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ITU-APT Foundation of India (IAFI[1])

UPDATES TO WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[CAV]

1 Introduction

WP 5A is working towards a new report on "Connected Automated Vehicles (CAV)". The working document on CAV was developed in the WP 5A 23rd meeting in July 2020 and further progress on working document towards a Preliminary Draft New Report ITU-R M.[CAV] continued in WP 5A 25th meeting in May 2021. The current working document is included in Attachment 24 to the Chairman's report (Attachment 24/ Document 5A/359). As described in the Question ITU-R 261/5, WP 5A is studying several aspects including 1) service requirements: service type, service concept, grade of service; 2) radiocommunication requirements: sensors, radio interfaces, data rate, latency, reliability; 3) improvement factors: safety, control, energy savings, traffic management, congestion control.

2 Proposal

In this contribution, we are providing some updates and comments to the working document towards Preliminary Draft New Report ITU-R [M.CAV]. These are highlighted in yellow.
The proposed changes include:

- Notes on pages 14 and 50
- Added text on page 54
- Reformatting and renumbering of tables in section 8.

3 Enclosures

Annexure 1: Editorial updates to the draft Document 5A/TEMP/106, Annex 24 to Document 5A/359-E

[1] ITU-APT Foundation of India is sector member of ITU-R. For details, please see https://itu-apt.org

ANNEXURE 1

Annex 24 to Working Party 5A Chairman's Report

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[CAV]

Question ITU-R 261/5

Scope

[This Report provides…]

[Japan's comments: it is suggested to include Scope in this Report.]

[Editor's note: Page numbers below need to be updated as this document is revised.]

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1 Introduction

There are around 1.5 billion road vehicles in the world, including trucks and buses. Connected Automated Vehicles (CAVs) have the potential to reduce crashes, thereby reducing traffic fatalities and crash-related injuries. CAVs also provide information to road operators about congestion and traffic crashes to support increased efficiency of traffic and comfortable driving.

There is a potential for CAVs to smooth traffic flows. This could reduce the congestion, increase fuel and energy economy, and increase the road and highway capacity.

Higher levels of vehicle automation are currently under extensive development. Wireless communication requirements are a consideration for inclusion of coordinated automated driving maneuvers and other advanced use cases in connected automated vehicle developments and deployments. Harmonization of frequency bands facilitates global markets and innovation. As well, spectrum harmonization may be the best approach to facilitate interoperability among CAVs.

CAVs are being planned to be or are deployed in various regions encompassing various stages of automation involving different levels of human intervention and radiocommunications for CAVs may be implemented in frequency bands already allocated to the land mobile service.

This Report addresses overall objectives and radiocommunication requirements for CAVs, including the consideration of global or regional harmonization of frequency spectrum for CAVs.

2 Vocabulary

2.1 Vocabulary of terms

2.2 Acronyms and abbreviations

CAV	Connected automated vehicle
ITS	Intelligent Transport System
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2N2V	Vehicle to Network to Vehicle
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle to Anything

3 Related ITU-R Texts

Recommendation ITU-R M.1452 “Millimetre wave vehicular collision avoidance radars and radiocommunication systems for intelligent transport system application”

Recommendation ITU-R M.1453 “Intelligent transport systems - Dedicated short range communications at 5.8 GHz”

Recommendation ITU-R M.1890 “Operational radiocommunication objectives and requirements for advanced Intelligent Transport Systems”

Recommendation ITU-R M.2057 “Systems characteristics of automotive radars operating in the frequency band 76-81 GHz for intelligent transport systems applications”

Recommendation ITU-R M.2084 “Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications”

Recommendation ITU-R M.2121 “Harmonization of frequency bands for Intelligent Transport Systems in the mobile service”

Report ITU-R M.2228 “Advanced intelligent transport systems (ITS) radiocommunications”

Report ITU-R M.2322 “Systems characteristics and compatibility of automotive radars operating in the frequency band 77.5-78 GHz for sharing studies”

Report ITU-R M.2444 “Examples of arrangements for Intelligent Transport Systems deployments under the mobile service”

Report ITU-R M.2445 “Intelligent transport systems (ITS) usage”

[Draft new] Report ITU-R M.[IMT.C-V2X] “Application of the Terrestrial Component of IMT for Cellular-V2X”

Handbook on Land Mobile (including Wireless Access) - Volume 4: Intelligent Transport Systems. Year 2021

4 Connected automated vehicles in the context of ITS

There are some specific terms used that are related to CAV, including:

1) Connected Vehicle (CV). A vehicle is referred to as a CV if V2X communication equipment is mounted and an Advanced ITS application is supported by using cooperative V2X connectivity.

2) Automated Vehicle (AV). A vehicle is referred to as an AV if in-vehicle perception sensors like automotive radar, camera, lidar are mounted and automated driving applications are supported using those sensors only.

3) Connected Automated Vehicles (CAV). A vehicle is referred to as a CAV if in-vehicle perception sensors and V2X communication equipment are mounted and automated driving applications are supported using both in-vehicle perception sensors and cooperative V2X connectivity.

4) Connected and Cooperative Automated Vehicle (CCAV). The intended understanding is essentially the same as CAV above.

5) Connected and Cooperative Automated Mobility (CCAM). The intended understanding is essentially the same as CAV above.

6) Connected Automated Driving (CAD). The intended understanding is essentially the same as CAV above.

7) [IoT based CAV (referred to as IoT-CAV). Recently, a vehicle is labeled as IoT-CAV if the ultra-connectivity using IoT devices and platforms is applied for CAV.]

8) Vehicle to Anything (V2X). V2X consists of short range communication - V2V, V2I, V2P; and, optionally, long range communication with V2N. Both short-range and long-range V2X support a hybrid communication concept to serve for CAV applications.

For the purposes of this Report, the definition of CAV is:

CAVs are vehicles with V2X communication capability blended with automated functionality beginning at SAE Level 2+ up to Level 5. The latter consists of a combination of advanced driver assistance system (ADAS) using sensors such radar, camera, and lidar (line-of-sight technologies). The V2X communication extends the *awareness horizon of ADAS by obtaining information outside the detection range of on-board sensors, providing information of one's own vehicle, and communicating intention mutually with other vehicles and infrastructure via V2X connectivity as well as by charting both location and intention of other road users such as vehicles, and it has the ability to "see" and "talk" beyond other objects in real-time (non-line-of-sight). This achieves safer and smoother automated driving control based on the automated driving system.*

[Japan's comments: Adding the aspect of "talk" in the CAV definition.]

Automated Vehicles (AVs), also sometimes referred to as driverless cars or autonomous vehicles, are under development by most of the major global automakers. Developments are important in technical areas, but also in regulatory areas, as the potential impacts on society become better understood. "The U.S. Government is actively pursuing a range of regulatory and non-regulatory activities that will enable the adoption of AVs, with the overall goal to facilitate the safe and full integration of AV technologies into the national surface transportation system. Integration would help realize the great potential AV technologies have for enhancing public safety, making systems more efficient, and facilitating economic vitality."[2]

To better define what is meant by the term "AV", SAE International has developed a standard description of six levels of vehicle automation, ranging from Level 0 – no automation, to Level 5 – full automation[3]. These descriptions of the six levels of driving automation provide a thorough, systematic technical definition of CAVs. While the capabilities for Level 5 - full automation in all conditions - have generated public expectations, the realization of Level 5 automation has not been as rapid as initially thought. For the purposes of this Report, Levels 3, 4 and 5 form the 'automated' portion of the CAV definition. This is viewed as necessary, but not yet sufficient, for the overall CAV definition.

As indicated in the definition of CAV, V2X communication is an essential component of CAVs. V2X communication provides ears and mouth to the automated vehicle and enables cooperative ITS where the end users are not only consuming information but also providing it. V2X communication is essential for bringing automated driving to the streets. V2X communication enables applications intended to improve road traffic safety and boost road traffic efficiency on all SAE levels.

A vehicle possesses information on its own status and the surrounding traffic environment obtained from GNSS and on-board sensors. Such information is required for, and contributes to, smooth automatic driving. In addition, cooperative V2X connectivity enables mutual communication among the vehicles or between the vehicle and the external stakeholders, such as road administrators, traffic managers. Negotiation between the vehicles can be initiated with communicating the intentions to the surrounding vehicles. Requests for mediation may be made by the vehicle to the traffic manager.

[Japan's comments: Describing one of the characteristics of CAVs that they communicate their collected data to other vehicles and infrastructure.]

There are specific relationships between applied technologies and vehicle functionality. The vehicles can be classified into Connected Vehicle (CV), Automated Vehicle (AV), Connected and Automated Vehicle (CAV) (or CAV equivalent terminologies) from the view of applied technologies and

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[2] https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/360956/ensuringamericanleadershipav4.pdf.

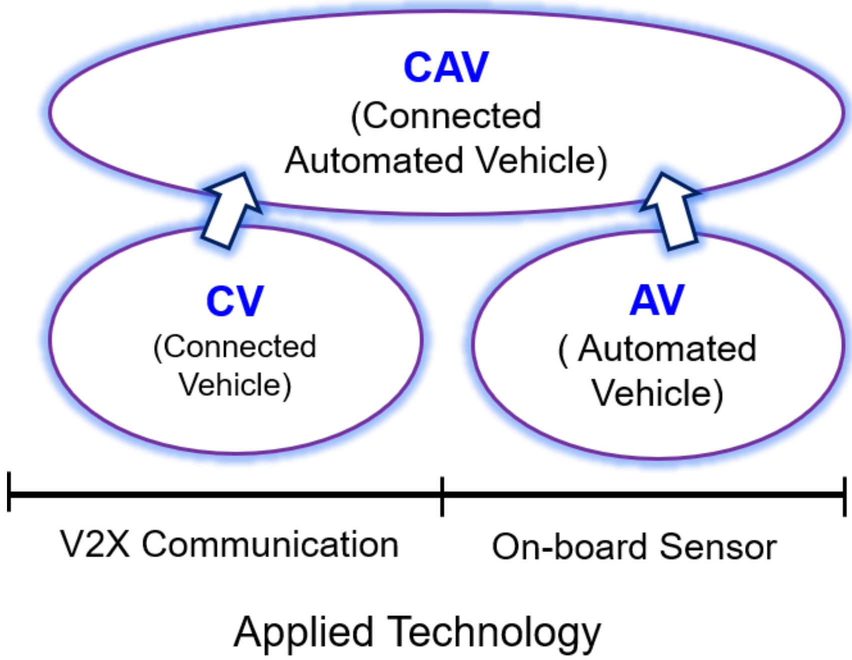
[3] https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic.

expected vehicle functionality. CAV contains the scope and contents of the CV and AV domains to enhance the in-vehicle perception sensors (ADAS) of AV with short range ad hoc V2X communication.

Figure 1 illustrates relationship between CAV, CV and AV.

FIGURE 1

Relationship between CAV, CV and AV



Relationship for crash avoidance between short range ad hoc communication (V2V, V2I, V2P) and Advanced Driver Assistance Systems (ADAS) based on in-vehicle perception sensors:

I) Vehicle versus vehicle crashes: when looking at vehicle versus vehicle crashes, different driving scenarios can be distinguished where ADAS can avoid certain percentages of such accidents. A BASt study[4] gives potential percentages of the total crash avoidance depending on different driving maneuvers. Overall, up to 50% of vehicle versus vehicle road traffic crashes can be addressed by ADAS, see Table 1.

TABLE 1

Driving maneuvers and corresponding crash avoidance potential by ADAS. Source BASt

	All crashes	**Severe crashes**
Turning-in/ crossing vehicle	16.3%	21.2%
Turning with oncoming vehicle	2.2%	4.1%
Turning with rear-end crash	3.8%	2.4%

[4] BASt, German Federal Highway Authority. “Requirements to ADAS from the road safety perspective”, 2007. https://www.bast.de/BASt_2017/DE/Publikationen/Archiv/Infos/2007-2006/11-2007.html.

	All crashes	Severe crashes
Longitudinal traffic with real-end crash	21.9%	15.1%
Longitudinal traffic with lane-change crash	6.1%	3.1%
Total	50%	46%

V2V, V2I and Vehicle-to-Pedestrian (V2P) or V2VRU communication systems complement the Line-of-Sight (LoS) ADAS with additional information such as Non-Line-of-Sight (NLoS) object detection, intention recognition, vehicle speed, acceleration information, as well as other status information. V2V message types like BSM, CAM, CPM, MCM[5] are used to communicate directly between V2X vehicles. Using direct V2X communication, there will be fewer restrictions due to LoS obscurations. Also, kinematics data and driver behaviour information such as pedal actuation is exchanged.

Short range ad hoc communication is able to close the gap and to address vehicle versus vehicle crashes which cannot be prevented by in-vehicle perception ADAS alone.

II) Vehicle versus Vulnerable Road User (VRU) crashes: The effectiveness of preventing vehicle vs VRU crashes using in-vehicle perception ADAS has been analyzed in PROSPECT D2.3 [x[6]]. An overall potential of 55% in fatality and injury reduction was determined for state of the art ADAS.

Short range ad hoc communication is able to close the gap and to address vehicle versus VRU crashes which cannot be prevented by ADAS.

At a fundamental level, the 'basic safety' use cases; described, for example, in Report ITU-R M.2445-0 (11/2018) - Intelligent transport systems (ITS) usage, provide the foundational safety-of-operation required for CAVs. These use cases also provide the rationale for the inclusion of wireless communication capabilities as a basis for the definition of CAVs. Therefore, the advanced ITS radio interface standards in Recommendation ITU-R M.2084-1 (11/2019) - Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure two-way communications for Intelligent Transport System applications, provide the minimum connectivity requirement in the definition of CAVs. Furthermore, CAV developments are expected to generate additional communication capabilities necessary for Level 5 – full automation – by 2023.

4.1 Communication technologies

4.2 Types of communication

[Editor's note (J): Texts need to elaborate for the following 3 types.]

Three types of communication technologies are used for CAV communications.

4.2.1 Unicast

This technology is used for 1 to 1 communication.

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[5] BSM Basic Safety Message; CAM Cooperative Awareness Message; CPM Collective Perception Message; MCM Maneuver Coordination Message.

[6] European H2020 research project PROSPECT, PROactive Safety for PEdestrians and CyclisTs, analyse and tested in-vehicle perception ADAS to protect VRUs, finalized 2018. Deliverable D2.3, https://ec.europa.eu/inea/en/horizon-2020/projects/H2020-Transport/Safety/PROSPECT.

4.2.2 Multicast

This technology is used for 1 to Multiple communication, e.g. group communication. The source of the transmission is always the same, so the 1 in 1 to n is always the same transmitter.

4.2.3 Broadcast

This technology is used for CAV communication among unspecified number of vehicles, e.g. traffic light information and/or road sign information to vehicles around there. The source of the transmission can be different, so it is n to m.

5 Radiocommunication elements for CAVs

There are two main radiocommunication elements for operation of CAVs – ad hoc wireless direct communication and cellular connectivity (requiring base station coverage). Ad hoc communication is essential for CAVs and cellular connectivity is important. Both technology families have their advantages and drawbacks but it should be noted that they are supporting different types of applications in the CAV domain.

Access layer technologies:

The ad hoc access layer V2X communication technologies are either:

– IEEE based, or

– 3GPP based.

IEEE technology is based on the amendment to IEEE 802.11 called IEEE 802.11p (2010), now part of IEEE 802.11-2016[7]. This access technology is deployed in Europe under the name of ITS-G5, and dedicated short-range communication (DSRC) in the US as well as ITS Connect in Japan. A successor to IEEE 802.11p is currently drafted in IEEE under the working name IEEE 802.11bd, which is not violating backward compatibility, coexistence nor interoperability. Both IEEE 802.11p and IEEE 802.11bd can use the same frequency channel in the same geographical area at the same time in a spectrum efficient manner.

3GPP based access layer technology supporting ad hoc communication is LTE-V2X (release 14) and 5G-NR V2X (release 16). These two radio technologies cannot talk to each other, are not backward compatible nor coexistent in the same channel and consequently cannot share the same frequency channel.

The cellular connectivity is based on 4G and 5G, requiring coverage by base stations and subscriptions to traditional operators.

Higher layer technologies for V2X above access layer are available at:

– ETSI ITS set of standards,

– CEN set of standards,

– IEEE 1609 set of standards,

– SAE set of standards.

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[7] In the following 802.11p is used to refer to the relevant part for V2X communication in the IEEE 802.11-2016 "Outside the Context of a Basic Service Set (OCB)".

6 Overall objectives and radiocommunication requirements for CAVs

CAV development is an evolution and not a revolution. CAVs will exist side-by-side with other non-automated road users for the foreseeable future. Different use cases and levels of automation have different requirements. SAE level 1 and level 2 automation systems are already on the market illustrated through, e.g., adaptive cruise control and lane keep assistance systems, these are solely based on line-of-sight sensors such camera and radar. Ad hoc V2X communication based on IEEE 802.11p as part of IEEE 802.11-2016 are deployed in Road Side Units and serial vehicles in all three regions Europe (ITS-G5), US (WAVE) and Japan (ITS Connect) for increasing road traffic safety by extending the awareness horizon for the driver (increasing the time to react on dangerous events). Next step is to marry ADAS with ad hoc V2X communication and include the ad hoc V2X communication as a new sensor to the overall sensor fusion framework towards V2X enhanced ADAS.

In the CAV domain, vehicles will support step-by-step more functionalities. Once the ad hoc V2X sensor is included in the sensor set, new V2X enhanced ADAS features will be enabled such as cooperative ACC that can avoid rear-end collisions as well as increase road traffic efficiency (closer spacing between vehicles and reduced fuel consumption). The only mature technology for ad hoc V2X communication is IEEE 802.11p (ITS-G5, WAVE, ITS-Connect). All proposed applications in the CAV domain (e.g., platooning, collective perception, maneuver coordination) are fully supported by IEEE 802.11p based V2X technologies. The applications, however, cannot be supported by one single radio on one frequency channel. The necessary exchange of data by direct, communication to support CAV applications is estimated to need at least 70 MHz of spectrum by automotive proponents[8,9].

6.1 Higher layer including application layer requirements

CAV requirements (higher layer requirements):

Ad hoc V2X communication will be an essential part for CAVs. Nevertheless, there are many other parts in the CAV domain that needs more attention such as functional safety, robust positioning, sensor fusion, machine learning, high definition maps etc. All parts need to be carefully orchestrated to make CAVs happen. In this respect, communication is just one piece in this giant puzzle.

It takes around 3-5 years for adding a new feature to a vehicle, this long product development cycle is due to the rigorous process of placing safe products on the market. Vehicles have an average lifetime of 12 years. Given the long product development cycles and expected life-time, legal certainty is of utmost importance for vehicle manufacturers. For example, a sudden removal of spectrum resources causes much headache and creates insecurities resulting in unwillingness to make necessary investments for realizing certain technologies. Further, new technology for inclusion in vehicles needs to be mature when the product development starts, and it needs to be available for the coming 15 years.

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[8] 5GAA TR S-200137: Working Group Standards and Spectrum, “Study of spectrum needs for safety related intelligent transportation systems - day 1 and advanced use cases”, https://5gaa.org/wp-content/uploads/2020/06/5GAA_S-200137_Day1_and_adv_Use_Cases_Spectrum-Needs-Study_V2.0-cover.pdf.

[9] Communication technology independent CAR-2-CAR Communication Consortium Spectrum Study for V2V and V2I safety message types defined in ETSI and SAE: “Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving” https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2050_Spectrum_Needs.pdf.

Cellular specific requirement for CAV:

– full road coverage with cellular communication.

– cross-border interoperability.

– cross-provider interoperability.

6.2 Radiocommunication requirements: sensors, interoperability, radio interfaces, data rate, latency, reliability

[Editors note: For missing information, further input expected – topics on Interoperability / backward compatibility / coexistence are suggested.]

Access layer requirements

1) Communication topology

By nature, V2X communication is a many-to-many omnidirectional type of communication.

2) Dynamic channel:

The highly mobile environment of road traffic leads to much higher requirements on the V2X receiver. Consequently, CAV services using the ad hoc V2X sensor requires continuous adaption to the current channel status, which is affected by, e.g., severe multipath, doppler effect of the channel resources. V2X receivers need to comply with dynamic channel conditions as described in, e.g., ETSI EN 302 663 Annex A. Despite the reason for poorer wireless communication, CAV services need to have graceful performance degradation.

3) Dynamic number of participants

Dynamic load change in the channel due to few to very many traffic participants at the same time in the communication range of ITS stations. High density scenarios show that 100-800 vehicles can be in the functional relevant distance. Vulnerable Road Users (VRU) like bicyclist and pedestrians can be V2X traffic participants and have to be calculated on top of that.

4) Dynamic use of channels:

Further, not all CAV services can be hosted on one channel but needs to be divided between channels using several radios and multi-channel operation.

5) Dynamic V2X message:

For most efficient use of spectrum V2X messages are generated only if required and necessary content is adapted by application layer to the minimum. V2X messages change dynamically in sending rate and message size over time with an aperiodic behaviour. An analysis of this behaviour for the broadly used ETSI Cooperative Awareness Message CAM is given in IEEE “Empirical Models for the Realistic Generation of Cooperative Awareness Messages in Vehicular Networks”[10]. Other CAV related messages such as CPM, MCM, PSM/VAM[11], deploy the same dynamic generation rules. In

[10] R. Molina-Masegosa, M. Sepulcre, J. Gozalvez, F. Berens and V. Martinez, "Empirical Models for the Realistic Generation of Cooperative Awareness Messages in Vehicular Networks," in IEEE Transactions on Vehicular Technology, Vol. 69, No. 5, pp. 5713-5717, May 2020, doi: 10.1109/TVT.2020.2979232.

[11] PSM: Personal Safety Message, VAM: Vulnerable Road User VRU Awareness Message.

addition to spectrum efficiency, this dynamic generation supports the principle of data minimization for privacy reasons.

