SECUR

Safety Enhancement through Connected Users on the Road

Deliverable 2.2

Suitability of the different technologies for the selected use cases

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EXECUTIVE SUMMARY

The SECUR project aims to study the potential of connectivity, especially the V2X technology, in improving the safety of different road users. To this end, this project brings together diverse and complementary stakeholders: automotive OEM and Tier1 manufacturers as well as V2X-market-stakeholders and automotive test systems providers.

The second Work Package (WP2) of SECUR evaluates the applicability of different V2X technologies to a set of pre-defined use cases for road safety improvement - WP2 also investigates the possibility of concurrent employment of different V2X technologies to improve the reliability of V2X-based systems.

This document follows the deliverable D2.1 which focus on the evaluation of the performances of all the technologies define in the SECUR scope. This document is a synthesis of the work achieved by the WP2.

In WP2, first, using the deliverable D2.1, different V2X technologies are studied in terms of technical performance as well as market situation. For the former case, parameters such as data rate, latency, congestion control, etc., and for the latter one, market penetration and limitations for employment are considered.

Then, a set of timing requirements is defined whose role is to determine the expected behaviour of a V2X-based system at different points in time in different scenarios. The definition of timing requirements is based on the existing documents such as the ETSI TR 102 638, 5GAA white paper “C-V2X Use cases – Methodology, Examples and Service – Level Requirements” and Annex 1.1 of C-Roads project.

Moreover, it contains all the results of the studies performed by the V2X experts coming from the different SECUR partners. This synthesis permitted to compile in one document the capability, the deployment state and the limitation of the different technologies.

The following picture is a summary of the WP2 conclusion in terms of V2X Technologies deployment state in Europe.

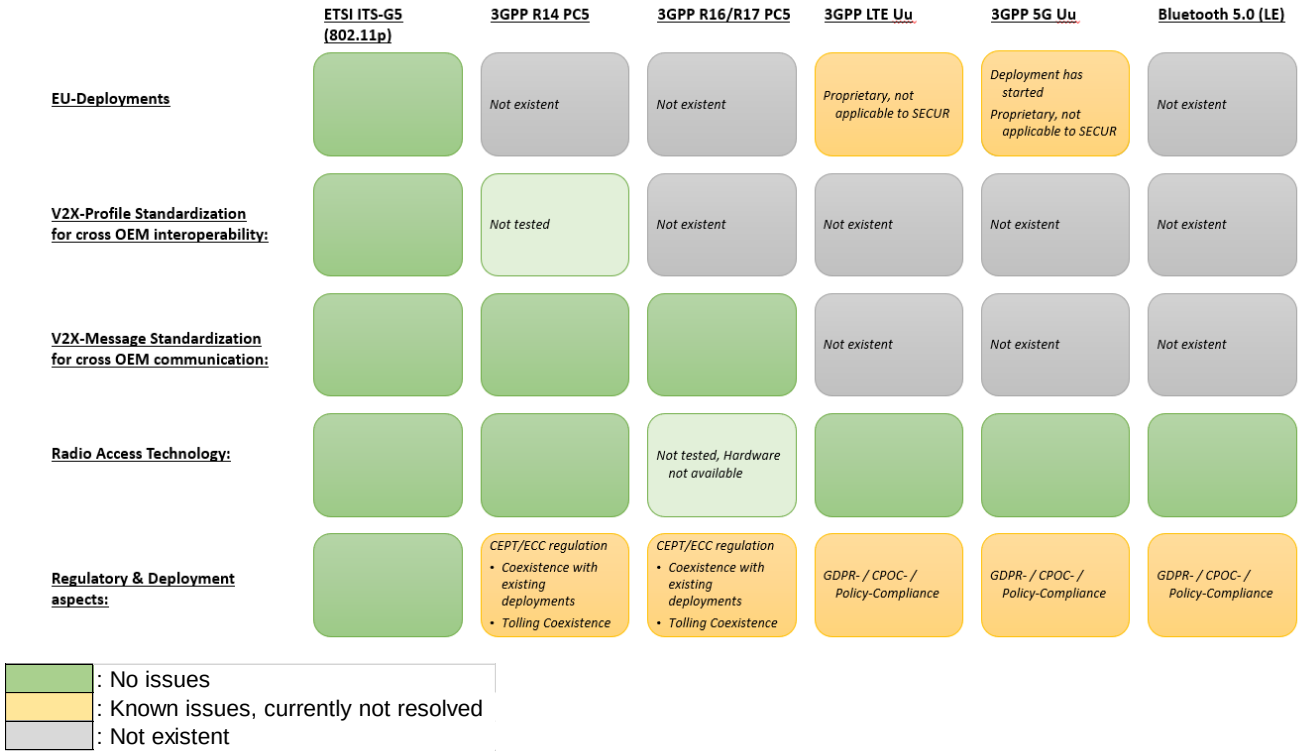

Figure 1: SECUR V2X Deployment matrix

REVISION HISTORY

Revision	Date	Description, updates and changes	Status
0.1	Feb. 2022	Creation of the structure of the report	Draft
1.0	30th of June 2022	First structure of the document	Draft
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1.4	23rd of September 2022	Final revision of the document and validation	Approved

ABBREVIATIONS

3GPP	3rd Generation Partnership Project
4G	4G is the fourth generation of broadband cellular network technology, succeeding 3G and preceding 5G
5G	In telecommunications, 5G is the fifth-generation technology standard for broadband cellular networks
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Breaking
ASIL	Automotive Safety Integrity Level
BC	Bicyclist
BLE	Bluetooth Low Energy
C2C-CC	Car 2 Car Communication Consortium
CAM	Cooperative Awareness Message
CBR	Channel Busy Ratio
C-ITS	Cooperative Intelligent Transport Systems
CPM	Cooperative Perception Message These messages broadcast information on detected object to its surrounding.
D2VO	Datex-II Vehicle Obstruction
D2WRRC	Datex-II Weather Related Road Conditions
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standards Institute
EU	European Union
GPS	Global Positioning System
HMI	Human Machine Interface
ITS-G5	Direct communication technology based on Wi-Fi. European name for WAVE or DSRC.
IVS	In-Vehicle Signage
KPH	Kilometers per hour
LOS	Line-of-sight
LTE	Long Term Evolution
MAPEM	MAP Extended Message
NLOS	Non-line-of-sight
PC	Passenger Car
PC5	Direct communication technology based on mobile network (3GPP). PC5 is one part of C-V2X/LTE-V2X that enable direct communication between objects.
PD	Pedestrian
PDR	Packet Delivery Ratio
PER	Packet Error Rate
PKI	Public Key Infrastructure
PTW	Powered Two-wheeler
RCS	Radar Cross Section
REL	Release
RHS	Road Hazard Signalling
SAS	Speed Assist Systems
SB	Steering Board
SPATEM	Signal Phase And Timing Extended Message
TTC	Time To Collision

UC	Use case
UK	United Kingdom
Uu	Radio interface in cellular communication between a user equipment (UE) and the cellular network base station.
V2I	Vehicle-To-Infrastructure
V2N	Vehicle-To-Network (Uu communication)
V2P	Vehicle-To-Pedestrian
V2V	Vehicle-To-Vehicle
V2VRU	Vehicle-To-Vulnerable Road User
V2X	Vehicle-To-Everything (i.e. vehicle to any type of other station)
VAM	VRU Awareness Message
VRU	Vulnerable Road User (motorcyclist, bicyclist and pedestrian)
WG	Working Group
WP	Work Package
WP1	SECUR Work Package n°1: Accidentology study
WP2	SECUR Work Package n°2: V2X technology study
WP3	SECUR Work Package n°3: Potential of V2X to improve ADAS performances and final use cases selection
WP4	SECUR Work Package n°4: Development of testing connected targets
WP5	SECUR Work Package n°5: Test and assessment procedures

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1. Introduction

1.1 THE SECUR PROJECT

Through its 2030 roadmap, the European New Car Assessment Programme (Euro NCAP) aims to encourage, by a consumer approach, ever more safety on the roads thanks to the use of new inter-vehicle communication solutions. In pursuit of Vision Zero, a functional validation protocol will be developed, and mass-produced vehicles' safety performance will be evaluated.

The SECUR project brings great importance to technological neutrality, while there was at the time a certain rivalry around the V2X (Vehicle-to-Everything) preventing a homogeneous development of connectivity solutions. This pioneering project aims to study the potential of connectivity, especially of V2X technologies, to improve the safety of different road users.

Coordinated by UTAC, the SECUR project expect to push a coherent proposal for V2X testing and assessment protocols to Euro NCAP. To this end, the industrial consortium brings together some twenty international stakeholders, from the entire automotive and V2X ecosystem – automotive OEM, Tier1 manufacturers, V2X-market-stakeholders and automotive test systems providers. They will share knowledge and collaborate through Workshops and Working Groups. First, the most common accident situations on European roads will be studied. Then, the current knowledge on V2X communication systems will be shared and studied. Thereafter, the potential of V2X systems will be studied, either alone or combined with ADAS systems. Finally, multi-technologies connected targets and protocols for evaluating these V2X systems, will be developed.

