Guidance for day 2 and beyond roadmap

CAR 2 CAR Communication Consortium

About the C2C-CC

Enhancing road safety and traffic efficiency by means of Cooperative Intelligent Transport Systems and Services (C-ITS) is the dedicated goal of the CAR 2 CAR Communication Consortium. The industrial driven, non-commercial association was founded in 2002 by vehicle manufacturers affiliated with the idea of cooperative road traffic based on Vehicle-to-Vehicle Communications (V2V) and supported by Vehicle-to-Infrastructure Communications (V2I). The Consortium members represent worldwide major vehicle manufactures, equipment suppliers and research organisations.

Over the years, the CAR 2 CAR Communication Consortium has evolved to be one of the key players in preparing the initial deployment of C-ITS in Europe and the subsequent innovation phases. CAR 2 CAR members focus on wireless V2V communication applications based on ITS-G5 and concentrate all efforts on creating standards to ensure the interoperability of cooperative systems, spanning all vehicle classes across borders and brands. As a key contributor, the CAR 2 CAR Communication Consortium and its members work in close cooperation with the European and international standardisation organisations.

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Table 1: Document information

Changes since last release

Date	Changes	Edited by	Approved
2021-07-09	• New roadmap graphical representation and description to highlight supporting functionalities introduced at subsequent deployment phases besides communication services and sample use case categories • Introduction and contextualization in the roadmap of concepts such as Functional Safety and Misbehaviour Detection • Extension of concepts for infrastructure-to-vehicles support and their contextualization in the roadmap following ISAD definitions • Considerations on improvement of the V2X exchanged information along subsequent deployment phases • Complete restructuring and extension of the tables listing and describing sample use cases and their associated V2X messages (inclusion of C-Roads use cases as well as new use cases for Day 2 and Day 3+) • Considerations on how development targets identified in the previous version of the white paper have been or are being addressed in dedicated C2C-CC work items	Release Management	Steering Committee
2019-09-25	Initial release	Release Management	Steering Committee

Table 2: Changes since last release

Content

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1 Introduction

1.1 Abstract

The Working Group Functional of the C2C-CC generates and continuously updates an automotive-based strategical roadmap for C-ITS deployment in Europe. The scope of this roadmap covers guidelines, R&D needs and implementation options for C-ITS systems to be deployed on both short- and long-term periods. For this purpose, this working group works in close cooperation with the other working and competence groups of the C2C-CC and, when needed, establishes links with ongoing European R&D projects, other stakeholders (e.g. C-Roads) as well as standardization bodies on C-ITS.

In this context, this white paper constitutes a consolidated reference document highlighting a coherent list of functional development goals to be fulfilled for future C-ITS deployment phases beyond Day 1. In particular, this white paper highlights the C2C-CC C-ITS deployment strategy organized in subsequent phases of deployment where new generations' use cases, communication services and supporting functionalities are increasingly introduced on top of the pre-existing ones and evolve in such a way to gradually enable cooperative automated driving. The white paper also indicates the most important enabling concepts to be developed for the next deployment phases and highlights how many of them are already being addressed by dedicated C2C-CC work items. For deployment beyond Day 2, the white paper also summarizes the future scenarios to be considered as result of the many ongoing R&D activities on related topics. C2C-CC roadmap positions on purely technological aspects of C-ITS in support of cooperative automated driving (e.g. seamless evolution of direct short-range communication technologies in the context of multi-channel operation scenarios, combination of short- and long-range technologies and their adoption for different use cases, etc.) are being currently consolidated and will be highlighted in next versions of this document.

1.2 Summary of the document

The C2C-CC roadmap is organized in subsequent deployment phases named Day 1, Day 2, …, Day N (Figure 2-1). The sequence of these deployment phases will allow transition from dissemination of local status information and warnings to cooperative automated driving. The C2C-CC roadmap foresees, at each phase, introduction of specific communication services and supporting functionalities enabling different types of use cases. Figure 2-1 depicts only a representative subset of such use cases. A more detailed, yet not exhaustive list can be found in Appendix 1. Communication services are ETSI ITS architecture facilities administrating message management for data exchange between C-ITS stations. At a given deployment phase, different types of information will be exchanged by these services. Cross-layer supporting functionalities will be also needed to shape evolution of C-ITS-based use cases. The Day 1 deployment phase uses Cooperative Awareness (CA) and Decentralized Environmental Notification (DEN) services to disseminate vehicle state information as well as occurrence of dangerous situations. Exchanging this type of information allows realizing warning applications. At the same time, infrastructure-based services providing static and dynamic information about the road infrastructure are introduced (In-Vehicle Signage, Traffic Light Signal Phase and Time, Road Topology Description services) allowing implementation of other traffic safety, efficiency or information applications. Specifications for implementation of the Day 1 V2X vehicular system and its V2V use cases are collected in the C2C-CC Basic System Profile (BSP) release bundle [5]. Specifications on infrastructure-related services and their profiling for a correct usage at receiving vehicles' applications are provided by the C-Roads initiative [6].

In the Day 2 phase, vehicles and RSUs will take advantage of being equipped with environment-sensing technologies to share information about detected objects. This capability will enable receiving vehicles to be aware of obstacles they would not otherwise detect with their own sensors (e.g. pedestrians or cyclists hidden behind a corner in intersection areas). In this way, enhanced safety applications compared to the Day 1 can be introduced. Enhanced applications will also be possible thanks to extension of the information conveyed in the messages shared via cooperative awareness and decentralized notification services. These applications will not necessarily aim at warning drivers but will, wherever possible, implement semi-automated reactions like automated braking for Vulnerable Road User (VRU) and Powered Two-Wheelers (PTW) protection or control functions like Cooperative Adaptive Cruise Control (C-ACC). As described in this paper, the C2C-CC is currently working on the definition of new supporting functionalities needed to increase information accuracy, guarantee functional safety and enable detection of misbehaving stations. Finally, Day 2 applications will take advantage of new infrastructure-related services extended to provide more precise and articulated information to vehicles (e.g. priority/pre-emption data, more complex road topologies and/or combined warning and signage information).

A third phase of deployment, namely Day 3+, will take advantage of the introduction of vehicles with increasingly automated driving capabilities (level 3-4) and their ability to share planned trajectories/routes and coordinate manoeuvres with other traffic participants and the infrastructure. Sharing this information will enable the implementation of cooperative automated driving use cases in which automated cars can implicitly or explicitly coordinate the execution of manoeuvres in order to avoid conflicts and hence ensure safety (e.g. cooperative lane change, cooperative merging, advanced C-ACC applications, and so on). In this phase the road infrastructure could play different supporting roles. One of these may be the provision of suggestions like speed-, lane change- and gap advices as well as indications of restrictions to automated driving, advices to implement transition of control to manual driving and/or notifications of available safe spots for the execution of minimum risk manoeuvres. Such advises would be useful in highway as well as urban and interurban environments to increase the overall traffic safety and efficiency, but receiving vehicles would still be entitled to follow or refuse them. In other scenarios, the infrastructure could play an even more active role like for example providing guidance to automated vehicles in controlled environments (e.g. valet parking applications where individual vehicle trajectories are centrally computed and provided by infrastructure entities). Moreover, in the Day 3+ phase, VRUs are expected to be V2X-equipped and play a more “active” role in announcing their presence and detect risky situations, hence contributing to further increase of road traffic safety.

Each subsequent phase will inherit the capabilities of the previous ones in a backwards-compatible manner. In other words, newer vehicles and infrastructure will keep transmitting the information needed by older vehicles to run the applications they are supporting. New services and supporting functionalities will be coexisting with old ones at a given deployment phase and will be equally used by new use cases, if needed.

The work done in the C2C-CC, C-Roads and ETSI TC ITS for introduction of Day 2 services and use cases has allowed identifying some core technological concepts that need to be specified as well as technical issues that need to be addressed. For many of these, the C2C-CC has already provided concrete solutions or is working for their accomplishment. At application level, new triggering conditions and message generation rules must be tailored to the requirements of new use cases. As an example, to flawlessly adopt the Collective Perception (CP) service, additional work was needed to specify criteria for inclusion of detected objects in transmitted messages. To ease this task, the C2C-CC has proposed a harmonized definition for “detected object quality” combining specifications for confidence and accuracy levels [32]. This metric, unambiguously justifies inclusion of detected objects in CP messages among different vendors’ implementations. Similarly, new triggering conditions and message adaptations for special vehicle types like powered two-wheelers are under development. As use cases adopting the exchanged information for (semi)-automated reaction will be introduced, the need will arise for this information to guarantee functional safety. Taking this requirement into account, the C2C-CC is proposing, in a dedicated work item, extension of V2X messages for inclusion of “Safety Containers” enabling receiving stations to ensure the determined ASIL levels of their reactions. Another key point that is being addressed in a dedicated C2C-CC task force is misbehaviour detection. In this context, methods to detect and isolate stations that provide incorrect information are being specified to make sure that the exchanged information does not undermine traffic safety.

While for the Day 2 deployment phase dedicated work items on specific functional and technical aspects are running, for Day 3+ systems the C2C-CC is in the preliminary process to identify a stable and complete common set of functionalities and requirements at the moment of writing this document. Despite this, this document lists relevant examples of Day 3 and beyond use cases as studied in past and current R&D activities and implemented with similar and/or complementing approaches. These use cases set the basis for identification of new functional and technical features. It is recognized that cooperative manoeuvring (both V2V-distributed and I2V-centralized/infrastructure-assisted) can be an important enabler for automated driving, and that common rules for distributed fulfilment of common goals, distributed coordination and traffic optimization in specific situations would be needed. The road infrastructure can have an important role in providing additional/complementary/redundant support, via V2X, to some fundamental technological and functional aspects that will be key for automated driving (position correction, map update and collective perception are just a few examples).

In general, the information exchanged via V2X must improve along different dimensions at subsequent deployment phases to fulfil the stricter requirements of use cases characterized by increasing levels of automation. Information must improve in trustworthiness in order to be of reliable application at receiving stations for functional safety reasons. For this purpose, it must become more accurate in position and timing to reflect at high precision the real status and properties of the exchanged data. Moreover, the capability to provide such accuracy must be certified and indicated in the exchanged messages. The exchanged information will also need to be updated more frequently to reflect variation of data at very short time intervals. This will be in fact necessary as distributed control algorithms running in parallel at communicating automated vehicles will be asked to take sudden critical decisions such as in collective coordination of evasive manoeuvres.

