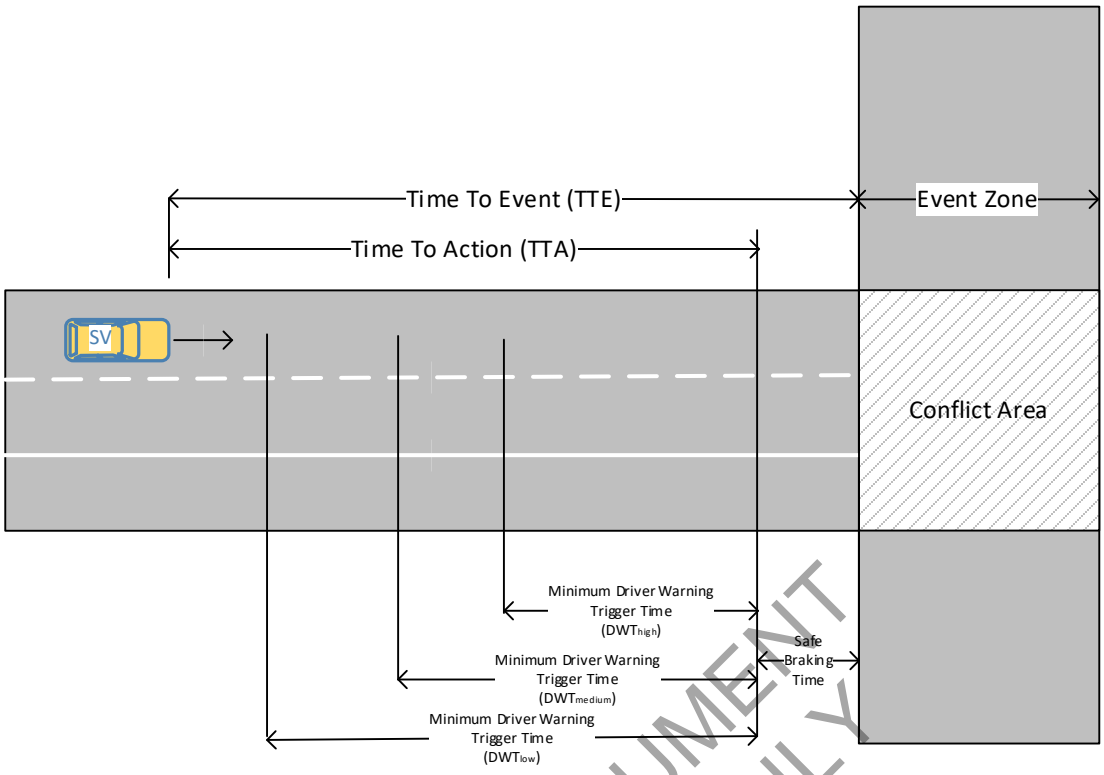


Figure 7.2 – Minimum Warning Trigger Time

Based on the TTA, the trigger is determined based on the graph in Figure 7.3.

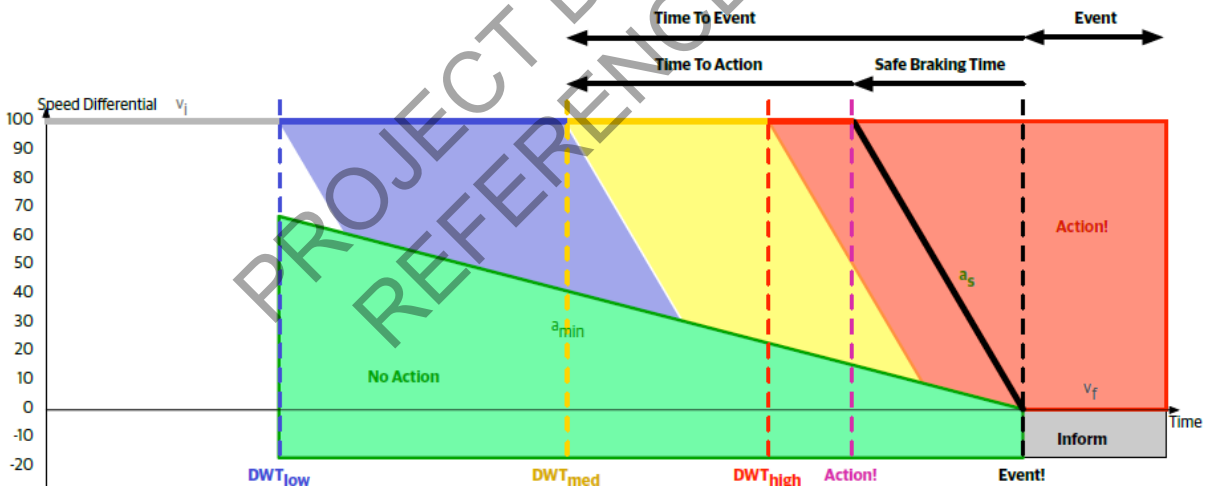


Figure 7.3 – Determining triggers from TTA

Requirement: Distance (d_{TV_INT} in metres) to the stop bar shall be calculated based on the map and the vehicle location.