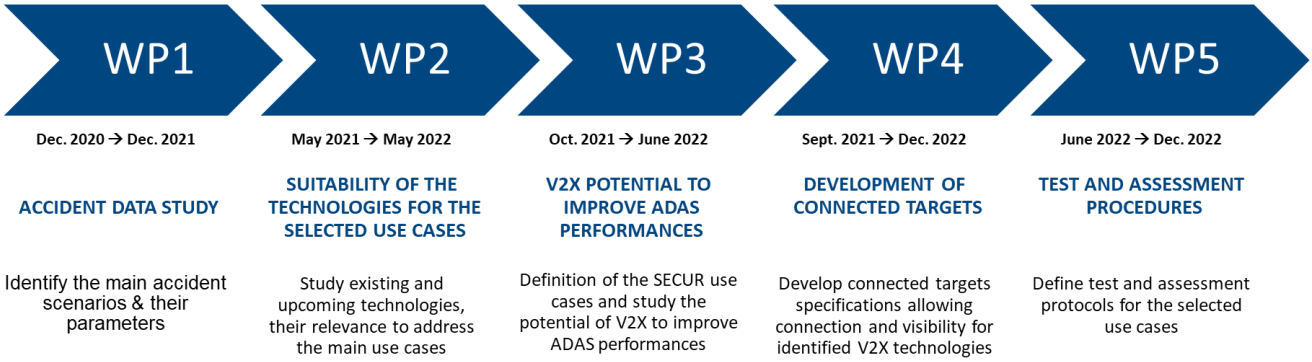


Figure 2: SECUR project Work Packages

1.2 OBJECTIVES AND SCOPE OF THE STUDY (WP2)

The WP2 of SECUR is dedicated to the evaluation of the suitability of the different technologies to address the selected use cases from a safety point of view and to meditate on the possible solutions to improve the confidence on the V2X systems by combining the technologies. All technologies that are able to transmit V2X messages are taken in account in this study: ITS-G5 based on 802.11p, PC5 Release 14, PC5 Release 16, 4G Uu, 5G Uu, BLE 5.0. Moreover, the aim of the project is to give guidelines and content for the next Euro NCAP ratings, and so, the study is focused on technologies deployable on the European market up to 2026. This means focusing on the EU standardization, profiles, and regulation. For the same reason, the safety related use-cases are the focus of the WP2. For this, the methodology used was the following:

Selection of wireless technologies suitable for V2X communication.

Literature review to gather and study the results of existing V2X projects and research papers focused on the technologies selected by the project.

Issuance of technologies' technical documents, one per technology, that express the capability of technologies on technical features based on multiple KPIs.

Definition of matrices linking use cases and V2X Types (V2V, V2I, V2N and V2VRU), technologies and messages for each scenario provided by the WP1 (Accident Data Study). For each scenario, it will be defined which V2X messages, type of communication and technologies can enhance the safety on road.

In parallel of those steps, WG2 have provided inputs on the V2X relevance by use cases to the Accidentology working group (WG1) to contribute to the scenario selection.

1.3 OBJECTIVE OF THE DELIVERABLE

Following the deliverable D2.1 which delivers a technical study of each V2X technology selected, this report provides all the information gathered, analysed and compiled during WP2. The working group outcomes will be detailed in the sections below, and their observations will be synthesised. Three matrices (use cases x V2X types of communication, use cases x V2X messages and use cases x V2X technologies) are available as main output, in addition of timing requirements and V2X messages roadmaps. In the end, the deliverable establishes the capability of the technologies to address use cases coming from the accident data study performed during the WP1.

2. Study the technologies technical features

During the launch of the WP2, the partners defined a list of connectivity technologies to be studied in detail in order to complete the technical document (D2.1). The considered technologies are:

- ITS-G5 based on 802.11p
- PC5 based Release 14
- PC5 based Release 16
- 4G Uu
- 5G Uu
- Bluetooth Low Energy (BLE) 5.0

Note: PC5 release 16 (and following) interface can refer to both LTE-V2X and NR-V2X
Note: On this diagram, technologies not studied in SECUR have been implemented (PC5 Release 17 and 802.11bd)

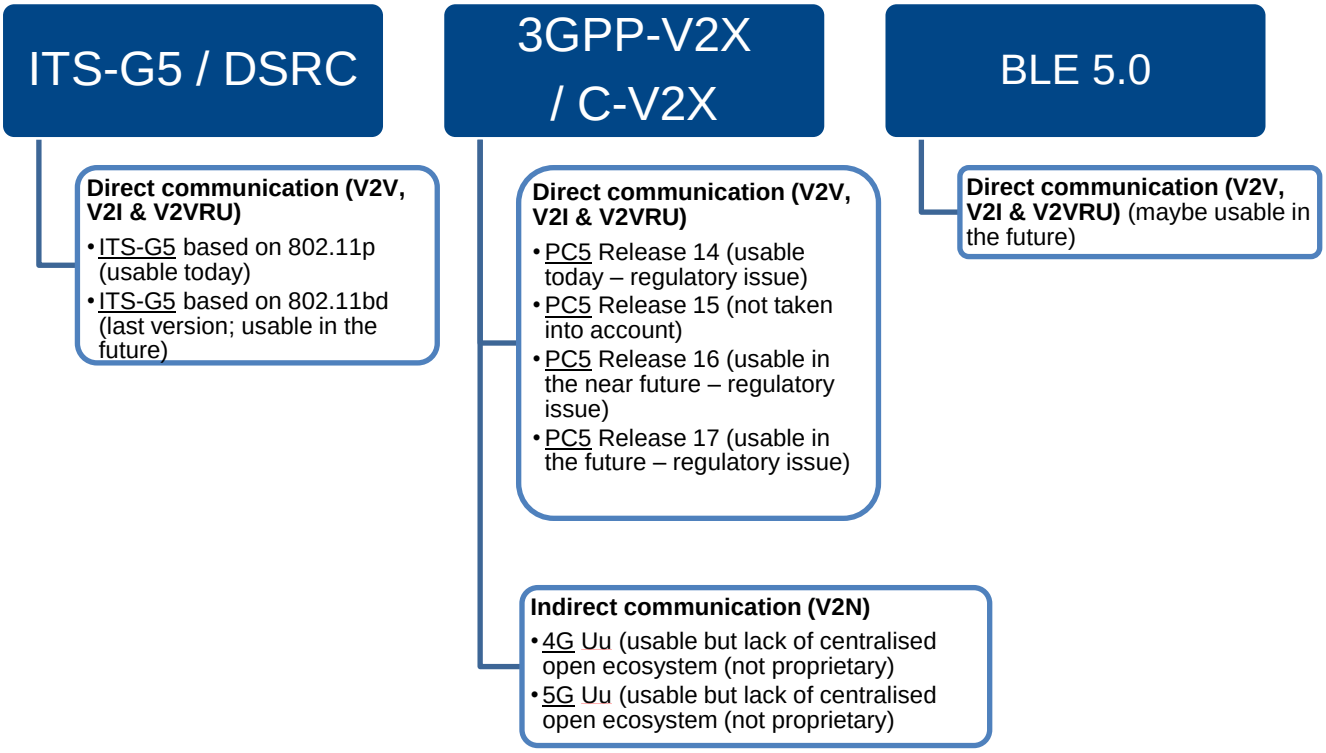


Figure 3: List of the technologies studied in the SECUR project

Each V2X technology has a dedicated document accessible in the deliverable D2.1 that evaluates the technology in terms of range, latency, congestion control & mobility behaviour. Moreover, it discusses technology maturity and its compliance to the European certificate and security policies, GDPR requirements, and radio spectrum regulation. All this information is based on scientific papers, existing projects, or partners expertise. The study focuses solely on technologies which were considered deployable by 2026. Hence, the study does not consider PC5 Release 17 & ITS-G5 based on 802.11bd as these technologies are still under development and it is very unlikely to have them in the market until 2026.

2.1 TECHNOLOGIES CAPABILITY

For the analysis of the mentioned technologies, the following measures or information has been acquired in order to build the technical documents focusing on the technologies (D2.1):

- General information
  Communication profile, communication type & maturity

- Data rate:
  The speed at which data is sent over a data link or channel

- Range:
  The maximum distance at which the communication is reliable

- Reliability:
  A communication is reliable if the packet reception ratio is at least 90%

- Latency:
  Time taken for a packet to be transmitted across a network from source to destination (End-To-End)

- Congestion control:
  Mechanism that exist to maintain a certain quality of service even with a crowded network

- Mobility:
  Behaviour of the technology to maintain a certain quality of service even with moving objects

- Positioning:
  Mechanism of the technology to increase the positioning accuracy

- Co-existence and interference:
  Capability of a radio technology including its application to avoid harmful interference in co-channel and adjacent channel operation of different services and applications to allow an efficient spectrum utilization.

- Supported messages:
  Different type of messages supported by the technology.

- Regulatory compliance:
  The technology conforms to policies (such as European security & certificate policies) and regulation (such as General Data Protection Regulation & radio regulation).

After the study, the partners agreed that the direct communication technologies (ITS-G5 based on 802.11p & PC5 Release 14) meet the similar performances and could address the same use cases, which are the ones' defined by the WP1 that address Car-To-Car and Car-To-PTW use cases. In the case of Car-To-Pedestrian and Car-To-Bicyclist the direct communication could be also beneficial thanks to third party detection based on CPM or DENM (Infrastructure or other vehicle) since these opponents will not be connected by direct communication by 2026.

Besides, concerning the PC5 Release 16, since the consortium did not have access to in-depth study on the technology it has been said that based on the current standard and the simulation provided by literature study, the technology could perform the same use cases as the PC5 Release 14.

Moreover, concerning the indirect communication, ITS communication using 4G operator networks could provide connectivity for some of the ITS services including safety related services when the network coverage is very good on the best effort, when issue of network coverage, servers' interoperability. Anyway, usually the latency is too variable and depend too much on the load of the network to be trusted for safety related services. In terms of 5G operator networks, the capability to meet the SECUR use-cases requirements strongly depend on the coverage. In Europe, the coverage is limited but increasing outside urban area.

Finally, concerning the BLE 5.0, this technology is of limited value for mobility use cases, because today, all the V2X standards and profiles are not applicable to BLE communication. And so, the capability of the technology is very limited for vulnerable use-cases (pedestrian & Bicyclists) and non-existent for higher speed devices.

2.2 TECHNOLOGIES DEPLOYMENT

The second key point of this study is the deployment state of the different technologies in the world in general but with a focus on the European situation only.

Today, in Europe, concerning the direct communication technologies, the only mass deployment is of the ITS-G5 technology. Indeed, several cities and highways in Europe and Israel are equipped with ITS-G5 RSU and Volkswagen already employed the V2X technologies on commercial vehicle equipped with ITS-G5 communication (500 000 vehicles in 2021).