2 The C2C-CC Roadmap

Over the past years, the C2C-CC has worked at specifying the so-called Day 1 V2X system running on vehicles and has identified the first set of use cases using V2V communications. A first phase of deployment started in 2019 with the introduction of V2X in the Volkswagen Golf 8 [1]. At the same time, road operators and road authorities in various European countries have joined efforts for the specifications and pre-deployment of C-ITS communication infrastructure and services. The experience initiated in the Amsterdam Group [2] with the C-ITS infrastructure pre-deployment projects C-ITS Corridor (in Germany, Netherlands and Austria) and SCOOP (France) has been consolidated and harmonized in the context of the C-ROADS platform [3], which is facilitating a European-wide deployment of C-ITS as mentioned in the Memorandum of Understanding signed with the C2C-CC [4].

The specifications of the Day 1 V2X vehicular system are collected in the C2C-CC Basic System Profile (BSP) release bundle [5]. The BSP is based on the ETSI TC ITS set of standards defining suitable protocols from access- up to facilities layer to support the Day 1 use cases. The BSP indicates the standards considered by the C2C-CC Day 1 system, profiles them in the most suitable way and defines HW and SW requirements that must be respected to ensure that different implementations provide the needed interoperability support and quality to form part of a trusted ad-hoc vehicular network. In addition, the C2C-CC has defined a set of triggering conditions for in-vehicle applications supporting the Day 1 use cases [5]. Similarly, the V2X infrastructure-related system and Day 1 services have been specified by C-ITS infrastructure experts in C-ROADS [6]. The C2C-CC and the C-Roads specifications were harmonized in order to provide I2V interoperability and were considered as the basis for the publicly available European Commission delegated act on C-ITS [7]. Despite the delegated act was not finally accepted by the EU council, C2C-CC and C-Roads are jointly moving forwards deployment of C-ITS and keep conducting specifications alignment and test activities to foster flawless interoperability [34][35][41]. The C2C-CC collaboration with C-Roads is not only focused on deployment of Day 1 use cases, but is also aimed at strategically setting the basis for evolution of C-ITS to support future cooperative automated driving.

In this context, the C2C-CC conceives a V2X deployment roadmap organized in subsequent phases named after the time of deployment (Day 1, Day 2, …, Day N) (Figure 2-1). This roadmap is based on the nowadays tangible increase of automation functions in series vehicles as well as an expected rising penetration of V2X equipped systems. This will allow transition from phases in which V2X is a technology primarily used for dissemination of local status information towards phases where V2X is a key factor to enable cooperative automated driving.

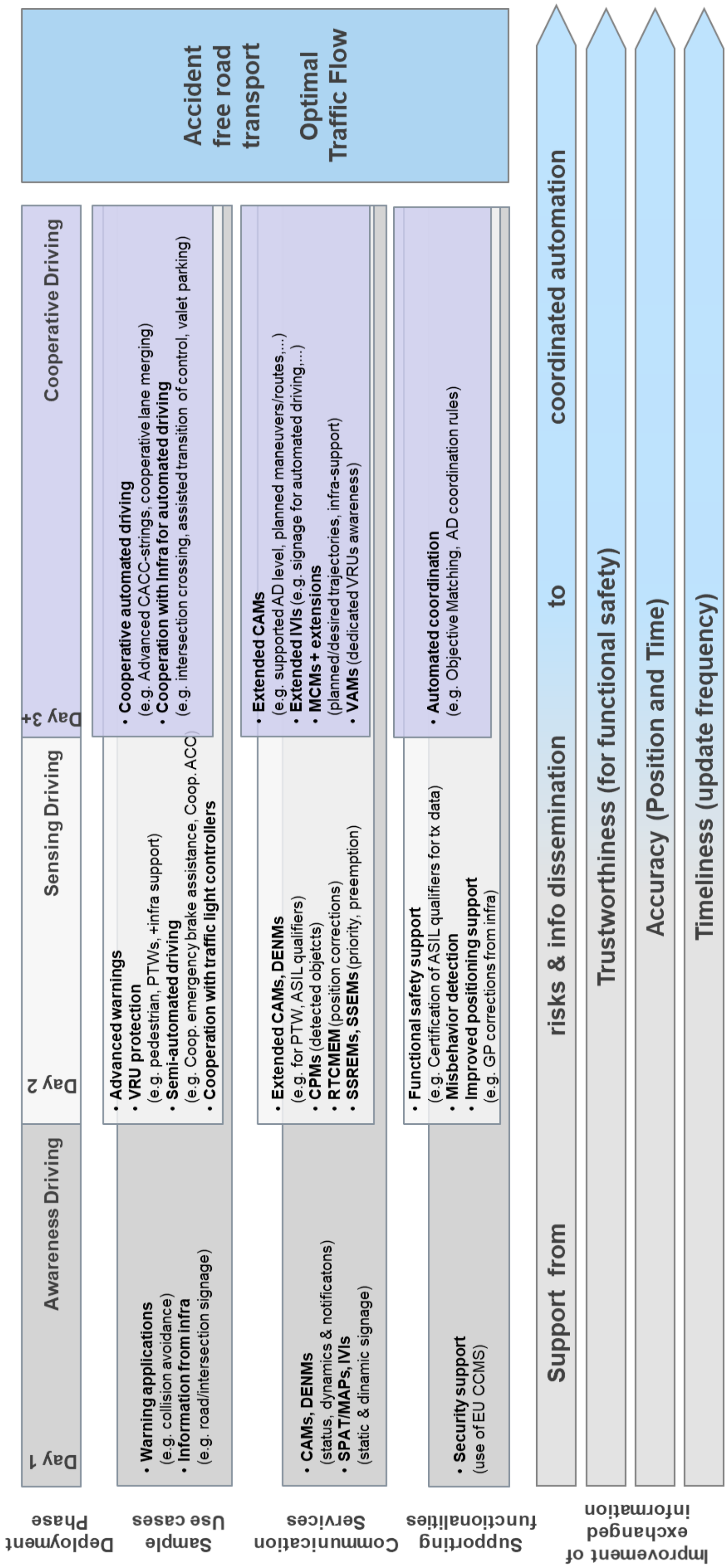


Figure 2-1: C2C-CC roadmap

The C2C-CC roadmap indicates representative examples of “use cases” that are expected to be deployed in subsequent phases, as well as the “communication services” and “supporting functionalities” needed for the execution of those use cases. The Day 1 use cases are essentially based on safety applications[1] running at transmitting and receiving vehicles, aimed at increasing the awareness horizon in both time and space, in a way for the driver or the vehicle to have more time to react to dangerous and unexpected situations. Examples of these use cases are the stationary/slow vehicle warning, intersection collision warning, emergency electronic brake light, emergency vehicle approaching, adverse weather conditions, etc. (Please find a more exhaustive list in Appendix 1). Use cases and applications are based on availability of “communication services” and “supporting functionalities”.

Following the definitions of the ETSI ITS Communications Architecture [8], “services” are defined and available at the Facilities level of the C-ITS stack for supporting common message management for data exchange between ITS stations. In the C2C-CC roadmap, these services allow vehicles, infrastructure, and other road users to exchange, in subsequent phases, different classes of data which are specific to that phase and in turn enable implementation of applications with increasing level of complexity. Examples of Day 1 communication services are those that enable exchange of the Day 1 messages, namely Cooperative Awareness Message (CAM) and Decentralized Environmental Notification Message (DENM).

Similarly, “supporting functionalities” are introduced at subsequent phases to enable further use cases. They are implemented at diverse levels of the C-ITS transmitting and receiving stations’ architectures and can require cross-layer interactions. As a representative example, Day 1 C-ITS stations need to guarantee “security support” to ensure authentication of exchanged C-ITS messages so that transmitted information can be trusted and hence is usable by receiving applications.

It can be seen that the Day 1 system and applications are based on the paradigm of sharing basic individual vehicle and infrastructure status information in order to increase the receiver’s awareness of the surrounding with the final aim to improve traffic safety. At the same time, vehicles are nowadays being equipped with more and more technologies enabling automated driving functions. An increasing penetration of on-board sensors (e.g. radars, lidars and cameras) allows vehicles to have a better perception of their close surroundings. Advanced algorithms use the achieved environmental perception to compute planning and control outputs that can support or even substitute driving tasks. In this context, for subsequent V2X deployment phases it is reasonable to let vehicles exchange the results of perception (detected objects) as well as planning and control algorithms (intentions or trajectories) in order to gradually enable cooperative automated driving scenarios. Similar considerations apply for road infrastructure. Road infrastructure operators already employ numerous traffic and environmental sensors that can provide inputs for connected and automated vehicles. A classification of the information that can be provided is defined by the Infrastructure Support Levels for Automated Driving (ISAD) which reflect the capability for a road network to support the future automated mobility era with increasing “readiness” grades [29].

Even if each phase is associated a given class of exchanged data, services and representative use cases, each subsequent phase will inherit the capabilities of the previous ones in an increasing way. Therefore, newer generations’ vehicles must still provide support for older generations’ vehicles in a backward compatible manner. In other words, newer vehicles will keep transmitting the information needed by older vehicles to run their supported applications. This concept is reflected in Figure 2-1 by grouping example use cases, services and supporting functionalities into dedicated boxes that are overlapping over subsequent deployment phases. This indicates that new services and functionalities will be coexisting with old ones at a given deployment phase and that new use cases can make use of old and new services and functionalities, if needed. In addition, services and functionalities must ensure backwards

[1] It is always an individual decision of OEMs when exactly to deploy a given application on their vehicles.

compatibility in case they get extended or improved at a given phase compared with the previous one. For example, a possible Day 2 CAM service extended for sharing additional information has to ensure that Day 1 use cases based on reception of Day 1 CAMs are still supported when receiving Day 2 CAMs.

As previously mentioned, the use cases reported in Figure 2-1 are just examples of what can be deployed by any OEM at a given deployment phase. For the Day 1 use cases, the naming has been harmonized with the terminology previously used by the EU C-ITS Delegated Act [7]. For the Day 2 and 3+ use cases, examples are taken from ETSI ITS WG1, relevant R&D projects, and inputs from individual OEMs. Again, the use of overlapping boxes to group the use cases indicates that new use cases will be incrementally added on top of existing ones and will coexist with them. Also, it is a valid assumption that use cases based on a previous set of services can still be introduced in later phases when new services are already available. For example, a red-light violation protection use case, which in general relies on the Day 1 SPATEM/MAPEM based services, might be introduced by an OEM when Day 2 services are already available.

