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Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Cooperative Adaptive Cruise Control (CACC) system is an enhancement to the Adaptive Cruise Control (ACC) system by the addition of wireless communication with preceding vehicles and/or the infrastructure to augment the ACC active sensing capability. It uses active sensing data such as ranging to forward vehicle, subject vehicle data, over the air data from other surrounding vehicles and from infrastructure, and driver input to longitudinally control the vehicle via throttle and brake controls, and to convey the appropriate CACC status information to the driver (see Figure 1).

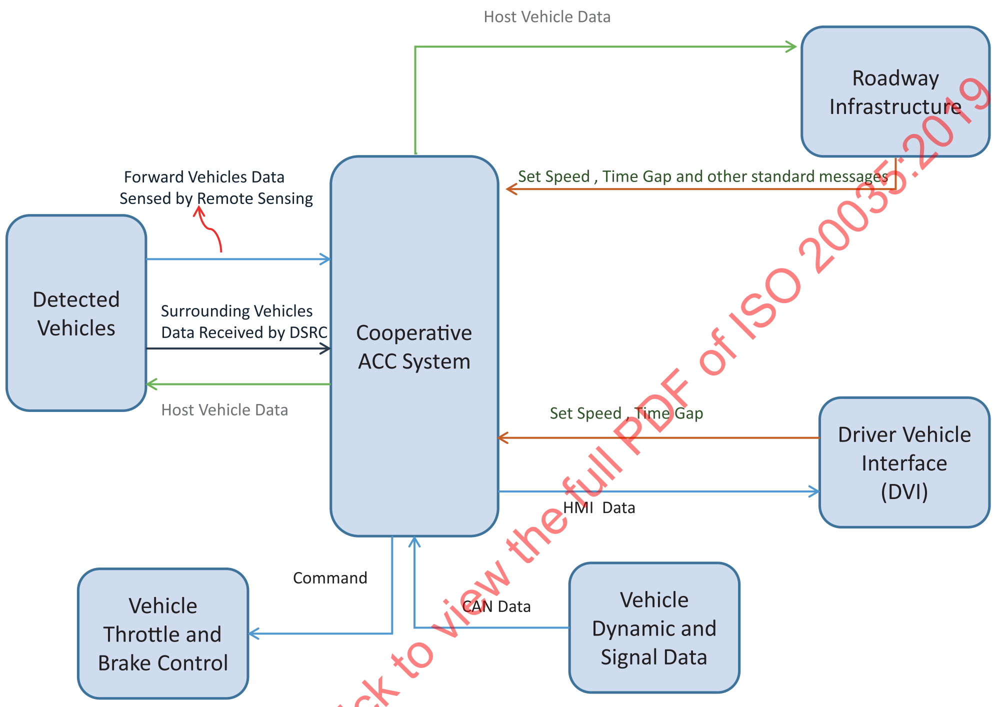

Figure 1 — Functional CACC elements

ACC systems can be made cooperative by adding vehicle-vehicle (V2V) and/or infrastructure-vehicle (I2V) communication capabilities and adjusting the performance of the system to make use of the information received via the communication system, e.g. Dedicated Short Range Communication System (DSRC) (see Figure 2).