6) Communication ranges:

V2X applications intended to reduce traffic accidents in short range need 90% packet success rate at 150m in urban, suburban environment and at 500 m in highway environment or fast rural environment in combination with omnidirectional communication requirement.

7) Selection of V2X modulation characteristics:

The requirements for most, especially safety applications, CAV applications (V2X services using the following messages BSM/CAM, CPM, MCM, PSM/VAM) are:

– dynamic radio channel changes, e.g. mobile environment,
– dynamic message generation, e.g. dynamic changes in Tx rate and message size from message to message,
– omnidirectional communication,
– dynamic channel load at at least 500 m range with Packet Success Rate 90%.

These requirements lead to a preferred selection of low data rates and the choice of a robust modulation like QPSK ½ [12]. There are some CAV applications which can use higher order modulations and/or multiple/directional antenna systems, e.g. truck platooning.

8) Service layer latency:

Below 10 ms as in table "Technical characteristics on Advanced ITS and CAV".

From the view of wireless connectivity, V2X communication technology for many new CAV applications need to support lower latency and higher reliability. The 3rd Generation Partnership Project (3GPP) specifications, ETSI, SAE, and IEEE standards provide the categories of enhanced V2X applications and technical requirements in terms of packet size, data latency, reliability, and data rate for currently-defined CAV applications. Based on these specifications and standards, the radio communication technology for CAV applications requires less than 10 msec in packet latency on the service / application level [x[13]] and greater than 90% packet success rate. V2X applications intended to reduce traffic accidents in short range need 90% packet success rate at 150 m in urban, suburban environment and at 500 m in highway environment or fast suburban environment, in combination with omnidirectional communication requirement. Those safety applications like e.g.

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[12] D. Jiang, Q. Chen, L. Delgrossi, "Optimal data rate selection for vehicle safety communications", *Proc. ACM international workshop on VehiculAr Inter-NETworking (VANET)*, San Francisco, California, USA, pp. 30-38, 15 Sept. 2008.

[13] 5GAA white paper "C-V2X Use Cases Volume II: Examples and Service Level Requirements" Service Level Latency definition:

- Measurements of time from the occurrence of the event in a scenario application zone to the beginning of the resulting actuation. Depending on implementation, this includes one or more of the following:
- Processing of the event into information by the information generator;
- Communication of the information to end-user;
- Processing of the information by the end-user;
- Time to actuation driven by the result of processing of the information.

collective perception lead to lower data rates and the choice of a robust modulation. Other applications with much shorter communication range requirements or directional communication may choose an increased data rate. [1-4].

TABLE X

Technical characteristics on Advanced ITS and CAV

[Editor's note: Korea to propose text revision to clarify typical cellular coverage range for CAV]

Items	Advanced ITS	CAV
Applications	Cooperative Awareness Collective Perception	Cooperative Driving with Maneuver Coordination Service Platooning Automated Valet Parking
ITS Connectivity Scope	V2V, V2I, V2N, V2P	V2V, V2I, V2N, V2P
Radio Performance		
Typical Coverage Range	Short range ad hoc and direct communication up to 1 000 m	Short range ad hoc and direct communication up to 1000 m [Short range communication also may include hybrid use of cellular communication]
Packet size including necessary overheads and security certificate	380 bytes – 1 900 byte	400 byte - 6 000 bytes
End to End Service Level Latency	Less than 100 msec	less than 10 msec
Packet Success Rate	Greater than 90% in highway scenario within 500 m communication range Greater than 90% in suburban scenario within 150 m communication range Greater than 90% in urban scenario within 150 m communication range	Greater than 90%

The initial, and continuing, focus in most AV development has been upon onboard sensors to provide the necessary sensory inputs to the AV computational systems to enable automated operation. Thus, there have been major investments in video systems, radar systems, and LIDAR systems to provide these onboard sensors. These sensors replicate the human driver's function of sight; and, arguably, can provide better reliability, detailed discrimination, and wide-angle coverage than human eyesight. This should allow better safety performance for vehicles with these systems that replace the human drivers' eyesight.

There are functional limits to the onboard sensors, however, since these are inherently line-of-sight sensors. This limitation is shared by human vision. Wireless communication, however, offers the possibility to provide AVs with 'extra-sensory' perception especially in Non-Line-of-Sight conditions. Besides detecting potential hazards hidden behind line-of-sight obstructions, wireless communication can allow AVs to share driving intentions, collectively negotiate and execute maneuvers and share onboard sensor data. These additional capabilities will greatly enhance the safety and efficiency of AV operations.

[IAFI Note: Section 6.3 and 6.4 may be merged to consolidate the use-cases and avoid duplication.]

6.3 Use Cases

[Editor's note (J): the following sections

– *first describes CAV use cases and analyse them to derive CAV elements,*

– *Identifies their required types of radio links, e.g. V2V, V2N, V2N2V,*

– *Also identifies their requirements, e.g. throughput, latency, reliability, coverage area*

– *preferable frequency ranges, if any,]*

Looking at worldwide R&D towards service deployment of CAVs, current prototype use cases include Cooperative Driving/Coordinated automated driving maneuvers, Platooning, Automated Valet Parking. The communication system architecture of CAV is basically the same as that of Advanced ITS.

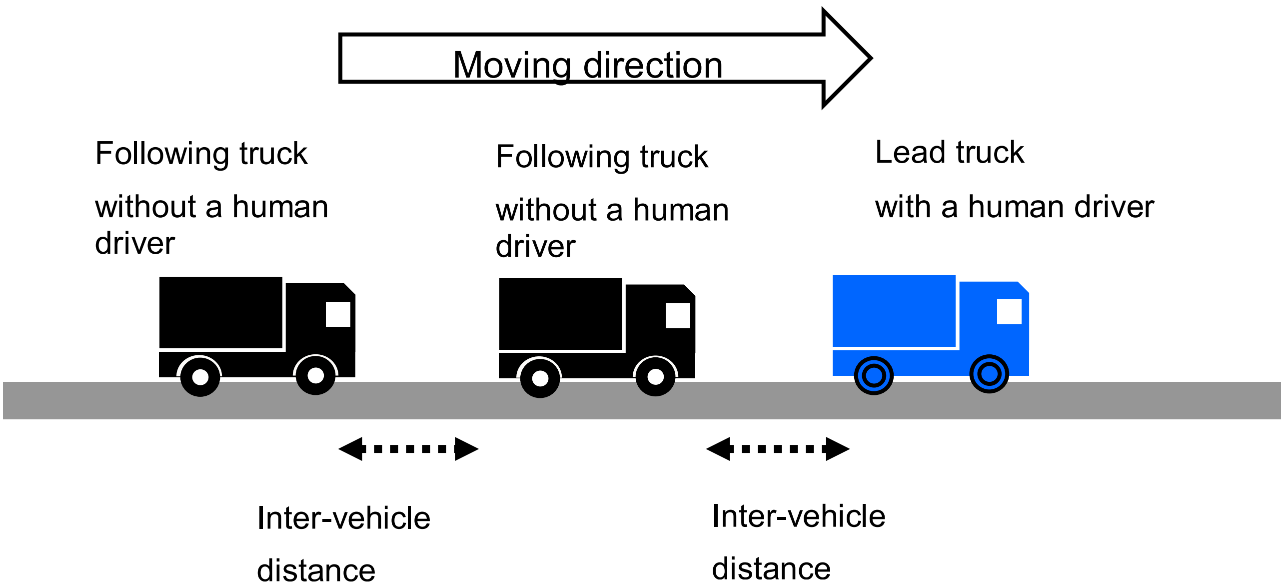
Coordinated automated driving maneuvers are one of the main reasons that wireless communications are being viewed as critically important for AVs. One of the first use cases in this category is platooning but coordinated merging and coordinated lane changing are also being developed.

1) Platooning

Platooning involves multiple vehicles driving together in a convoy. The platoon is controlled as a unit by using inter-vehicle radiocommunication. In a truck platooning, leading truck is driven by a human driver while following trucks follow the leading truck by keeping a certain inter-vehicle distance using Automatic Cruise Control (ACC) and automated-steering / automatic-tracking of the previous truck, as shown in Figure 6-3-1.

FIGURE 6.3-1

Truck platooning



Development to implement platooning is currently underway in several countries around the world. For example, in Japan, a field trials of truck platooning are underway[MY2019], as shown in Figure 6.3-1.

FIGURE 6.3-1

Field Trial of Truck platooning (CACC and automated steering) on a highway

a) Rear view **b) Bird view**

Several social issues can be resolved through the use of truck platooning. Platooning can enable trucks to drive closer together to reduce wind resistance, which can reduce fuel consumption and reduce CO_2 emissions. It has been shown that a platoon of three trucks travelling 4 m apart at 80 km/h consumes 15% less fuel[A2013]. If the distance between trucks is reduced to 2 m, the fuel consumption would be reduced by 25%. Reducing the distance between vehicles can also increase the traffic capacity of roads, i.e. the number of vehicles per km, mitigating congestion. This could further reduce fuel consumption and CO_2 emission.

In some countries, including Japan, an aging driver population and driver overwork, due to shortage of truck drivers, are also social issues, so truck platooning can reduce the burden on drivers and increase safety.

Adaptive Cruise Control (ACC) measures the distance between a lead vehicle and following vehicle using radar or other technology and maintains a safe separation between vehicles according to their cruising speed. ACC has been implemented and many vehicles are already equipped with it. However, when controlling based only on the measured distance between vehicles, there is a significant delay between when the lead truck begins to slow down and when the following distance changes. There is further delay until the following truck begins to slow down. For this reason, if only ACC is used, a longer following distance must be maintained to prevent collisions.

On the other hand, Cooperative ACC (CACC) controls vehicle speed based on other vehicles' speed and position information sent from other trucks to a truck by inter-vehicle radiocommunication, which can greatly improve control of the following distance when the truck needs to brake suddenly. This also enables stable operation with less fluctuation in following distance (hunting or vibration) due to less control delay. Fuel consumption can be further reduced and traffic capacity of roads, i.e. number of vehicles per km, can also be increased while maintaining safety by further reducing the following distance and increasing the number of platooned trucks, if reliable and low-latency radiocommunication would be applied to the radio communication between the vehicles.

The V2V radiocommunication between vehicles in a platoon needs group communication which is carried out within a specific platoon, i.e. a group of trucks which forms platooning. In this V2V communication, directional antenna is preferable to limit the area of the communication in order to reduce interference to other convoys/platoons and to use less spectrum. Video streaming of side/rear view and/or sensor information, beyond typical basic safety message exchange, is needed to transmit from the trailing truck, i.e. the tail truck of the convoy, to the lead truck for safety monitoring of the side/rear of the platoon. This group communication application is unique to the platooning.

There are two sub-use-cases in truck platooning, as shown in Figures 6.3-3 and 6.3-4.

Figure 6.3-3 shows group radiocommunications between vehicles in truck platooning. There are two Radiocommunication links in Figure 6.3-3; one is a link of Vehicle-to-Network-to-Vehicle (V2N2V), using typical cellular up- and down-link, i.e. a radio link via a cellular base station. Another is a direct radio link of Vehicle-to-Vehicle (Direct V2V) between two vehicles, which can be realized by using DSRC (Dedicated Short Range Communication) or Cellular-V2X Sidelink.

As described above, the direct, V2V radiocommunication is used, for example, for control messages to support coordinated braking, as well as basic safety use cases. Cellular network-based radiocommunication is used, for example, in geofencing, traffic congestion warning and road restriction violation warning use cases. Cooperative merging and lane change assistance (see sections 6.4.2.3 (1) and (3)) is very useful for smooth merging of the platoon and other single-vehicles, particularly at highway branches and exits, since the platoon is very long being compared with typical trucks and/or trailers.

In the sub-use-case, three types of radiocommunication are required, (i) message communication for vehicle control, (ii) video communication for safety monitoring of rear and side views, being sent from the trailing vehicles to the lead vehicle human driver, and (iii) message communication for information of auxiliary equipment, e.g. fuel indicator, handbrake status, warning lamps and/or position of transmission gear.

The above (i) requires small packet but low latency communication for the control of the vehicles in a platoon, particularly in case of multiple vehicles form a platoon to avoid hunting/vibration of the inter-vehicle distance and to keep the control of the vehicles more stable. The above (ii) may require the transmission of full HD (1920 × 1080, i.e. 2.07 million pixels) video with around 60 fps, with the latency of 50 ms (glass-to-glass, including video coding and decoding), considering the requirements of 1 million pixels, 30 fps with the latency of 200 ms, which are defined for electric rear-view mirrors in Regulation 46 by United Nations European Commission, also taking some margins to them. The (iii) above requires very short messages and allows relatively higher latency but need to periodically exchange messages.

FIGURE 6.3-2

Radiocommunications between vehicles in truck platooning

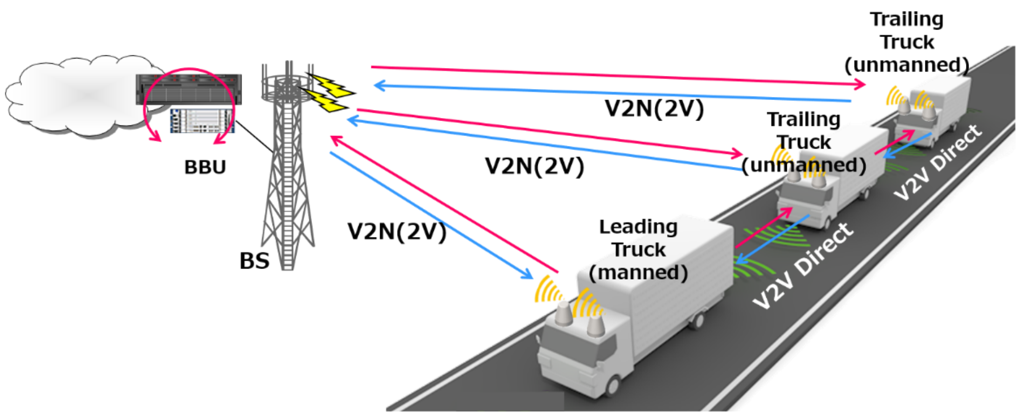
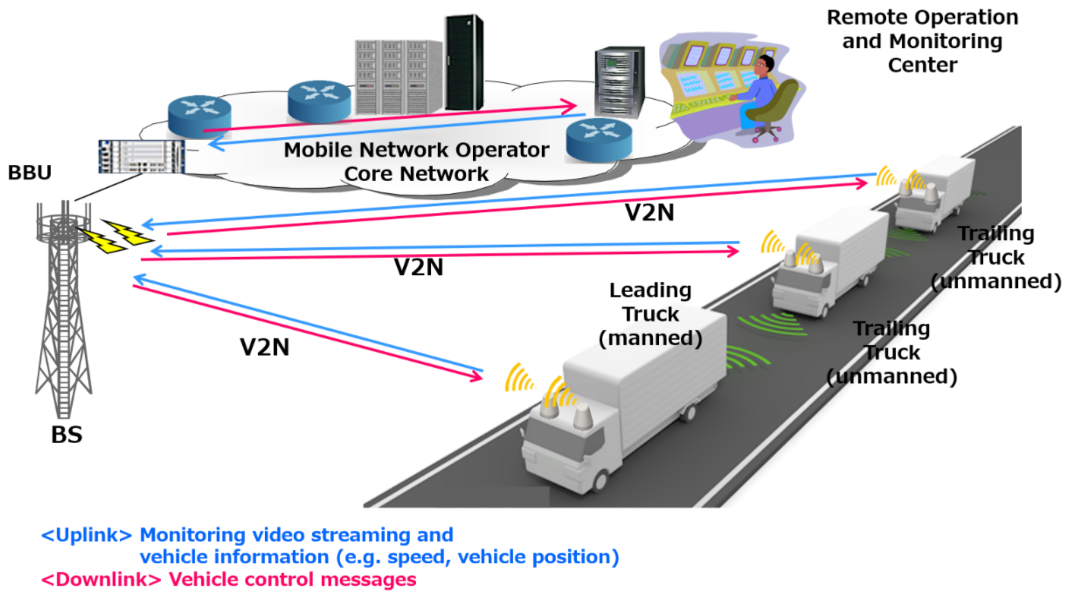


FIGURE 6.3-3

Radiocommunications between remote monitoring center (ground station) and moving vehicles in truck platooning



The above three radiocommunication may be provided by group communication among member vehicles, which would be provided by multiple of unicast or multicast V2V radiocommunications.

Coverage area is less than a few hundred meters in diameter in most of the cases in the direct V2V radiocommunications. Higher frequency range, e.g. upper portion of microwave or mm-wave are preferable for the direct-V2V group communications in a platoon, since communication distances are relatively short. In case of V2N2V, i.e. via a base station, typical cellular communication, i.e. up- and down-link, can be used for the V2V communication, as well. In this sub-use-case, typical cellular coverage is required.

Figure 6.3-3 shows another sub-use-case of the platooning, in which radiocommunication is required between a remote operation and monitoring center, i.e. ground station, and a moving platoon of trucks.

In the sub-use-case, a human operator at remote operation and monitoring center, monitors a truck platoon by video monitoring over a radiocommunication link. If the operator recognizes something wrong with a platoon, he or she sends a control message, e.g. a message to safely stop a platoon on a highway. This sub-use-case requires the same requirements as discussed in (i) and (ii) above. In the sub-use-case, typical cellular coverage and its network are required.

2) Automated Valet Parking

T.B.D.

3) Urban Driving

T.B.D.

4) Advanced Driving

T.B.D.

5) Remote Driving

Remote Driving - enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments.

6) Maneuver Coordination / Cooperative Driving / Advanced Driving

Maneuver Coordination Service also called Coordinated Driving or Advanced Driving enables e.g. coordinated merging, coordinated lane change of semi-automated or fully automated vehicles.

"Cooperative Automated Driving (CAD)[14] brings together driving automation technology with V2X communication in order to enable vehicles to coordinate their driving maneuvers and achieve a common global understanding of their surroundings, leading to safer and more efficient driving. The IMAGinE[15] [x] research project develops a CAD system based on collective perception and cooperative maneuver coordination, one example of CAD is a connected lane merge function"[16] [x]. By exchanging maneuver coordination messages (MCM), the intentions of the vehicles are shared and are transparent to nearby vehicles, which can negotiate the most efficient trajectories and thereby avoid incidents and accidents.

7) Object sharing / cooperative sensing driving / extended sensor sharing

Perception sensors are able to recognize and identify moving and fixed objects in Line-of-Sight view of sensors built in vehicles or infrastructure. Vehicles and infrastructure can communicate such identified objects to other V2X traffic participants with Collective Perception Messages (CPM). This is known as collective perception, object sharing, cooperative sensing driving as well as extended sensor sharing.

Collective Perception with object sharing means exchange of sensed object data between vehicles and vehicles with smart infrastructure as well as between vehicles and smart infrastructure itself. Cameras, radars, LiDAR sense all object types (such as vehicles, pedestrians, bicycles, scooters, motorcycles or obstacles) in the Line-of-Sight environment and transmit the object data to all ITS traffic participants, including roadside infrastructure. Pedestrians are not equipped with camera, radar, LiDAR and cannot send CPM.

Vulnerable road users such as pedestrians are especially protected by collective perception services.

[Japan's comments: It is suggested to add the aspect of communications between infrastructure and the vehicles.]

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[14] Note that CAD has the same meaning as CAV.

[15] IMAGinE is a German research project implementing Collective Perception Service and Maneuver Coordination Service into passenger cars, https://imagine-online.de/en/home/:

"The IMAGinE (Intelligent Maneuver Automation – cooperative hazard avoidance in realtime) project is developing innovative driving assistance systems for cooperative driving. Cooperative driving refers to road traffic behaviour in which road users cooperatively plan and execute driving maneuvers. Individual driving behaviour is coordinated with other road users and the overall traffic situation based on automatic information exchange between vehicles and infrastructure. Critical situations can be avoided or mitigated, thereby making driving safer and more efficient."

[16]] Ignacio Llatser, Thomas Michalke, Maxim Dolgov, Florian Wildschütte, Hendrik Fuchs, IEEE 2nd 5G World Forum "Cooperative Automated Driving Use Cases for 5G V2X Communication", 2019.

In cases where direct V2V communication is impossible due to non-connected participants (like VRU, non connected vehicles), cooperative sensing driving adds additional traffic safety by exchanging object data through indirect communication. CPM provides information about objects such as other traffic participants or other objects in the surrounding area as detected by the vehicle or infrastructure, using their own radars, cameras, or lidar. Collective perception capability enhances the communication between V2X-equipped participants and incorporates non-equipped V2X traffic participants. CPM can accelerate the effective V2X communication rate by using information from third-party vehicles or from smart infrastructure as an information source. Thus, CPM can help protect vehicles and VRUs which are not yet equipped with V2X.

- Interaction with non CAVs such as VRUs and non-CAV vehicles.

All of the advanced use case categories described above require ubiquitous, highly reliable, low-latency wireless communications. Key performance indicators for these use cases were developed and used to further improve ITS communication technologies and applications. However, there are additional advanced use cases emerging for automated driving, for which communication requirements have not yet been developed. These requirements are expected to become better defined by 2023 as the developments in both technology and regulation become better understood for Level 5 automated driving.

In addition to the perspective of the vehicles providing and obtaining information using V2V and V2I, it is also important to address the perspective of the infrastructure collecting and aggregating data from vehicles (e.g., location and speed) and generate information for automated driving. The information generated and provided by infrastructure to vehicles includes those for traffic flow optimization and updating dynamic maps. With these, vehicles are able to keep up with the latest road conditions, such as traffic congestion and traffic restrictions due to accidents.