Although the use case examples reported in Figure 2-1 are in general applicable to any vehicle category, other use cases specifically applicable to a particular vehicle category (commercial vehicles, powered two-wheelers, enforcement authorities vehicles, agriculture vehicles, etc.) can be considered. This is the case for platooning applications currently considered by truck OEMs. Truck platooning applications and platooning-supporting services have been widely tested and showcased over the last years and are currently being specified and harmonized in the ongoing EU funded ENSEMBLE project [9]. Platooning will be implemented by truck OEMs using the services indicated in Figure 2-1 and also dedicated platooning-supporting services whose specifications are also derived from the ENSEMBLE project. The platooning service and use case evolution will anyhow follow a similar roadmap as the one depicted in the figure, which reflects an introduction of platooning of increasing performance levels as automation and communication capabilities increase. The possibility to outline separate parallel roadmaps for vehicles of different types (passenger cars, trucks, Powered Two Wheelers (PTW) / motorcycles) is currently under discussion in the C2C-CC.

The following subchapters provide a more detailed description of each V2X deployment phase following the C2C-CC roadmap.

2.1 Day 1 phase – Awareness Driving

The Day 1 phase marks the introduction of C-ITS and has already started. In this phase vehicles and infrastructure transmit information regarding their status (e.g. vehicle dynamics for cars and PTWs, information about tolling stations from RSUs), as well as information describing unexpected events (e.g. adverse weather conditions, dangerous situations). The communication services adopted for the generation and management of this information are the Cooperative Awareness Service [10] handling CAMs, and Decentralized Environmental Notification Service [11] handling DENMs. CAMs are continuously broadcasted to convey dynamic information of the transmitter such as vehicle speed, position, heading, etc. with a variable frequency between 1 and 10 Hz depending on vehicle dynamics and the experienced channel load conditions. DENMs are event-triggered and are broadcasted to notify environmental situations detected by the ego vehicle whose knowledge is beneficial for receivers located in a specific zone of relevance (e.g. vehicles approaching roadworks from a specific traffic direction). Unlike CAMs, DENMs can be multi-hopped (i.e. forwarded from one C-ITS station to another) over the relevance area and their transmission repeated as long as the event is detected or considered valid.

In this context, the previously mentioned C2C-CC triggering conditions documents define the way a given anomalous or dangerous event (e.g. a stationary vehicle) shall be recognized by the vehicle system (e.g. monitoring specific CAN signals), outline which V2X messages shall be transmitted accordingly, and how they shall be populated in the available data fields/elements. Similarly, C-Roads (and its pre-deployment predecessor projects) has defined and tested, in collaboration with the automotive industry, profiling specifications for CAMs and DENMs transmitted by RSUs and road infrastructure-related vehicles (e.g. roadworks trailers) to ensure their exploitability at the vehicle reception side. All these activities have focused on specifying the requirements at the transmitting side for ensuring quality and interoperability. The implementation of the receiving side (including applications) is left open to automakers in a way to allow competitiveness while accounting for liability on how the received information is handled. Exchanging CAM and DENM information allows realizing warning applications like Emergency Vehicle Warning, Electronic Emergency Brake Light Warning, Stationary Vehicle Warning, Traffic-Jam Warning, Pre-Crash Information Exchange, Adverse Weather Warning, Intersection Collision Warning, Short Term Roadworks Warning, Hazardous Location Warning, and so on.

The Day 1 phase is also characterized by the introduction of infrastructure-based services providing static and dynamic information (see also ISAD Level C, [29]) about the road infrastructure [12]. Examples of these services are: the Cooperative Awareness Service [10] handling CAMs, the Decentralized Environmental Notification Service [11] handling DENMs, the Traffic Light Manoeuvre (TLM) service and Road and Lane Topology (RLT) service handling SPATEM/MAPEM conveying information about topology and signal time and phasing at signalized road intersections, as well as the Infrastructure to Vehicle Information (IVI) service handling IVIM informing about dynamically changing and vehicle type-specific information (e.g. on highways) [12]. Processing and fusing this information at the receiving side allows implementing new use cases for traffic safety (e.g. red-light violation protection), efficiency (e.g. GLOSA), or information (e.g. about traffic light, dynamic speed limits, specific vehicle restrictions, etc.).

Through all the above mentioned services, receiving vehicles increase their awareness of the surroundings (even beyond their line of sight) in terms of other vehicles' presence, occurrence of road hazards and traffic information. In this way, applications processing the received information permit providing suitable warnings and information to the driver.

To understand how PTWs can be included in the Day 1 concept, some considerations are needed. The triggering conditions for certain applications cannot be applied for PTWs in the same way as defined for cars. The following two examples give an impression of the differences:

- A car may notify other vehicles about the end of a traffic jam, whereas a group of motorcycles may pass this traffic jam on the corridor for emergency vehicles. As a result, following vehicles may interpret this situation wrongly.
- Motorcycles typically have no doors and no hand brakes. This way, the trigger of a breakdown vehicle will not be possible by using the trigger conditions defined for cars.

PTW-related use cases are basically triggered by PTWs, but the main action needs to be taken at the receiving vehicle. As a consequence, in this first phase, PTW-related use cases will be introduced as a Motorcycle Approaching Information (MAI) that will be based on the already specified CAM format for Day 1 use cases. However, only those data fields that can be provided by PTWs are used. MAI basically works as a simple "beaconing function" using CAMs. The goal is that surrounding vehicles are informed about the presence of an approaching PTW. The information is mainly triggered based on the relative distance between the motorcycle and the receiving vehicle[2].

[2] In this context, the C2C-CC CG PTW provided in the completed WI "F0008 MAI/MAW" guidelines for car manufacturers on what needs to be considered of typical PTW situations at the receiving side. For example, for MAI some more context information may be important: if only considering the relative distance between car and PTW, the car driver may be permanently informed about approaching PTWs in typical "PTW cities" like Rome or Paris. This negative effect can be mitigated if the number of surrounding PTWs, their headings and the ego and relative speed is considered.

2.2 Day 2 phase – Sensing driving

In this phase, the V2X system will be extended to additionally permit vehicles and RSUs (at ISAD Level B) to share information about objects detected via on-board sensors such as cameras, lidars or radars. This information, conveyed via Collective Perception Messages (CPMs), is generated and managed by the Collective Perception Service [13][14]. This additional information enables receiving vehicles to be aware of objects that would otherwise not be locally detectable (e.g. VRUs standing behind a corner in intersection areas (see Figure 2-2), or vehicles and PTWs behind a truck on interurban roads). The effect of this extension is twofold. On the one hand, it mitigates the limitation deriving from the coexistence with road users that are not equipped with V2X technologies and hence are unable to advertise their presence (VRUs, legacy vehicles, etc.). On the other hand, it allows implementing advanced warning use cases compared to the Day 1 system (e.g. VRU and PTW protection, Overtaking Warning, Advanced Intersection Collision Warning[3]) and semi-automated driving use cases.

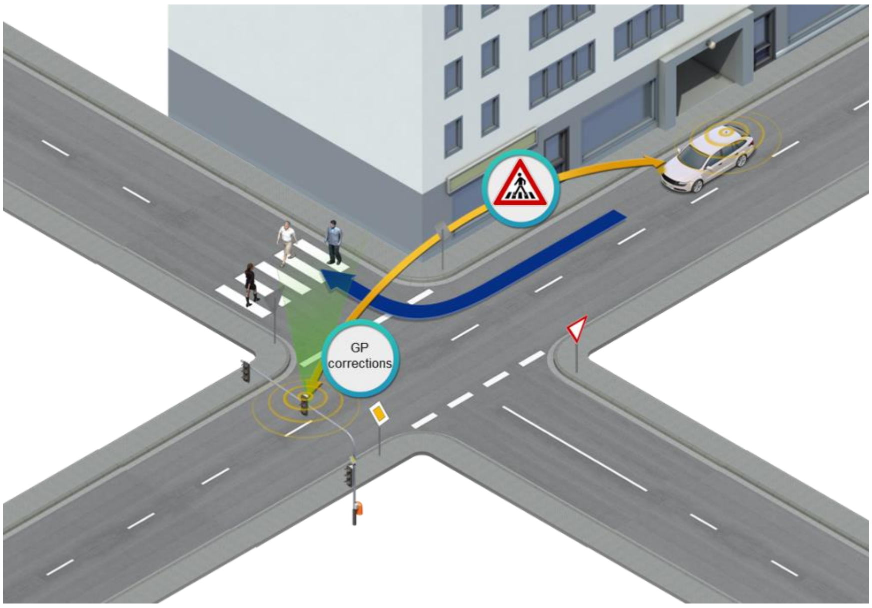


Figure 2-2: Example of VRU protection use case via C-ITS infrastructure support

In the Day 2 deployment phase, infrastructure services will also be extended. Firstly, they will provide the possibility to support prioritization of special categories of vehicles (e.g. public transport) via the Signal Request Extended Message (SREM) and Signal Request Status Extended Message (SSEM) [12], hence enabling use cases for cooperation with traffic light controllers (prioritization, pre-emption of special categories of vehicles). Secondly, the Day 1 infrastructure supporting services will be extended with Radio Technical Commission for Maritime services Extended Message (RTCMEM) for providing geographical position corrections (GP corrections in the above figure) to receiving vehicles [12]. In this phase, infrastructure services could even be applied in a combined way for allowing more precise warning and information applications. This is in particular the case for Long-term Roadworks warning use cases, whose implementation was studied in the ECo-AT project, seeking for solutions leveraging combination and extensions of DENMs and IVIMs [15]. Providing more detailed and precise information about a long-term roadworks zone can also be beneficial for the implementation of semi-automated applications in those zones. This may include also guidance information through the work zone

[3] A richer (yet not exhaustive) list of Day 2 Use case examples can be found in Appendix 1

based on very accurate geographic location information in IVIM, complemented with additional information useful to support in-lane positioning in work zones by automated vehicles.

The Day 2 deployment is also expected to introduce extensions of CA and DEN Services. CAMs and DENMs can be extended to allow implementation of specific use cases accounting for PTWs (e.g. more explicit motorcycle approaching warnings). To this aim, dedicated efforts are being spent by the C2C-CC work items “F0025 CAM Day 2 for PTW” and “F0027 Use cases and test cases for PTW”. In the former one, solutions are being proposed for calculation and transmission of data usable to derive motorcycles curvature and thus in turn also their path prediction. In the latter one, additional important use cases for MAI/MAW and associated test cases are being identified.