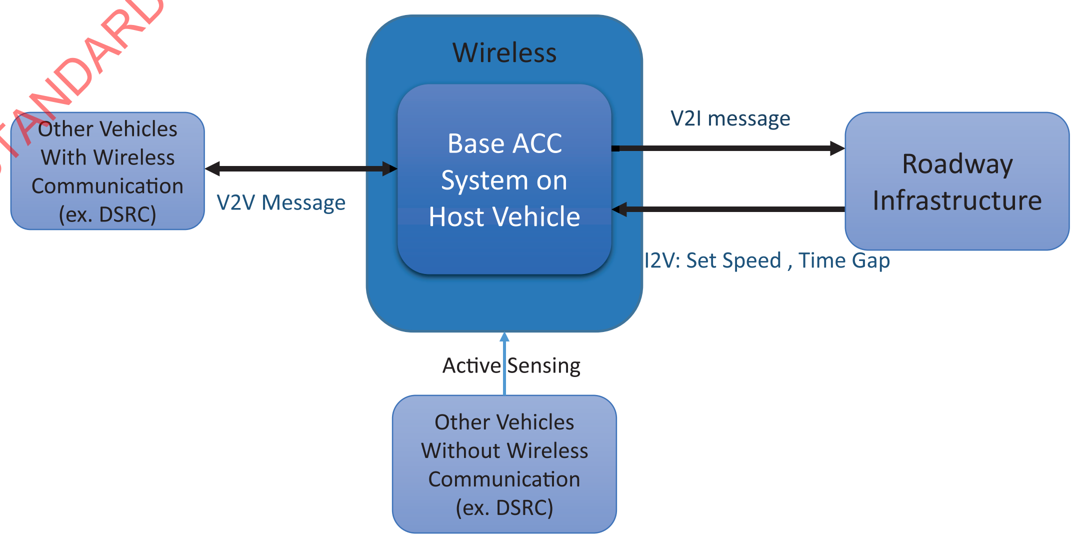

Figure 2 — CACC additions to ACC

The V2V communications can provide the ACC system with frequent updates about the speed, acceleration and commands (throttle and brake) of multiple vehicles driving in the surrounding area of the CACC-equipped vehicle. This enables the following performance improvements over ACC:

— higher-accuracy control of vehicle following gap, while maintaining smooth ride quality;

— significantly faster responses to speed changes by multiple forward vehicles, not only the vehicle immediately ahead of the subject vehicle;

— shorter vehicle-following gap settings, without compromising safety or driver confidence and comfort with the system.

These performance improvements produce the following benefits:

— increased driver confidence in the responsiveness of the system, leading to willingness to select shorter gap settings and use ACC under a wider range of traffic conditions;

— fewer cut-ins at the shorter gaps may make ACC acceptable to a wider range of drivers;

— significant damping of traffic flow disturbances, improving traffic flow dynamics and thereby reducing energy use and emissions;

— significant increase in the effective capacity (throughput) per lane of highway traffic.

The I2V communications can provide the ACC system with inputs from the local traffic management system, which determines the recommended values for set speed and vehicle-following gap. These can be used to enhance the effectiveness of traffic management strategies on limited access highways, where it is possible to determine the speed and gap settings that are likely to maximize the effective capacity of a bottleneck section. When the I2V CACC vehicles follow these recommended values, the overall traffic flow capacity can be optimized with a minimum of active intervention by the vehicle drivers (other than opting in to decide to follow the infrastructure-based guidance). This means that the driver of the subject vehicle gains a smoother trip, with less acceleration and braking and lower energy consumption, and the highway as a whole gains a higher effective capacity, reduced energy consumption and pollution, and reduced traffic delays.

Intelligent transport systems — Cooperative adaptive cruise control systems (CACC) — Performance requirements and test procedures

1 Scope

Cooperative Adaptive Cruise Control (CACC) system is an expansion to existing Adaptive Cruise Control (ACC) control strategy by using wireless communication with preceding vehicles (V2V) and/or the infrastructure (I2V). Both multi vehicle V2V data and I2V infrastructure data are within the scope of this document. When V2V data is used CACC can enable shorter time gaps and more accurate gap control, which can help increase traffic throughput and reduce fuel consumption. It can also receive data from the infrastructure, such as recommended speed and time gap setting, to improve traffic flow and safety.

This document addresses two types of Cooperative Adaptive Cruise Control (CACC): V2V, and I2V. Both types of CACC system require active sensing using for example radar, lidar, or camera systems. The combined V2V and I2V CACC is not addressed in this document. The following requirements are addressed in this document:

— classification of the types of CACC;

— definition of the performance requirements for each CACC type;

— CACC state transitions diagram;

— minimum set of wireless data requirements;

— test procedures.