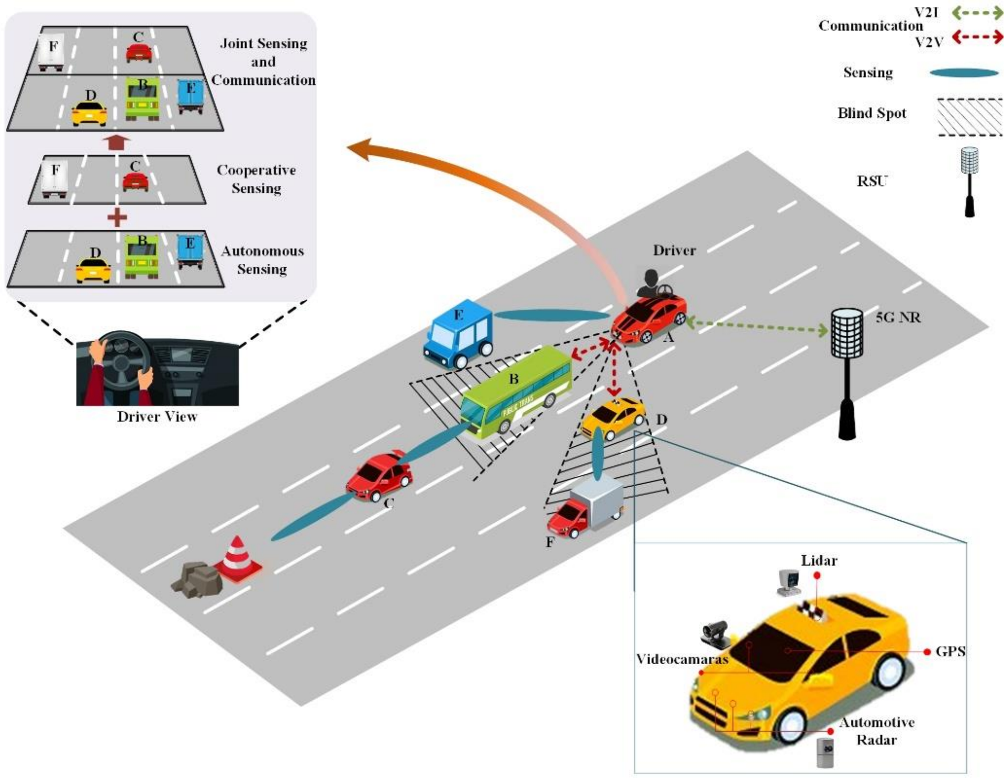
[Japan’s comments: It is suggested to describe the aspect of infrastructure collecting and aggregating data obtained from vehicles.]

8) Raw perception data sharing

To guarantee the driving safety for Level 5 full automation of CAVs, automated driving vehicles of different manufacturers may have different data processing algorithms and vehicle control decisions based on different sensors, such as video, radar, and LIDAR. In terms of the susceptible perception data from various sensors, the raw perception data sharing among CAVs should be considered to guarantee the effective perception data fusion and utilization for Level 5 full automation. Therefore, the data rate and latency requirements for the raw perception data sharing among CAVs will be in the order of Gbps and msec. As defined by 3GPP Release 16 specifications in the “Collective perception of environment” scenario [5], for high-level automatic driving vehicles, the delay requirement for collision prevention is as low as 3 ms, and the transmission rate is required to be more than 1Gbps. Therefore, related studies on new technologies should be considered to ensure the high data rate raw perception data sharing among CAVs with the low latency requirement.

FIGURE XX

Typical scenario of raw perception data sharing among CAVs.



As shown in Figure XX, there are multiple sensor in CAV, such as the millimeter wave radar, camera, LIDAR and other on-board sensors. Both low-frequency and high-frequency bands will be used to provide the broadband communication ability among CAVs and road side units. We assume that vehicle B, D and E are the targets that can be directly detected by the millimeter wave radar of vehicle A. However, due to the blockage of vehicles B and D in front, the sensing range of vehicle A is greatly limited, resulting in vehicles C and F in the blind area of vehicle A. Therefore, in order to expand the detection range of vehicle A, the broadband communication links can be used to transmit the raw perception information from radar or camera of vehicle B and D to vehicle A. Vehicle A carries out the multi-source perception information fusion to improve the "See-through" ability. In some cases, the raw data are needed for liability reasons in case of accidents, for distributed verification of local and remote sensor data [1].

The raw data rate of computer vision based video camera will reach 100-700 Mbps [2] (e.g. six cameras with a resolution of 1280 x 720, 24 bit per pixel, 30 frames per second) , which will rely on vendors' specific classifiers [3][4]. In terms of the millimeter wave radar, when the scanning bandwidth is 200 MHz and the sampling rate is 200 Ms/s, the raw data rate of one radar will reach 1.6 Gbps [5].

[1] S. W. Kim *et al.*, "Multivehicle Cooperative Driving Using Cooperative Perception: Design and Experimental Validation," in IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 2, pp. 663-680, Apr. 2015.

[2] J. Choi, N. González-Prelcic, R. Daniels, C. R. Bhat, and R. W. Heath, Jr., "Millimeter Wave Vehicular Communication to Support Massive Automotive Sensing," IEEE Communications Magazine, vol. 54, no. 12, pp. 160-167, Dec. 2016.

[3] N. Andersen, C2C-Consortium "Towards Accident Free Driving", ETSI Summit "5G from Myth to Reality", 2016.

[4] 3GPP TR 22.886, "Study on enhancement of 3GPP Support for 5G V2X Services (Rel.16)", December 2018.

[5] Continental Engineering Services, SRR 308-21 Short Range Radar 24 GHz Data sheet, http://conti-engineering.com/wp-content/uploads/2020/02/SRR308-21_EN_HS.pdf.

6.4 Functional elements of the use cases

6.4.1 Concept of Connected Automated Vehicles (CAV)

The automated vehicles achieve automated driving control by using information obtained from on-board sensors of one's own vehicle. Meanwhile, the connected automated vehicles achieve advanced automated driving by adding information obtained through radiocommunication to the connected vehicles. The Connected Automated Vehicles were defined based on the above concepts.

***1 Smoother automated driving control**

This refers to enabling driving control with enough time margin by adding information obtained through radiocommunication to the automated vehicles (in which automated driving system makes the final judgment on driving control) based on the information obtained through on-board sensors of one's own vehicle. Specific examples include the following:

a) Preliminary acceleration and deceleration/speed adjustment toward lane change and merging

b) Mutual concessions and mediation with other traffic participants

c) Selection of an optimal route

d) Response to control instructions.

***2 Information outside the detection range of on-board sensors**

Information outside the detection range of on-board sensors refers to the following:

a) Information beyond the detection range of on-board sensors of the automated vehicles

b) Definite information in the future (e.g., traffic signal phase and timing information)

c) Statistical prediction information (e.g., traffic congestion prediction information)

***3 Providing information of one's own vehicle**

Providing information of one's own vehicle refers to providing information about the status of one's own vehicle and the surrounding traffic environment obtained from GNSS, on-board sensors, etc. to the infrastructure.

***4 Mutual communication by using V2I and V2V**

Mutual communication by using V2I and V2V refers to communication between an automated vehicle and vehicles around it and between an automated vehicle and infrastructure, respectively. Specifically, it refers to the following:

a) Transmission of intention of an automated vehicle to vehicles around it (unspecified)

b) Mutual communication between an automated vehicle and vehicles around it (specified or unspecified)

c) Provision of information from external stakeholders related to a vehicle's driving (e.g., road administrators, traffic managers) to the vehicle or vice versa

d) Driving behavior instructions from external stakeholders related to a vehicle's driving (e.g., road administrators, traffic managers) to the vehicle, or requests for mediation from the vehicle to external stakeholders.

6.4.2 Process of studying the use cases

6.4.2.1 Principle in selecting the functional elements of the use cases

This Report aims to propose future radiocommunication protocols and radiocommunication resources. The use cases collected as described in Section 6.3 include those functional elements that are less likely to be used in practice. Those less likely are described in Annex 1. If radiocommunication resources are secured to achieve all the functional elements, such resources are likely to be wasted. For this reason, this Section proposes the functional elements of these cases that may be likely to be used in practice.

6.4.2.2 Overview of the functional elements of the use cases

1) Functional elements of the use cases

The functional elements compiled based on classification by function are listed Table AA below.

TABLE AA[17]

Functional elements for CAV use cases

(1) Functional elements in which information outside the detection range of on-board sensors must be obtained

Classification by function	Name of the functional element	Overview
a. Merging/lane change assistance	a-1-1. Merging assistance by preliminary acceleration and deceleration	Information, such as the speed of vehicles driving on the main lane at the measurement location on the main lane and predicted time to arrive at a merging section, is provided by the infrastructure to merging vehicles to assist preliminary acceleration and deceleration.
	a-1-2. Merging assistance by targeting the gap on the main lane	Continuous measurement information (e.g., location and speed of vehicles driving on the main lane) is continuously provided by the infrastructure to merging vehicles to assist merging by targeting the gap between vehicles driving on the main lane.
b. Traffic signal information	b-1-1. Driving assistance by using traffic signal information (V2I)	Current traffic signal color and traffic signal phase and timing information (the next traffic signal color and the time until change), etc. at intersections are provided by the roadside infrastructure to vehicles that enter intersections to assist deceleration and stopping, and thereby avoid a dilemma.
	b-1-2. Driving assistance by using traffic signal information (V2N)	Traffic signal phase and timing information (the next traffic signal color and the time until change), etc. at intersections is provided through the network to vehicles that enter intersections to assist deceleration and stopping, and thereby avoid a dilemma.

[17] https://en.sip-adus.go.jp/rd/rddata/usecase.pdf.

Classification by function	Name of the functional element	Overview
c. Lookahead information: collision avoidance	c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly	Sudden braking information as well as location and speed information are provided by the vehicle that suddenly decelerates to the following vehicles to prompt them to stop or decelerate in advance and prevent multiple-vehicle collision accidents.
	c-2-1. Driving assistance based on intersection information (V2V)	Location and speed information of vehicles that approach intersections is provided by the approaching vehicles to other vehicles that approach or pass through intersections to assist them to pass through or make a right turn at intersections with many blind spots.
	c-2-2. Driving assistance based on intersection information (V2I)	Location and speed information of vehicles that approach intersections, which is obtained from roadside sensors or vehicles, is provided by the infrastructure to other vehicles that approach or pass through intersections to assist them to pass through or make a right turn at intersections with many blind spots.
	c-3. Collision avoidance assistance by using hazard information	When an automated driving vehicle performs emergency deceleration or emergency lane change, emergency hazard information is transmitted to the following vehicles to assist smooth avoidance control.
d. Lookahead information: trajectory change	d-1. Driving assistance by notification of abnormal vehicles	Event information of abnormal vehicles that are stopped on roads (e.g., malfunctioning vehicles, vehicles involved in accidents) and location information (sections and lanes where such vehicles are located) are provided by the infrastructure to the surrounding vehicles or by abnormal vehicles to the surrounding vehicles to assist lane change and trajectory change at an early stage.
	d-2. Driving assistance by notification of wrong-way vehicles	Location and speed information of wrong-way vehicles and information about the presence of wrong-way vehicles are provided by the infrastructure to the surrounding vehicles to prompt lane change, etc. in advance and assist collision avoidance.
	d-3. Driving assistance based on traffic congestion information	Traffic congestion status information obtained from vehicles that are caught in traffic congestion is provided by the infrastructure to the surrounding vehicles to assist driving.
	d-4. Traffic congestion assistance at branches and exits	Information about traffic congestion on shoulders (location, speed) is provided by the infrastructure to vehicles on the main lane to assist entry to branches.
	d-5. Driving assistance based on hazard information	Information about obstacles, construction work, traffic congestion, etc. is provided by the infrastructure to the surrounding vehicles to assist driving.
e. Lookahead information: emergency vehicle notification	e-1. Driving assistance based on emergency vehicle information	Information about the driving direction, speed, and planned driving route (planned driving lane) of emergency vehicles is provided by the emergency vehicles to the surrounding vehicles to prompt the surrounding vehicles to drive at reduced speed or to stop, etc. and thereby assist the emergency vehicles to pass smoothly.

(2) Functional elements in which information of one's own vehicle must be provided

Classification by function	Name of the functional element	Overview
f. Information collection/ distribution by infrastructure	f-1. Request for rescue (e-Call)	Rescue information is transmitted from abnormal vehicles (e.g., vehicles involved in accidents) to the infrastructure to request rescue.
	f-2. Collection of information to optimize the traffic flow	Information about the location and speed of driving vehicles is collected via the infrastructure to analyze and optimize the traffic flow.
	f-3. Update and automatic generation of maps	Vehicles' information is collected by the infrastructure to update and automatically generate the map data.
	f-4. Distribution of dynamic map information	Dynamic map information is provided by the infrastructure to vehicles.

(3) Functional elements in which V2V and V2I interaction must be ensured

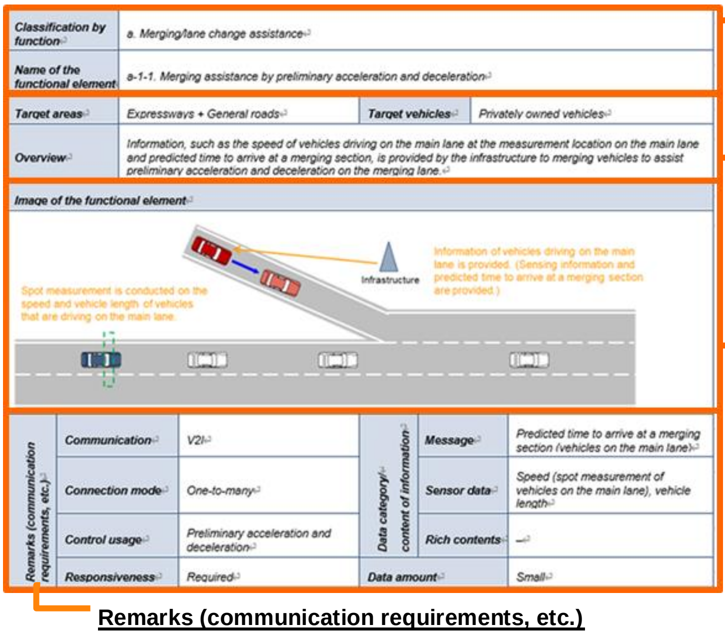
Classification by function	Name of the functional element	Overview
a. Merging/lane change assistance	a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control	Measurement information (e.g., location, speed) of vehicles driving on certain range of main lane is provided by the infrastructure to merging vehicles. Meanwhile, instructions (e.g., adjustment of the gap between vehicles) are given by the infrastructure to vehicles on the main lane to assist merging.
	a-1-4. Merging assistance based on negotiations between vehicles	During merging to a main lane with heavy traffic, vehicles on the main lane communicate with merging vehicles (e.g., location and speed information, gap adjustment requests) to conduct negotiations between vehicles for merging assistance.
	a-2. Lane change assistance when the traffic is heavy	During lane change to a lane with heavy traffic, the location and speed information and the intention of lane change, etc. are communicated between vehicles for lane change assistance.
	a-3. Entry assistance from non-priority roads to priority roads during traffic congestion	At unsignalized intersections, location and speed information and the intention of entry are communicated between vehicles near intersections for driving assistance to enter priority roads from non-priority roads.
g. Platooning/ adaptive cruise control	g-1. Unmanned platooning of following vehicles by electronic towbar	Operation information, etc. of platooning vehicles is communicated between trucks that form a platoon to assist platooning (electronic towbar).
	g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control	Location and speed information and driving operation information of vehicles at the front, etc. are communicated with the following vehicles to assist adaptive cruise control.
h. Teleoperation	h-1. Operation and management of mobility service cars	In a traffic environment that is difficult for an automated driving system, an operation manager in a remote location communicates a remote control instruction to the mobile service car based on video information from the mobile service car.

2) The diagrams of functional elements

To present the functional elements in an easy-to-understand manner, images and additional information were compiled as diagrams.

[Editor's note: Need definition of terminology, in particular communication, connection mode (this definition is already included in main body and needs to be consistent), control usage, responsiveness]

How to read the diagrams



Classification by function and name of functional element

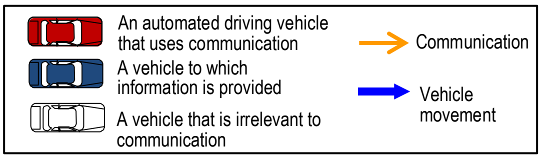
The functional elements were classified based on functionality (a to h) and named depending on the usage scene of communication for automated driving.

Overview of the functional element

The classification by function, name of the functional element, target areas (e.g., expressways, general roads), target vehicles (privately owned vehicles, logistics/mobility service cars), and overview of the functional element are indicated. For functional elements that were not considered, the reason for that is indicated.

Image of the functional element

The legend for icons in the images of functional elements is as follows.



Remarks (communication requirements, etc.)

Remarks (overall information including communication requirements) are indicated as shown below for future analysis of technology requirements for functional elements.

- Communication: V2V, V2I, etc.
- Connection mode: one-to-one, one-to-many
- Control usage: vehicle control or provision of information, etc.
- Responsiveness: vehicle response after obtaining information
- Data category/content of information: typical information that is exchanged through communication in respective categories (message, sensor data, rich contents)
- Data amount : large (data size that cannot be transmitted by DSRC)
  : small (data size that can be transmitted by DSRC)

6.4.2.3 The diagram of functional elements of the use case

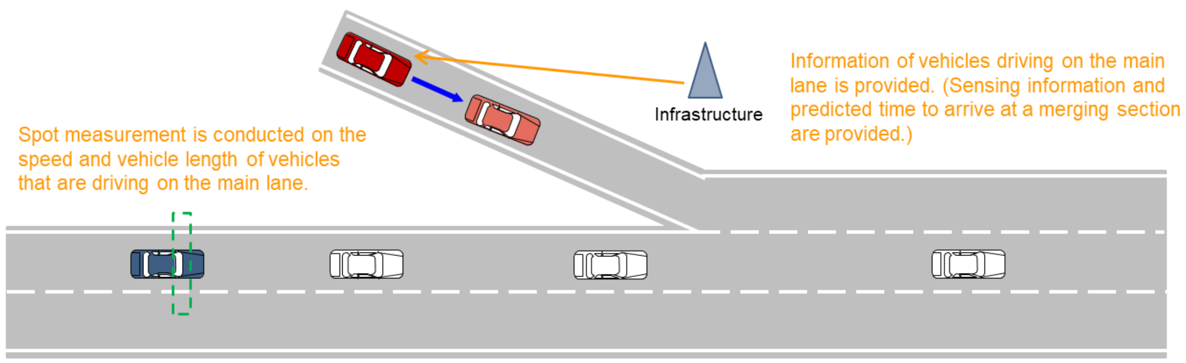
[Japan's comments: Only CAV-related functional elements should be selected by WP 5A.]

(1) Functional elements in which information outside the detection range of on-board sensors must be obtained

a. Merging/lane change assistance

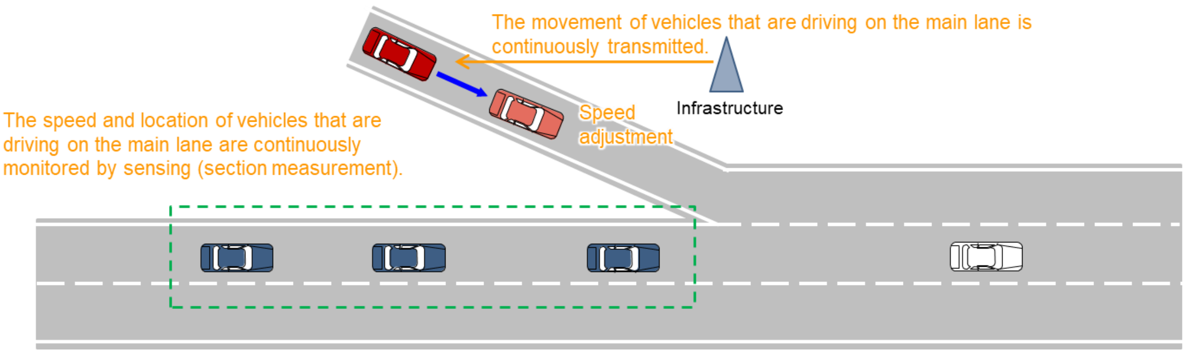
a-1-1. Merging assistance by preliminary acceleration and deceleration

Classification by function	*a. Merging/lane change assistance*		
Name of the functional element	*a-1-1. Merging assistance by preliminary acceleration and deceleration*		
Target areas	*Expressways + General roads*	***Target vehicles***	*Privately owned vehicles*
Overview	*Information, such as the speed of vehicles driving on the main lane at the measurement location on the main lane and predicted time to arrive at a merging section, is provided by the infrastructure to merging vehicles to assist preliminary acceleration and deceleration on the merging lane.*		
Image of the functional element			