Besides for support of PTW use cases, CAMs can be extended as well for use cases based on semi-automated functionalities such as Cooperative Emergency Brake Assistance (C-EBA, see Figure 2-3) or Cooperative Adaptive Cruise Control (C-ACC). As foreseen by the ETSI pre-standardization study (and differently from platooning, which specifically applies to trucks) [31] C-ACC might be initiated individually by a passenger vehicle when following the leading one, or “suggested” and influenced by the road infrastructure. In this sense, IVIM service extensions can be used to indicate for example where to initiate this function, with what classes of vehicles, with how many vehicles (C-ACC strings) and at which speed.

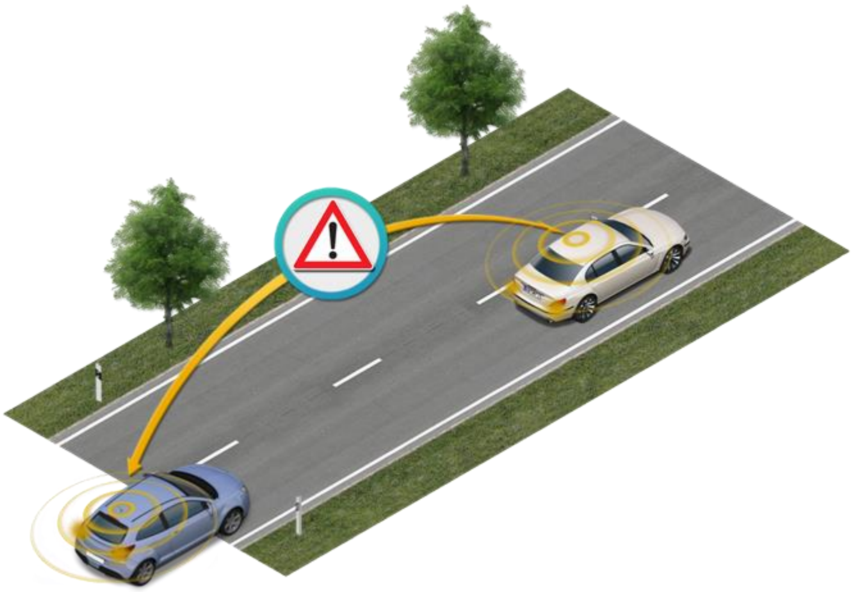


Figure 2-3: Example of Cooperative-Emergency Brake Assistance

For all the mentioned use cases to correctly and optimally operate, not only new communication services, but also new supporting functionalities are required. The already mentioned support for improved positioning will allow receiving vehicles to better assess the geographical relevance of the received information compared to their own position. In the example of Figure 2-2, the white approaching car continuously receives a description of detected objects via CPMs from the RSU, including positions and dynamics of crossing pedestrians. At the same time, RTCMEM geo position corrections are received. By improving its own position information, the car can better evaluate if the crossing pedestrians are relevant in its driving direction and planned route, and hence can minimize the occurrence of inappropriate warnings or automated reactions.

Inappropriate application responses when sharing descriptions of detected objects via collective perception can be also prevented by sharing unambiguous definitions of detected objects’ “quality”, equally applicable for any type of detecting station with specific sensing capabilities. To address this target, the C2C-CC has recently completed the work item “F0014 – Collective Perception” that has defined a concept for collective perception detections’ quality combining “accuracy” and “object confidence” specifications. The results of the work item are described in [32] and have been provided as inputs to the ETSI standard [13]. Calculation and handling of quality of objects for collective perception is hence another important supporting functionality for Day 2.

Another important innovation for Day 2 will be the inclusion of the Functional Safety supporting functionality, especially for the operation of semi-automated driving use cases at receiving vehicles. The need for this functionality can be explained based on the C-EBA use case of Figure 2-3. The follower vehicle applies an automated braking in reaction to CAMs from a hard-braking leading vehicle. To minimize any unreasonable risks [30] at the receiving vehicle, it is needed that the dynamic information included in the transmitted CAMs is of sufficient quality to guarantee specific ASIL targets. As proposed by the currently running C2C-CC work item “T0019 – Technical Functional Safety Concept”, this can be achieved by extending CAMs (similarly DENMs and possibly CPMs) by “Safety Containers” (SFs) explicitly indicating which accuracy/confidence and ASIL level is supported by specific message data elements [36][42]. SFs can be associated to Service Specific Permissions (SSPs) in such a way to allow their inclusion in transmitted messages only to vehicles or RSUs that have been “certified” to guarantee accuracy of the transmitted information according to the ASIL targets.

As the exchanged information will be used to support cooperative use cases with increasing level of vehicle automation, it will be also key to cooperatively detect and isolate misbehaving transmitting stations. The Misbehaviour Detection supporting functionality can be better understood considering the example in Figure 2-4. The red car transmits in CAMs position and confidence information that do not reflect its actual status in the reality. Both a nearby vehicle and RSU can overhear these CAMs and compare the received information with detections performed by their sensors. As discrepancies are detected and mutually confirmed by exchange of CPMs, the transmitting red car is marked as misbehaving. A misbehaviour report can follow to inform the common Security Credential Management System about the misbehaving vehicle, which might turn into revocation of certificates for authentication of messages from that station. This and other mechanisms for misbehaviour detection have been studied in a number of projects such as SEVECOM [37], PRESERVE [38], EVITA [39], and most recently in the Secure Cooperative Autonomous systems (SCA) project and are currently being specified for their introduction in Day 2 by the C2C-CC work item “D0022 - Misbehavior Detection”. The work item intends to specify the functional requirements and to detail the main operational technical requirements for on-board misbehavior detection, reaction and reporting system, esp. considering requirements for existing Day 1 C-ITS applications and necessary agility to support further Day 2 and beyond applications. In the end, the various consistency and plausibility checks on safety messages need to be integrated into a common framework for misbehavior detection where detectors can be added in a flexible way. The detectors should be distributed in the C-ITS communication stack and further integrated in the various real-time, safety applications in the vehicle system, i.e. integrated in the ADAS/AD domains.

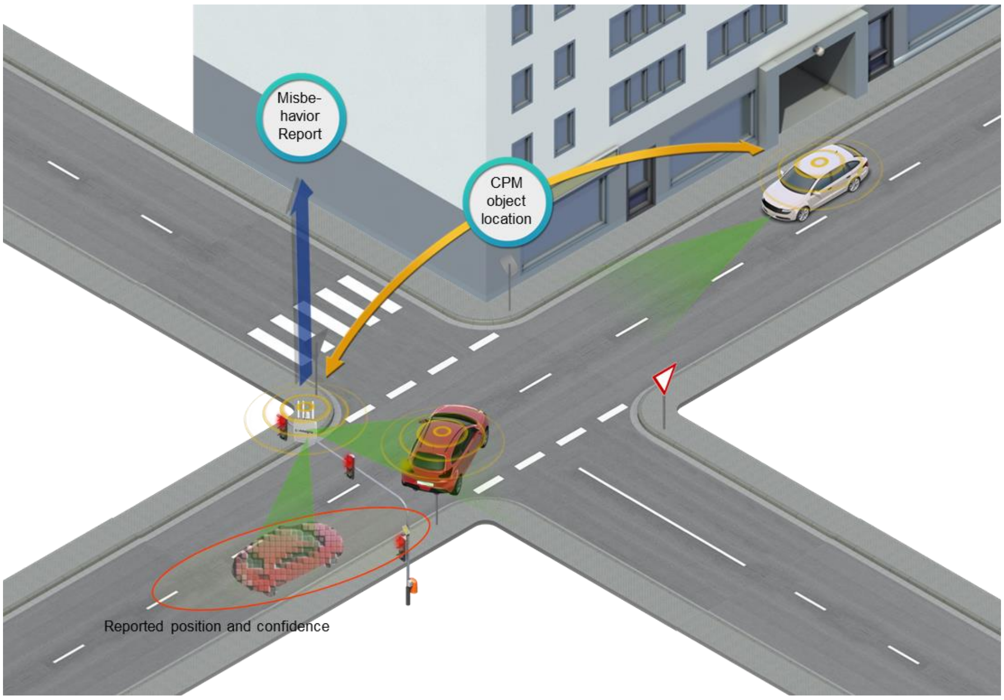


Figure 2-4: Example of misbehavior detection

2.3 Day 3+ phase – Cooperative Driving

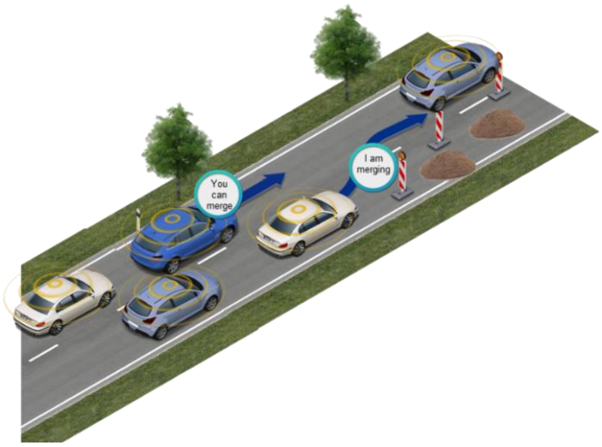
After the Day 2 deployment phase, a so-called Cooperative Driving phase is expected to follow. This deployment phase will take advantage of the introduction of vehicles with increasing automated driving capabilities (SAE level 3-4). The particularity of these Cooperative Automated Vehicles (CAVs) is their capability to “plan” and “execute” driving tasks and hence share with other traffic participants target intentions (e.g. desired routes, manoeuvres or trajectories) as well as currently implemented actions (e.g. short- and long-term trajectories). Moreover, CAVs are able to communicate messages to coordinate specific manoeuvres for avoiding conflicts with other vehicles or traffic actors. At this moment, it is not clear whether applications relying only on intention sharing will be deployed before those relying on coordination data exchange. For this reason, the current C2C-CC roadmap does not make a distinction between the two and conceives a generic Day 3+ phase making use of both services.

An early example of exchanging intentions and sharing coordination messages to support cooperative automated driving is represented by the Cooperative Lane Merging (CLM) service experimented in the Autonet2030 project [16]. Through this service, the merging vehicle communicates its intention to merge on a given section of the road (target driving area reservation). The merging is then coordinated with the incoming vehicles by an exchange of reply/request CLM messages that finally allow executing the desired manoeuvre safely.