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

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

$$\text{Safe Braking Distance} = d_{safe} = v_i * t_{safe} + ½ * a_{safe} * t_{safe} * t_{safe}$$

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

Where:

v_i = Current Speed

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

Requirement: The TWVR 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:

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

$$\text{No Action Distance} = d_{no\_action} = v_i * t_{no\_action} + ½ * a_{min} * t_{no\_action} * t_{no\_action}$$

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

Where:

v_i = Current Speed

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

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

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

1. A high level HMI warning shall persist for the whole conflict area if the vehicle entered the conflict area while currently in a HMI warning
2. A high level HMI warning shall be created if the vehicle enters the conflict area. This may only be detected once in the conflict area due to the speed of the vehicle which may have been stopped just prior to the conflict area.

Requirement: The TWVR shall determine the direction of the relevant pedestrian crossing as either left, right or both.

Requirement: Based on the traffic signal state, vehicle location pedestrian movement, DWT min calculation and TTC, the V-ITS-S shall associate a HMI warning identifier.

Table 7.1 – Driver Warning Trigger time to HMI Warning

Vehicle Location	Current Signal State	TTE	Likely Signal State at time of entering conflict area	Conflict Risk	HMI Warning ID
Approach	Green	N/A	Not provided in SPaT	TTA < *thresholdHigh*	TWVR_HIGH_<pedestrian direction>
				thresholdHigh < TTA < *thresholdMedium*	TWVR_MEDIUM_<pedestrian direction>[1]
				thresholdMedium < TTA < *thresholdLow*	TWVR_LOW_<pedestrian direction>[1]
				TTA > *thresholdLow*	No HMI change
				TTA_{min} > 0	No HMI change
	Yellow	TTE < $Yellow_{max}$ end time	Yellow	As for Green above	As for Green above
	Yellow	TTE > $Yellow_{max}$ end time	Red	N/A	No HMI change
	Red	N/A	Red	N/A	No HMI change
Event Zone	Green	N/A	N/A	N/A	TWVR_HIGH_<pedestrian direction>_EVENT
	Yellow	N/A	N/A	N/A	TWVR_HIGH_<pedestrian direction>_EVENT
	Red	N/A	N/A	N/A	No HMI change

[1]Note: In ICVP implementation the *thresholdHigh, thresholdMedium* and *thresholdLow* were configured to the same value based on HMI experiments and optimisation from field testing. The result is that only TWVR_HIGH and TWVR_HIGH_EVENT are displayed.

7.3 HMI Warning

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

Requirement: The HMI shall display the image and play the audio sound based on the information presented in Table 7.2. The HMI warning requested from the TWVR application shall be through the HMI Presentation Manager (defined in *V-ITS-S Specification PSTS002*).

Requirement: The V-ITS-S and HMI shall allow image and audio sound configuration updates based on the HMI Warning ID.

Table 7.2 – HMI warning look-up

HMI Warning ID	Description	Image	Audible Sound
TWVR_LOW_BOTH	Comfort warning in both directions	None[1]	None
TWVR_MEDIUM_BOTH	Safety warning in both directions	None[1]	None
TWVR _HIGH_BOTH	Critical warning in both directions[2]		TWVR_HIGH.wav
TWVR_LOW_LEFT	Comfort warning on the left	None[1]	None
TWVR_MEDIUM_LEFT	Safety warning on the left	None[1]	None
TWVR _HIGH_LEFT	Critical warning on the left[2]		TWVR_HIGH.wav
TWVR_LOW_RIGHT	Comfort warning on the right	None[1]	None
TWVR_MEDIUM_RIGHT	Safety warning on the right	None[1]	None

TWVR _HIGH_RIGHT	Critical warning on the right[2]		TWVR_HIGH_EVENT.wav

[2] The image for HIGH warnings is yellow (associated with MEDIUM warnings) instead of red (associated with HIGH warnings), as the lower urgency yellow image was determined as more suitable for ICVP purposes. The image was assigned to HIGH warnings for technical ease as High warnings had audio mapping already available, not because it is the preferred image for HIGH warnings.

7.4 Continuity

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

Requirement: Other C-ITS equipped vehicles in between the vehicle and intersection conflict area shall not affect the operation of the use case. SPATEM and MAPEM forwarding is not required.