Remarks (communication requirements, etc.)	***Communication***	*V2I*	***Data category/ content of information***	***Message***	*Predicted time to arrive at a merging section (vehicles on the main lane)*
	Connection mode	*One-to-many*		***Sensor data***	*Speed (spot measurement of vehicles on the main lane), vehicle length*
	Control usage	*Preliminary acceleration and deceleration*		***Rich contents***	–
	Responsiveness	*Required*	***Data amount***		*Small*

a-1-2. Merging assistance by targeting the gap on the main lane

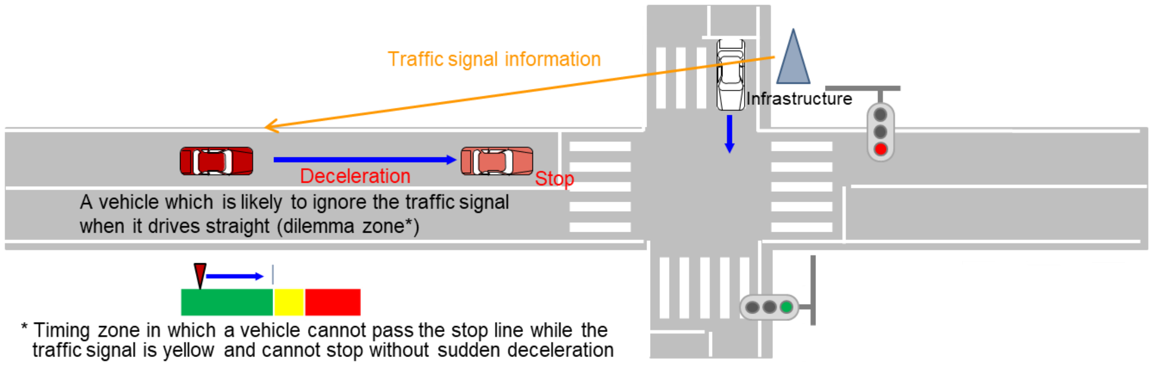
<table>
<tr><td colspan="2">Classification by function</td><td colspan="4">a. Merging/lane change assistance</td></tr>
<tr><td colspan="2">Name of the functional element</td><td colspan="4">a-1-2. Merging assistance by targeting the gap on the main lane</td></tr>
<tr><td colspan="2">Target areas</td><td>Expressways + General roads</td><td colspan="2">Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td colspan="2">Overview</td><td colspan="4">Continuous measurement information (e.g., location and speed of vehicles driving on the main lane) is continuously provided by the infrastructure to merging vehicles to assist merging by targeting the gap between vehicles driving on the main lane.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2I</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Predicted time to arrive at a merging section (vehicles on the main lane)</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Speed, location (continuous measurement of vehicles on the main lane), vehicle length</td></tr>
<tr><td>Control usage</td><td>Speed adjustment</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

b. Traffic signal information

b-1-1. Driving assistance by using traffic signal information (V2I)

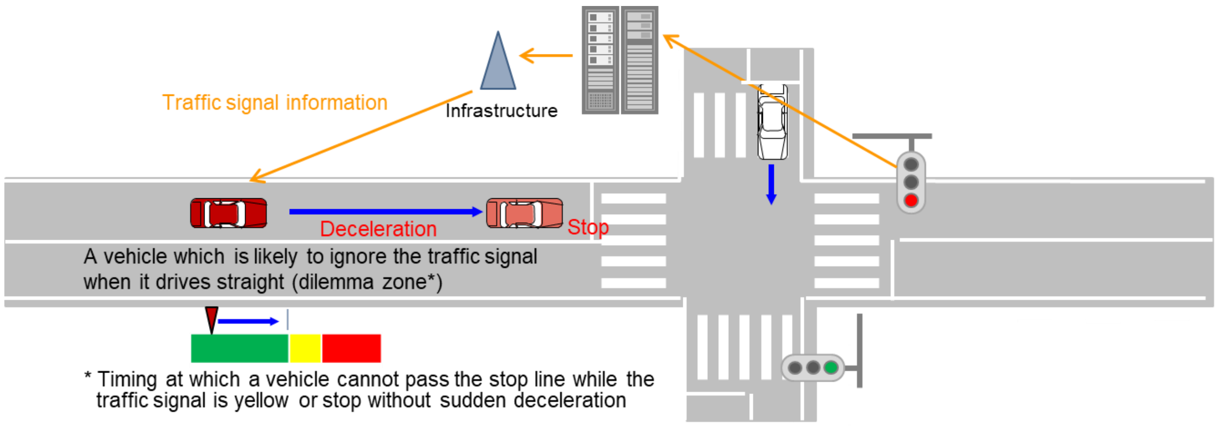
Classification by function	**b. Traffic signal information**		
Name of the functional element	**b-1-1. Driving assistance by using traffic signal information (V2I)**		
Target areas	**General roads + Expressways**	**Target vehicles**	**Privately owned vehicles**
Overview	**Current traffic signal color and traffic signal phase and timing information (the next traffic signal color and the time until change), etc. at intersections are provided by the roadside infrastructure to vehicles that enter intersections to assist deceleration and stopping, and thereby avoid a dilemma.**		

Image of the functional element



Remarks (communication requirements, etc.)	**Communication**	**V2I**	**Data category/ content of information**	**Message**	**Current traffic signal color, traffic signal phase and timing information**
	Connection mode	**One-to-many**		**Sensor data**	**–**
	Control usage	**Speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

b-1-2. Driving assistance by using traffic signal information (V2N)

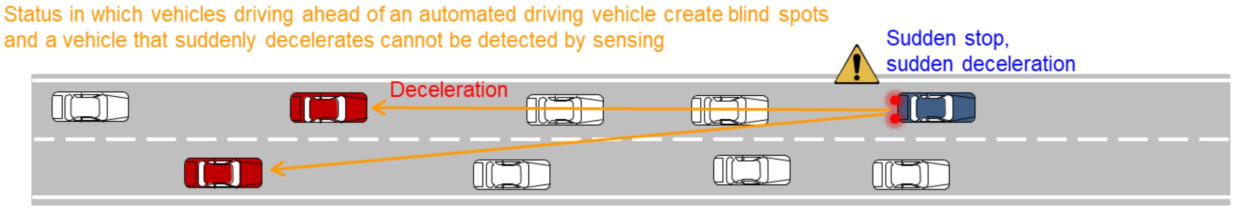
<table>
<tr><td>Classification by function</td><td colspan="4">b. Traffic signal information</td></tr>
<tr><td>Name of the functional element</td><td colspan="4">b-1-2. Driving assistance by using traffic signal information (V2N)</td></tr>
<tr><td>Target areas</td><td colspan="2">General roads + Expressways</td><td>Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="4">Traffic signal phase and timing information (the next traffic signal color and the time until change), etc. at intersections is provided through the network to vehicles that enter intersections to assist deceleration and stopping, and thereby avoid a dilemma.</td></tr>
<tr><td colspan="5">Image of the functional element</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

<table>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2N</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Traffic signal phase and timing information</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>–</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, stop</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

c. Lookahead information: collision avoidance

c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly

Classification by function	**c. Lookahead information: collision avoidance**		
Name of the functional element	**c-1. Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Sudden braking information as well as location and speed information are provided by the vehicle that suddenly decelerates to the following vehicles to prompt them to stop or decelerate in advance and prevent multiple-vehicle collision accidents.**		
Image of the functional element			

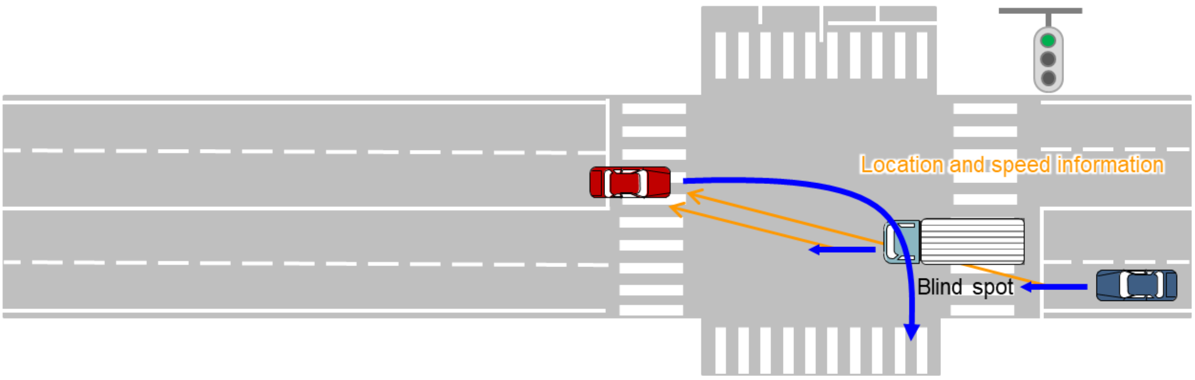


Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Sudden braking information**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

c-2-1. Driving assistance based on intersection information (V2V)

[Editor's note: Contributions to November WP5A meeting are requested to provide acceptable terminology to replace "privately owned CAV vehicles"]

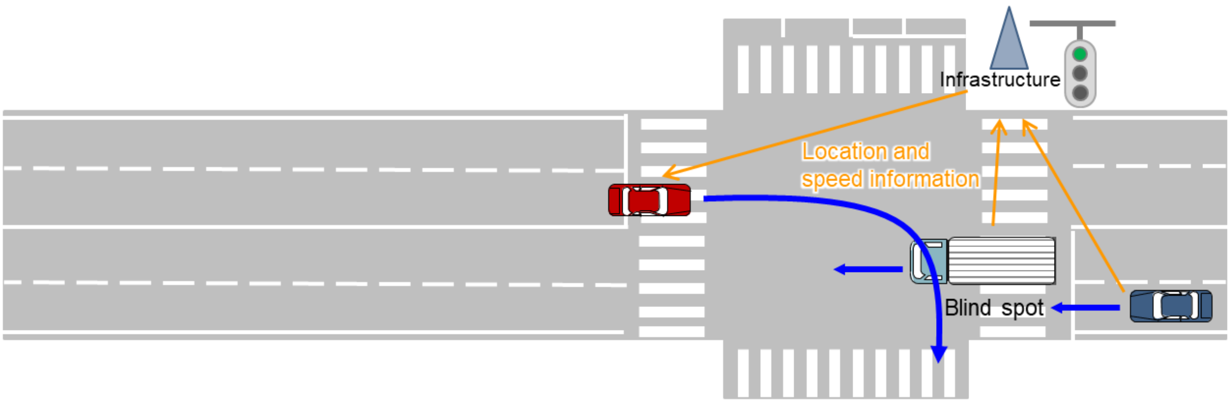
Classification by function	**c. Lookahead information: collision avoidance**		
Name of the functional element	**c-2-1. Driving assistance based on intersection information (V2V)**		
Target areas	**General roads**	**Target vehicles**	**[~~Privately owned~~ CAV vehicles]**
Overview	**Location and speed information of vehicles that approach intersections is provided by the approaching vehicles to other vehicles that approach or pass through intersections to assist them to pass through or make a right turn at intersections with many blind spots.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	–
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Judgment whether the vehicle can start, speed adjustment, stop**		**Rich contents**	–
	Responsiveness	**Required**	**Data amount**		**Small**

c-2-2. Driving assistance based on intersection information (V2I &V2N)

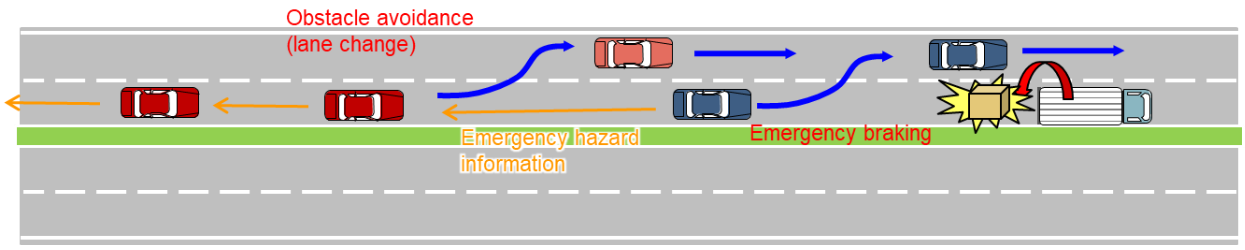
<table>
<tr><td>Classification by function</td><td colspan="3">c. Lookahead information: collision avoidance</td></tr>
<tr><td>Name of the functional element</td><td colspan="3">c-2-2. Driving assistance based on intersection information (V2I & V2N)</td></tr>
<tr><td>Target areas</td><td>General roads</td><td>Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="3">Location and speed information of vehicles that approach intersections, which is obtained from roadside sensors or vehicles, is provided by the infrastructure to other vehicles that approach or pass through intersections to assist them to pass through or make a right turn at intersections with many blind spots.</td></tr>
<tr><td colspan="4">Image of the functional element</td></tr>
</table>



<table>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2I</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>–</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Location, speed</td></tr>
<tr><td>Control usage</td><td>Judgment whether the vehicle can start, speed adjustment, stop</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

c-3. Collision avoidance assistance by using hazard information

Classification by function	**c. Lookahead information: collision avoidance**		
Name of the functional element	**c-3. Collision avoidance assistance by using hazard information**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**When an automated driving vehicle performs emergency deceleration or emergency lane change, emergency hazard information is transmitted to the following vehicles to assist smooth avoidance control.**		
Image of the functional element			

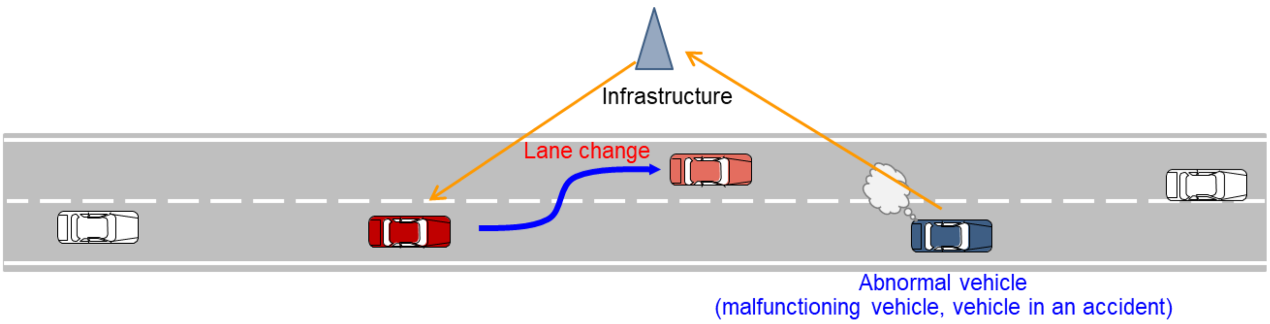


Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Obstacle information, emergency braking, steering**
	Connection mode	**One-to-many**		**Sensor data**	**Location**
	Control usage	**Trajectory change, lane change, automated driving control assistance level change**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

d. Lookahead information: trajectory change

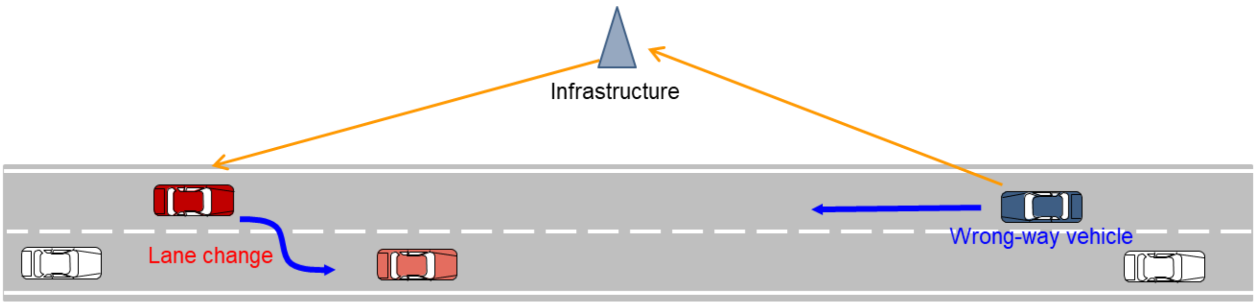
d-1. Driving assistance by notification of abnormal vehicles

Classification by function	**d. Lookahead information: trajectory change**		
Name of the functional element	**d-1. Driving assistance by notification of abnormal vehicles**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Event information of abnormal vehicles that are stopped on roads (e.g., malfunctioning vehicles, vehicles in accidents) and location information (sections and lanes where such vehicles are located) are provided by the infrastructure to the surrounding vehicles or by abnormal vehicles to the surrounding vehicles to assist lane change and trajectory change at an early stage.**		
Image of the functional element			



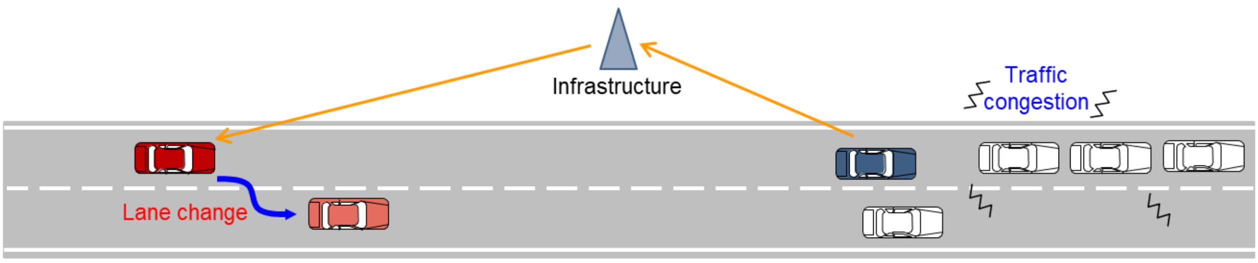
Remarks (communication requirements, etc.)	**Communication**	**V2I, V2N**	**Data category/ content of information**	**Message**	**Event information of abnormal vehicles**
	Connection mode	**One-to-many**		**Sensor data**	**Location**
	Control usage	**Lane change, trajectory change**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

d-2. Driving assistance by notification of wrong-way vehicles

<table>
<tr><td>Classification by function</td><td colspan="5">d. Lookahead information: trajectory change</td></tr>
<tr><td>Name of the functional element</td><td colspan="5">d-2. Driving assistance by notification of wrong-way vehicles</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways + General roads</td><td colspan="2">Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="5">Location and speed information of wrong-way vehicles and information about the presence of wrong-way vehicles are provided by the infrastructure to the surrounding vehicles to prompt lane change, etc. in advance and assist collision avoidance.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2I, V2N</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Presence of wrong-way vehicles</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Location, speed, and lane category of wrong-way vehicles</td></tr>
<tr><td>Control usage</td><td>Lane change, trajectory change, pulling over</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Not required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

d-3. Driving assistance based on traffic congestion information

Classification by function	**d. Lookahead information: trajectory change**		
Name of the functional element	**d-3. Driving assistance based on traffic congestion information**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Traffic congestion status information obtained from vehicles that are caught in traffic congestion is provided by the infrastructure to the surrounding vehicles to assist driving.**		
Image of the functional element			

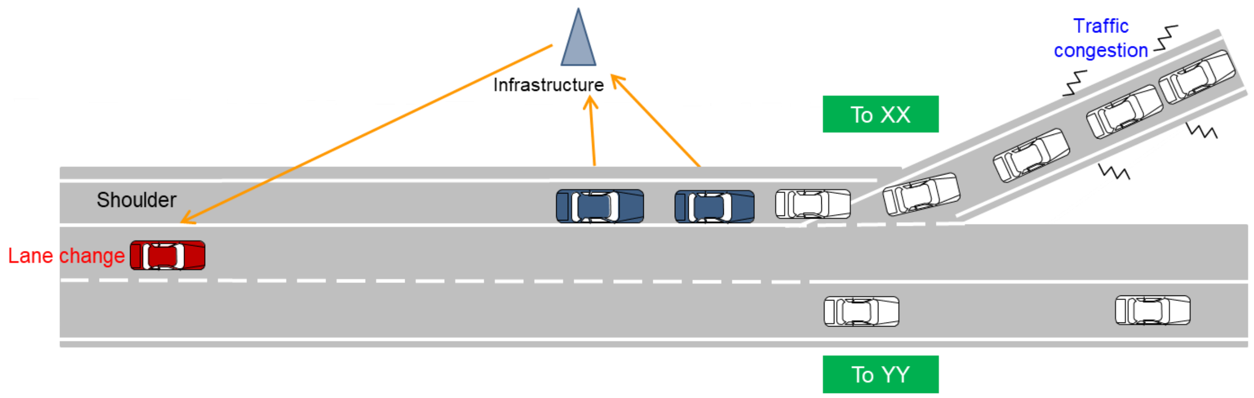


Remarks (communication requirements, etc.)	**Communication**	**V2I, V2N**	**Data category/ content of information**	**Message**	**Status of traffic congestion**
	Connection mode	**One-to-many**		**Sensor data**	**–**
	Control usage	**Trajectory change, speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

d-4. Traffic congestion assistance at branches and exits

Classification by function	**d. Lookahead information: trajectory change**		
Name of the functional element	**d-4. Traffic congestion assistance at branches and exits**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Information about traffic congestion on shoulders (location, speed) is provided by the infrastructure to vehicles on the main lane to assist entry to branches.**		

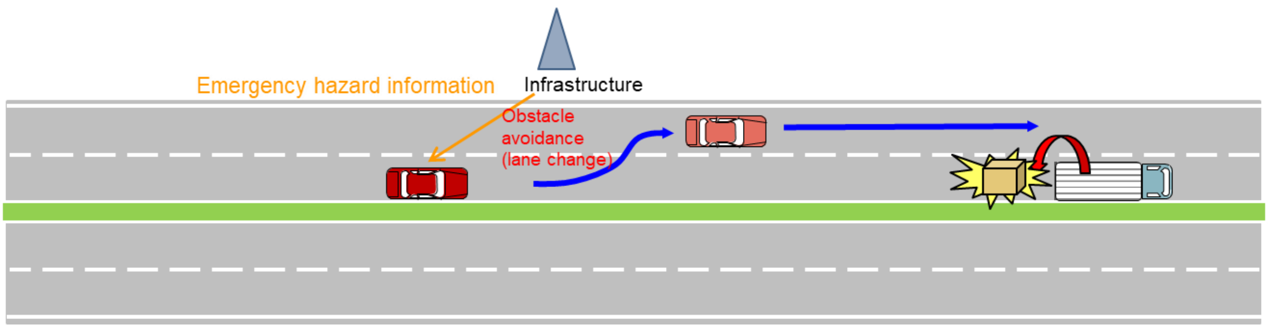
Image of the functional element



Remarks (communication requirements, etc.)	**Communication**	**V2I, V2N**	**Data category/ content of information**	**Message**	**Status of traffic congestion on shoulders (toward branches)**
	Connection mode	**One-to-many**		**Sensor data**	**Speed, location**
	Control usage	**Speed adjustment, trajectory change**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

d-5. Driving assistance based on hazard information

Classification by function	**d. Lookahead information: trajectory change**		
Name of the functional element	**d-5. Driving assistance based on hazard information**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Information about obstacles, construction work, traffic congestion, etc. is provided by the infrastructure to the surrounding vehicles to assist driving.**		
Image of the functional element			