CACC:

— does only longitudinal vehicle speed control;

— uses time gap control strategy similar to ACC;

— has similar engagement criteria as ACC.

Coordinated strategies to control groups of vehicles, such as platooning, in which vehicle controllers base their control actions on how they affect other vehicles, and may have a very short following clearance gap are not within the scope of this document. CACC system operates under driver responsibility and supervision.

This document is applicable to motor vehicles including light vehicles and heavy vehicles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15622, *Intelligent transport systems — Adaptive cruise control systems — Performance requirements and test procedures*

3 Terms and definitions

For the purpose of this document, the following definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
active brake control
function which causes application of the brake(s), controlled by the CACC system not by the driver

3.2
Adaptive Cruise Control
ACC
enhancement to conventional cruise control systems [see Conventional Cruise Control (3.7)], which allows the subject vehicle to follow a forward vehicle at an appropriate distance proportional to the time gap set by the driver by controlling the engine and/or power train and potentially the brake

3.3
brake
part in which the forces opposing the movement of the vehicle develop and which may be a friction brake (when the forces are generated by friction between two parts of the vehicle moving relatively to one another); an electrical brake (when the forces are generated by electro-magnetic action between two parts of the vehicle moving relatively but not in contact with one another); a fluid brake (when the forces are generated by the action of a fluid situated between two parts of the vehicle moving relatively to one another); or an engine brake (when the forces are derived from an artificial increase in the braking action, transmitted to the wheels, of the engine)

Note 1 to entry: For the purposes of this document, transmission control devices are not considered as brakes.

[SOURCE: UN ECE Regulation 13-H:1998, 2.6]

3.4
CACC system states
operation modes of the system presented in this document as three system states as shown in 6.1.4 and Figure 4

3.5
clearance
distance from the forward vehicle's trailing surface to the subject vehicle's leading surface

3.6
connected vehicle
any vehicle that has a V2X wireless communication system and broadcasts over the air standard message protocol

3.7
conventional cruise control
system capable of controlling the speed of a vehicle as set by the driver

3.8
forward vehicle
vehicle in front of and moving in the same direction and travelling on the same roadway as the subject vehicle

3.9
free-flowing traffic
smooth flowing and heavy traffic excluding stop and go and emergency braking situations

3.10
heavy vehicle category
single vehicle or combination of vehicles defined as Category 1-2 or Category 2 in the United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations (WP.29) TRANS/WP.29/1045

Note 1 to entry: A truck is in the heavy vehicle category.

3.11
Potential Vehicle of Interest
PVOI
connected vehicle that exists in the V2V CACC region of interest, communicates with the subject vehicle, is of possible interest to the longitudinal control, and is not the target vehicle (TV)

3.12
region of interest
ROI
area where PVOI and TV may exist and affect CACC system control operations

3.13
set speed
desired travel speed, set by either the driver or by some control system that is external to the CACC system and which is the maximum desired speed of the vehicle while under CACC control

3.14
stationary object
object in front of the subject vehicle which is stationary

3.15
steady state
condition whereby the value of the described parameter does not change with respect to time, distance, etc.

3.16
subject vehicle
SV
vehicle equipped with the system in question and related to the topic of discussion

3.17
target vehicle
TV
vehicle that the subject vehicle follows which may or may not be equipped with a connected vehicle device

3.18
time gap
τ
value calculated from vehicle speed v and clearance c by $\tau = c/v$

Note 1 to entry: to entry: v is the subject vehicle speed and c the distance between the subject vehicle and the forward vehicle.