However, concerning the PC5 Release 14, project pilots are conducted for years by OEMs and solutions providers, but today, there is no commercial vehicle with PC5 R14 technology in Europe. Concerning the PC5 Release 16, the technology is in exploration for multiple companies of the industry. However, there is today no pilots in EU.

Moreover, concerning the indirect communication (V2N) deployment state, since the Uu interface use back end in order to communicate, the deployment is directly linked to 4G & 5G network providers deployment state, capability and implementation. Today in Europe there is a good deployment of the two technologies in urban area. However, in more rural area, the deployment of these networks is very limited, especially for 5G.

Finally, concerning the BLE 5.0, it is a technology already used in automotive and its deployment is really advance in the mobility domain in general but not for this type of safety services. Indeed, there is no standardization done on the BLE at ETSI, and thus, would made impossible the usage of the technology for V2X communications. Moreover, BLE can't transit messages with a certain size which is a point that will need to be resolved for V2X.

2.3 UNCERTAINTIES RAISED

During the whole study, multiples uncertainties has been raised on the actual usage of the different technologies in a mass-market deployment where safety use-cases would be necessary.

Firstly, in the different study on all kind of technologies, there is no clear conclusion on the technologies' behaviour in huge congestion situation. Most of the papers are based on simulation and not on real devices tests, and when it's the case, the configuration is not clearly explained by the study carrier.

Besides, the interoperability between the direct communication technologies is a big issue when the mass-market deployment is the objective. There is also uncertainty with backward compatibility with releases of C-V2X technologies family (Release 14 & Release 16). However, this is not the case with ITS-G5 technology (between 802.11p and 802.11bd).
Moreover, concerning the indirect communication types of technologies, multiples uncertainties are raised by the different partners.

Firstly, the security and privacy requirements in the EU policies for deployment and operation of European cooperative intelligent transport systems (C-ITS) are not really suited for 4G or 5G Uu communication, since the EU policies and the EU C-ITS security framework do not cover C-ITS communication using V2N as of now.

Secondly, today there is pilots to work on the interoperability of different OEM & National roads authority servers to communicate and support the features. However, there is no European regulation yet to upload data to exchange servers.

Moreover, there is another regulatory issue around spectrum regulations. Compliance with European radio regulation needs to be fulfilled. Coexistence with other services and applications in the same band and adjacent bands like tolling, smart tachograph, satellite services have to be ensured with compatibility to ECC DEC (08)01 and its underlying CEPT reports.
LTE-V2X / NR-V2X has not yet specified in detail how compatibility with other services is reached, e.g. regarding 1% duty cycle per ITS device and reliable detection of fixed and mobile tolling stations.

Then, using 4G Uu communication will require a subscription with a telecommunication operator and the availability of services using such connectivity strongly depend on the 4G coverage. Depending on the business model and the European Regulations of the service, the subscription fees could be paid by the service provider or by the end user.

Finally, the major point that is required to permit a high efficiency of the V2X systems is the penetration rate of the technology on the road. Indeed, there is a need of having multiple nodes in this network in order to have an efficient mean of communication.

3 Most relevant technologies selection

After the V2X in-depth study, thanks to all the information gathered on the different KPI, matrices have been created to evaluate the capability of the different V2X messages, V2X types of communication and V2X technologies to address the SECUR scenarios.

Table 1 - List and description of the matrices detailed later in the document

N°	Matrix name	Description
1	SECUR Use cases x V2X types of communication	Matrix linking the WP1 use cases with the V2X types of communication (V2V, V2VRU, V2I, V2N).
2	SECUR Use cases x V2X messages	Matrix linking the WP1 use cases with the V2X messages (CAM, DENM, …).
3	SECUR Use cases x V2X technologies	Matrix linking the WP1 use cases with the V2X technologies (ITSG5, PC5, 4G, 5G and BLE).

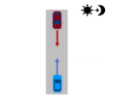
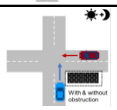
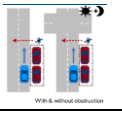
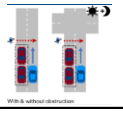
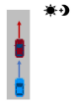
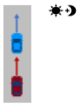
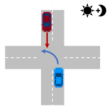
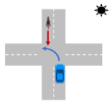
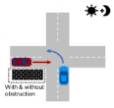
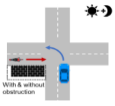
Thanks to these matrices, it will be possible to provide information to the WP3 & WP5 on the technologies capability to define the SECUR use cases and test protocols.

In every TOP15 use cases defined by the WP1, the WP2 expressed what types of communication, message or technology is relevant to enhance the safety. This relevance could be purely by the communication between the vehicles, the information provided by the traffic lights, or the information provided by the infrastructure detection.

3.1 SECUR WP1 USE CASES DESCRIPTION

You will find below a summary table of the SECUR WP1 use cases considered for the WP2 work.

Table 2 - SECUR WP1 use cases description

SECUR WP1 Use cases							Euro NCAP associated scenario
WP1 Scenario number	Designation	Acronym	Opponent	Pictogram	Obstruction	Description	
1	Oncoming	/	Passenger car		No	A collision where a vehicle is travelling along a straight path and strikes another vehicle travelling in the opposite direction.	CCFhol & CCFhos (Coming in 2023)
2	Straight Crossing Path – Right Direction	SCP-RD	Bicyclist		Yes & No	A collision in which a vehicle travels forwards along a straight path across a junction, towards a bicyclist crossing the junction on a perpendicular path, from the right direction.	CBNA & CBNAO
3	Straight Crossing Path – Right Direction	SCP-RD	Passenger car		Yes & No	A collision in which a vehicle travels forwards along a straight path across a junction, towards a vehicle crossing the junction on a perpendicular path, from the right direction.	CCCscp (Coming in 2023)
4	Straight Crossing Path – Right Direction	SCP-RD	Pedestrian		Yes	A collision in which a vehicle travels forwards towards an adult pedestrian crossing its path walking from the nearside and the frontal structure of the vehicle strikes the pedestrian.	CPNA
5	Straight Crossing Path – Left Direction	SCP-LD	Pedestrian		Yes	A collision in which a vehicle travels forwards towards an adult pedestrian crossing its path walking from the farside.	CPFA & CPNCO
6	Loss Of Control in CUrve	LOC-CU	None		No	An accident where the vehicle is alone, driving in a curve and the control of the vehicle is lost.	Not covered.
7	Straight Crossing Path – Left Direction	SCP-LD	Passenger car		Yes & No	A collision in which a vehicle travels forwards along a straight path across a junction, towards a vehicle crossing the junction on a perpendicular path, from the left direction.	CCCscp (Coming in 2023)
8	Loss Of Control in Straight Line	LOC-SL	None		No	An accident where the vehicle is alone, driving in a straight line and the control of the vehicle is lost.	No
9	Straight Crossing Path – Left Direction	SCP-LD	Bicyclist		Yes & No	A collision in which a vehicle travels forwards along a straight path across a junction, towards a bicyclist crossing the junction on a perpendicular path, from the left direction.	CBFA
10	Rear End - Following Vehicle	RE-FV	Passenger car		No	A collision in which a vehicle travels forwards towards another vehicle that is travelling in the same direction and the frontal structure of the vehicle strikes the rear structure of the other. From the following vehicle point of view.	CCRm & CCRb & CCRs
11	Rear End - Previous Vehicle	RE-PV	Passenger car		No	A collision in which a vehicle travels forwards towards another vehicle that is travelling in the same direction and the frontal structure of the vehicle strikes the rear structure of the other. From the previous vehicle point of view.	Not covered. Case partially covered by CCRm & CCRb & CCRs but not with this point of view (previous vehicle).
12	Left Turn Across Path – Opposite Direction	LTAP/OD	Passenger car		No	A collision in which a vehicle turns across the path of an oncoming vehicle, and the frontal structure of the vehicle strikes the front structure of the other.	CCFtap
13	Left Turn Across Path – Opposite Direction	LTAP/OD	PTW		No	A collision in which a vehicle turns across the path of an oncoming motorcycle, and the frontal structure of the vehicle strikes the front structure of the other.	CMFtap (Coming in 2023)
14	Left Turn Across Path – Left Direction	LTAP/LD	Passenger car		Yes & No	A collision in which a vehicle turns across the path of a vehicle crossing the junction on a perpendicular path from the left direction.	'Not covered. Partially covered by CCCscp.
15	Left Turn Across Path – Left Direction	LTAP/LD	PTW		Yes & No	A collision in which a vehicle turns across the path of a motorcycle crossing the junction on a perpendicular path, from the left direction.	Not covered. Partially covered by CMC, coming in 2025.

3.2 TIMING REQUIREMENTS DEFINITION

To support the study on the relevance of V2X technologies for the SECUR use cases, timing requirements are defined in order to estimate what would be the minimum latency performances. This work is based on existing documents from the literature such as the ETSI TR 102 638, 5GAA white paper "C-V2X Use cases – Methodology, Examples and Service – Level Requirements" and Annex 1.1 of C-Roads project documents that propose maximum latency requirements on several use-cases.

The study of the timing requirements and the Time-To-Collision categories has been based on the documents mentioned previously. This study permits to define which timings suits the use-cases the best:

- **Driver Information**: The purpose of this application is to provide static (or semi-static) information to the driver for a safe and comfort drive. V2X can bring for example in-Vehicle Signage (IVS) information on the road to the driver (e.g., dynamic speed limit information, dynamic lane management, etc).

- **Driver Awareness**: The purpose of this application is to point the driver's attention to a situation ahead on its vehicle trajectory that has the potential to become dangerous or critical if overlooked by the driver. This service can for example increase the driver vigilance to avoid a collision, in situations, which do not require an immediate action (e.g., roadwork, traffic jams, VRU awareness, etc).

- **Driver Warning**: The purpose of this application is to issue alerts to the driver requiring an immediate action to avoid an accident (e.g., emergency brake, stay in lane, collision risks, etc). V2X could be used as an additional sensor.