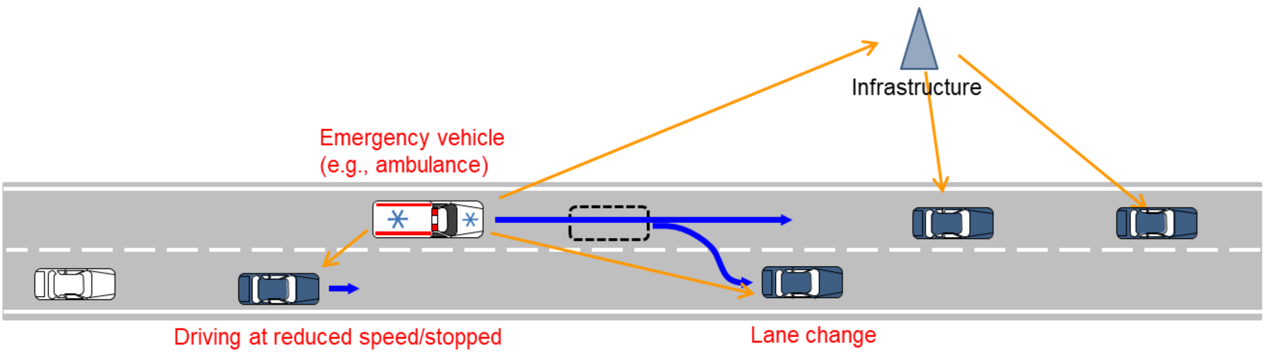


Remarks (communication requirements, etc.)	**Communication**	**V2I, V2N**	**Data category/ content of information**	**Message**	**Obstacle information**
	Connection mode	**One-to-many**		**Sensor data**	**Location**
	Control usage	**Trajectory change, lane change, automated driving control assistance level change**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

e. Lookahead information: emergency vehicle notification

e-1. Driving assistance based on emergency vehicle information

Classification by function	**e. Lookahead information: emergency vehicle notification**		
Name of the functional element	**e-1. Driving assistance based on emergency vehicle information**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Information about the driving direction, speed, and planned driving route (planned driving lane) of emergency vehicles is provided by the emergency vehicles to the surrounding vehicles to prompt the surrounding vehicles to drive at reduced speed or to stop, etc. and thereby assist the emergency vehicles to pass smoothly.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V, V2I, V2N**	**Data category/ content of information**	**Message**	**Information about approaching emergency vehicles**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Speed adjustment, lane change, stop (shoulder)**		**Rich contents**	**–**
	[Quick Responsiveness]	**Not required**	**Data amount**		**Small**

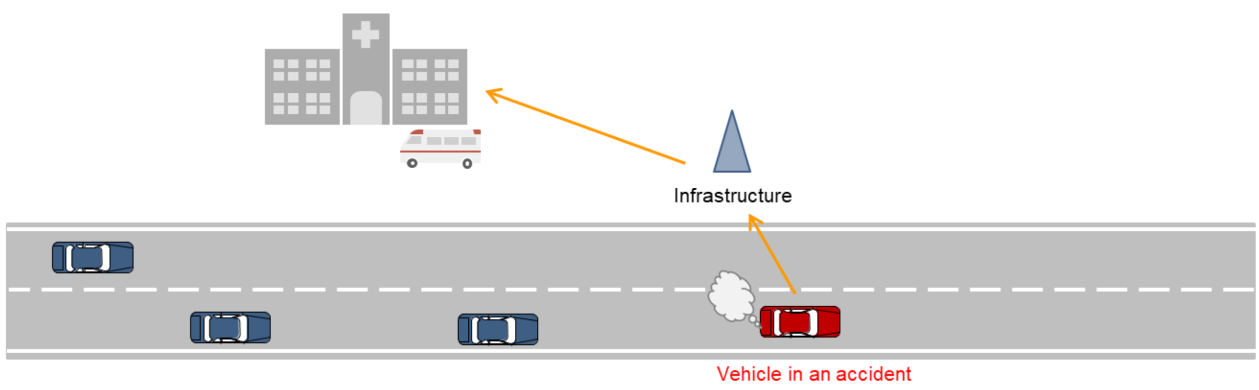
[Editor's note: Contributions to the November WP5A Meeting are requested to replace "Quick Responsiveness" in conjunction with the definitions requested at the beginning of this section]

(2) Functional elements in which information of one's own vehicle must be provided

f. Information collection/distribution by infrastructure

f-1. Request for rescue (e-Call)

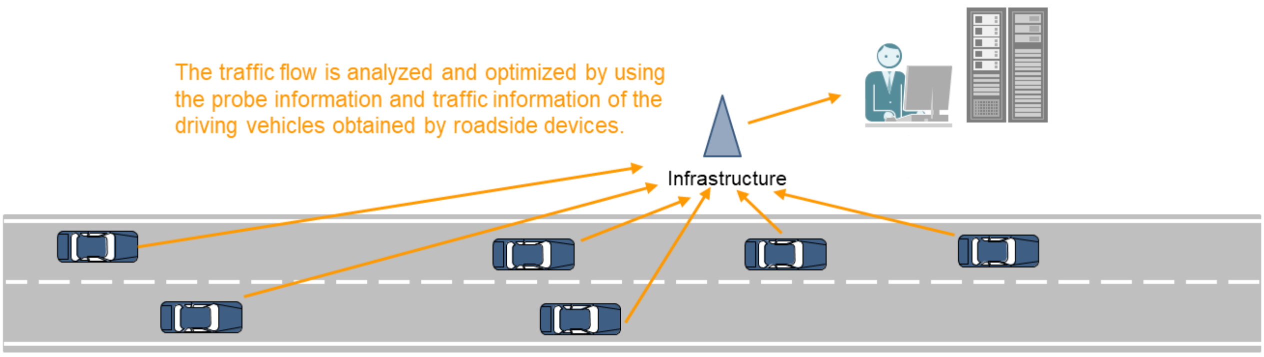
Classification by function	**f. Information collection/distribution by infrastructure**		
Name of the functional element	**f-1. Request for rescue (e-Call)**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Rescue information is transmitted from abnormal vehicles (e.g., vehicles in accidents) to the infrastructure to request rescue.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2N**	**Data category/ content of information**	**Message**	**Request for rescue**
	Connection mode	**One-to-one**		**Sensor data**	**Location**
	Control usage	**Notification**		**Rich contents**	–
	Responsiveness	**–**	**Data amount**		**Small**

f-2. Collection of information to optimize the traffic flow

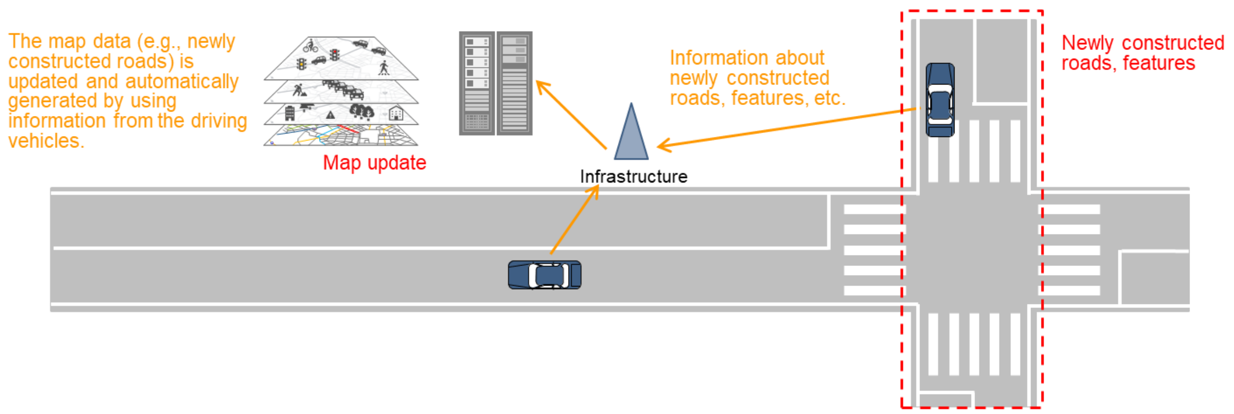
Classification by function	**f. Information collection/distribution by infrastructure**		
Name of the functional element	**f-2. Collection of information to optimize the traffic flow**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Information about the location and speed of driving vehicles is collected via the infrastructure to analyze and optimize the traffic flow.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2I, V2N**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-one**		**Sensor data**	**Location, speed**
	Control usage	**–**		**Rich contents**	**–**
	Responsiveness	**–**	**Data amount**		**Small**

f-3. Update and automatic generation of maps

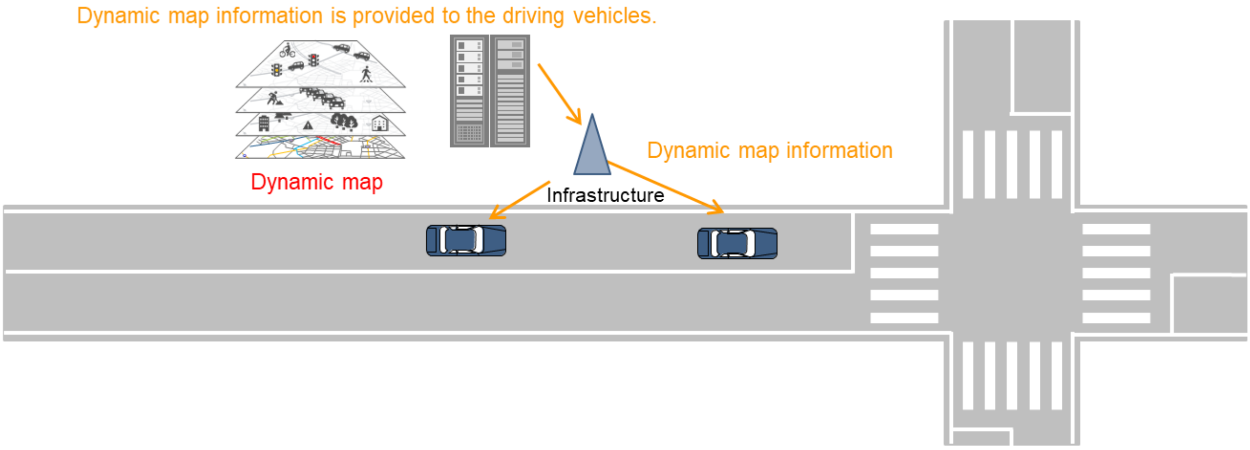
Classification by function	**f. Information collection/distribution by infrastructure**		
Name of the functional element	**f-3. Update and automatic generation of maps**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Vehicles' information is collected by the infrastructure to update and automatically generate the map data.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2N**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-one**		**Sensor data**	**Location**
	Control usage	**–**		**Rich contents**	**Image captured by on-board cameras**
	Responsiveness	**–**	**Data amount**		**Large**

f-4. Distribution of dynamic map information

Classification by function	**f. Information collection/distribution by infrastructure**		
Name of the functional element	**f-4. Distribution of dynamic map information**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Dynamic map information is provided by the infrastructure to vehicles.**		
Image of the functional element			

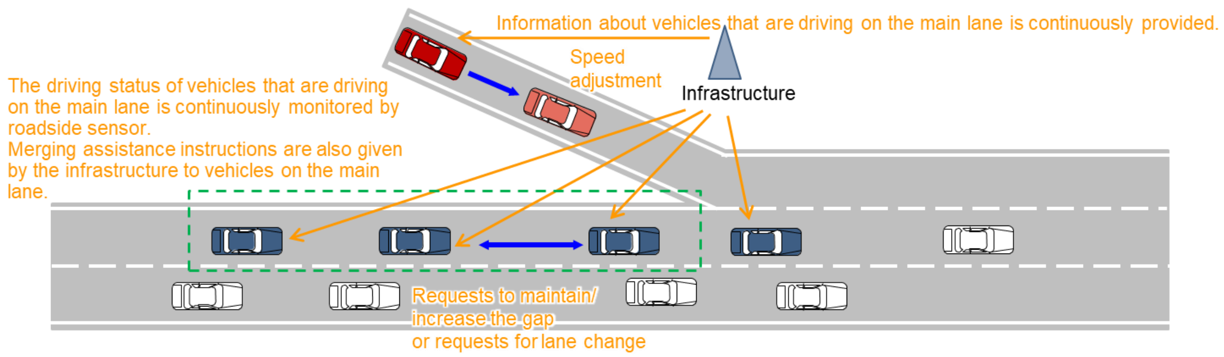


Remarks (communication requirements, etc.)	**Communication**	**V2N**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**–**
	Control usage	**Trajectory change**		**Rich contents**	**Road data, feature location, etc.**
	Responsiveness	**–**	**Data amount**		**Large**

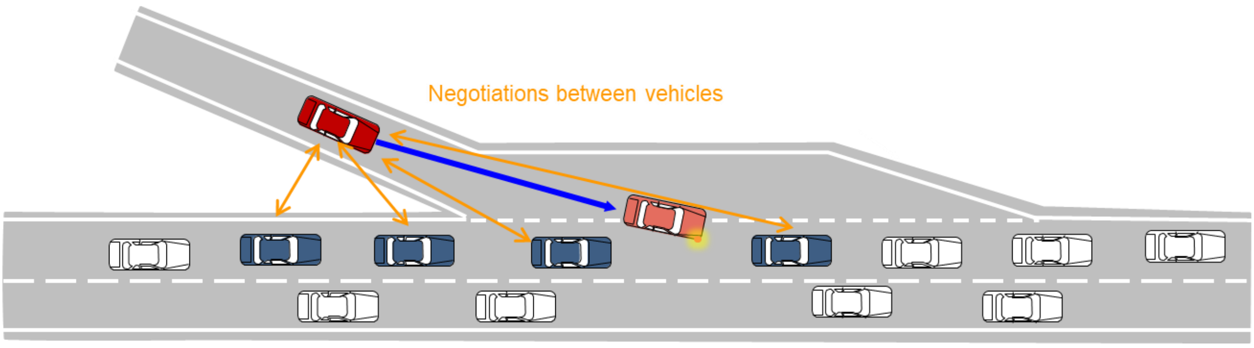
(1) Functional elements in which V2V and V2I interaction must be ensured

a. Merging/lane change assistance

a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control

<table>
<tr><td colspan="2">Classification by function</td><td colspan="4">a. Merging/lane change assistance</td></tr>
<tr><td colspan="2">Name of the functional element</td><td colspan="4">a-1-3. Cooperative merging assistance with vehicles on the main lane by roadside control</td></tr>
<tr><td colspan="2">Target areas</td><td colspan="2">Expressways + General roads</td><td>Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td colspan="2">Overview</td><td colspan="4">Measurement information (e.g., location, speed) of vehicles driving on certain range of main lane is provided by the infrastructure to merging vehicles. Meanwhile, instructions (e.g., adjustment of the gap between vehicles) are given by the infrastructure to vehicles on the main lane to assist merging.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2I</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Time to arrive at a merging section (vehicles on the main lane), requests for gap adjustment</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Speed, location</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, gap adjustment</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

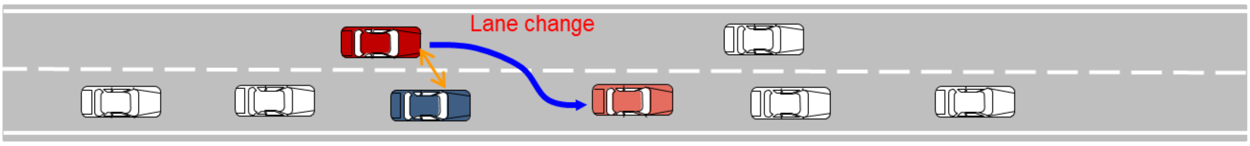
a-1-4. [Merging assistance based on negotiations between vehicles]

<table>
<tr><td>Classification by function</td><td colspan="5">a. Merging/lane change assistance</td></tr>
<tr><td>Name of the functional element</td><td colspan="5">a-1-4. Merging assistance based on negotiations between vehicles</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways + General roads</td><td colspan="2">Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="5">During merging to a main lane with heavy traffic, vehicles on the main lane communicate with merging vehicles (e.g., location and speed information, gap adjustment requests) to conduct negotiations between vehicles for merging assistance.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Requests for gap adjustment, permission for acceptance</td></tr>
<tr><td>Connection mode</td><td>One-to-many → One-to-one</td><td>Sensor data</td><td>Speed, location</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, gap adjustment</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

Note: please also see Section 6.3 and https://imagine-online.de/en/home/

a-2. Lane change assistance when the traffic is heavy

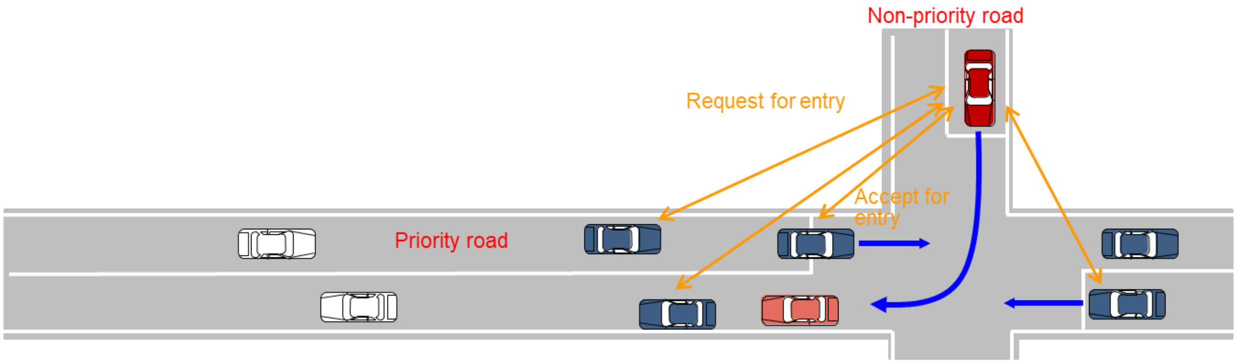
Classification by function	**a. Merging/lane change assistance**		
Name of the functional element	**a-2. Lane change assistance when the traffic is heavy**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**During lane change to a lane with heavy traffic, the location and speed information and the intention of lane change, etc. are communicated between vehicles for lane change assistance.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Requests for gap adjustment, permission for acceptance**
	Connection mode	**One-to-many → One-to-one**		**Sensor data**	**Speed, location**
	Control usage	**Gap adjustment, lane change**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

a-3. Entry assistance from non-priority roads to priority roads during traffic congestion

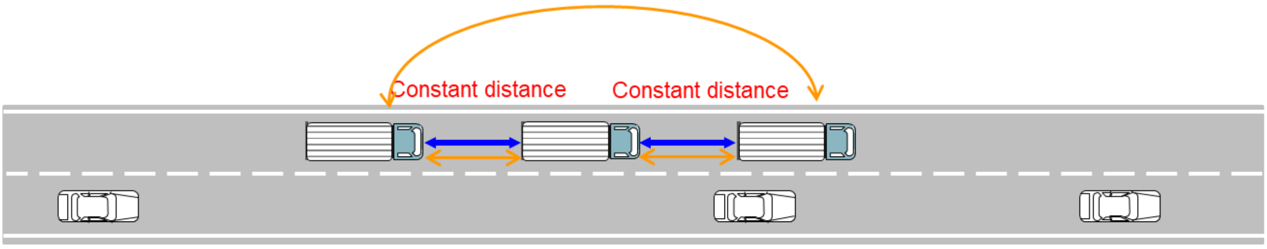
Classification by function	**a. Merging/lane change assistance**		
Name of the functional element	**a-3. Entry assistance from non-priority roads to priority roads during traffic congestion**		
Target areas	**General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**At unsignalized intersections, location and speed information and the intention of entry are communicated between vehicles near intersections for driving assistance to enter priority roads from non-priority roads.**		
Image of the functional element			



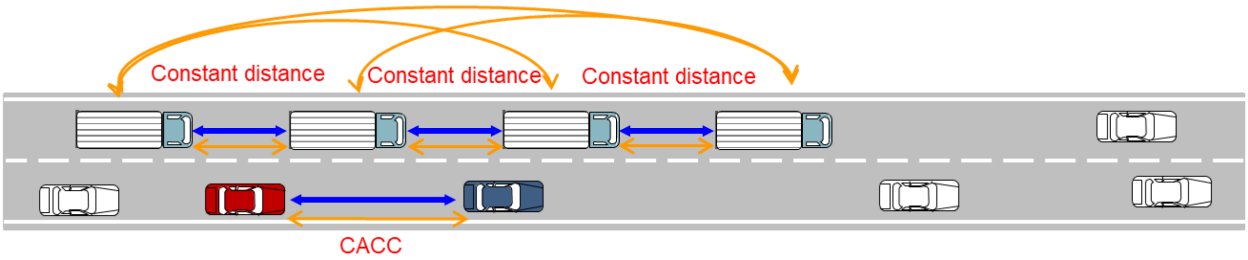
Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Requests for entry, permission for acceptance**
	Connection mode	**One-to-many → One-to-one**		**Sensor data**	**Location, speed**
	Control usage	**Right and left turns, gap adjustment**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

g. Platooning/adaptive cruise control

g-1. Unmanned platooning of following vehicles by electronic towbar

<table>
<tr><td>Classification by function</td><td colspan="5">g. Platooning/adaptive cruise control</td></tr>
<tr><td>Name of the functional element</td><td colspan="5">g-1. Unmanned platooning of following vehicles by electronic towbar</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways</td><td colspan="2">Target vehicles</td><td>Logistics service cars</td></tr>
<tr><td>Overview</td><td colspan="5">Operation information, etc. of platooning vehicles is communicated between trucks that form a platoon to assist platooning (electronic towbar).</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Acceleration, braking, steering operation, information about following vehicles</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Location, speed, gap, acceleration/deceleration speed</td></tr>
<tr><td>Control usage</td><td>Keeping distance, platoon maintenance</td><td>Rich contents</td><td>Transmission of image from the second truck to the first truck by using an electronic mirror</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Large</td></tr>
</table>