Exchanging messages for intention sharing is also envisioned in the context of I2V scenarios. As studied in the MAVEN project [17], CAVs heading towards a signalized cooperative intersection can explicitly communicate their intended manoeuvre (ingressing/egressing lane) in forms of additional information included in extended CAMs. By analysing this information, the traffic light controller can more effectively and precisely compute its phases for the benefit of a smoother overall traffic flow (raffic light info optimizations with V2I). A more precise computation of traffic light phases can additionally enable stable traffic light signal plans and communication of speed advices to be automatically followed by receiving automated vehicles (automated GLOSA).

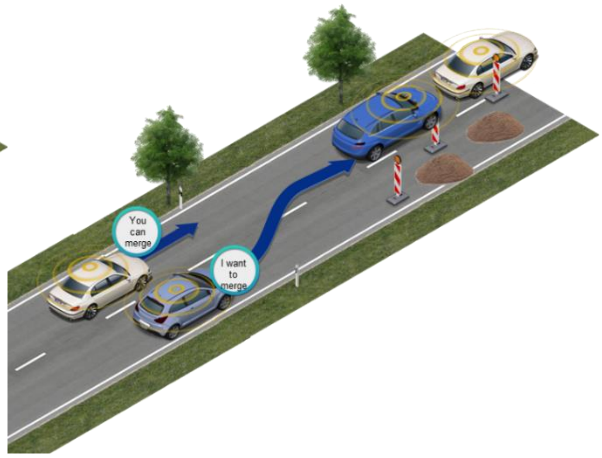
In addition to the above mentioned examples, the IMAGinE [18] and TransAID [20] projects adopted a Manoeuvre Coordination Service (MCS) that uses exchange of V2V messages for unambiguous coordination of CAVs' manoeuvres [19]. Coordination is needed whenever a CAV's desired trajectory is in conflict with the planned trajectory of another CAV that possesses the right of way. In this situation, the MCS allows both CAVs to exchange information about their currently planned and desired trajectories, which implicitly enables a negotiation solving the conflict. Through the use of the MCS, a number of cooperative automated driving applications are possible such as Cooperative Merging, Cooperative Lane Change, Cooperative Overtaking just to mention a few. An example of Cooperative Merging using MCS is depicted in Figure 2-5. The vehicles approaching on two parallel lanes have to coordinate their movement to drive automatedly on the only available lane downstream. Without any coordination, vehicles on the left lane would always have the right of way, hence vehicles on the right lane would get blocked indefinitely. Nevertheless, with exchange of MCS messages, the white car on the right lane can notify its intention to merge by starting to broadcast its "desired trajectory". At instant (a), the white car identifies that this would imply a conflict, because the blue car on the left lane is concurrently broadcasting its "planned trajectory". By overhearing the white car's desired trajectory, the blue car can decide to give way to the white car's merging manoeuvre. This is practically acknowledged by the blue car starting to broadcast an adapted planned trajectory (instant b). By receiving this implicit acknowledgment, the white car starts transmitting the previously shared desired trajectory as planned trajectory (instant b). In this way, the white car informs all other vehicles in the surrounding that it is going to initiate and execute the merging manoeuvre. At instants c and d the other two following cars will implement a similar coordination that will successfully address any possible driving conflict in the sample situation in a fully automated way (hence without requesting the drivers to take over control of the involved vehicles).

(a)



(b)

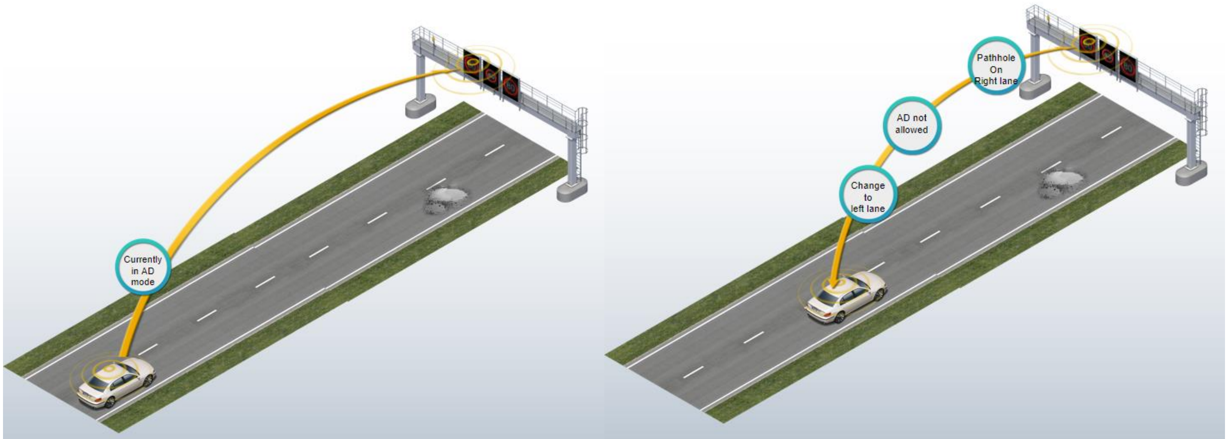
(c)



(d)

Figure 2-5: Example of Cooperative Merging via MCS

The IMAGinE MCS concept is focused on V2V interactions only. Extending this approach, the TransAID and INFRAMIX projects [20][26] envision that the road infrastructure can help coordinating CAVs' manoeuvres in a centralized way, or at least influence their behavior, when needed, in order to improve the overall traffic flow. This is done by establishing a bidirectional "conversation" between vehicles and infrastructure. Let us consider the situation in Figure 2-6 where a vehicle is driving towards a road section where the infrastructure detects that AD would be hampered[4]. Day 3 vehicles are expected to use CAM extensions to inform about the currently supported levels of automation (Figure 2-6 a). By overhearing approaching automated cars, the road infrastructure (at ISAD Level A, see [29]) can react in different ways (Figure 2-6 b). On one side the road infrastructure can adopt extended IVI communication services defined by INFRAMIX and included in the latest version of the IVI ISO standard [27]. Extended IVI services are used in this case to notify about restrictions applicable to all the vehicles currently running a given automation level (in the example of Figure 2-6 b, a given automation level would not be allowed). On the other side, the road infrastructure could adopt an I2V manoeuvre coordination service, where individualized suggestions (e.g. lane change advice or speed advice in Figure 2-6 b) are sent to CAVs to overcome this situation without necessarily implying transition of control (ToC) to manual driving in multiple vehicles at the same time[5]. I2V extensions of the MCS have been used by TransAID and are currently considered in the ETSI MCS standardization process [19]. Besides lane change suggestions indicated in Figure 2-6 b, the infrastructure could use I2V MCS to suggest vehicles to optimally manage ToCs and minimum risk manoeuvres (MRMs), if ToCs or MRMs are inevitable. The infrastructure could in fact advise vehicles to perform ToCs at individualized distances from a road section not suitable for AD, hence preventing accumulation of ToCs at the same location, as well as suggest vehicles to use individualized safe spots where to park in case a ToC is not successful and an MRM is executed. Besides this, as TransAID takes into account the possibility for CAVs to interrupt their automated status at any time, it identifies the need to announce ToC intentions to the surrounding road users. This is done by including ToC notifications in the MCMs broadcasted by vehicles.



(a) (b)

Figure 2-6: Example of I2V cooperation use cases for automated driving

It is envisioned that in the Day 3+ phase, cooperative services like the above mentioned will be leveraging advanced C-ACC and platooning applications. Similarly to platooning (which

[4] In the figure a path hole on the right lane is detected by the infrastructure and is used here just as a representative example. Nevertheless, factors limiting AD can be very diverse and of different nature. Also, these factors can be limiting for one specific car and not for others. In this sense it is always up to the receiving vehicle to decide whether to follow possible suggestions from the road infrastructure or not.

[5] Preventing concurrent transitions of control in many vehicles in the same area has been demonstrated to improve overall traffic efficiency and safety [20].

specifically applies to trucks) C-ACC strings will be formed by passenger vehicles where the following ones get longitudinally and laterally automatically controlled. Management of C-ACC strings including dynamic joining and leaving vehicles, string break-up, and so on is envisioned.

Highly automated vehicles will be able to support comfort use cases like valet parking in controlled environments where the driver is no longer needed. Future parking facilities capable of sensing, planning and communication functionalities would allow delegating parking trajectory calculation of individual vehicles and their manoeuvre coordination to centralized infrastructure entities. In such implementations, vehicles and infrastructure would exchange relevant information before and during the parking tasks: extensions of MAPEMs could be used to map parking spots and their occupancy status, CPMs could allow achieving a more complete environmental perception at each stage, and new messages containing individualized trajectories could be used for infrastructure-to-vehicle guidance (similar implementations of such approaches technologies are already available [33]).

Moreover, while in the previous deployment phases protection of VRUs is covered with applications where the VRUs have just a “passive” role (being detectable by vehicles or infrastructure sensors and advertised via CPMs), in the Day 3+ phase, VRUs are expected to play a more “active” role. VRUs are expected to be in fact V2X-equipped and able to explicitly announce their presence whenever necessary and convenient using dedicated VRU Awareness Messages (VAMs) (e.g. by construction site workers on the road upon detecting that a vehicle is approaching in a dangerous way [21]).

In terms of supporting functionalities in the Day 3+ phase, all the previously mentioned functionalities introduced in Day 2 will be reused and applied in a stricter way to support highly automated driving use cases. As the driver will be less and less involved in the driving tasks, the V2X shared information has to keep guaranteeing the required quality for functional safety and possibly support higher ASIL levels. Moreover, even if the last decision on whether to implement or not a given automated reaction will always lie at the receiving vehicle side, such functional safety support will be equally necessary for information transmitted by the road infrastructure.

Additionally to those of the Day 2 phase, new supporting functionalities need to be introduced in Day 3+ to unambiguously run distributed algorithms for cooperative manoeuvres at the involved vehicles (Automated Coordination functionalities in Figure 2-1). In fact, when not implicit due to common traffic rules, CAVs need to adopt common AD coordination rules to overcome specific situations in such a way to fairly guarantee traffic safety and efficiency to all traffic participants. In the example of Figure 2-5, all the vehicles should in fact adopt the same coordination rules to make sure that vehicles on the right lane do not get stuck and rather alternate their transit through the bottleneck with vehicles on the left lane. Besides this, “objective matching” functionalities will be needed whenever CAVs have to coordinate actions for fulfilment of common goals (e.g. overhearing information like planned route/manoeuvre in received messages to determine if building a string of C-ACC vehicles with current neighboring vehicles is feasible and/or convenient).