Requirement: The TWVR HMI warning request escalates immediately (for example from medium to high warning level) as defined in *V-ITS-S Specification PSTS002*. However, a TWVR event shall not deescalate (for example from high to low warning level) for the duration of that event.

Requirement: On completion of the TWVR 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 *V-ITS-S Specification PSTS002*).

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 – Key Configurable Parameters

Reference Clause	Description	Unit	Factory Default	Min	Max	Device(s), systems affected
7.1	*speedMin*	km/h	1	0	200	V-ITS-S
7.1	*speedmax*	km/h	40	0	200	V-ITS-S
7.1	*speedClear*	km/h	1	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	40	0	250	V-ITS-S

Reference Clause	Description	Unit	Factory Default	Min	Max	Device(s), systems affected
7.2	*thresholdMedium*	ds	40	0	250	V-ITS-S
7.2	*thresholdLow*	ds	40	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 Definitions

The message structures of SPATEM in Figure 9.1 and MAPEM in Figure 9.2, describes the overview of the TWVR SPATEM AND MAPEM 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. Variable data frame identifier
6. Data element

Requirement: The TWVR application shall use SPATEM AND MAPEM data elements in accordance with the *Data Entity Catalogue PSTS006*.

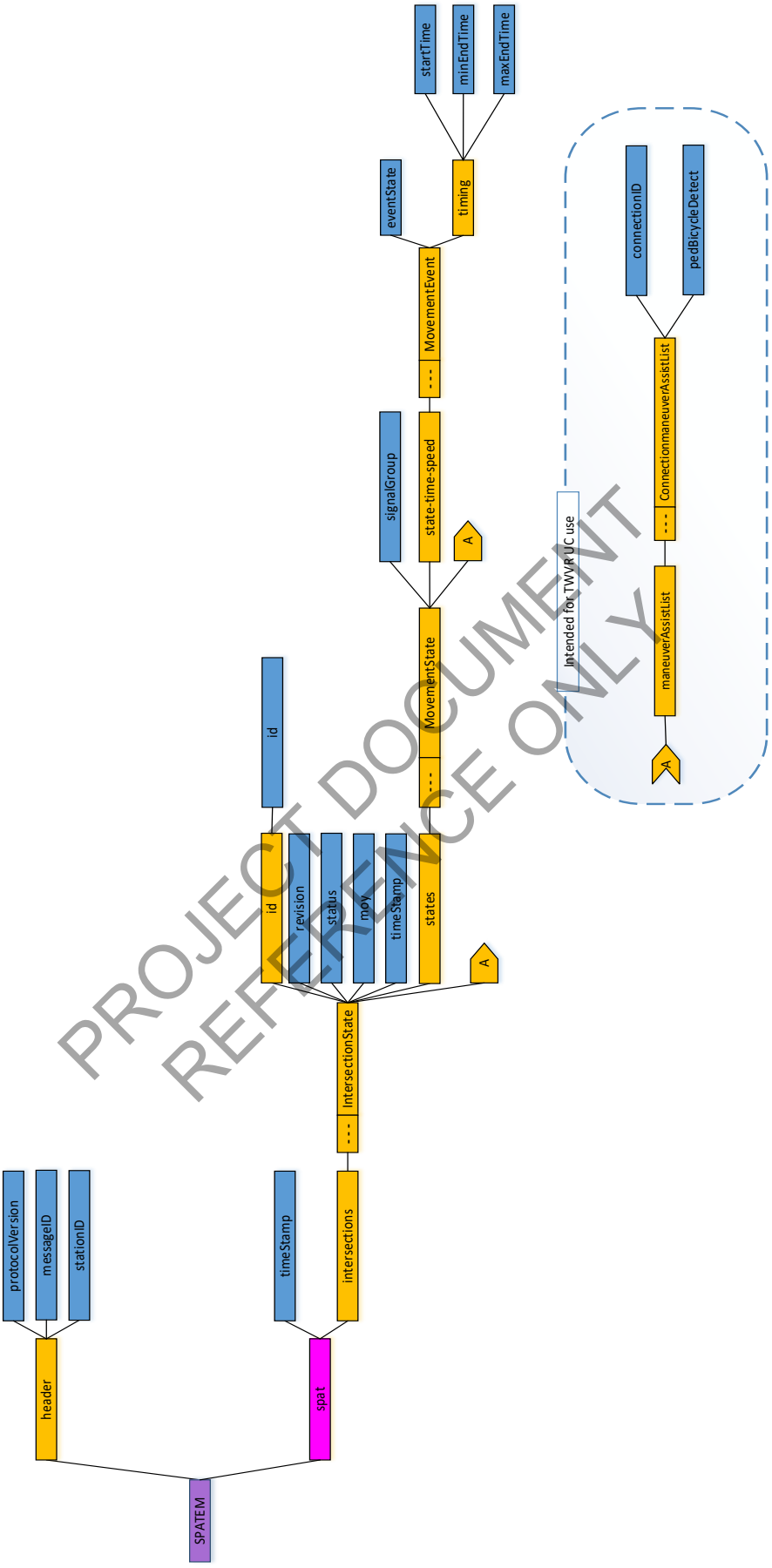


Figure 9.1 – TWVR SPATEM Structure

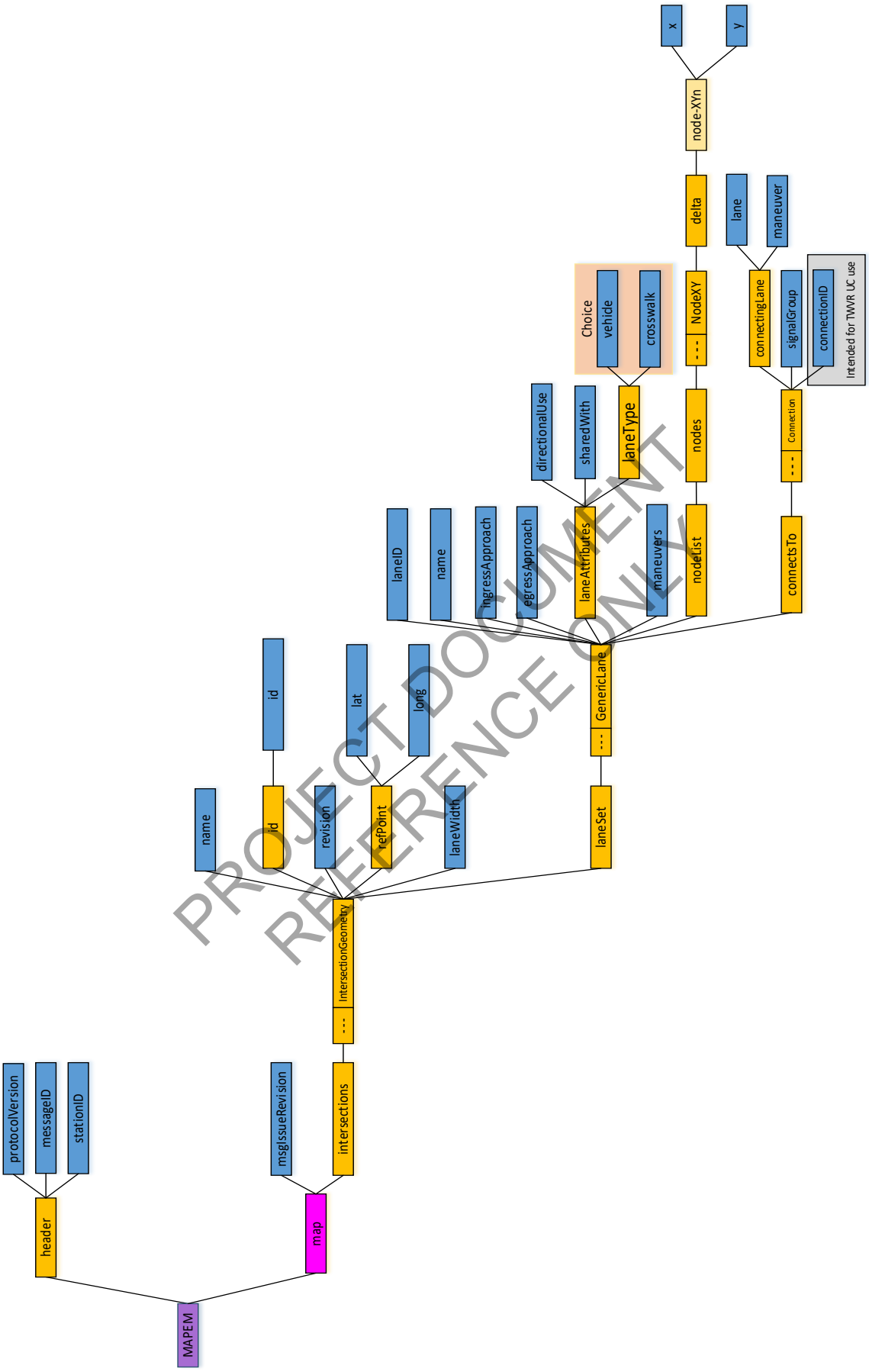


Figure 9.2 - TWVR MAPEM Message Structure