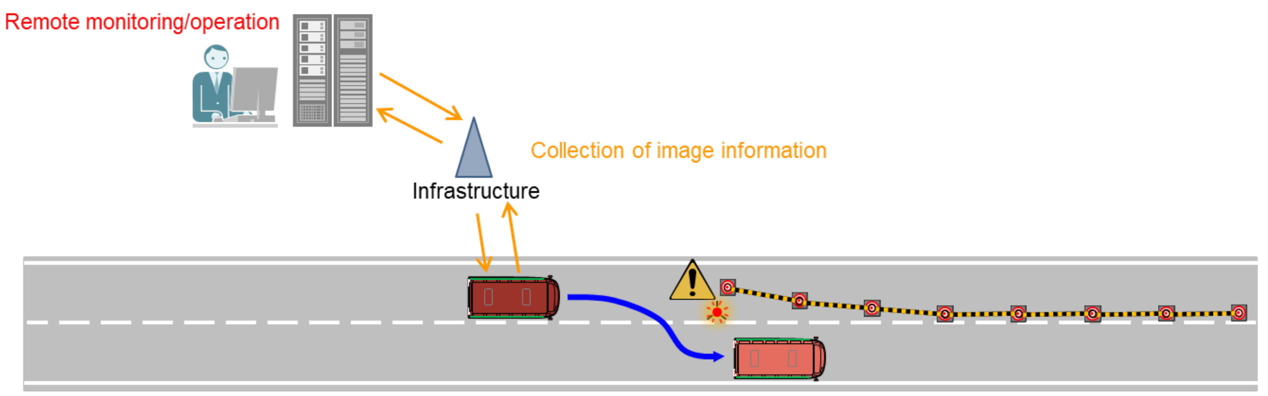
g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control

<table>
<tr><td>Classification by function</td><td colspan="5">g. Platooning/adaptive cruise control</td></tr>
<tr><td>Name of the functional element</td><td colspan="5">g-2. Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways (Logistics service cars)
Expressways + General roads (Privately owned vehicles)</td><td colspan="2">Target vehicles</td><td>Logistics service cars, Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="5">Location and speed information and driving operation information of vehicles at the front, etc. are communicated with the following vehicles to assist adaptive cruise control.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Acceleration/braking operation</td></tr>
<tr><td>Connection mode</td><td>One-to-one or one-to-many</td><td>Sensor data</td><td>Location, speed, acceleration/deceleration speed</td></tr>
<tr><td>Control usage</td><td>Keeping distance</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

h. Teleoperation

h-1. Operation and management of mobility service cars

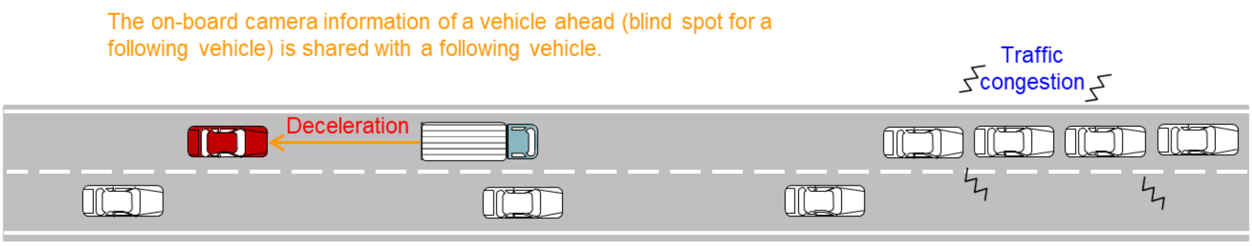
Classification by function	**h. Teleoperation**		
Name of the functional element	**h-1. Operation and management of mobility service cars**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Mobility service cars**
Overview	**In a traffic environment that is difficult for an automated driving system, an operation manager in a remote location communicates a remote control instruction to the mobile service car based on video information from the mobile service car.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2N**	**Data category/ content of information**	**Message**	**Teleoperation instructions**
	Connection mode	**One-to-one**		**Sensor data**	**Location, speed**
	Control usage	**Teleoperation**		**Rich contents**	**Image captured by on-board cameras**
	Responsiveness	**Required**	**Data amount**		**Large**

x-5. Provision of blind spot information ahead (see-through)

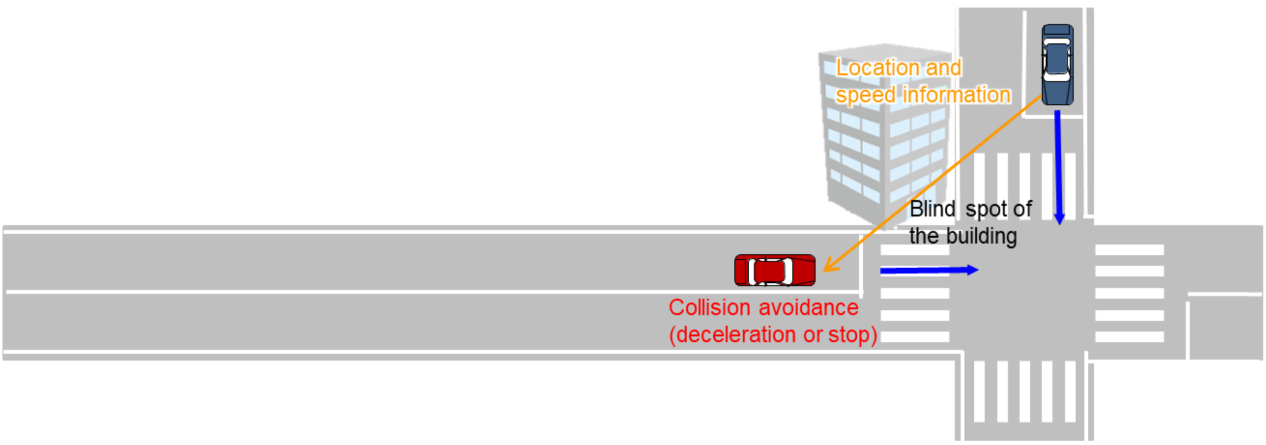
[Editor's note – X-5 has been moved to the main body from Annex 1, and necessary editorial adjustments completed.]

<table>
<tr><td>Name of the functional element</td><td colspan="4">x-5. Provision of blind spot information ahead (see-through)</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways + General roads</td><td>Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="4">The road situation ahead captured by a camera is provided by a vehicle that recorded the image to the following vehicles to assist collision avoidance.</td></tr>
<tr><td>Reason for not considering this functional element</td><td colspan="4">Collision avoidance is possible if the movement of vehicles ahead is detected using on-board sensors.</td></tr>
<tr><td colspan="5">Image of the functional element</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

<table>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Status of traffic congestion</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>–</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, stop</td><td>Rich contents</td><td>Image captured by on-board cameras</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Large</td></tr>
</table>

x-7. Collision avoidance assistance at intersections

[Editor's note – X-7 has been moved to the main body from Annex 1, and necessary editorial adjustments completed.]

<table>
<tr><td>Name of the functional element</td><td colspan="5">x-7. Collision avoidance assistance at intersections</td></tr>
<tr><td>Target areas</td><td colspan="2">General roads</td><td colspan="2">Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="5">Location and speed information is exchanged between vehicles that approach intersections to assist collision avoidance.</td></tr>
<tr><td>Reason for not considering this functional element</td><td colspan="5">Driving is possible by complying with the laws and regulations related to road traffic.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>–</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Location, speed</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, stop, right and left turns</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

6.4.2.4 Functional elements that are not considered

Functional elements that do not meet the principles for examining the connected automated vehicles in Section 6.4.2.1 and those that are integrated with other functional elements were not considered. However, this report decides to retain these functional elements as a reference when needed to review in the future. The diagram of these elements is shown in Annex 1 of this Report.

1) Overview of functional elements that are not considered

Name of the functional element	Overview
x-1. Driving assistance based on traffic signal information before a tunnel	Current traffic signal color information, etc. transmitted by a traffic signal before a tunnel is provided by the infrastructure to vehicles to assist deceleration and stopping.
x-2. Collision avoidance assistance when a vehicle ahead (suddenly) stops or decelerates	Sudden braking information and location and speed information are provided by a vehicle that suddenly decelerates to the following vehicles to assist collision avoidance by stopping or deceleration.
x-3. Collision avoidance assistance when a vehicle ahead changes lanes	Location and speed information is provided by a vehicle that will change lanes to enter the same lane to vehicles on either side to assist collision avoidance.
x-4. Lane change assistance	Location and speed information transmitted by the surrounding vehicles is communicated between vehicles to assist lane change.
x-6. Driving assistance based on lookahead information (notification of speed limit)	Speed limit information (including variable information) is provided by the infrastructure to the surrounding vehicles to assist driving.
x-8. Assistance of entry from non-priority roads to priority roads at unsignalized intersections	At unsignalized intersections, location and speed information is provided by vehicles on the priority roads to vehicles on the non-priority roads to assist driving to enter the priority roads.
x-9. Warning when a bus starts	Location and speed information and the intention of lane change are provided by vehicles that are going to make a left turn ahead of a bus that has stopped, to assist the bus to start safely.
x-10. Driving assistance at an alternating traffic section	In a section that switches from two-way traffic to alternating traffic or in a waiting section for alternating traffic, the location and speed information is communicated between vehicles of both directions to assist driving, such as passing through the alternating traffic section or waiting until oncoming vehicles pass.
x-11. Driving assistance based on pedestrian information	Location and speed information is provided by pedestrians and bicycles to vehicles to assist driving and stopping of vehicles, etc.
x-12. Driving assistance based on streetcar information	Location and speed information is provided by streetcars to the surrounding vehicles to assist driving of the surrounding vehicles.
x-13. Driving assistance based on traffic congestion information (V2V)	Traffic congestion status information is provided by vehicles caught in traffic congestion to the following vehicles to assist the trajectory change.
x-14. Traffic congestion assistance at branches and exits (V2V)	Location and speed information and information about traffic congestion on shoulders are provided by vehicles caught in traffic congestion to the following vehicles on the main lane to assist entry to branches.

6. 5 Summary of the radiocommunication requirements to meet the CAV functionalities

Each of the functional elements of the use cases can be broken down into a group of individual functional elements. Some of such elements are commonly used in multiple use cases. For examples, assistance for merging or lane change would be activated in the situation during Urban Driving and Maneuver Coordination / Cooperative Driving / Advanced Driving.

This report develops a list of functional elements for the Connected Automated Vehicles as a basis for identifying radiocommunication requirements in Table XX.

*[Editor's note (Japan): Some parameters or the elements of them which are used to calculate "**Table X Minimum Spectrum needs for different message types for direct, V2X communication**" in Section 8.2 need to be inserted in the Table XX below to derive spectrum needs in Chapter 8, e.g. CAM, DENM, SPATEM , VAM, PCM, CPM(Collective Perception Message) and MCM(Maneuuver Coordination Message)]*

TABLE XX

Functional elements of radiocommunication for CAV

Functional element	Description	Type of communication	Transmission Interval	Message Size	Bit Rate	Transmission Latency
Merging/lane change assistance (a)	- Merging assistance by preliminary acceleration and deceleration - Merging assistance by targeting the gap on the main lane	V2I(Multicast)	[100 ms]	[100 kB]	[XXX kbps]	[100 ms]
	- Cooperative merging assistance with vehicles on the main lane by roadside control - Merging assistance based on negotiations between vehicles - Lane change assistance when the traffic is heavy - Entry assistance from non-priority roads to priority roads during traffic congestion	V2I(Multicast), V2V(Multicast), V2V(Unicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Traffic signal information (b)	- Driving assistance by using traffic signal information	V2I(Multicast), V2N(Multicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Lookahead information: collision avoidance (c)	- Collision avoidance assistance when a vehicle ahead stops or decelerates suddenly - Driving assistance based on intersection information - Collision avoidance assistance by using hazard information	V2V(Multicast), V2I(Multicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Lookahead information: trajectory change (d)	- Driving assistance by notification of abnormal vehicles - Driving assistance by notification of wrong-way vehicles - Driving assistance based on traffic congestion information - Traffic congestion assistance at branches and exits - Driving assistance based on hazard information	V2I(Multicast), V2N(Multicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]

Functional element	Description	Type of communication	Transmission Interval	Message Size	Bit Rate	Transmission Latency
Lookahead information: emergency vehicle notification (e)	- Driving assistance based on emergency vehicle information - Collection of information to optimize the traffic flow	V2V(Multicast), V2I(Multicast), V2N(Multicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Information collection/ distribution by infrastructure (f)	- Request for rescue (e-Call) - Update and automatic generation of maps - Distribution of dynamic map information	V2I(Multicast), V2N(Unicast) V2N(Multicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Platooning/ adaptive cruise control (g)	- Unmanned platooning of following vehicles by electronic towbar - Adaptive cruise control and manned platooning of following vehicles using adaptive cruise control	V2V(Multicast), V2V(Unicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]
Teleoperation (h)	- Operation and management of mobility service cars	V2N(Unicast)	[T.B.D.]	[T.B.D.]	[T.B.D.]	[T.B.D.]

[Editor's note: need to consider terminology multicast vs broadcast for V2V and V2I; related to comment on communication mode, reference to definition in the main body of the test – request contributions for November meeting]

7 Radiocommunication systems that support CAV

[IAFI Note: This section may be better organized with separate sub-sections 7.1 and 7.2 for the different families of technologies IEEE and 3GPP. They can describe both current specifications and the under-development specifications.]

Wireless communication technologies are on an accelerating innovation cycle. For example, the 3GPP completed Release 16 Stage 3 specifications and froze the related ASN.1 in June 2020, incorporating the New Radio access technology, which is meant to satisfy the IMT-2020 performance requirements. In addition, 3GPP is currently working on Release 17, and intends to complete Release [17 by February 2022] [Note this needs to be checked & changed to Q3-22]. In Release 17, 3GPP intends to extend the flexibility of the cellular technologies into an expanding number of vertical industries. For ad hoc technologies based on 3GPP technology such as LTE-V2X and 5G-NR V2X, it is still unclear if all CAV requirements as listed above are fulfilled since deployment has not started with the former and the latter has just been approved. Independent results from large field tests or pilots are missing.

IEEE 802.11p supports already today CAV requirements especially in terms of latency. Draft IEEE 802.11bd will enhance the robustness of the physical layer thereby increasing the reliability at longer distances (the information horizon will increase for the automated vehicle). IEEE 802.11p supports a latency below [1 ms[18]] [Note: This needs to be checked and confirmed].

The IEEE 802.11p based ITS-G5 and WAVE communication technologies support the required performance criteria for CAV applications. This is now proven with Collective Perception and

[18] Y. Y. Nasrallah, I. Al-Anbagi, H. T. Mouftah, "A realistic analytical model of IEEE 802.11p for wireless access in vehicular networks," in Proceedings of IEEE 2014 International Conference on Connected Vehicles and Expo (ICCVE).

Maneuver Coordination Services which are successfully tested for CAV with IEEE 802.11p based ITS-G5 in IMAGinE[19] [x].

This Report will provide further details of capabilities, technical demands and operational characteristics associated with C-V2X using the terrestrial component of IMT systems, as these capabilities become better known.

[Editor's note (J): The following texts are moved from Section 6.3.]

The 3GPP Release 16 specifications are designed to support four categories of advanced use cases, including fully automated driving vehicle scenarios. These categories are:

– Vehicles Platooning – enables the vehicles to dynamically form a group travelling together.

– Extended Sensors – enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers.

– Advanced Driving – enables semi-automated or fully automated driving.

– Remote Driving – enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments.

All of the advanced use case categories described above require ubiquitous, highly reliable, low-latency wireless communications. Key performance indicators for these use cases were developed and used to guide the design of the 3GPP Release 16 capabilities. However, there are additional advanced use cases emerging for automated driving, for which communication requirements have not yet been developed. These requirements are expected to become better defined during the next two or three years as the developments in both technology and regulation become better understood for Level 5 automated driving.

The IEEE has initiated IEEE P802.11-Task Group BD - "Enhancements for Next Generation V2X"[20] which includes "Automated Driving Support" and Sensor Sharing" use cases, as well as the "Basic Safety" use cases currently supported by IEEE 802.11 and IEEE 1609.x WAVE standards. The IEEE 802.11bd standard is planned for completion by the middle of 2022.

Regarding V2N cellular connectivity, CAVs are more in need of better coverage of existing deployment of 4G networks then 5G and better cross-border/cross-operator functionality. OEMs design CAVs for surviving without network coverage.

[19] Research project IMAGinE; https://imagine-online.de/en/home/ - The IMAGinE (Intelligent Maneuver Automation – cooperative hazard avoidance in realtime) project is developing innovative driving assistance systems for cooperative driving. Cooperative driving refers to road traffic behaviour in which road users cooperatively plan and execute driving maneuvers. Individual driving behaviour is coordinated with other road users and the overall traffic situation based on automatic information exchange between vehicles and infrastructure. Critical situations can be avoided or mitigated, thereby making driving safer and more efficient.

[20] http://www.ieee802.org/11/Reports/tgbd_update.htm.

8 Spectrum needs for CAV radiocommunication

8.1 Suitable frequency bands

Recommended spectrum for global and regional harmonization of ITS wireless communication was included in Recommendation ITU-R M.2121-0 (01/2019) - Harmonization of frequency bands for Intelligent Transport Systems in the mobile service. However, this Recommendation does not directly address emerging automated driving use cases. The spectrum needs for automated driving are expected to be further clarified as CAV developments and resulting communication requirements become better known.

Spectrum other than that previously recommended for ITS may be desirable for CAV communications. For example, it may be possible that platooning and/or other very close range cooperative maneuvering communications could best be effectively supported in EHF (30-300 GHz) bands. Laboratory experimentation and field test results becoming available during this ITU-R study period are likely to identify suitable frequency bands, if any, for these types of communication, which could be specifically used for CAV use cases.

8.2 Spectrum bandwidth needed

Currently, the Basic Safety use cases for CVs are supported by the spectrum as described in Recommendation ITU-R M. 2121-0. CAVs need to be interoperable with CVs for the Basic Safety use cases; however, different spectrum may be needed to support CAV-specific use cases. One of the initial major considerations to answer Question ITU-R 261/5 is to determine the spectrum needs for CAV Radiocommunication, including suitable bands and spectrum bandwidth needed.

CAVs require spectrum dedicated to safety-related communication. Spectrum may need to be physically uncorrelated to provide fully redundant communication conditions. Tables 1 (1A, 1B &1C) summarizes spectrum needs for CAV direct communication. Table 1 does not address the spectrum needs for cellular network connectivity such as 4G/5G, which is subject to another spectrum regime.

In the process of spectrum bandwidth needed calculation, the variety of vehicle density and traffic conditions in different regions and countries should be considered, which will lead to different spectrum needs. Table 1 only represents the potential spectrum needs for CAVs in specific regions and countries. [Therefore, China opposes the proposal of 70 MHz spectrum band demand for CAV in the 5.9 GHz band.]

[Editor's note: contributions to the November 2021 WP5A meeting are requested to clarify regional plans and spectrum requirements for CAV. The following table should reflect regional and countries views as necessary, comments suggested the possibility to split this table into regional or country plans, etc.]

[IAFI Note: it is proposed to split Table 1 into 1A, 1B and 1C each for the three proposed bands

TABLE 1A

Current and future spectrum needs for CAVs in 5.9 GHz band

Frequency band	Status/description	Current availability	CAV current & foreseen Spectrum needs
5.9 GHz	Main spectrum today for deployment of road traffic safety and efficiency applications	5.9 GHz band (5850/5855-5925 MHz)is recommended for evolving ITS needs (see Recommendation ITU-R M.2121); and 70-75 MHz of bandwidth is allocated in several parts of the world (see Report ITU-R M.2444)	[Region 1 - As a minimum 70 MHz of spectrum is required for CAVs, see table x in present document, around 140 MHz is required as a typical need]
Regional and Country notes on use of 5.9 GHz band for CAV:			

TABLE 1B

Current and future spectrum needs for CAVs in mm Wave bands

Frequency band	Status/description	Current availability	CAV current & future Spectrum needs
mmWave	Short-range, high-capacity and low-latency communication potentially combined with radio location capabilities	Europe has an allocation of mmWave for ITS at 60 GHz	[At least 2 GHz bandwidth is needed for enabling high transfer rates]
Regional and Country notes on use of mmWave bands for CAV:			

TABLE 1C

Current and future spectrum needs for CAVs in bands below 1 GHz

Frequency band	Status/description	Current availability	CAV current & foreseen Spectrum needs
< 1 GHz	For long range strategic control information between CAVs, redundant communication channel to enable certain functional safety levels	Japan has an allocation at 760 MHz band for road traffic safety	[At least 10 MHz]
Regional and Country notes on use of <1 GHz band for CAV:			

70 MHz spectrum band for transportation safety

A spectrum study[21] (2020) shows that deployed as well as planned applications for increasing road traffic safety towards cooperative automated driving may consume more than 70 MHz. This study only takes the applications' needs of bandwidth in MHz into account and it is communication technology agnostic. Table 2 summarizes the results of this study by tabulating different message types and their spectrum needs in MHz given three different scenarios (urban intersection, suburban intersection, highway fast traffic). The results show that the 7x10 MHz channels are required for existing and planned safety applications, thus preserved spectrum is a necessity.

Table 2 also explains the different message types found in Table 3, which are already well defined and specified in standardization bodies, such as ETSI.