- **Vehicle Action**: Mitigation and crash avoidance by active safety systems. V2X could be used as an additional sensor. According to SECUR, it might not be possible to rely on V2X for ASIL level applications before 2029.

  The Vehicle Action category could be divided between non-safety-critical and safety-critical actions:
  - **Non-safety-critical Vehicle Action** is not subject to ASIL requirements due to the low consequence severity. V2X is very relevant to reinforce quickly (2026) these applications' type (e.g., speed reduction, acceleration limitation, system parameter/sensitivity update, etc.). Non-safety-critical vehicle actions combined with V2X are already sufficient to have a quick impact on road safety.

  - **Safety-critical Vehicle Action** is subject to ASIL requirements due to the high consequence severity. V2X should ensure enough safety confidence (ASIL level) before data fusion with those applications like Autonomous Emergency Braking (AEB).

- **Pre-crash**: The purpose of this application is to bring information to the vehicle active systems in case of upcoming crash in order to pre-empt crash safety systems such as seatbelts and automatic closing windows.

- **Post-crash**: The purpose of this application is after an accident to bring information to the surrounding road users to avoid additional accidents or other security issues.

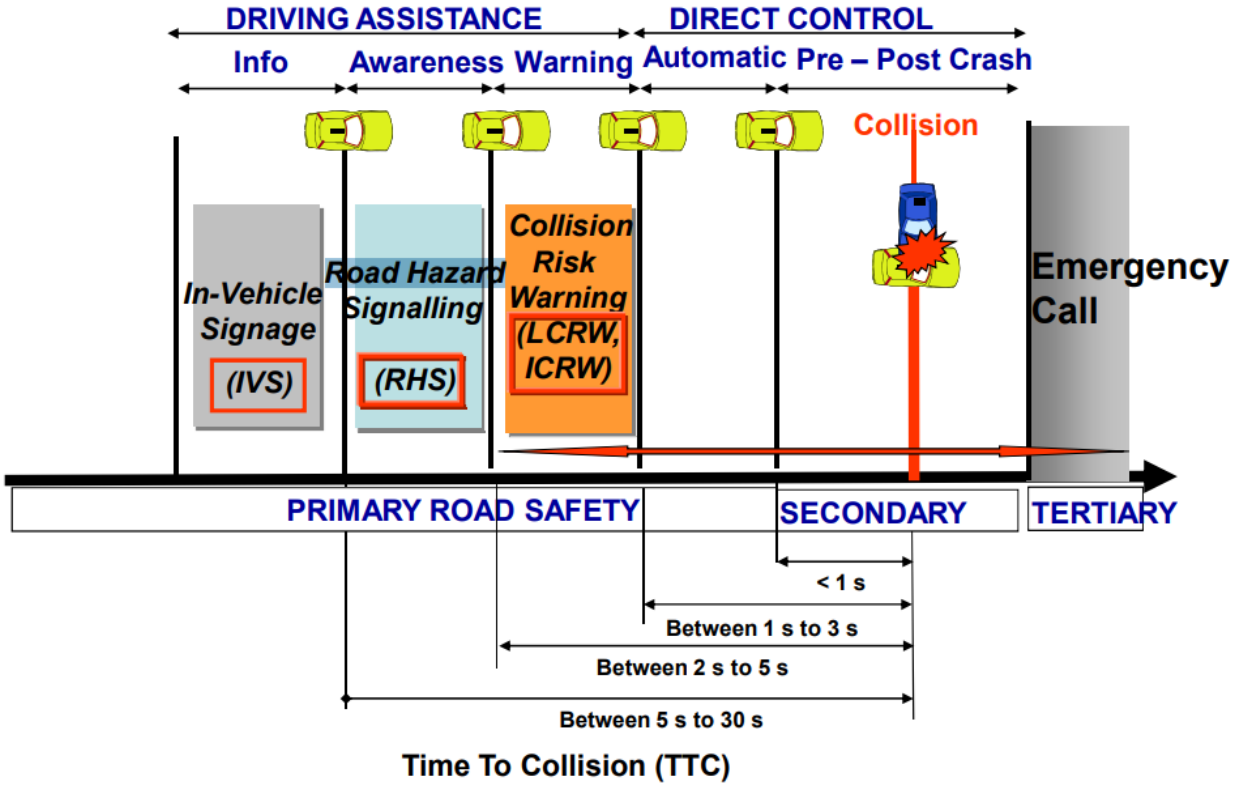
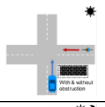
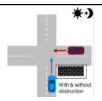
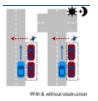
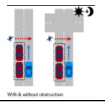
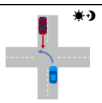


Figure 4: Road safety model in C-ITS [3]

Note: SECUR conclusion timings refers to warning and vehicle actions measure. In the case of warning only, those timings could be relaxed.
Note: The timing defined in this table correspond to End-to-End latencies

Table 3 - Latency requirements for each SECUR use cases

SECUR WP1 Use cases				V2X timing requirement (based on ETSI TR 102 638, Annexe 1.1 of C-Roads)	V2X timing requirement (based on 5GAA C-V2X Use cases Methodology, Examples and Service Level requiremetns)	V2X timing requirement (based on Annex 1.1 of C-Roads)	Most critical time for the application/service
Designation	Acronym	Opponent	Pictogram				
Oncoming	/	Passenger car		Critical time (<100 ms) (cf. C.1.4.1 of ETSI TR 102 638)	No latency requirements mentionned	No latency requirements mentionned	100ms
Straight Crossing Path – Right Direction	SCP-RD	Bicyclist		Critical time (<100 ms) (cf. C.1.2.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.12)	"Low latencies" (cf. G4)	100ms
Straight Crossing Path – Right Direction	SCP-RD	Passenger car		Critical time (<100 ms) (cf. C.1.5.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.2)	"Low latencies" (cf. G4)	100ms
Straight Crossing Path – Right Direction	SCP-RD	Pedestrian		Critical time (<100 ms) (cf. C.1.2.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.12)	"Low latencies" (cf. G4)	100ms
Straight Crossing Path – Left Direction	SCP-LD	Pedestrian		Critical time (<100 ms) (cf. C.1.2.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.12)	"Low latencies" (cf. G4)	100ms
Loss Of Control in CUrve	LOC-CU	None		No latency requirements mentionned (cf. C1.5.3 of ETSI TR 102 638)	No latency requirements mentionned	No latency requirements mentionned	No low latency requirement as here the aim is to prevent from a additional
Straight Crossing Path – Left Direction	SCP-LD	Passenger car		Critical time (<100 ms) (cf. C.1.5.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.2)	"Low latencies" (cf. G4)	100ms
Loss Of Control in Straight Line	LOC-SL	None		No latency requirements mentionned (cf. C1.5.3 of ETSI TR 102 638)	No latency requirements mentionned	No latency requirements mentionned	No low latency requirement as here the aim is to prevent from a additional
Straight Crossing Path – Left Direction	SCP-LD	Bicyclist		Critical time (<100 ms) (cf. C.1.2.4 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.2)	"Low latencies" (cf. G4)	100ms
Rear End - Following vehicle	RE-FV	Passenger car		Critical time (<100 ms) (cf. C.1.5.5 of ETSI TR 102 638)	Critical time (<120 ms) (cf 4.3)	"End-to-end latency need to be very tight" (cf. D13)	100ms
Rear End - Previous vehicle	RE-PV	Passenger car		Critical time (<100 ms) (cf. C.1.5.5 of ETSI TR 102 638)	Critical time (<120 ms) (cf 4.3)	"End-to-end latency need to be very tight" (cf. D13)	100ms
Left Turn Across Path – Opposite Direction	LTAP/OD	Passenger car		Critical time (<100 ms) (cf. C.1.5.1 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.1)	"Low latencies" (cf. G4)	100ms
Left Turn Across Path – Opposite Direction	LTAP/OD	PTW		Critical time (<100 ms) (cf. C.1.2.3 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.12)	"Low latencies" (cf. G4)	100ms
Left Turn Across Path – Left Direction	LTAP/LD	Passenger car		Critical time (<100 ms) (cf. C.1.5.1 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.1)	"Low latencies" (cf. G4)	100ms
Left Turn Across Path – Left Direction	LTAP/LD	PTW		Critical time (<100 ms) (cf. C.1.2.3 of ETSI TR 102 638)	Critical time (<100 ms) (cf 4.12)	"Low latencies" (cf. G4)	100ms

3.3 MATRIX N°1: SECUR USE-CASES LINKED TO V2X TYPES OF COMMUNICATION

The first matrix links the SECUR use cases to the types of communication which are:

- **V2V - Vehicle-To-Vehicle**:
  Direct communication between vehicles.

- **V2VRU - Vehicle-To-Vulnerable Road User:**
  Direct communication between a vehicle and a VRU.

- **V2I - Vehicle-To-Infrastructure**:
  Direct communication with connected infrastructure (e.g. connected VRU/vehicle detection infrastructure).

- **V2N - Vehicle-To-Network**:
  Indirect communication between a vehicle and another road user with the network (i.e. V2N2V or V2N2VRU).

As the following figure shows, in one hand, V2V and V2VRU can address all types of use cases, even the one relying on low latency because of the safety critical situations. In another hand, V2N sees less use cases where it could be directly relevant for enhancing the safety on roads. However, it will permit to provide more information to the vehicles such as traffic lights information or local hazards which could be beneficial for the decision making of the driver.