4 Symbols and abbreviated terms

A	utilised area, general for area
A_t	illuminated surface
$a_{lateral\_max}$	maximum allowed lateral acceleration in curves

a_{min} minimum allowed longitudinal acceleration = Maximum allowed longitudinal deceleration

a_{max} maximum allowed longitudinal acceleration

a_{test} maximum allowed acceleration during curve test

$a_{vehicle\_max}$ maximum possible deceleration capability during manual driving

CTT coefficient for Test Target for infrared reflectors

c clearance, inter vehicle distance

PVOI Potential Vehicle of Interest

ROI region of interest

TV target vehicle

V2V vehicle to vehicle

v the true subject vehicle speed over ground

τ gap, time gap between vehicles

5 Classification

5.1 Type of CACC systems

Types of CACC are based on the type of the over the air data that may affect the longitudinal control of the vehicle. Two types of CACC systems are addressed in this document: V2V and I2V.

Table 1 — CACC system types

CACC type	Active sensing required	Wireless communication requirement (for example: DSRC is low latency, and 4G is higher latency)	Type of data affecting the longitudinal control
V2V	Yes	Low latency is minimum requirement	V2V over the air data
I2V	Yes	Some data can be broad-cast using higher latency as appropriate to message urgency.	I2V over the air data

5.2 Curve capabilities

This document is applicable to CACC systems of different curve capabilities as specified in ISO 15622.

5.3 Classes of on-board V2X devices

Type A: OEM device that receives and processes vehicle CAN data.

Type B: OEM device that does not receive or process CAN data.

Type C: Non-OEM device that receives and processes CAN data.

Type D: Non OEM device that does not receive or process CAN data.

6 Requirements

6.1 V2V CACC

6.1.1 V2V CACC response

V2V CACC system reacts to V2V over the air data in addition to the active sensing data originated from sensors such as radar or camera.

6.1.2 Region of interest

Region of interest (ROI) is defined for a straight road as in Figure 3. This ROI is 32 m wide and extends from the driver position in the subject vehicle up to 250 m ahead of the subject vehicle and 100 m behind the subject vehicle. The ROI in Figure 3 is illustrated for a straight road. For a curved road, the ROI is to bend itself to follow the curvature of the road.