*[Editor's note (Japan): Some parameters or the elements of them which are used to calculate **Table 2 "Minimum Spectrum needs for different message types for direct, V2X communication"** below need to be inserted in the Table XX in **Section 6.5 "Summary of the radiocommunication requirements to meet the CAV functionalities"**, to derive spectrum needs in Chapter 8, e.g. CAM, DENM, SPATEM , VAM, PCM, CPM(Collective Perception Message) and MCM(Maneuver Coordination Message), which are listed below;]*

TABLE 2

Minimum Spectrum needs for different message types for direct, V2X communication

Spectrum Need (MHz).

message type	urban	suburban	Highway
CAM cooperative awareness message	9	10	10
DENM decentralized environmental notification message	4	2	1
SPATEM signal phase and timing**, MAPEM** road/lane topology and traffic maneuver **, IVI** in-vehicle-information and other I2V messages	1	1	1
VAM VRU awareness message	4	0.2	2
PCM platooning control message	3	6	10
CPM collective perception message	23	26	24
MCM maneuver coordination message	23	26	24
Minimum basic spectrum needs in MHz	**67**	**72**	**72**
total number of 10 MHz channels required	**7**	**7**	**7**

Applications based on V2X communication are introduced in steps, where so-called day one scenarios increasing the information horizon for the driver are introduced first. Day one scenarios or basic safety applications are intended to inform the driver about impending dangerous situation and the driver needs to react accordingly. Day two scenarios intend to increase the information horizon for the vehicle and day-two applications involve for example truck platooning and cooperative adaptive cruise control (CACC).

Figure 1 shows the roadmap C2C-CC has developed to plan for reaching true cooperative automated driving with reduced number of accidents, increased road traffic efficiency with decreased

[21] CAR-2-CAR Communication Consortium Spectrum Study: "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"

environmental footprint. The roadmap shows V2X applications starting with awareness driving over sensing driving with CPM towards higher levels of cooperative automation including the message types MCM and PCM detailed in Table 2, three phases of V2X deployment:

– awareness driving (day-1) (BSM, I2V, PSM),
– sensing driving (CPM),
– cooperative automated driving (MCM, PCM).

TABLE 3

Explanation of different message types

Phases of V2X application roadmap Error! Bookmark not defined.	**Message types**[22]			**Examples of applications based on the message types**
	Europe	**USA**	**Abbreviations explained**	
Awareness driving	CAM, DENM	BSM	Cooperative Awareness message, Decentralized Environmental Notification Message, Basic Safety Message	Intersection Collision Warning Emergency Vehicle Warning Dangerous Situation Warning Stationary Vehicle Warning Traffic Jam warning Pre-/Postcrash Warning
	SPaT, MAP, IVI	SPaT, MAP, IVI	Signal Phase and Time, MAP message, In-Vehicle-Information message	Enabling Infrastructure-to-Vehicle Communication at e.g. traffic lights
	VAM	PSM	VRU Awareness Message, Personal Safety Message	VRU warning for (C-ITS) equipped Vulnerable Road Users

[22] CAM, Cooperative Awareness Message, specified in ETSI EN 302 637-2

DENM, Decentralized Environmental Notification Message, specified in ETSI EN 302 637-3

SPATEM, Signal, Phase, and Timing, ISO/TS 19091:2017

MAPEM, road/lane topology and traffic maneuver ISO/TS 19091:2017

VAM, Vulnerable Road User (VRU) Awareness Message ETSI TS 103 300-3, Pedestrian protection with Personal Safety Messages (PSM) according to SAE J2735, SAE J2945/9_201703 https://www.sae.org/standards/content/j2945/9_201703/

PCM, Platooning Control Message draft specification in ETSI TR 103 298, currently being drafted in the European H2020 project ENSEMBLE (multi-brand truck platooning) https://platooningensemble.eu/

https://platooningensemble.eu/news/using-its-g5-for-efficient-truck-platooning5c1a203e7a226

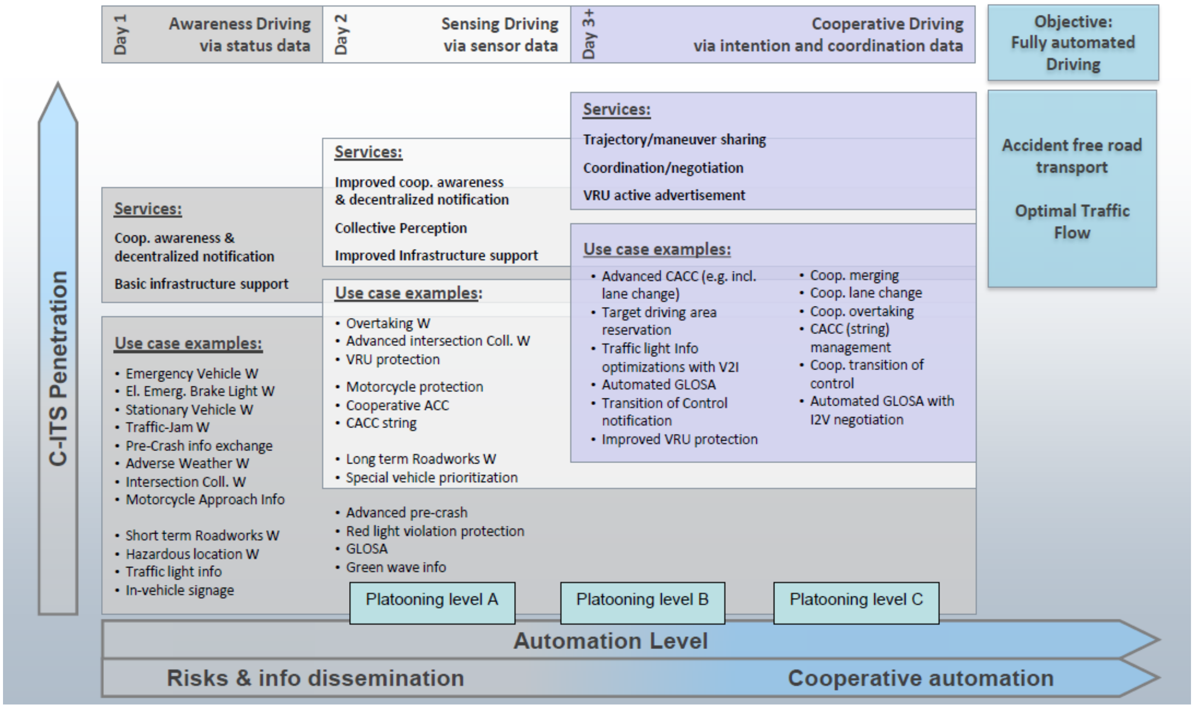
CPM Collective Perception Message, draft ETSI TS 103 324, ETSI TR 103 562

MCM Manoeuvre Coordination Message, according to ETSI TR 103 578 (draft) “Informative report for the Manoeuvre Coordination Service”; https://imagine-online.de/en/home/

Phases of V2X application roadmap Error! Bookmark not defined.	**Message types**[22]			**Examples of applications based on the message types**
	Europe	**USA**	**Abbreviations explained**	
Sensing Driving / sensor sharing	CPM	CPM	Collective Perception Message	Overtaking Warning Extended Intersection Collision Warning Vulnerable Road User Warning for non-equipped VRU´s Cooperative Adaptive Cruise Control Long-term Road Works Warning Special Vehicle Prioritisation
Cooperative Driving with Coordinated maneuvering and cooperative automated driving	MCM, PCM	MCM, PCM	Maneuver Coordination Message, Platooning Control Message	(Static or dynamic) Platooning Area reservation Cooperative Merging Cooperative Lane Change Cooperative Overtaking

FIGURE 1

C2C-CC roadmap for V2X application[23]



23 Source C2C-CC: https://www.car-2-car.org/fileadmin/downloads/PDFs/roadmap/CAR2CAR_Roadmap_Nov_2018.pdf

The following study[24] (see Table 3) details the spectrum needs for CPM and MCM:

The parameters to calculate the spectrum needs were briefly described in the study. Each parameter can vary to some degree within a certain range. Only the lower end for parameters in the numerator of the spectrum calculation formula, and only the higher end for parameters in the denominator of the spectrum calculation formula, were chosen to calculate the spectrum needs (see last column), which means that the spectrum needs shown are the minimum requirements to enable these CPM and MCM live-saving applications. For CAV it is recommended to choose at least the typical instead of the minimum values of the following parameters, because all values between best and worst case can occur in realistic scenarios.

TABLE 3

CPM (Collective Perception Message)		**Min = current parameter setting**	**Max = future estimation**	**Typical parameter setting**
Packet Size (Including security, payload, overhead) in Bytes	Message size changes depending on number of detected objects, including vehicles, pedestrians, cyclists, all seen by the in-vehicle-perception sensors such as cameras and radars	1000	1900	1450
Periodicity in Hz	Dynamic, up to 10 Hz			
Periodicity	In Urban	3	5	4
Periodicity	In Suburban	6	10	8
Periodicity	In Highway	10	10	10
Communication range in m				
Communication range	In Urban	150	300	225
Communication range	In Suburban	150	500	325
Communication range	In Highway	500	1000	750
ITS stations in communication range				
	In Urban	320	640	480
	In Suburban	180	360	270
	In Highway	100	200	150
Spectrum efficiency		0.55	0.6	0.575
Max allowed channel load		0.6	0.75	0.675
Spectrum efficiency x max allowed channel load		0.33	0.45	0.39
Spectrum needs in MHz:				
CPM	**Urban**	**23**	**108**	**57**
CPM	**Suburban**	**26**	**122**	**65**
CPM	**Highway**	**24**	**68**	**45**

[24] Continental, July 10th 2020, published on US FCC website, https://ecfsapi.fcc.gov/file/10710018216099/Ex-Parte%20-%20July%2010%202020.pdf

MCM (Maneuver Coordination Message)		Min = current parameter setting	Max = future estimation	Typical parameter setting
Packet Size (Including security, payload, overhead) in Bytes	Message size changes depending on number of detected objects, including vehicles, pedestrians, cyclists, all seen by the in-vehicle-perception sensors such as cameras and radars	1000	1300	1150
Periodicity in Hz	Dynamic, up to 10 Hz			
Periodicity	In Urban	3	5	4
Periodicity	In Suburban	6	10	8
Periodicity	In Highway	10	10	10
Communication range in m				
Communication range	In Urban	150	300	225
Communication range	In Suburban	150	500	325
Communication range	In Highway	500	1000	750
ITS stations in communication range				
	In Urban	320	640	480
	In Suburban	180	360	270
	In Highway	100	200	150
Spectrum efficiency		0.55	0.6	0.575
Max allowed channel load		0.6	0.75	0.675
Spectrum efficiency x max allowed channel load		0.33	0.45	0.39
Spectrum needs in MHz:				
MCM	**Urban**	**23**	**74**	**46**
MCM	**Suburban**	**26**	**83**	**51**
MCM	**Highway**	**24**	**46**	**36**

9 Spectrum harmonization

Interoperability is of critical importance for safety-related CAV functions. This is especially true for direct ad hoc wireless communications among CAVs and between CAVs and infrastructure, since these types of communications do not depend upon commercial wireless networks, which have been used in the past to provide limited intermediation among different generations of wireless technologies. Direct safety-related communications, such as Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I), could therefore likely greatly benefit from harmonization of spectrum. This would support interoperability for vehicles and infrastructure among different Administrations and potentially among different Regions.

Specific CAV functions currently developed, or currently in planning stages, and which are likely to benefit from spectrum harmonization, include, for example:

– Basic crash-avoidance vehicle safety,

– Interaction with non CAVs like such as VRUs and non-CAV vehicles,
– Automated platooning and Cooperative Adaptive Cruise Control C-ACC,
– Object sharing with Collective Perception or Cooperative Perception,
– Cooperative Driving with Intent/Trajectory Sharing.

The rationale for inclusion of basic crash-avoidance safety functions in the CAV category, rather than just in the connected vehicle portion of ITS, is that it is important for CAVs to communicate with less-automated connected vehicles at a basic safety level, in addition to the communications required among CAVs to support the more advanced CAV functions. There will always be a mixed traffic scenario containing CAVs, non-CAVs, and VRUs. This has to be taken into account in the definition and specification of required functionalities and applications.

Due to the cross border and cross region nature of road traffic and future automated road traffic, all functions (safety related and road efficiency related) benefit significantly from a world-wide harmonization of designated spectrum resources.

10 Relevant provisions in the Radio Regulations

ITS applications are operated under mobile service allocations in Article **5** of the Radio Regulations. Specific frequency bands harmonized for ITS applications should be used for CAVs as noted in relevant ITU-R texts found in Section 2 of this report.

11 Status of global development on CAV

[Editor's note (J): CAV activities including R&D across the Regions are introduced here. Input contributions are invited to this section.]

11.1 Region 1 – Europe, Africa and Middle East

11.1.1 Europe

[T.B.D.]

11.1.2

[T.B.D.]

11.2 Region 2 – Americas

11.2.1 Canada

[T.B.D.]

Industry initiatives on automated vehicles

Area X.O

Established and operated by Invest Ottawa, Area X.O enables and accelerates the safe and secure development, testing, and application of next generation technologies in smart mobility, autonomy and connectivity for sectors that span telecom; smart agriculture; defense, security, and public safety; unmanned aerial vehicles; and smart cities. This 1 866-acre facility offers:

1 V2X (vehicle-to-everything) testing, validation and demonstration in a four-season climate with temperatures from -39 to +39 degrees Celsius (-102 to +102 degrees Fahrenheit).

2 Integrated test facilities with GPS systems, terrestrial wireless systems, and satellite communication systems; networking infrastructure; cybersecurity solutions; and industry-leading data gathering, analysis and cloud capabilities.

In CAVs and smart mobility, Area X.O enables innovation in:

1 Vehicle-to-Vehicle (V2V) communication applications and systems

2 Vehicle-to-Infrastructure (V2I) technologies and systems

3 Next-generation networks that underpin V2V and V2I innovation and applications

4 Software, hardware, and associated cybersecurity technologies required to integrate these capabilities into automated vehicles and municipal infrastructure

5 CAV operations in inclement weather, including systems that pinpoint the location of hidden objects, cybersecurity, interoperability and use of CAV-generated data

For additional information, please visit www.AreaXO.com and www.investottawa.ca.

11.2.2 United States of America

[T.B.D.]

11.3 Region 3 – Asia-Pacific

11.3.1 China, Peoples Republic of

[T.B.D.]

11.3.2 Japan

SIP-adus Programme in Japan

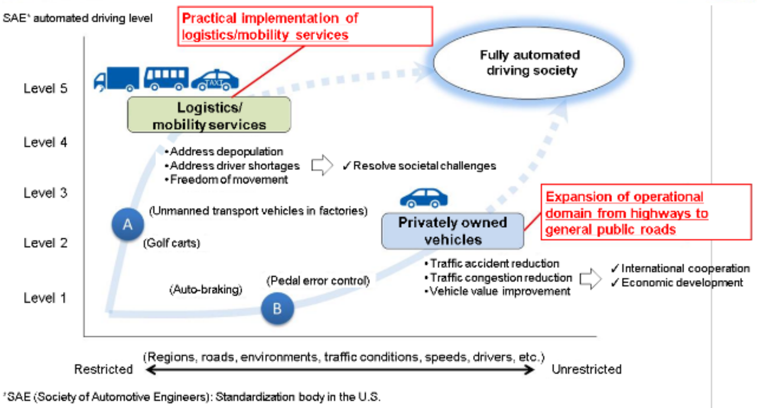
The Government of Japan initiated SIP-adus (SIP[25]'s Automated Driving for Universal Services) programme[26] aiming to solve issues of concern in today's society through realizing automated driving, including reducing traffic accidents, alleviating traffic congestion and securing a means of transportation for people with limited mobility, such as the elderly living in remote regions, among other issues. This programme started in Fiscal Year 2014 and entered its 2nd Phase in Fiscal Year 2018. In the 2nd Phase the scope has been extended to include automated driving on general public roads and application to logistics and transportation services, as shown in Figure SIP.

[25] SIP stands for The Cross-Ministerial Strategic Innovation Promotion Program (SIP) and is a group of R & D programmes for achieving science, technology and innovation as a result of the Council for Science, Technology and Innovation exercising its headquarters function to accomplish its role in leading science, technology and innovation beyond the framework of government ministries and traditional disciplines. SIP-adus is one of SIP programmes.

[26] For further information, see https://en.sip-adus.go.jp/.

FIGURE SIP

Overview of the 2nd Phase SIP-adus



The programme envisions a scenario for the commercialization and service of fully automated driving by 2025. For this, it has targeted to establish the cooperative areas technologies essential for implementation by 2023 and to create multiple example cases for commercialization through Field Operational Test (FOTs) by involving various businesses and local government.

In October 2019, FOTs started in the Tokyo waterfront city area (general roads and Metropolitan Expressway / Haneda area) with wide participations. The program has undergone testing to provide signal display and change timing information to vehicles, even in environments where recognition is difficult using in-vehicle cameras; to assist vehicles merge onto the main lane of highways; and to operate public transport system (self-driving buses) by using automated driving technology in mixed traffic flow.

Under SIP-adus programme, a study was conducted regarding cooperative driving automation and advanced safety driver assistance. Firstly, in the study, as many use cases as possible were collected from projects in Europe, the United States and Asia, including those studied by the Japan Automobile Manufacturers Association, Inc. (JAMA). The use cases collected varied in terms of the expected time frame of the launch. Instead of securing all the use cases, the study decided to focus on those cases with certain assumptions. Firstly, the study assumed that all traffic participants would comply with the law and regulations in principle. Secondly, the study excluded from the scope, functional elements that can be realized by autonomous automatic driving systems. Lastly, three features were taken into account as those that characterize cooperative automated vehicles: that vehicles 1) obtain information beyond the detection range of on-board sensors, 2) provide information of one's own vehicle, and 3) interact with other vehicles or infrastructure with V2V and V2I connectivity. Consequently, eight (8) functional elements of use cases are selected for consideration. In September 2020, the results of this study were documented as the first output[27]. Based on the results, the study is now moving to the next phase on the subject of communication technology requirements and new communication protocols.

11.3.2 Korea, Republic of

[T.B.D.]

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[27] https://en.sip-adus.go.jp/rd/rddata/usecase.pdf.

12 References

[Editor's note (J): References need to be renumbered when finalizing this document.]

[1] TTAK.KO-06.0487, "Vehicle Communication for Connected Automated Driving Stage 1: Requirement, June, 2019.

[2] TTAK.KO-06.0505, "Vehicle Communication for Connected Automated Driving Stage 2: Architecture, December, 2019.

[3] 3GPP TS 22.185, "Service Requirements for V2X services; Stage 1(Rel.15)", June, 2018.

[4] 3GPP TS 22.186, "Enhancement of 3GPP support for V2X scenarios; Stage 1(Rel.16)", June, 2019.

[5] 3GPP TR 22.886, "Study on enhancement of 3GPP Support for 5G V2X Services (Rel.16)", December 2018.

TS 22.185: Service requirements for V2X services: https://www.3gpp.org/DynaReport/22185.htm

TS 22.186: Service requirements for enhanced V2X scenarios: https://www.3gpp.org/DynaReport/22186.htm

TS 23.285: Architecture enhancements for V2X services: https://www.3gpp.org/DynaReport/23285.htm

TS 23.287: Architecture enhancements for 5G System (5GS) to support Vehicle-to-Everything (V2X) services: https://www.3gpp.org/DynaReport/23287.htm

TS 23.286: Application layer support for Vehicle-to-Everything (V2X) services; Functional architecture and information flows: https://www.3gpp.org/DynaReport/23286.htm

TR 37.985: Overall description of Radio Access Network (RAN) aspects for Vehicle-to-everything (V2X) based on LTE and NR: https://www.3gpp.org/DynaReport/37985.htm

TS 36.300: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2: https://www.3gpp.org/DynaReport/36300.htm

TS 38.300: NR; NR and NG-RAN Overall description; Stage-2: https://www.3gpp.org/DynaReport/38300.htm

– T-200111 TR C-V2X Use Cases and Service Level Requirements Vol I V3.0

– "Study of spectrum needs for safety related intelligent transportation systems – day 1 and advanced use cases" relates to Question 6 and provides an analysis on spectrum requirements for the implementation of ITS services.

– “A Visionary Roadmap for Advanced Driving Use Cases, Connectivity Technologies, and Radio Spectrum Needs” relates to Question 3 and introduces a timeline related to identified Use Cases.

– “White Paper C-V2X Use Cases Volume II: Examples and Service Level Requirements” and Technical Report “C-V2X Use Cases and Service Level Requirements Volume I” relate to Question 3 and detail Use Cases and related requirements.

– ETSI GS MEC 030 V2.1.1 (2020-04), “Multi-access Edge Computing (MEC); V2X Information Service API”, Link: https://www.etsi.org/deliver/etsi_gs/MEC/001_099/030/02.01.01_60/gs_MEC030v020101p.pdf

[Editor’s note: The material from ETSI ERM TGSRR in Document 5A/142 contains information on vehicular radar sensors which may be pertinent for CAVs.]

[Editor’s note (J): References for Section 6.3 Use Cases.]

[MY2019] M. Mikami and H. Yoshino, “Field Trial on 5G Low Latency Radio Communication System Towards Application to Truck Platooning,” pp. 1447-1457, IEICE Transactions on Communications Vol.E102-B, No.8, Aug. 2019.

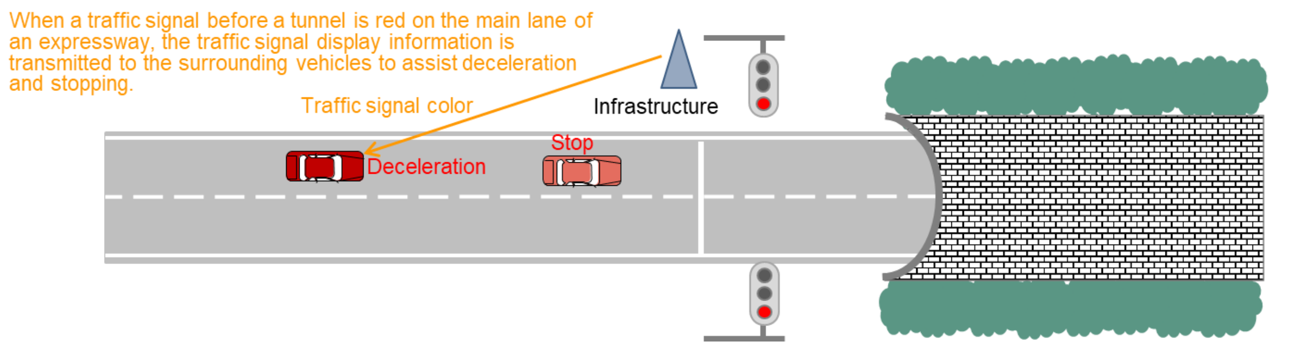
[A2013] K. Aoki, “Current Activities of Development on the Automated Truck Platoon,” pp. 303-309, IPSJ Journal, Vol. 54 No. 4, Apr. 2013 (in Japanese).