Legend of the matrix below:

	: V2X type relevant for the use case
	: V2X type relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
	: V2X type not relevant for the use case
	: V2X type incompatible with the use case

Table 4 - Matrix n°1: SECUR use cases in front of V2X types of communication for 2026 scope

	WP1 Use case	Opponent	Types of V2X communication: V2V* (direct communication between vehicles)	V2VRU** (direct communication between a vehicle and a VRU)	V2I (direct communication between a vehicle and a connected infrastructure)	V2N (indirect communication, e.i. V2N2V or V2N2VRU)
1	Oncoming	Passenger car	**Relevant** Only if the opponent vehicle is connected		**Not relevant**	Not relevant due to the latency req. of 100ms.
2	Straight Crossing Path – Right Direction (**SCP-RD**)	Bicyclist	**Not relevant** But possible with collective perception (>2026) - not in SECUR scope	**Relevant** Only for connected bicyclist	**Relevant** - Use of connected infrastructure for VRU detection and information sharing with the surrounding road users (DENM and CPM in a second stage) - Traffic light information (SPATEM+MAPEM) could add additional benefit	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	**Relevant** Only if the opponent vehicle is connected		- Traffic light information (SPATEM+MAPEM) could add additional benefit	
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	**Not relevant** But possible with collective perception (>2026) - not in SECUR scope	**Not relevant** But possible with a direct communication connected device (>2029) (e.g. smartphone)	**Relevant** - Use of connected infrastructure for VRU detection and information sharing with the surrounding road users (DENM and CPM in a second stage) - Traffic light information (SPATEM+MAPEM) could add additional benefit - Possible with collective perception (>2026) - not in SECUR scope	**Not relevant** But possible with a connected device (e.g. smartphone)
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian				
6	Loss Of Control in CUrve (**LOC-CU**)	None	**Relevant**		**Relevant** - To broadcast the information to the surrounding road users	**Relevant**
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	**Relevant** Only if the opponent vehicle is connected		- Traffic light information (SPATEM+MAPEM) could add additional benefit	- Additional information could be brought to the devices (traffic light, local hazard)
8	Loss Of Control in Straight Line (**LOC-SL**)	None	**Relevant**		**Relevant** - To broadcast the information to the surrounding road users	**Relevant**
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	**Not relevant** But possible with collective perception (>2026) - not in SECUR scope	**Relevant** Only for connected bicyclist	**Relevant** - Use of connected infrastructure for VRU detection and information sharing with the surrounding road users (DENM and CPM in a second stage) - Traffic light information (SPATEM+MAPEM) could add additional benefit - Possible with collective perception (>2026) - not in SECUR scope	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	**Relevant** Only if the opponent vehicle is connected		**Relevant** - To broadcast the information to the surrounding road users - Traffic light information (SPATEM+MAPEM) could add additional benefit near an intersection	
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car	**Relevant** Only if the opponent vehicle is connected		**Not relevant**	
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	**Relevant** only if the opponent vehicle is connected		**Relevant** - Use of connected infrastructure for VRU detection and information sharing with the surrounding road users (DENM and CPM in a second stage) - Traffic light information (SPATEM+MAPEM) could add additional benefit	
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	**Not relevant** But possible with collective perception (>2026) - not in SECUR scope	**Relevant** Only for connected PTW		
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	**Relevant** Only if the opponent vehicle is connected			
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	**Not relevant** But possible with collective perception (>2026) - not in SECUR scope	**Relevant** Only for connected PTW		

: V2X type relevant for the use case
: V2X type relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
: V2X type not relevant for the use case
: V2X type incompatible with the use case

* V2V = Passenger car
** V2VRU = PTW + Byclicle + Pedestrian

The previous table is summarized below:

Table 5 - Summary of the matrix n°1 - SECUR use cases in front of V2X types of communication for 2026 scope

			Types of V2X communication			
	WP1 Use case	**Opponent**	V2V	V2VRU	V2I	V2N
1	Oncoming	Passenger car	✓		×	×
2	Straight Crossing Path – Right Direction (**SCP-RD**)	Bicyclist	×	✓	✓	©
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	✓		©	©
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	×	×	✓	×
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian	×	×	✓	×
6	Loss Of Control in CUrve (**LOC-CU**)	None	✓		✓	✓
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	✓		©	©
8	Loss Of Control in Straight Line (**LOC-SL**)	None	✓		✓	✓
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	×	✓	✓	©
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	✓		✓	©
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car	✓		×	©
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	✓		✓	©
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	×	✓	✓	©
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	✓		✓	©
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	×	✓	✓	©

✓ : V2X type relevant for the use case
© : V2X type relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
× : V2X type not relevant for the use case
: V2X Type incompatible with the use case

3.4 MATRIX N°2: SECUR USE CASES LINKED TO V2X MESSAGES

The second round of work had been to link the considered scenarios to different V2X Messages in order to show a picture of the actual capability of the technologies. The messages studied are the ETSI messages standardized (and soon to be standardized) but also messages used in V2N communication:

- **DENM**: Decentralized Environmental Notification Message
  These messages are alert messages that are broadcast in a specific geographic area when a particular event occur.
- **CAM**: Cooperative Awareness Message
  These messages are awareness messages to share locally devices dynamic information to surrounding devices (e.g., speed, localization, heading).
- **MAPEM**: MAP Extended Message
  These messages model the topology of intersections and road, including their automated driving authorizations.
- **SPATEM**: Signal Phase And Timing Extended Message
  These messages provide dynamic information on the state of traffic lights, providing

information on both the phase (red/green) and the remaining time of this phase.
- **CPM**: Cooperative Perception Message
  These messages broadcast information on detected object to its surrounding.
- **VAM**: VRU Awareness Message
  These messages are dedicated to awareness for VRU.
- **D2VO**: Datex-II Vehicle Obstruction
- **D2WRRC**: Datex-II Weather Related Road Conditions

Moreover, other messages had been taken in account but the impact on their deployment being limited by 2026, there are not relevant for the SECUR scenarios, all information on these messages can be found on ETSI specifications documents. (IVIM, SREM, SSEM, MCM, MCDM, SAEM)

Finally, SPATEMs are not self-contained and thus requires a parallel transmission of MAPEMs, that's why these two columns are identical on the following figures. And as a clarification point, DEMNs are sent with a high priority and represent a hazardous event and thus normal driving situations are not represented by DENMs.

As the following figure shows, SPATEM and MAPEM are highly relevant in intersections scenarios because those messages are linked to infrastructure status such as traffic lights. Having information of the phase and the time-to-green could be relevant in the decision making of the driver. Moreover, CAM are always relevant in the scenarios by its standardization. Indeed, these messages are sent out by the devices from 1 Hz to 10 Hz to give information on its status (speed, position, heading…) and this information is mandatory to intersection scenarios and the path prediction mechanism used in those scenarios, is mandatory to other types of scenarios to give information on the vehicle status for the local vehicles and infrastructures. Finally, DENM are useful in hazardous events and so more relevant in anormal situation of driving such as traffic jams, dangerous road conditions or in certain case presence of VRU on the road. Concerning the CPM & VAM, those messages being very new, they have been studied by there is still uncertainties on their capability in 2026.

Legend of the matrix below:

	: V2X Message relevant for the use case
	: V2X Message only relevant to provide complementary information.
×	: V2X Message Not Relevant for the use case

Note: This matrix addresses the relevance of messages in scenarios. However, the profiles /specifications absences are not taken in account.

Table 6 - Matrix n°2: SECUR use cases in front of V2X Messages for 2026 scope

	WP1 use case	Opponent	V2X Messages									
			DENM	CAM	MAPEM	SPATEM	CPM	VAM	D2VO	D2WRRC	IVIM	Other types of messages*
1	**Oncoming**	Passenger car	×	**Relevant**	×	×	×	×	×	×	×	×
2	Straight Crossing Path – Right Direction **(SCP-RD)**	Bicyclist	**Relevant** DENM dedicated to VRU (CauseCode 97, SubCC 4)	**Relevant**	Traffic light information (SPATEM+MAPEM) could add additional benefit	Traffic light information (SPATEM+MAPEM) could add additional benefit	**Relevant**	**Relevant**	×	×	×	×
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	×	**Relevant**			**Relevant**	×	×	×	×	×
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	**Relevant** DENM dedicated to VRU (CauseCode 97, SubCC 4)	**Relevant**			**Relevant**	**Relevant**	×	×	×	×
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian		**Relevant**			**Relevant**	**Relevant**	×	×	×	×
6	Loss Of Control in CUrve (**LOC-CU**)	None	**Relevant** DENM dedicated to SVW (CauseCode 99, SubCC 3 (ESP activated))	**Relevant**	×	×	×	×	×	**Relevant**	×	×
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	×	**Relevant**	Traffic light information (SPATEM+MAPEM) could add additional benefit	Traffic light information (SPATEM+MAPEM) could add additional benefit	**Relevant**	×	×	×	×	×
8	Loss Of Control in Straight Line (**LOC-SL**)	None	**Relevant** DENM dedicated to SVW (CauseCode 99, SubCC 3 (ESP activated))	**Relevant**	×	×	×	×	×	**Relevant**	×	×
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	**Relevant** DENM dedicated to VRU (CauseCode 97, SubCC 4)	**Relevant**	Traffic light information (SPATEM+MAPEM) could add additional benefit	Traffic light information (SPATEM+MAPEM) could add additional benefit	**Relevant**	**Relevant**	×	×	×	×
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	**Relevant** DENM dedicated to EEBL (CauseCode 99, SubCC 1) and PreCrash (CauseCode 99, SubCC 2)	**Relevant**			×	×	**Relevant**	×	×	×
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car		**Relevant**	×	×	×	×	**Relevant**	×	×	×
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	×	**Relevant**	Traffic light information (SPATEM+MAPEM) could add additional benefit	Traffic light information (SPATEM+MAPEM) could add additional benefit	**Relevant**	×	×	×	×	×
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	×	**Relevant**			**Relevant**	×	×	×	×	×
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	×	**Relevant**			**Relevant**	×	×	×	×	×
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	×	**Relevant**			**Relevant**	×	×	×	×	×

: V2X Message relevant for the use case
: V2X Message only relevant to provide complementary information.
× : V2X Message Not Relevant for the use case

* : SREM, SSEM, MCM, MCDM, SAEM, D2OA, D2NWRRC

The previous table is summarized below:

Table 7 - Summary of the matrix n°2 – SECUR use cases in front of V2X messages for 2026 scope