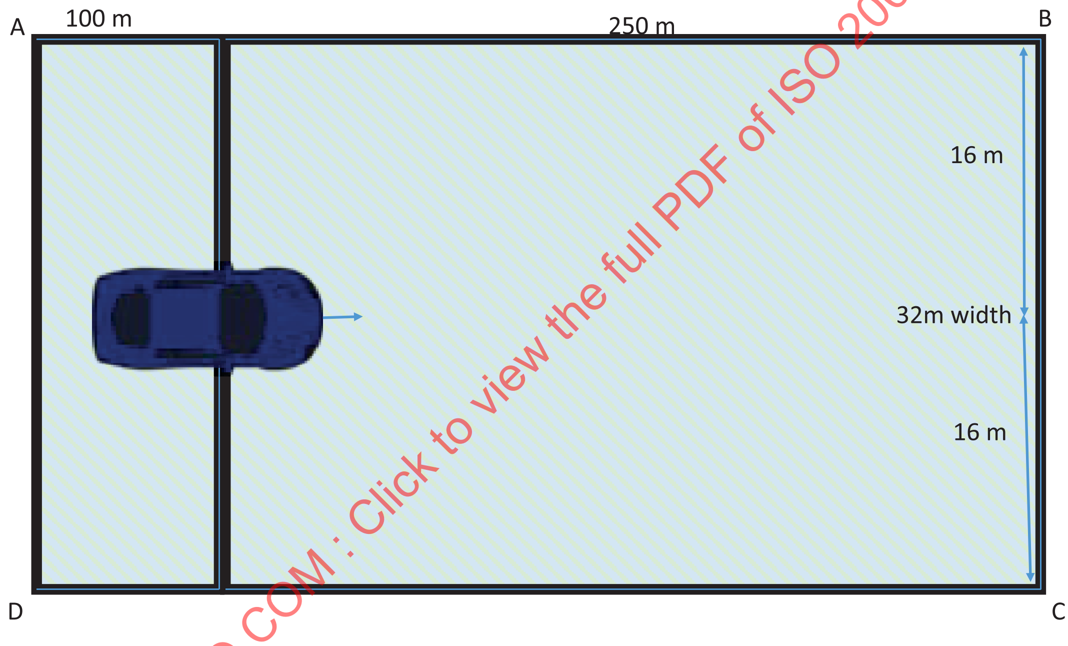

Figure 3 — V2V CACC region of interest

6.1.3 Potential Vehicle of Interest (PVOI)

PVOI is any connected vehicle that exists in the V2V CACC ROI, communicates with the subject vehicle, is of possible interest to the longitudinal control, and is not the target vehicle (TV), e.g. a vehicle that is predicted to merge into the subject vehicle's lane (for illustration please refer to Figure 7). Another example: a vehicle that is braking hard ahead of and in the same lane as the target vehicle (for illustration, please refer to Figure 8). PVOI may have the potential to become a TV.