ANNEX 1

The functional elements that are not considered

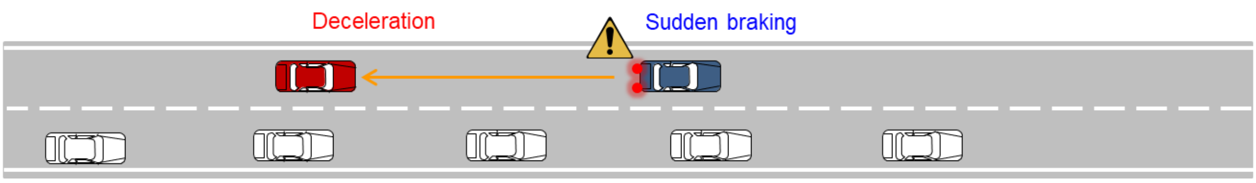
[Editor's note: Added text about why these are listed here and reference to SIP document contributions to the November meeting are requested.]

x-1. Driving assistance based on traffic signal information before a tunnel

<table>
<tr><td>Name of the functional element</td><td colspan="5">x-1. Driving assistance based on traffic signal information before a tunnel</td></tr>
<tr><td>Target areas</td><td colspan="2">Expressways</td><td colspan="2">Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="5">Current traffic signal color information, etc. transmitted by a traffic signal before a tunnel is provided by the infrastructure to vehicles to assist deceleration and stopping.</td></tr>
<tr><td>Reason for not considering this functional element</td><td colspan="5">This functional element is similar to driving assistance by using traffic signal information on general roads. Thus, it was integrated into b-1-1.</td></tr>
<tr><td colspan="6">Image of the functional element</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2I</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>Traffic signal color</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>–</td></tr>
<tr><td>Control usage</td><td>Speed adjustment, stop</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

x-2. Collision avoidance assistance when a vehicle ahead (suddenly) stops or decelerates

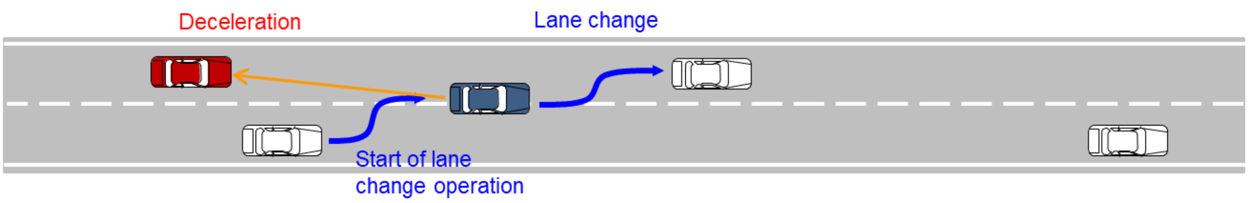
Name of the functional element	**x-2. Collision avoidance assistance when a vehicle ahead (suddenly) stops or decelerates**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Sudden braking information and location and speed information are provided by a vehicle that suddenly decelerates to the following vehicles to assist collision avoidance by stopping or deceleration.**		
Reason for not considering this functional element	**Vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Sudden braking information**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-3. Collision avoidance assistance when a vehicle ahead changes lanes

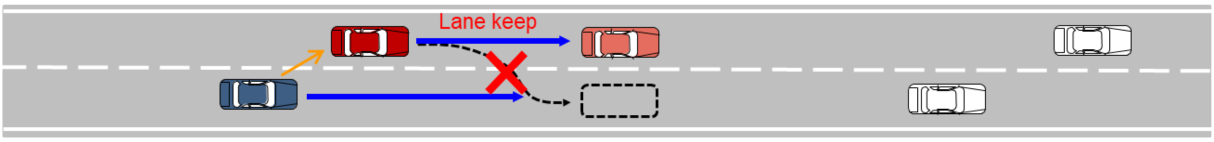
Name of the functional element	**x-3. Collision avoidance assistance when a vehicle ahead changes lanes**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Location and speed information is provided by a vehicle that will change lanes to enter the same lane to vehicles on either side to assist collision avoidance.**		
Reason for not considering this functional element	**Vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-4. Lane change assistance

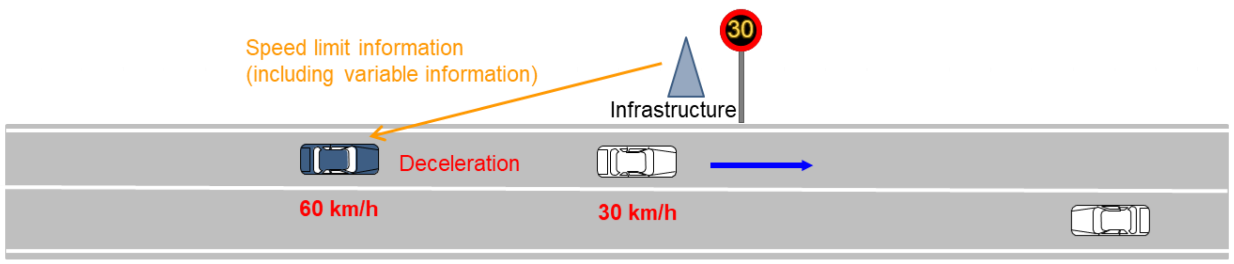
Name of the functional element	**x-4. Lane change assistance**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Location and speed information transmitted by the surrounding vehicles is communicated between vehicles to assist lane change.**		
Reason for not considering this functional element	**Vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**Speed, location**
	Control usage	**Lane change**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-6. Driving assistance based on lookahead information (notification of speed limit)

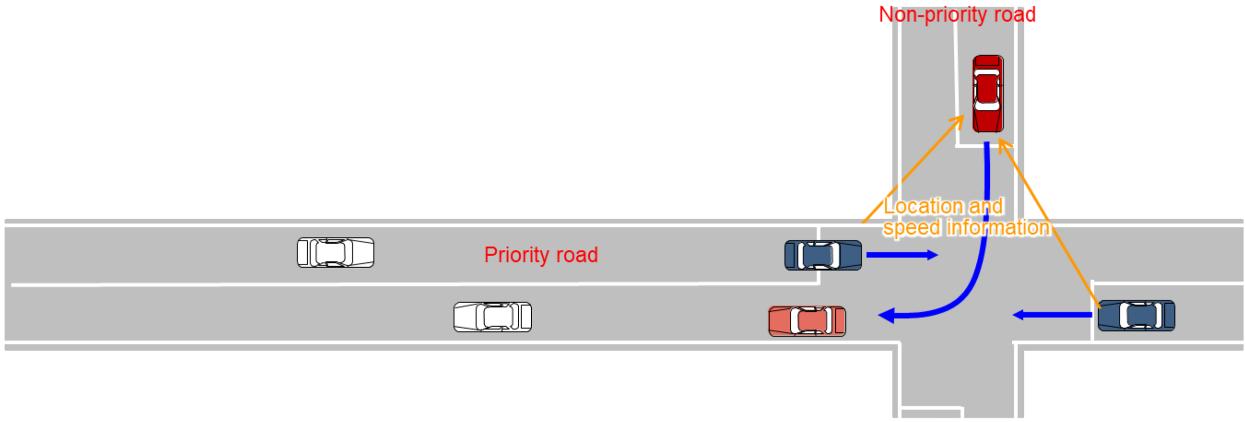
Name of the functional element	**x-6. Driving assistance based on lookahead information (notification of speed limit)**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Speed limit information (including variable information) is provided by the infrastructure to the surrounding vehicles to assist driving.**		
Reason for not considering this functional element	**Information can be obtained using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2I**	**Data category/ content of information**	**Message**	**Speed limit**
	Connection mode	**One-to-many**		**Sensor data**	**–**
	Control usage	**Trajectory change**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

x-8. Assistance of entry from non-priority roads to priority roads at unsignalized intersections

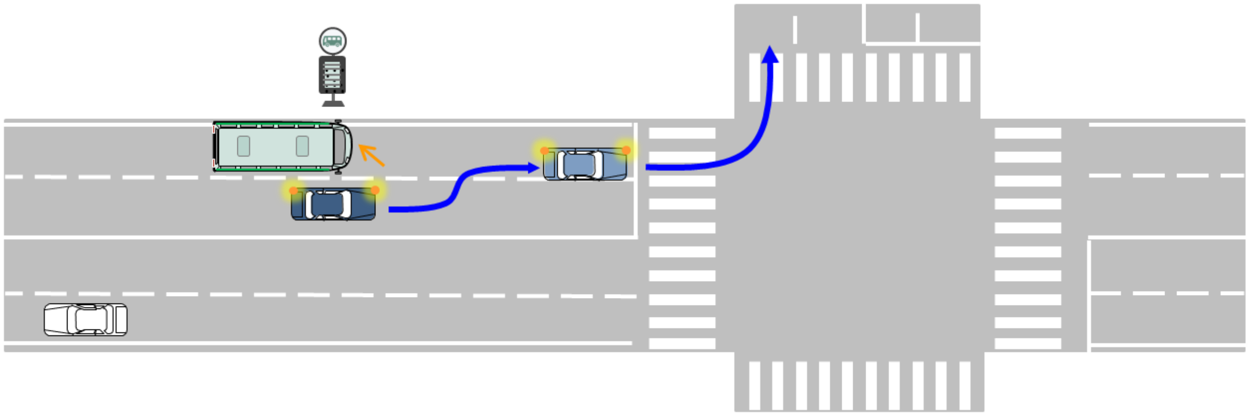
Name of the functional element	**x-8. Assistance of entry from non-priority roads to priority roads at unsignalized intersections**		
Target areas	**General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**At unsignalized intersections, location and speed information is provided by vehicles on the priority roads to vehicles on the non-priority roads to assist driving to enter the priority roads.**		
Reason for not considering this functional element	**Driving is possible by complying with the laws and regulations related to road traffic.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Speed adjustment, stop, right and left turns**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-9. Warning when a bus starts

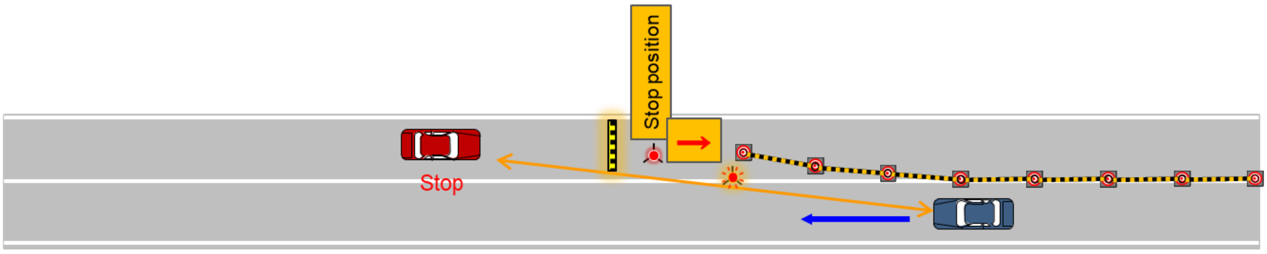
Name of the functional element	**x-9. Warning when a bus starts**		
Target areas	**General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Location and speed information and the intention of lane change are provided by vehicles that are going to make a left turn ahead of a bus that has stopped, to assist the bus to start safely.**		
Reason for not considering this functional element	**Vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Intention of lane change**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Judgment whether the bus can start**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-10. Driving assistance at an alternating traffic section

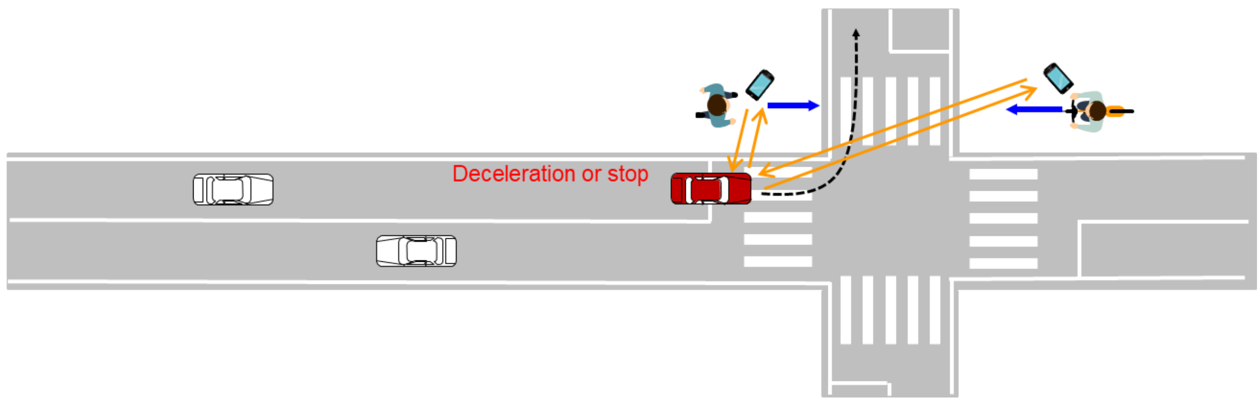
Name of the functional element	**x-10. Driving assistance at an alternating traffic section**		
Target areas	**General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**In a section that switches from two-way traffic to alternating traffic or in a waiting section for alternating traffic, the location and speed information is communicated between vehicles of both directions to assist driving, such as passing through the alternating traffic section or waiting until oncoming vehicles pass.**		
Reason for not considering this functional element	**Driving is possible by complying with the laws and regulations related to road traffic, and vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Judgment whether the vehicle can start**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-11. Driving assistance based on pedestrian information

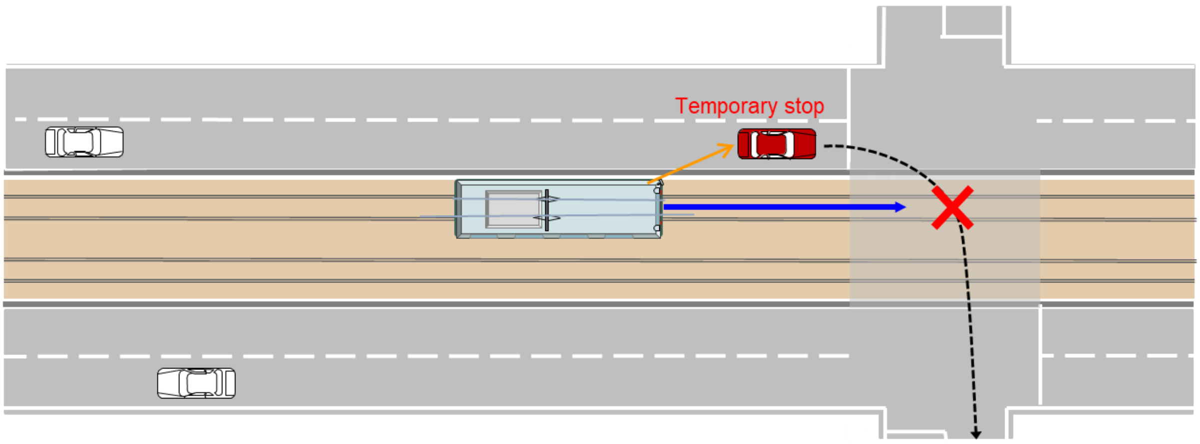
Name of the functional element	**x-11. Driving assistance based on pedestrian information**		
Target areas	**General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Location and speed information is provided by pedestrians and bicycles to vehicles to assist driving and stopping of vehicles, etc.**		
Reason for not considering this functional element	**Vehicle control is possible using on-board sensors.**		
Image of the functional element			



Remarks (communication	**Communication**	**V2P, V2I**	**Data category/ content of**	**Message**	**–**
	Connection mode	**One-to-many**		**Sensor data**	**Location, speed**
	Control usage	**Deceleration, stop, right and left turns**		**Rich contents**	**–**
	Responsiveness	**Required**	**Data amount**		**Small**

x-12. Driving assistance based on streetcar information

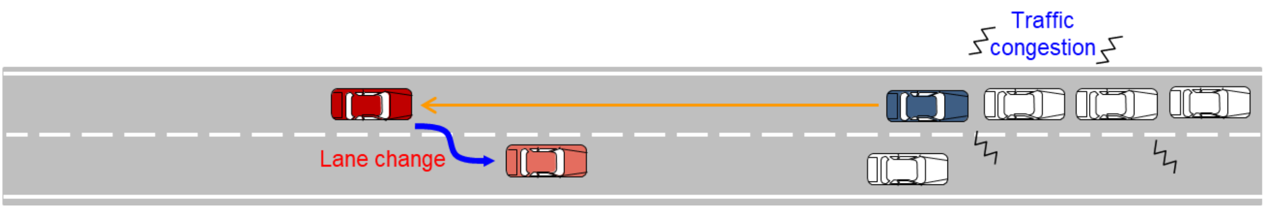
<table>
<tr><td>Name of the functional element</td><td colspan="3">x-12. Driving assistance based on streetcar information</td></tr>
<tr><td>Target areas</td><td>General roads</td><td>Target vehicles</td><td>Privately owned vehicles</td></tr>
<tr><td>Overview</td><td colspan="3">Location and speed information is provided by streetcars to the surrounding vehicles to assist driving of the surrounding vehicles.</td></tr>
<tr><td>Reason for not considering this functional element</td><td colspan="3">Vehicle control is possible using on-board sensors.</td></tr>
<tr><td colspan="4">Image of the functional element</td></tr>
</table>



<table>
<tr><td rowspan="4">Remarks (communication requirements, etc.)</td><td>Communication</td><td>V2V</td><td rowspan="3">Data category/ content of information</td><td>Message</td><td>–</td></tr>
<tr><td>Connection mode</td><td>One-to-many</td><td>Sensor data</td><td>Location, speed</td></tr>
<tr><td>Control usage</td><td>Judgment whether the vehicle can start</td><td>Rich contents</td><td>–</td></tr>
<tr><td>Responsiveness</td><td>Required</td><td colspan="2">Data amount</td><td>Small</td></tr>
</table>

x-13. Driving assistance based on traffic congestion information (V2V)

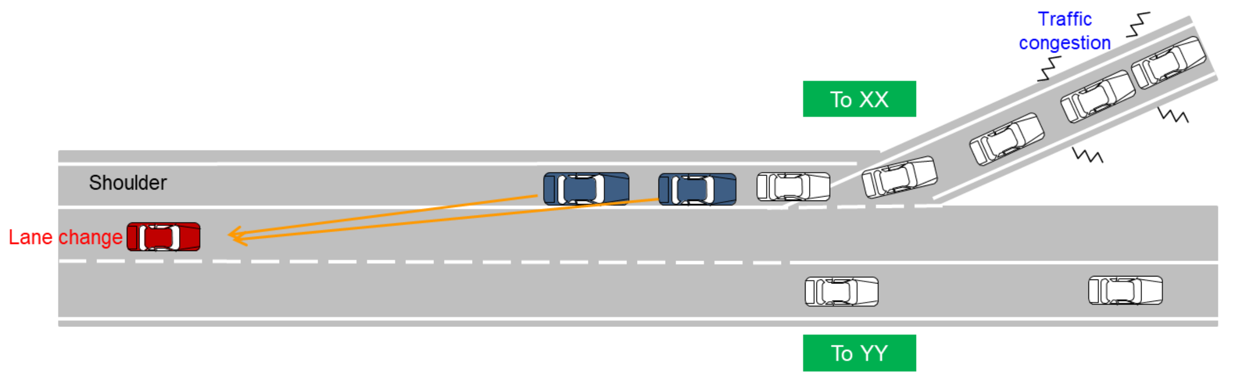
Name of the functional element	**X13. Driving assistance based on traffic congestion information (V2V)**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Traffic congestion status information is provided by vehicles caught in traffic congestion to the following vehicles to assist the trajectory change.**		
Reason for not considering this functional element	**The time margin for avoidance is limited due to short range when information is provided from the tail of a traffic congestion. Thus, this functional element was dropped from those of trajectory change. (It may be regarded as a functional element of collision avoidance, but collision avoidance will be enabled by the functionality of automated driving. Thus, it was also dropped as a functional element of collision avoidance.)**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Status of traffic congestion**
	Connection mode	**One-to-many**		**Sensor data**	**–**
	Control usage	**Trajectory change, speed adjustment, stop**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

x-14. Traffic congestion assistance at branches and exits (V2V)

Name of the functional element	**X14. Traffic congestion assistance at branches and exits (V2V)**		
Target areas	**Expressways + General roads**	**Target vehicles**	**Privately owned vehicles**
Overview	**Location and speed information and information about traffic congestion on shoulders are provided by vehicles caught in traffic congestion to the following vehicles on the main lane to assist entry to branches.**		
Reason for not considering this functional element	**In V2V, the time margin from acquisition of information to stopping at the tail of a traffic congestion queue on the shoulder is limited, and it is difficult to change the trajectory.**		
Image of the functional element			



Remarks (communication requirements, etc.)	**Communication**	**V2V**	**Data category/ content of information**	**Message**	**Status of traffic congestion on shoulders (toward branches)**
	Connection mode	**One-to-many**		**Sensor data**	**Speed, location**
	Control usage	**Speed adjustment, trajectory change**		**Rich contents**	**–**
	Responsiveness	**Not required**	**Data amount**		**Small**

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