Different approaches for running Day 3+ use cases, including the adopted communication services and supporting functionalities, are being collected and classified by the C2C-CC work item “F0017 – Connected and Cooperative Automated Driving” (a more detailed, yet not exhaustive, list of Day 3+ use cases can be found in Appendix 1). This work item aims at setting the basis for establishing consolidated Day 3+ specifications at C2C-CC.

2.4 Considerations

From the provided overview, it appears clear that the information exchanged via V2X must improve along different dimensions at subsequent deployment phases to fulfil the stricter requirements of use cases characterized by increasing levels of automation. While at the beginning the exchanged V2X information is used basically for warning and information purposes, at later phases it enables semi-automated reactions at receiving vehicles such as C-ACC or C-

EBA. Finally, once joint well-established penetration of C-ITS and automation will be reached, the exchanged V2X data will allow coordination of automated driving tasks on distributed systems. As part of this vision, one role of cooperative road infrastructure is to support and influence cooperative automated vehicles according to its ISAD level [29].

As depicted in Figure 2-1, to realize this vision the exchanged information must improve in trustworthiness in order to be of reliable application at receiving stations for functional safety reasons. Consequently, it will be needed that the information becomes always more accurate in position and timing in order to reflect with high precision the real status and properties of communicating systems. The capability to transmit accurate information and hence support functional safety up to determined extents must be certified and reflected in specific elements of the messages like the above mentioned Safety Containers. Such Safety Containers shall be included as integral part of Day 3 messages like MCMs or as extensions of the Day 1 and Day 2 messages (including I2V message like SPATEM, MAPEM and IVI) as soon as they are used to support automated functions at receiving vehicles.

Beyond the needs of functional safety, data trustworthiness management should be included as a Day 2/Day 3 security functionality solution for verifying trustworthiness of transmitting stations and detect possible misbehaviours. Using various node-centric or data-centric trust assessment methods, the C-ITS station would be able to asses, hence confirming or negating, the trust level of its neighbouring stations by monitoring all the incoming messages. For instance, data-centric mechanisms can be applied to evaluate the quality of received periodic messages such as CAMs and in a similar way, an event-based mechanism can be used to evaluate the effectiveness of issued traffic warnings (DENMs) by other stations. Trust-based detection can occur either locally or with cooperation between neighbouring stations [44]: in the latter case, the estimated trust level can be shared between stations using CAMs with a specific additional container similar to the above mentioned Safety Container, and regularly updated.

Last but not least, distributed control and coordination algorithms running in parallel on communicating automated stations could require that the exchanged information is more timely updated in order to always create an up-to-date picture of the situation, especially when immediate coordinated reactions are needed (e.g. to evade in a collaborative automated way a possible collision as envisioned by the MuCCA project [28]).

3 Appendix 1

3.1 Sample use cases and adopted messages

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
CGR	Co-operative glare reduction	This use case enable a capable vehicle from automatically switching from high-beams to low-beams when detecting a vehicle arriving in the opposite direction.	Safety, Comfort	V2V	Day1	Day1 CAM		ETSI TR 102 638
DSW	Dangerous Situation Warning for Electronic Emergency Break Light (EEBL) / automatic brake intervention / intervention of reversible occupant restraint system	This use case consists for any vehicle to signal its hard breaking to its local followers. The hard braking is corresponding to the switch on of emergency electronic brake lights, an automated braking reaction, or intervention of reversible occupant restraint system	Safety	V2V	Day1	Day1 DENM	SimTD, SCOOP@F	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 C2C-CC, "Triggering Conditions and Data Quality - Dangerous Situation"
EVCSN	Electric Vehicle Charging Spot Notification	The objective of this use case is to notify the EV drivers about the availability and characteristics of the EV Charging Station(s) in the vicinity and/or surrounding areas of the vehicle. By using this application, the driver is enabled to choose a charging spot for re-charging his/her electrical vehicle. Furthermore, the driver is enabled to reserve, measure and pay for the access to one of the spots. Note: This service has been generalized into a “Parking POI service” within the french deployment project (SCOOP@F).	Efficiency, Comfort	I2V	Day1	EVCSN		ETSI TS 101 556-1
HLN-APR	Animal or person on the road	A road operator knows that one or several animal(s) is(are) present on the road network and broadcasts the information to road users. A warning is generated in the vehicle.	Safety	I2V	Day1	Day1 DENM	C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 ETSI draft TR 103 562

[6] As it is impossible predict which standard release number will support future use cases, the “Day X” indication for messages and their extensions is here meant to relate given communication service evolution expectations to given deployment phases.

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
								Eco-AT consortium, "SWP 2.1 Use Cases, other DENMs, WP 2 – System Definition; C-Roads, Common C-ITS Service and Use Case Definitions
HLN-AWWD	Alert Wrong Way Driving	This Use case is to warn a driver that he could encounter a vehicle that is driving in the wrong way.	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-AZ	Hazardous Location Notification – Accident Zone	The road operator detects that an accident has happened on the network and broadcasts the information to road users who can benefit from this information with a corresponding warning	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-EVA	Hazardous Location Notification - Emergency Vehicle Approaching / In operation	This use case allows an active emergency vehicle to indicate its presence. In many countries, the presence of an emergency vehicle imposes an obligation for vehicles in the path of the emergency vehicle to give way and to free an emergency corridor. For this reason, a corresponding warning can be generated	Safety	V2V	Day1	Day1 DENM Day1 CAM	SimTD C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 C2C-CC, "Triggering Conditions and Data Quality - Special Vehicle Warning" C-Roads, Common C-ITS Service and Use Case Definitions
HLN-EVI	Hazardous Location Notification - Emergency Vehicle in Intervention / stationary safeguarding emergency vehicle / stationary recovery service warning	This use case is to warn drivers about the location (e.g. a traffic accident, rescue and recovery work) of an emergency vehicle in intervention so the drivers will be able to adjust their speed or lane position on the road. The equipped emergency vehicle is sending a warning message when the vehicle is stationary with an activated light bar and being stationary for more than the defined time period	Safety	V2V, I2V	Day1	Day1 DENM	C-Roads	C2C-CC, "Triggering Conditions and Data Quality - Special Vehicle Warning" C-Roads, Common C-ITS Service and Use Case Definitions
HLN-OR	Obstacle on the road	A road operator knows that there is one or several obstacles on one or several lanes of his network and broadcasts the information to road users. However, traffic can still pass the obstacles (not a blockage). A warning is generated in the vehicle.	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-PTVC	Public Transport Vehicle Crossing	This use case is to alert a Vehicle that is approaching a location of a high risk of collision with PT vehicles.	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-PTVS	Public Transport Vehicle at a Stop	This use case is about providing in-car information and warning about public transport vehicle at a stop	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-RLX	Railway Level Crossing	The railway infrastructure manager or a service provider informs the driver about the presence of a railway level crossing and its type/parameters/status. This use case covers both	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
		protected level crossings along with unprotected ones. A warning is generated in the vehicle.						
HLN-SV	Hazardous Location Notification - Stationary Vehicle/ stopped vehicle / broken down vehicle / post-crash situation	This use case warns approaching drivers about stationary/broken down vehicles ahead, which may represent obstacles on the road. It is a preventive safety service, as drivers will have advanced notice and more time to prepare for the hazard. The stationary vehicle situation can be detected by the stationary vehicle itself, or by the infrastructure	Safety	V2V, I2V	Day1	Day1 DENM	C-Roads	C2C-CC Triggering Conditions and Data Quality Stationary Vehicle Warning" C-Roads, Common C-ITS Service and Use Case Definitions
HLN-TJA	Hazardous Location Notification – Traffic Jam Ahead / dangerous end of queue	This use case allows vehicles to warn about the presence of a traffic Jam or a dangerous end of queue ahead. Alternatively, A road operator detects a traffic jam, and sends the information to the road user (mentioning the position, the length of the traffic jam and the section/ lanes concerned if the information is available).	Safety	V2V, I2V	Day1	Day1 DENM	SimTD, SCOOP@F, C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 C2C-CC, "Triggering Conditions and Data Quality - traffic jam", C-Roads, Common C-ITS Service and Use Case Definitions
HLN-TSR	Temporarily slippery road	A road operator knows that a section of a road (or a single lane or point) is temporarily slippery and sends this information to the road user. A warning is generated in the vehicle.	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-UBR	Unsecured Blockage of a Road	An operator in the TCC gets the information that there is a blockage of a road. Till the time that operating agents arrive to the site to protect and manage it, the operator sends a warning message to road users. A blockage means that there is no traffic going through the road segment and passing it by on a single or several lanes. The complete road is blocked (not an obstacle on one or more lanes).	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
HLN-WCW	Hazardous Location Notification - Weather condition Warning /fog / precipitation / traction loss	This use case warns about both static and dynamic information of weather conditions and road status in-vehicle.	Safety	V2V, I2V	Day1	Day1 DENM	SimTD, SCOOP@F, C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 C2C-CC, "Triggering Conditions and Data Quality - Adverse Weather Conditions" C-Roads, Common C-ITS Service and Use Case Definitions
ICW	Intersection Collision Warning	By exchanging information about their position and dynamics two vehicle can detect the risk of an intersection collision and warn the driver accordingly.	Safety	V2V	Day1	Day1 CAM Day1 DENM Day1 IVIM SPATEM MAPEM	SimTD	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 ETSI TS 101 539-2