			V2X Messages							
	WP1 use case	**Opponent**	DENM	CAM	MAPEM	SPATEM	CPM	VAM	D2VO	D2WRRC
1	**Oncoming**	Passenger car	×	✓	×	×	×	×	×	×
2	Straight Crossing Path – Right Direction (**SCP-RD**)	Bicyclist	✓	✓	©	©	✓	✓	×	×
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	×	✓	©	©	✓	×	×	×
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	✓	✓	©	©	✓	✓	×	×
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian	✓	✓	©	©	✓	✓	×	×
6	Loss Of Control in CUrve (**LOC-CU**)	None	✓	✓	×	×	×	×	×	✓
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	×	✓	©	©	✓	×	×	×
8	Loss Of Control in Straight Line (**LOC-SL**)	None	✓	✓	×	×	×	×	×	✓
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	✓	✓	©	©	✓	✓	×	×
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	✓	✓	©	©	×	×	✓	×
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car	✓	✓	×	×	×	×	✓	×
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	×	✓	©	©	✓	×	×	×
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	×	✓	©	©	✓	×	×	×
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	×	✓	©	©	✓	×	×	×
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	×	✓	©	©	✓	×	×	×

✓ : V2X Message relevant for the use case
© : V2X Message only relevant to provide complementary information.
× : V2X Message not relevant for the use case

The following messages are not in the above summary table as considered as relevant for none of the SECUR WP1 use cases: IVIM, SREM, SSEM, MCM, MCDM, SAEM, D2OA, D2A, D2NWRRC.

3.5 MATRIX N°3: SECUR USE CASES LINKED TO V2X TECHNOLOGIES

The third matrix links the SECUR use cases to the different V2X technologies studied in WP2.

Like mentioned in the 2.1 Technology capability section, all direct communication technologies (ITS-G5, PC5 Release 14 and PC5 Release 16) can address SECUR scenarios because performances on latency and range are reached by those technologies. The only uncertainties on these technologies are the congestion control when there will be hundreds of devices. However, in intersection scenarios, which are highly represented in the WP1 study, it would not be likely that much congested.

Moreover, on the following table, the 4G Uu and 5G Uu capability is focusing purely on the ideal deployment of the technology. Thus, the scenarios would be more likely occur in an urban area with a cellular network deployed. Besides, all the uncertainties define in the 2.3 section of the document are ignored because these topics are link to a legal and economic point of view more than a technical point of view.

Finally, concerning the BLE 5.0 capability, the only use cases where the relevance was found are the VRU use-cases where a smartphone would be the device communicating. However, the WP2 agreed that it will not be likely deployed by 2026.

Legend of the matrix below:

✓	: Technology relevant for the use case
©	: V2X Technology relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
×	: Technology not relevant for the use case

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Table 8 - Matrix n°3: SECUR use cases in front of V2X Technologies for 2026 scope

	WP1 use case	Opponent	V2X Technologies					
			ITS-G5 - 802.11p	PC5 release 14	PC5 release 16	4G UU	5G UU	BLE 5.0
1	Oncoming	Passenger car	**Relevant**	**Relevant**	**Relevant**	Not relevant due to the latency req. of 100ms.	Not relevant due to the latency req. of 100ms.	**Not relevant** due to mobility and range requirements in addition of inability to use certain messages due to size
2	Straight Crossing Path – Right Direction (**SCP-RD**)	Bicyclist	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	- Could be relevant to add precision on positionning for vulnerables if we consider smartphone used by vulnerables - not in SECUR scope -VRU2I --> I2V
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	**Relevant**	**Relevant**	**Relevant**			**Not relevant** due to mobility and range requirements in addition of inability to use certain messages due to size
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	- Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	**Not relevant** due to latency requirements	**Not relevant** but could become relevant in the futur with network connected device on the VRU (e.g. smartphone)	- Could be relevant to add precision on positionning for vulnerables if we consider smartphone used by vulnerables - not in SECUR scope -VRU2I --> I2V
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian						
6	Loss Of Control in CUrve (**LOC-CU**)	None	**Relevant**	**Relevant**	**Relevant**	**Relevant** but depend of the coverage	**Relevant** but depend of the coverage	**Not relevant** due to mobility and range requirements in addition of inability to use certain messages due to size
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	**Relevant**	**Relevant**	**Relevant**	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	
8	Loss Of Control in Straight Line (**LOC-SL**)	None	**Relevant**	**Relevant**	**Relevant**	**Relevant** but depend of the coverage	**Relevant** but depend of the coverage	
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	- Requires a connected VRU - Use of connected infrastructure to detect the VRU and share its information (localization, speed, direction, …) with the surrounding vehicles with DENM message - Possible with collective perception (>2026) - not in SECUR scope	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	-Not relevant for crash avoidance scenario due to the latency requirement at 100 ms -Additional information could be brought to the devices (traffic light, local hazard)	- Could be relevant to add precision on positionning for vulnerables if we consider smartphone used by vulnerables - not in SECUR scope -VRU2I --> I2V
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	**Relevant**	**Relevant**	**Relevant**			**Not relevant** due to mobility and range requirements in addition of inability to use certain messages due to size
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car	**Relevant**	**Relevant**	**Relevant**			
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	**Relevant**	**Relevant**	**Relevant**			
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	**Relevant**	**Relevant**	**Relevant**			
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	**Relevant**	**Relevant**	**Relevant**			
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	**Relevant**	**Relevant**	**Relevant**			

: V2X Technology relevant for the use case
: V2X Technology relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
: V2X Technology Not Relevant for the use case

The previous table is summarized below:

Table 9 - Summary of the matrix n °3 – SECUR use cases in front of V2X Technologies for 20265 scope

			V2X Technologies					
	WP1 use case	**Opponent**	**ITS-G5 - 802.11p**	**PC5 release 14**	**PC5 release 16**	**4G UU**	**5G UU**	**BLE 5.0**
1	**Oncoming**	Passenger car	✓	✓	✓	×	×	×
2	Straight Crossing Path – Right Direction (**SCP-RD**)	Bicyclist	©	©	©	©	©	©
3	Straight Crossing Path – Right Direction (**SCP-RD**)	Passenger car	✓	✓	✓	©	©	×
4	Straight Crossing Path – Right Direction (**SCP-RD**)	Pedestrian	©	©	©	×	×	©
5	Straight Crossing Path – Left Direction (**SCP-LD**)	Pedestrian	©	©	©	×	×	©
6	Loss Of Control in CUrve (**LOC-CU**)	None	✓	✓	✓	✓	✓	×
7	Straight Crossing Path – Left Direction (**SCP-LD**)	Passenger car	✓	✓	✓	©	©	×
8	Loss Of Control in Straight Line (**LOC-SL**)	None	✓	✓	✓	✓	✓	×
9	Straight Crossing Path – Left Direction (**SCP-LD**)	Bicyclist	©	©	©	©	©	©
10	Rear End - Following vehicle (**RE-FV**)	Passenger car	✓	✓	✓	©	©	×
11	Rear End - Previous vehicle (**RE-PV**)	Passenger car	✓	✓	✓	©	©	×
12	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	Passenger car	✓	✓	✓	©	©	×
13	Left Turn Across Path – Opposite Direction (**LTAP/OD**)	PTW	✓	✓	✓	©	©	×
14	Left Turn Across Path – Left Direction (**LTAP/LD**)	Passenger car	✓	✓	✓	©	©	×
15	Left Turn Across Path – Left Direction (**LTAP/LD**)	PTW	✓	✓	✓	©	©	×

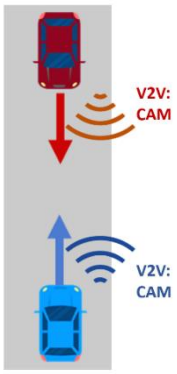
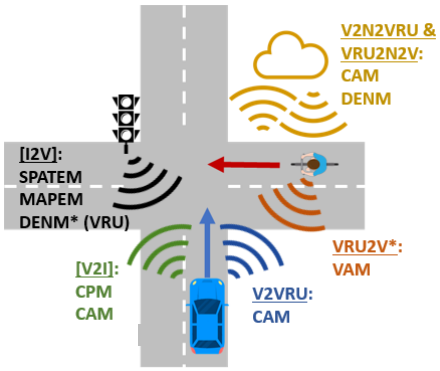
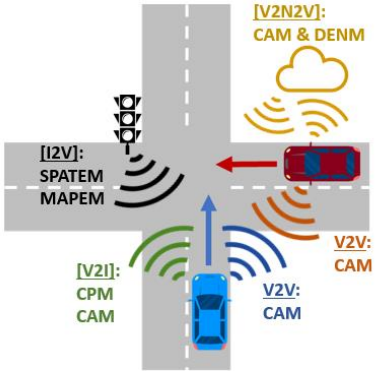
✓ : Technology relevant for the use case
© : V2X Technology relevant to provide complementary information; as well as for countermeasures that do not require low latency (e.g. awareness)
× : Technology not relevant for the use case