6.1.4 State transition diagram

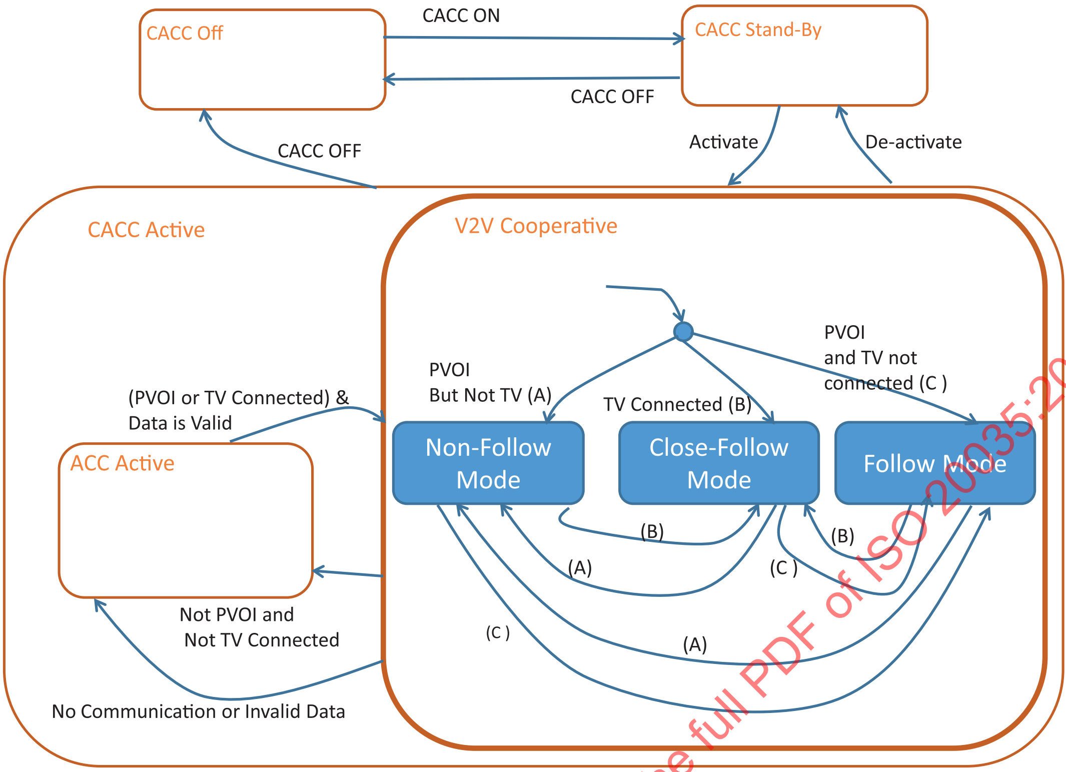

Figure 4 — State transition diagram

The CACC transition diagram in Figure 4 contains the same main ACC states described in ISO 15622, i.e. Off State, Stand-By State and Active State. The CACC active state has two main active states: the ACC Active state which is the same as the ACC active state in ISO 15622, and V2V Cooperative which represents the difference between the conventional ACC transition diagram in ISO 15622 and the CACC state transition diagram described in this document. This state is only reached when a valid connected vehicle data is received from a vehicle that is located in the CACC ROI defined in Figure 3. This V2V Cooperative state contains three child states: Non-Follow, Close-Follow and Follow mode states. The transition between these states depends on the existence of the TV, its connectivity, and also on the PVOI existence in the ROI.

The following is a description of all the states and their transition conditions:

CACC OFF: the CACC Off state operation and transition conditions are the same as the ACC OFF state operation and transition condition described in ISO 15622.

CACC STAND-BY: the STAND-BY state operation and transition conditions are the same as the ACC STAND-BY state operation and transition condition described in ISO 15622.

CACC ACTIVE: the CACC ACTIVE state transition conditions are the same as the ACC ACTIVE state transition condition described ISO 15622. However, the CACC ACTIVE state operates in two different modes. The first mode is the ACC ACTIVE operation which the same as the ACC ACTIVE operation in ISO 15622. The second mode is the V2V Cooperative state operation which allows the vehicle longitudinal control to be influenced by the V2V over the air data.

V2V COOPERATIVE: In this state the vehicle longitudinal control may be influenced by the V2V data. The CACC system transitions to this mode from the ACC Active state when there is a valid over the air data received from a PVOI vehicle or connected TV.

Non-Follow: The Non-Follow mode is operating inside the V2V cooperative state. In this mode, TV does not exist. The vehicle longitudinal control may be affected by the PVOI over the air data.

Close-Follow: The Close-Follow mode is operating inside the V2V cooperative state. In this mode, TV exists and is connected. The vehicle longitudinal control may be influenced by the TV and PVOI over the air data.

Follow: The Follow mode is operating inside the V2V cooperative state. In this mode, TV exists but is not connected. The vehicle longitudinal control may be influenced by PVOI over the air data. The vehicle longitudinal control will be affected by TV active sensing data.

The following are transition conditions among the child states in V2V cooperative state:

Transition A: TV does not exist in the ROI but PVOI does exist in the ROI.

Transition B: TV does exist and it is a connected vehicle. PVOI may exist.

Transition C: TV does exist in the ROI but it is not connected, and PVOI does exist in the ROI.

Valid data shall meet the minimum requirement of the CACC V2V connected vehicle data addressed in 6.1.6.

6.1.5 Control operation strategy

6.1.5.1 Table 2 explains the V2V CACC control requirements.

Table 2 — V2V CACC control requirements

TV exists	TV is connected	PVOI exists	CACC mode	Minimum time gap	Maximum deceleration	Maximum acceleration	CACC control is influenced by over the air data
no	no	no	ACC Active: Cruise	according to ISO 15622	according to ISO 15622	according to ISO 15622	no
yes	no	no	ACC Active: Follow	according to ISO 15622	according to ISO 15622	according to ISO 15622	no
no	no	yes	V2V Cooperative: Non-Follow	according to ISO 15622	according to ISO 15622	according to ISO 15622	yes
yes	yes	no	V2V Cooperative: Close-Follow	0,5 s	5 m/s^2	2,75 m/s^2	yes
yes	yes	yes	V2V Cooperative: Close_Follow	0,5 s	5 m/s^2	2,75 m/s^2	yes
yes	no	yes	V2V Cooperative: Follow	according to ISO 15622	according to ISO 15622	according to ISO 15622	yes