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
IVS-FT	Free Text	The goal of this use case is to display to the road user in-vehicle information of type “Free Text”. The information will either reproduce what is displayed at on a physical VMS (e.g. variable text panel) or display a completely new message that does not mirror a physical VMS (a virtual VMS).	Safety, Comfort	I2V	Day1	Day1 IVIM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
IVS-TS	Traffic Signs	This use case is meant to inform drivers via in-car information systems about these static and dynamic signs as indicated on either physical road signs along the road or the notion of virtual VMS i.e. where a physical VMS is not present.	Safety, Comfort	I2V	Day1	Day1 IVIM	SimTD, SCOOP@F; C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794; C-Roads, Common C-ITS Service and Use Case Definitions
MAI	Motorcycle Approaching Information	Inform the driver on approaching motorcycle in selected traffic situations. This is especially useful in case of reduced visibility. For Day1 it is based on information transmitted by PTWs.	Safety	V2V	Day1	Day1 CAM	DRIVE C2X	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638
PCSW	Pre-crash sensing warning	Prepare for imminent and unavoidable collision by exchanging vehicles attributes after unavoidable crash is detected.	Safety	V2V	Day1	Day1 DENM		ETSI TR 102 638 C2C-CC, "Triggering Conditions and Data Quality – exchange of IRC"
PVD-EDC	Probe Vehicle Data - Event Data Collection	Events (either automatically detected by the vehicle’s systems or either manually reported by road users) are collected by the roadside infrastructure or service provider.	efficiency	V2I	Day1	Day1 DENM		C-Roads, Common C-ITS Service and Use Case Definitions
PVD-VDC	Probe Vehicle Data - Vehicle Data Collection	Vehicle information is collected by the roadside infrastructure or service providers for detection of traffic situations	efficiency	V2I	Day1	Day1 CAM	ITS-Korridor,	Report DG MOVE MOVE/C.3./№ 2014-794, C-Roads, Common C-ITS Service and Use Case Definitions
RWW-LC	Lane Closure	This use case is about providing the road user with information about the closure of part of a lane, whole lane or several lanes (including hard shoulder), but without the road closure. The closure is due to a static road works site.	Safety	I2V	Day1	Day1 DENM	SimTD, ITS-Korridor, SCOOP@F, C-Roads	"Message Set and Triggering Conditions for Road Works Warning Service" from the Amsterdam Group, ETSI TR 102 638 C-Roads, Common C-ITS Service and Use Case Definitions
RWW-RC	Road Closure	This use case is about providing the user with information about a road closure due to a set of static road works. The closure is temporary	Safety	I2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
RWW-RM	Road Works Mobile	This use case is about providing the user with information about a zone on the road that contains, at some point, the closure of (part of) a lane (but without road closure) due to a planned mobile work site.	Safety	V2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
RWW-ROVA	Road Operator Vehicle Approaching	This use case is to provide information about a road operator vehicle in intervention that needs to access urgently an incident area to protect it. The vehicle requests road users that they facilitate the agent's way on the road, broadcasting a message	Safety	V2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
RWW-ROVI	Road Operator Vehicle in Intervention	This use case is to provide information about a road operator vehicle that is stopped in front of an accident/incident to protect the obstacles or is currently setting the equipment (lane delineation) to protect a site (in case of road works for example).	Safety	V2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
RWW-WM	Winter Maintenance	In this use case the winter maintenance vehicle sends a message signaling its activity (salting and/or snow/ice removal). The alerted road user can adapt its driving behaviour accordingly	Safety	V2V	Day1	Day1 DENM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
SI-EVP	Emergency Vehicle Priority	This use case is about actively contribute to the phase control of an equipped intersection to aid the passage of emergency vehicles (EV). It can also provide the prioritisation status to other users approaching and passing traffic light controlled intersections.	Efficiency, Safety	V2I, I2V	Day1	SREM SSEM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions
SI-GLOSA	Green Light Optimum Speed Advisory	This service will provide speed advice information to road users for a safe and efficient approach and crossing of a signalised intersection(s)	Efficiency	I2V	Day1	MAPEM SPATEM	SimTD, Compass4D, C-Roads	ETSI TR 102 638 Eco-AT consortium, "SWP 2.1 Use Cases, GLOSA – System Definition; C-Roads, Common C-ITS Service and Use Case Definitions
SI-ISVW	Imminent Signal Violation Warning	This use case allows warning or protecting affected users that they are about to violate a red signal and increase the risk of an accident.	Safety	I2V	Day1	MAPEM SPATEM	SimTD, C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794, ETSI TR 102 638 C-Roads, Common C-ITS Service and Use Case Definitions
SI-SPTI	Signal Phase and Timing Information	This use case is to provide information to road users approaching and passing traffic light controlled	Comfort, safety	I2V	Day1	MAPEM SPATEM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
		intersections, on the current phase as well as upcoming phase(s) and the moment these are expected to start and end.						
SI-TLP	Traffic Light Prioritisation	This service will give priority to designated vehicles (e.g. public transport, heavy goods vehicles, etc.) over individual vehicles at signalized intersections for assuring on time transportation schedule (e.g. bus, tram) and/or minimise emissions	Efficiency, Safety	V2I, I2V	Day1	SREM SSEM	C-Roads	Study on the Deployment of C-ITS in Europe: Summary Report DG MOVE MOVE/C.3./№ 2014-794 ETSI TS 103 301, C-Roads, Common C-ITS Service and Use Case Definitions
SVW	Slow Vehicle Warning	This use case consists in signaling presence of any “not road operator or emergency” slow moving vehicle (vehicle type) to other vehicles for generation of related warnings.	Safety	V2V, I2V	Day1	Day1 CAM Day1DENM		ETSI TR 102 638
AICW	Advanced Intersection Collision Warning	By receiving information about non-cooperative vehicles detected by environmental sensors, vehicle can detect the risk of an intersection collision and warn the driver accordingly	Safety	V2V, I2V	Day2	CPM		
AMAI	Advanced Motorcycle Approaching Information	For Day2, the MAI use case can be extended by letting vehicle and infrastructure exchange CPMs carrying information of detected non cooperative motorcycles	Safety	V2V, I2V	Day2	CPM		
APCSW	Advanced Pre-crash sensing warning	This use case describes the process for information provided by a vehicle, when a critical situation ahead is detected. Each receiving vehicle may activate its Pre-Crash measures when it assumes itself to be also under risk and the situation is considered as sufficiently critical.	Safety	V2V	Day2	Day2 DENM		C2C: “Triggering Conditions and Data Quality Pre-Crash Information.”
ASVW	Advanced Slow Vehicle Warning	Extends the Day1 SVW with information about slow vehicles detected by other vehicles or infrastructure units	Safety	V2V, I2V	Day2	Day1 CAM Day1 DENM CPM		ETSI TR 102 638
BlSpA	Blind Spot Assistant	Vehicles receive object data for BlSpa from road users that cannot be detected by the onboard sensor system due to sensor obstruction.	Safety	V2V, I2V	Day2	Day2 DENM CPM	MECView	
C-ACC	Cooperative ACC	This use case is based on the use of V2X to obtain lead vehicle dynamics and general traffic ahead in order to enhance the performances of current ACC. This is a semi-automated function, as the driver is requested to be in the loop. CAMs extended with safety containers (for functional safety reasons) and	Efficiency	V2V, I2V	Day2	Day1 CAM Day2 CAM Day2 IVIM		ETSI ITS TR 103 299, ETSI TR 102 638

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
		possibly transmitted at higher generation rates are envisioned. The infrastructure can play a role in suggesting the speed to be adopted in CACC mode as well as the point from where CACC is allowed using IVIM extensions						
C-ACC S	Cooperative ACC string	Extends the C-ACC by having multiple vehicles distributed in a string of C-ACC enabled vehicles. The control of the string is decentralized at each vehicle and differently from Platooning does not require a dedicated platoon control message. The infrastructure can play a similar role as for CACC using IVIM extensions. In this case it can additionally suggest how many vehicles could form a string.	Efficiency	V2V, I2V	Day2	Day1 CAM Day2 CAM Day2 IVIM	AutoNET 2030 MAVEN	ETSI ITS TR 103 299 Autonet2030 Deliverable D3.2 MAVEN deliverable D5.1
C-EBA	Cooperative Emergency Brake Assistance	A following vehicle applies an automated braking in reaction of a hard braking detected by messages received from a leading vehicle and when the time to collision falls below an application threshold. This is a semi-automated function, as the driver is requested to be in the loop. CAMs are extended with safety containers (for functional safety reasons)	Safety	V2V	Day2	Day1 CAM Day2 CAM		Reference from Continental
CPS-AD	Collective Perception Service for AD	CAV may use CPM data from other sources (vehicles and roadside units) as input to its semi-automated functions (e.g. C-EBA triggered by CPMs). As CPMs are supporting functions with increasing level of automation, it is envisioned that they will be complemented by safety container (to support functional safety)	Safety, efficiency	V2V/I2V	Day2	CPM	Inframix	Inframix deliverables
HLN-VA	Hazardous Location Notification – Vehicle Assistance	The vehicle assists the driver in dangerous situations notified via DENM by applying a semi-automated reaction (slow-down, braking, lane change). This is a semi-automated function, as the driver is requested to be in the loop. DENMs are extended with safety containers (for functional safety reasons)	Safety	I2V, V2V	Day2	Day1 DENM Day2 DENM		
IVS-PLATSI	Platoon Support Information	The purpose of the use case is to provide road operator based guidance and information on the unsuitability of "platooning" on certain automation levels on specific road or lane segments on their network, considering different vehicle classes, overall road conditions and the current traffic situation. A platoon is a group of vehicles sharing the same destination, travelling closely together at a common speed.	Safety, Comfort	I2V	Day2	Day2 and Day3 IVIM	C-Roads	C-Roads, Common C-ITS Service and Use Case Definitions

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
MAW	Motorcycle Approaching warning or protection	Inform the driver about a possible collision with approaching motorcycle in selected traffic situations. In extreme cases, the vehicle can automatically react via automated braking. CPMs can be used to warn about collisions with non-cooperative motorcycles	Safety	V2V	Day2	Day1 CAM Day1 DENM Day2 CAM Day2 IVIM CPM		Currently under development in C2C-CC dedicated WI
OVW	Overtaking vehicle warning	An overtaking vehicle detects the risk of collision thanks to information about vehicles coming from the other direction, which are detected by other vehicles	Safety	V2V	Day2	CPM	IMAGinE	ETSI TR 102 638 IMAGinE, deliverables
RWW LT	Road Work Warning (long term)	Via road infrastructure to vehicle communication, provides information on current valid roadwork and associated constraints. The information refers to long term roadworks and can include signaling information such as forbidden overtaking, forbidden access to special vehicle categories, alternative routes, as well as topological information about modified road layouts	Safety	I2V	Day2	Day1 DENM Day1 IVIM Day2 DENM Day2 IVIM		
VRUP	Vulnerable Road User Protection	Provides warning to vehicles of the presence of vulnerable road users, e.g. pedestrian or cyclist, in case of dangerous situation. While for Day1 applications the infrastructure can recognize the risk and send notifications to vehicles (see HLN-APR), for day 2, vehicles and infrastructure can share information about pedestrians or cyclists detected via local sensors, and let receiving vehicles detect the occurrence of risky situations associated to VRU presence	Safety	I2V, V2V	Day2	CPM	MAVEN	MAVEN deliverables
ACACC (-S)	Advanced Cooperative ACC (String)	This use case is based on the use of V2X to obtain lead vehicle dynamics and general traffic ahead in order to enhance the performances of current ACC. Compared to the normal CACC it includes support for lateral vehicle control in addition to longitudinal one. As a consequence, it will require usage of safety containers guaranteeing higher information quality. In case of a string of ACC vehicles, the control of the string is decentralized and differently from Platooning does not require a dedicated platoon control message. The infrastructure can play a similar role as for CACC and CACC-S using IVIM extensions. In this case IVIMs can additionally suggest lane changes. As this use case might be run by vehicles with high automation level IVIMs are	Efficiency	V2V, I2V	Day3+	Day1 CAM Day2 & Day3+ CAM Day2 & Day3+ IVIM	MAVEN, Autonet 2030, IMAGinE	IMAGinE, MAVEN, Autonet2030 deliverables