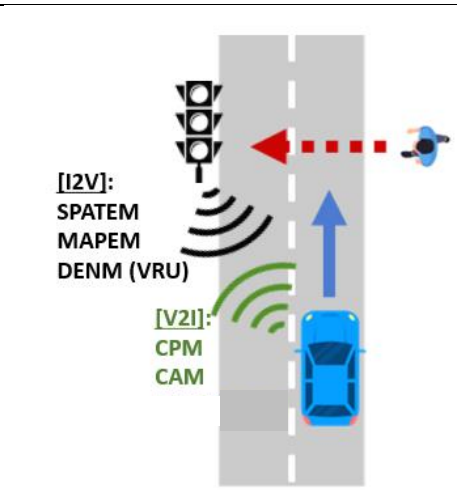
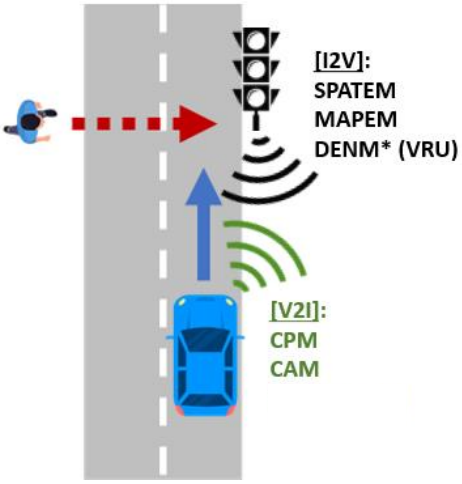
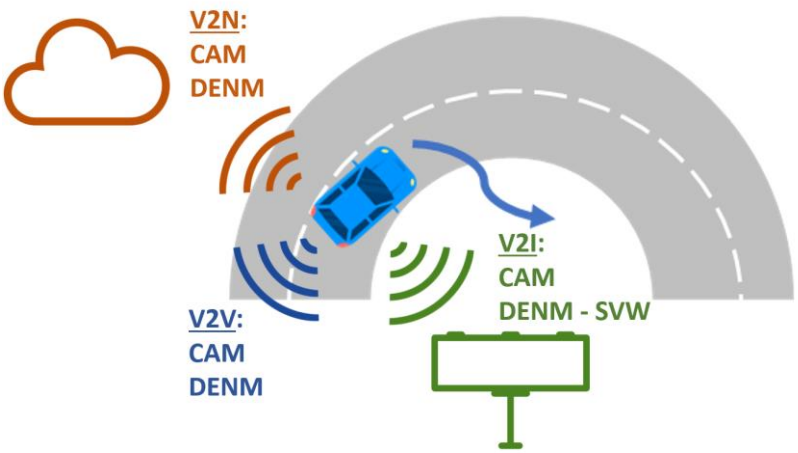
3.6 UPDATED PICTOGRAMS BASED ON THE V2X MATRICES

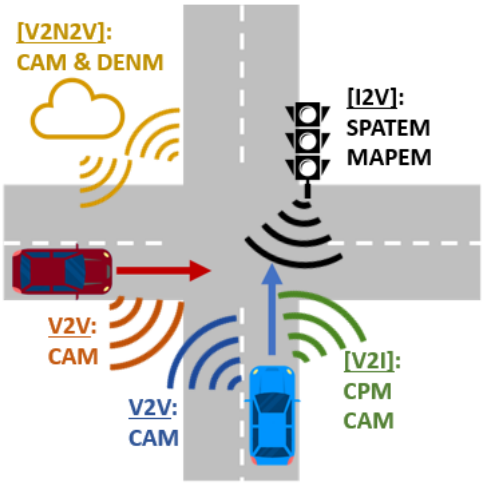
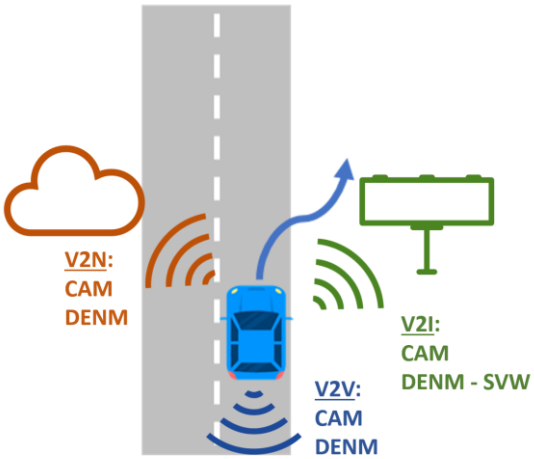
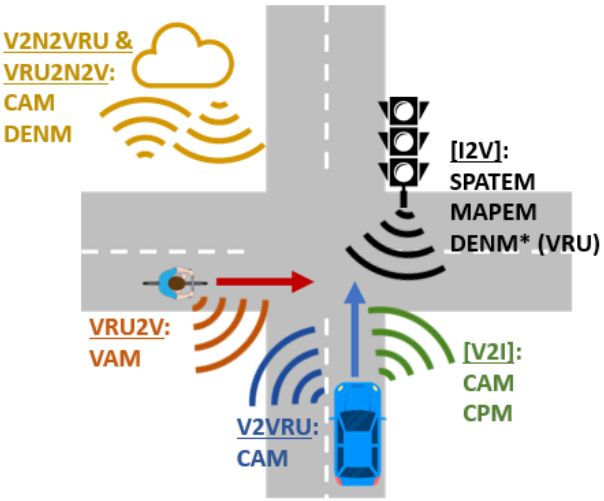
In this section, the information provided by the two first matrices are summarised on simplified-use-cases pictograms in order to have a complete picture.

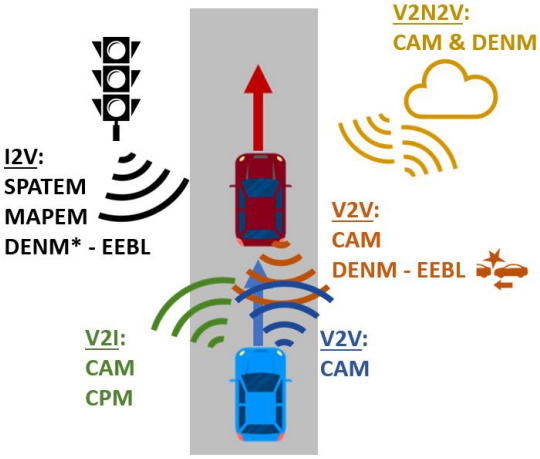
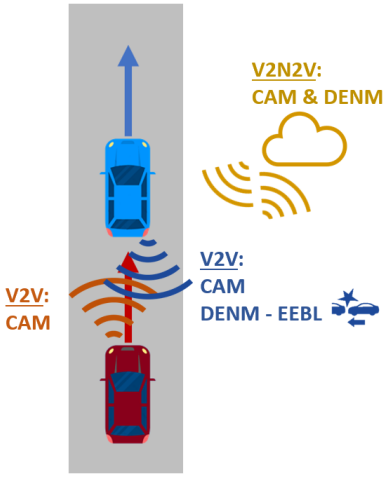
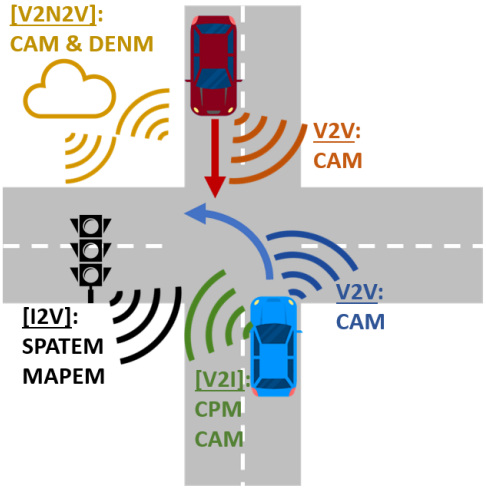
As used in the matrices of this report there are different levels of relevance (Green: relevant; Yellow: relevant to bring complementary information; Red: not relevant). To represent this difference on the pictograms, all the V2X types "only relevant to provide complementary information" (in yellow) will be noted between hooks (i.e., "[V2X type]") and not relevant ones (in red) will not appear.

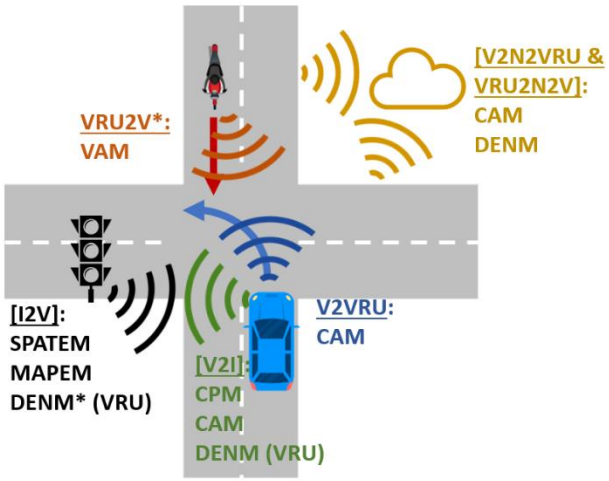
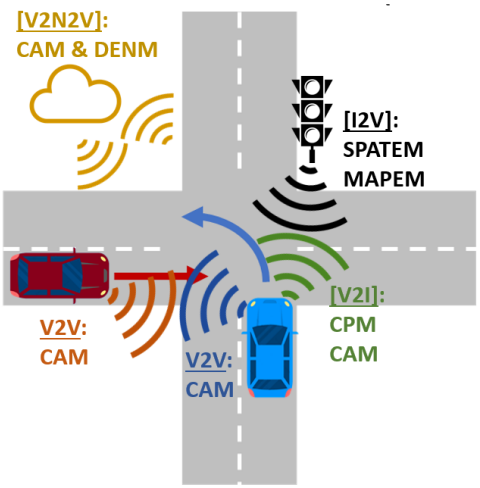
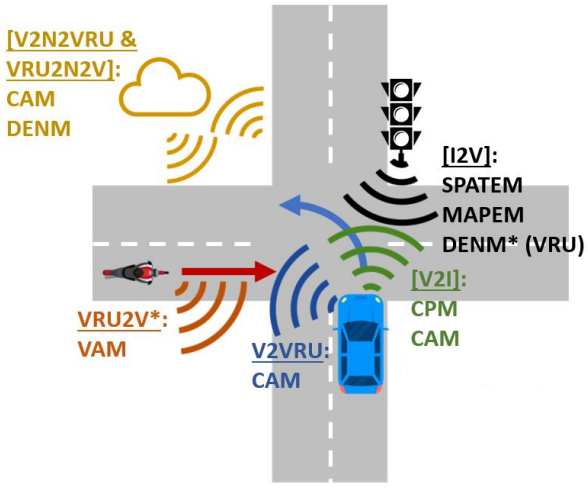
Table 10 - V2X SECUR Pictograms

Use Case	V2X Pictogram
1 – Oncoming (PC)	
2 – Straight Crossing Path – Right Direction SCP-RD (BC)	 *DENM* (VRU): infrastructure detection or collective perception* *VRU2V*: only for connected bicyclist*
3 - Straight Crossing Path – Right Direction SCP-RD	

4 - Straight Crossing Path – Right Direction SCP-RD (PD)	 *DENM (VRU): infrastructure detection or collective perception*
5 - Straight Crossing Path – Left Direction SCP-LD (PD)	 *DENM* (VRU): infrastructure detection or collective perception*
6 – Loss of Control in Curve (LOC – CU)	

7 - Straight Crossing Path – Left Direction SCP-LD	
8 – Loss of Control in Straight Line LOC – SL	
9 – Straight Crossing Path – Left Direction SCP-LD (BC)	 *DENM* (VRU): infrastructure detection or collective perception* *VRU2V*: only for connected bicyclist*

10 – Rear End – Following Vehicle RE – FV	 *DENM* (VRU): infrastructure detection or collective perception*
11 – Rear End – Previous Vehicle RE -PV	
12 – Left Turn Across Path – Opposite Direction LTAP/OD	

13 - Left Turn Across Path – Opposite Direction LTAP/OD (PTW)	 *DENM* (VRU): infrastructure detection or collective perception* *VRU2V*: only for connected PTW*
14 – Left Turn Across Path – Left Direction LTAP/LD	
15 - Left Turn Across Path – Left Direction LTAP/LD (PTW)	 *DENM* (VRU): infrastructure detection or collective perception* *VRU2V*: only for connected PTW*

4 V2X Roadmap & Guidelines after 2026

4.1 VRU SUPPORT IN THE ECOSYSTEM

Through the WP2, the question of the connectivity deployment on the VRU has been mentioned multiple times. Indeed, V2X communication requires hardware such has ITS station unit for direct communication, or certain configuration for indirect communication. This hardware is energy consuming, thus require access to a large amount of energy and also has a certain cost that would represent an important part of the final price, this is why the consensus led that powered vehicles could be connected by 2026, such as Powered-Two-Wheelers and e-Bikes. Concerning, the bicyclists and pedestrians, there is a capability to connect them with a smartphone or other V2X devices but V2X experts agreed that it is not likely doable and deployed for 2026, but beyond this date there would be a huge deployment of V2X via smartphones or dedicated devices due to evolution of the V2X hardware and V2X standards.

4.2 V2X MESSAGES DEPLOYMENT ROADMAP

In today's vehicles, and more particularly mass-market vehicles, not all use cases are implemented and so not all V2X messages are supported due to its dependence of the V2X messages and profiles standardization, which takes time. It's because of this situation that a V2X Messages deployment roadmap had been created. On the following figure there is the different messages listed with their standardization year at the top and their estimated deployment year in blue shaded colours:

Table 11 – Legend of the V2X Messages deployment roadmap

Color	Meaning
Light blue	Message already deployed and used in mass marketed vehicles
Blue	Message that would be likely implemented in vehicles by 2026
Dark blue	Message that would not be likely implemented in vehicles by 2026. Doted squared means that the messages are not standardized yet (in draft during the writing of the document)
Grey	No information provided by OEMs concerning the deployment of the messages

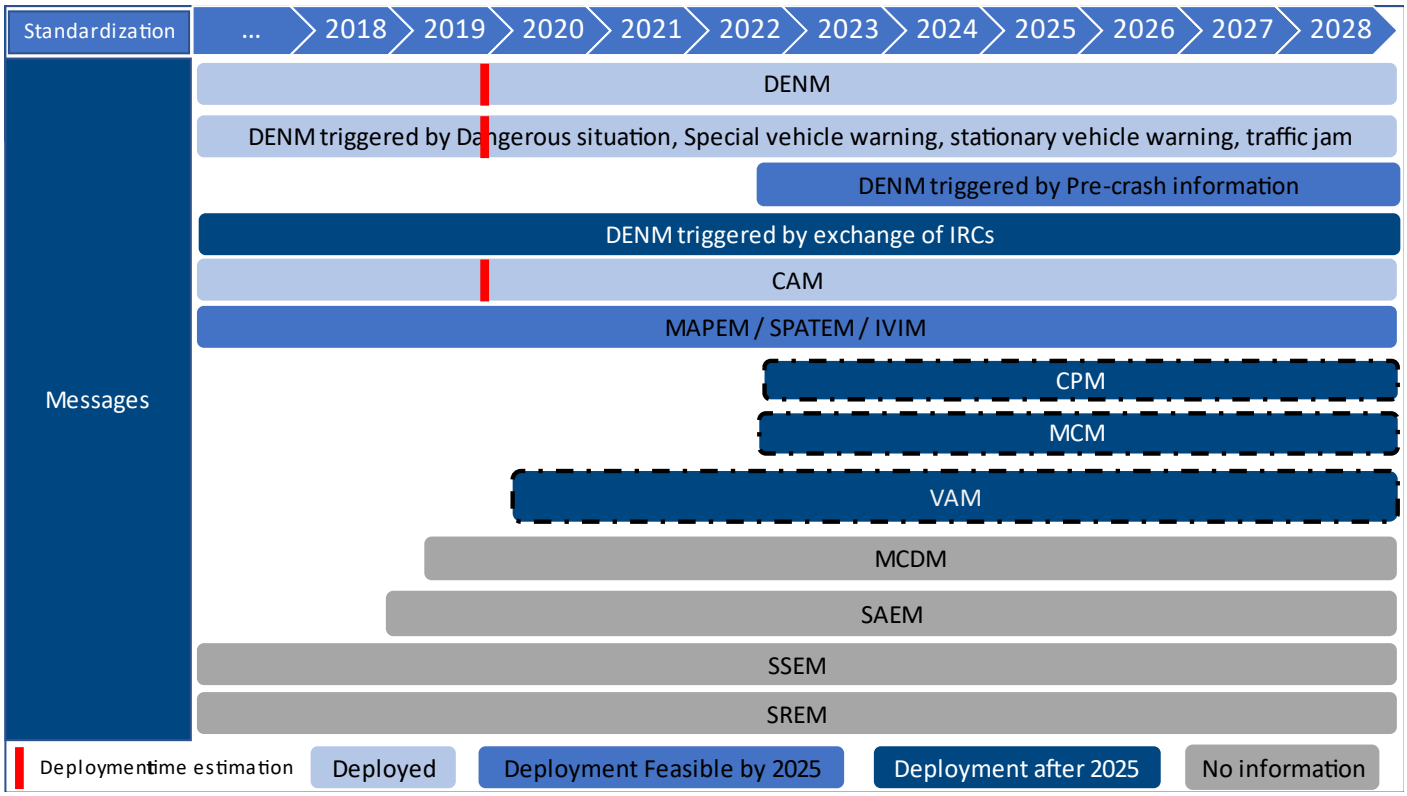


Figure 5: V2X Messages deployment roadmap

CONCLUSION

This deliverable D2.2 is the last report of the WP2 which is focused on the V2X capability to address SECUR scenarios defined by the WP1 while taking in account the technical characteristics, regulatory status, and the deployment status of the technologies. To have more details on these characteristics, D2.1 are the detailed technical documents of technologies, which supported the conclusions of the D2.2.

It contains all the results of the studies performed by the V2X experts coming from the different SECUR partners. This synthesis permitted to compile in one document the capability, the deployment state and the limitation of the different technologies.

Indeed, the status is that direct communication technologies (ITS-G5, PC5 Release 14 and PC5 Release 16) performances permits to address all kind of use-cases, even safety critical one. However, today in Europe, ITS-G5 is the only technology in mass-deployment in infrastructure and vehicles. Moreover, the current regulatory situation allows only ITS-G5 in mass deployment. Please refer to Annex for more details. Only project pilots are performed on the PC5 Release 14 side and thus the deployment is still uneven on the deployment part. Concerning BLE 5.0 technologies, the capability is very limited and could not address the SECUR use-cases, but the VRU ones (in the case where the pedestrian and bicyclists are connected, which is unlikely for 2026). Moreover, there is still all the standardization (messages and profiles) to do for BLE 5.0 communications.

Moreover, the status on indirect communication technologies (4G Uu & 5G Uu) performances permits to address various use cases, mostly information data such as local hazards and traffic light information. Indeed, for most safety critical use-cases, the low-latency requirements could only be met in area where the network is ideal and not congested. And even with these criteria met, the latency between the OEMs back-end servers is the main contributor of the global latency which is out of control of the OEMs. That is why in the document, the mention of the 5G Uu capability is conditioned by the 5G deployment in Europe by 2026. Besides, in addition of the deployment uncertainties there is legal and economical topics that are still blurry todays: the privacy issue raised by the possibility to identify a vehicle which is an EU policies violation, the back-end interoperability between OEMs and Road operators isn't standardized yet and so, the penetration on the market is still limited, and finally, the subscription to the network provider to be able to communication is not defined yet.

Besides, VRU would not be able to communicate directly if there is no power supply available. Thus, PTW and e-Bikes would be capable to be in the ecosystem for the 2026 scope, while pedestrian and bicyclist would be detected by connected infrastructure for the 2026 scope. However, it is not excluded that further 2026, mobile devices such smartphone will be a mean to communication through V2X communications.

Finally, concerning the messages deployment, today the messages profiled and used are CAMs to get information on the vehicle's status and DENMs to get information on hazardous events that will require a special action from the driver. OEMs that participate in the roadmaps sees the capability to implement SPATEMs, MAPEMs and IVIMs in vehicles for 2026 in order to treat services that would requires traffic lights information (e.g., GLOSA: Green Light Optimization Speed Assist). And in a second step include more recent messages such as CPM and VAM to protect vulnerable road users and MCM to facilitate dangerous manoeuvres.

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Partners

Contributors

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TABLE OF ILLUSTRATIONS