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
		expected to be as well complemented by safety containers (for functional safety reasons)						
ACACCSM	Cooperative ACC string management	Extends the CACC by allowing multiple vehicles to organize a string of C-ACC enabled vehicles that can dynamically administrate operation such as forming, leaving, break-up, or merging strings. For this purpose, and similarly to platooning, CAM extensions are used. The control of the string is decentralized and differently from Platooning does not require a dedicated platoon control message. As this use case will be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)	Efficiency	V2V	Day3+	Day1 CAMs Day2 and Day3+ CAM	MAVEN, IMAGinE	IMAGinE deliverables MAVEN deliverable D5.1
AGLOSA	Automated Green Light Optimum Speed Advisory	Extends the GLOSA by implementing automated functions for adaptation to the speed suggested by the infrastructure or computed by the vehicle. As this use case might be run by vehicles with high automation level SPATEMs are expected to be as well complemented by safety containers (for functional safety reasons)	Efficiency	I2V	Day3+	SPATEM MAPEM Day3+ SPATEM extensions	MAVEN	ETSI TC 103 301 (draft); ISO TS 19091 MAVEN deliverable D5.1
AGLOSA+N	Automated GLOSA with negotiation	CAVs and/or CAVs strings communicate if the GLOSA advices can be executed by updating their own transmitted messages. This feedback can be used by the traffic light controller to further refine the traffic light phase and time algorithms (e.g. to put priority at the phases whose GLOSA advices that can be applied, e.g. ensure a long enough and stable time to green for a big string of CAVs to pass the stop line before the next red starts.	Efficiency	V2I, I2V	Day3+	Day1 CAM Day2 & Day3+ CAM MAPEM SPATEM Day3+ SPATEM	MAVEN	MAVEN deliverable D5.1
CAP	Cooperative Automated Parking	Cars are parked automatically at parking facilities. Support for parking can be given by the fixed infrastructure in several ways, from providing information about free parking lots, location and billing up to assigning and updating centrally calculated trajectories and manoeuvres.	Safety, Efficency, Comfort	V2I	Day3+	Day3+ MAPEM, CPM MCM Other Day3+ extension	SmartEPark Bosch-Daimler collaboration [45]	SmartEPark deliverables Scientific papers [43]

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
CLC	Cooperative lane change	This use case considers that CAVs involved in a lane change negotiate together the manoeuvring process to avoid collision using MCMs. The road infrastructure can in special cases participate in the coordination process by suggesting individual lane, speed, gap advices using MCM extensions As this use case will be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)	Efficiency, Safety	V2V, I2V	Day3+	MCM	AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS, TransAID	ETSI TR 102 638 AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS, TransAID deliverables
CM	Co-operative merging assistance	This use case considers that CAVs involved in a lane merging negotiate the merging process with each other to avoid collision. For this purpose, MCMs are expected to be used. The road infrastructure can in special cases participate in the coordination process by suggesting individual lane, speed, gap advices using MCM extensions. As this use case will be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)	Efficiency, Safety	V2V, I2V	Day3+	MCM	AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS, TransAID	ETSI TR 102 638 AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS, TransAID deliverables
CO	Cooperative overtaking	This use case considers that the CAVs involved in an overtaking negotiate together the manoeuvring process to avoid collision. collision using MCMs. As this use case will be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)	Efficiency, Safety	V2V	Day3+	MCM	AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS,	ETSI TR 102 638 AutoNet2030, IMAGinE, KoHAF, i-GAME, AFAS deliverables
CPS-HAD	Collective Perception Service for Highly AD	CAV may use CPM data from other sources (vehicles and roadside units) as input to its Highly automated functions (e.g. strategical planning decisions like slow-down, manoeuvre changes in response to CPM objects not yet in the field of view of the CAV sensors). As CPMs are supporting functions with high level of automation, it is envisioned that they will be complemented by safety container (to support functional safety)	Safety, efficiency	V2V/I2V	Day3+	CPM	Inframix, MAVEN TransAID	Inframix deliverables MAVEN deliverables TransAID
CToC	Cooperative Transition of Control	CAVs can cooperate using CAMS and DENMs extension in performing a transition of control such that minimizes the risks. The road infrastructure can participate in this cooperation by using MCM extensions suggesting in individualized advises time or location where to safely trigger a ToC and	Safety, Efficiency	V2V, I2V	Day3+	Day1 CAMs Day1 DENMs Day2 and Day3+ CAM Day2 and Day3+ DENMs	TransAID	TransAID Deliverable D5.1

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
		eventually execute an MRM. As this use case will be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)				MCM		
IVRUP	Improved Vulnerable Road User protection	A VRU is equipped with active C-ITS notification capabilities to alert other traffic road users or to let them automatically react to prevent risky situations	safety	P2V	Day3+	VAM		
MuCCA	Multi-Car Collision Avoidance	Several cars exchange information to coordinate in a very short time collision-free evasive manoeuvres in reaction to a sudden dangerous situation ahead. As this use case will be run by vehicles with high automation level, the exchanged messages are expected to be complemented by safety containers ensuring very high quality of the shared information (for functional safety reasons)	Safety	V2V	Day3+	MCM	MuCCA	MuCCA deliverables online, https://mucca-project.co.uk/downloads/
OTLI	Optimized Traffic light information with V2I	In proximity of urban signalized intersections, isolated CAVs and/or CAVs organized in CACC strings continuously transmits information describing intentions (like planned route at intersection) or vehicle/string characteristics (like desired speed, string size, etc.). This information is envisioned for Day3+ CAM extensions. By collecting this explicit probing V2I information, the traffic light controller updates its queue models and calculates more efficient traffic light phases, durations and GLOSA that are communicated to vehicles. As this use case might be run by vehicles with high automation level SPATEMs are expected to be as well complemented by safety containers (for functional safety reasons)	Efficiency, Comfort	I2V, V2I	Day3+	Day1 CAM Day2 & Day3+ CAM extensions MAPEM SPATEM Day3+ SPATEM extensions	MAVEN	MAVEN deliverable D5.1
Platoon	Platooning	This use case is based on the use of V2X for trucks to operate safely as a platoon on a highway implementing longitudinal and/or lateral control depending on the level of automation supported by the interested vehicles. Management of platoon (forming leaving, joining) is done via CAM extensions). Platoon control is done via exchange of PCM messages. This information is envisioned to be complemented by safety containers (for functional safety reasons)	Efficiency, Safety	V2V, I2V	Day3+	Day1 CAM Day2 & Day3+ CAM extensions PCMs	Konvoi, COMPANION, AutoNET2030, ENSEMBLE	ETSI ITS TR 103 298, ETSI TR 102 638 Autonet2030 Deliverable D3.2 ENSEMBLE deliverables

ID	Name	Description	Category	Comm pattern	Deploy ment phase	Adopted message(s)[6]	Related projects	References
TDAR	Target Driving Area reservation	for a vehicle that is going to perform a manoeuvre aimed at occupying a given road section, this use case provides the possibility to notify other vehicles about the manoeuvre imminent occurrence. As this use case might be run by vehicles with high automation level the exchanged messages are expected to be complemented by safety containers (for functional safety reasons)	Safety	V2V	Day3+	MCM	IMAGinE, Autoner2030	ETSI Draft TS 103 561, IMAGinE, Autoner2030 deliverables
ToCN	Transition of Control Notification	A CAV that is about to give the control back to the driver can inform other traffic participants about this possibly risky event, or about the occurrence of a minimum risk manoeuvre in case the driver is not reacting accordingly. This information is envisioned to be included in DENM extensions and complemented by safety containers (for functional safety reasons)	safety	V2V	Day3+	Day2 DENM Day2 & Day3+ DENM extensions	TransAID	TransAID Deliverable D5.1

4 Appendix 2

4.1 List of abbreviations

BSP	Basic System Profile
C2C-CC	Car-2-Car Communication Consortium
CA	Cooperative Awareness
C-ACC	Cooperative Adaptive Cruise Control
CAM	Cooperative Awareness Message
CAV	Cooperative Automated Vehicle
CG	Competence Group
CI	Cooperative Intersection
C-ITS	Cooperative Intelligent Transport Systems
CLCM	Cooperative Lane Change Message
CLM	Cooperative Lane Merging
CG	Competence Group
CP	Collective Perception
CPM	Collective Perception Message
DEN	Decentralized Environment Notification
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standard Institute
EVCSN	Electric Vehicle Charging Spot Notification
GLOSA	Green Light Optimal Speed Advisory
HLN	Hazardous Location Notification
I2V	Infrastructure-to-Vehicle
IRC	Impact Reduction Container
ISAD	Infrastructure Support Levels for Automated Driving
ITS	Intelligent Transportation Systems
IVI	Infrastructure to Vehicle Information
IVIM	Infrastructure to Vehicle Information Message
MAI	Motorcycle Approaching Information
MAPEM	MAP Extended Message
MAW	Motorcycle Approaching Warning
MCM	Manoeuvre Coordination Message
MCS	Manoeuvre Coordination Service
MRM	Minimum Risk Manoeuvre
OEM	Original Equipment Manfacturer
PT	Public Transport
PTW	Powered Two-Wheeler
RSU	Roadside Unit
RWW	Roadworks Warning
SC	Safety Container
SPATEM	Signal Time and Phase Extended Message

SREM	Signal Request Status Extended Message
SSEM	Signal Request Extended Message
TC	Technical Committee
TCC	Traffic Control Center
ToC	Transition of Control
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-everything
VAM	VRU Awareness Message
VRU	Vulnerable Road User
WI	Work Item

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