6.1.5.2 The time gap lower limit is 0,5 s.

6.1.5.3 A minimum distance offset shall be added to the Close-Follow mode time gap based clearance according to the following equations:

$$\text{Clearance} = \tau * v_s + d$$

where τ is Close-Follow mode time gap, v_s is the subject vehicle speed, d is the required added minimum offset. The calculation of d shall follow the following formulas:

$$d = 2 \text{ m when } 0 \le v_s < 5 \text{ m/s}$$

$$d = 2 - 0{,}5 * (v_s - 5) \text{ when } 5 \le v_s < 9 \text{ m/s}$$

$$d = 0 \text{ when } v_s \ge 9 \text{ m/s}$$

6.1.5.4 The connected TV must be identified with very high confidence, i.e. for the connected TV to cause transition to the Close-Follow mode, its connected vehicle data received by the subject vehicle has to be adequately correlated with sensor data determined by the subject vehicle active sensing device (such as radar). Adequately correlated shall meet the following criteria:

1) The lane classification of the connected TV is in the subject vehicle lane (classified as in-lane).

2) The connected TV vehicle reported range is within the following distance from the reported sensor range: maximum of [(0,1 × reported sensor range) and the maximum of (0,7 × TV vehicle length and 5 m)].

3) The connected TV reported speed is within 1 m/s from the reported sensor speed.

6.1.5.5 Transition to Close_Follow mode shall not be allowed when connected TV is equipped with Type B or D devices. Transition to Close_Follow mode is allowed when connected TV is equipped with Type A or C devices. Types A, B, C and D devices are described in 5.3.

6.1.5.6 The system may select not to transition to the Close_Follow mode when the connected TV is equipped with Type C device.

6.1.5.7 The driver shall be able to deactivate, at all times, the Close-Follow mode.

6.1.5.8 The driver shall be always informed by the system about the current CACC system mode. HMI and functional implementation shall be left to the manufacturer.

6.1.5.9 CACC system installed in heavy vehicle category is only allowed to transition to the Close-Follow mode when the TV connected vehicle is of similar heavy vehicle category.

6.1.5.10 The driver shall be informed according to ISO 15622 when the CACC system reaches its maximum deceleration capability.

6.1.5.11 If the communication with the TV is disconnected (its connected data is no more received by the subject vehicle) or the TV connected data is not valid data while the vehicle is in close follow mode and braking, the following shall happen: the CACC system continues braking, the CACC system goes to conventional ACC active mode, and the ACC active mode is enabled to use the 5 m/s^2 maximum deceleration capabilities until braking is no more required and the gap becomes greater or equal than 0,8 s (minimum time gap in ACC).

6.1.5.12 If the communication with the TV is disconnected (its connected data is no more received by the subject vehicle) or the TV connected data is not valid data while the vehicle is in close follow mode and is not braking, the following shall happen: the CACC system goes to conventional ACC active mode, and the ACC active should avoid using hard braking to expand the gap back to the original ACC active setting if the relative velocity between the subject vehicle and host vehicle (Target Velocity-Host Velocity) is close to or above zero. This is in an attempt to reduce the possibility of string instability occurrence in the scenario when there are many CACC vehicles following each other and the communication is suddenly disrupted (for example: jammed).

6.1.5.13 It is up to the manufacturer to prohibit transition to close follow mode when slippery road environment conditions are detected. Detecting road environment conditions is not required for CACC to operate in any of its operational states.

6.1.5.14 Unless it is prohibited because of any of the requirements in 6.1.5.1 to 6.1.5.13, it is up to the manufacturer to decide the control action during any transition among the CACC system states specified in 6.1.4.

6.1.6 V2V CACC data requirements

6.1.6.1 The following shows a data set that may be required for V2V CACC.

1) Temporarily Vehicle ID/Mac address.
2) On board unit device type.
3) Vehicle data: type, dimensions, braking system performance limits, and total vehicle mass.
4) 3D positions (latitude, longitude and elevation).
5) Heading angle measured from north.
6) Vehicle speed.
7) Vehicle longitudinal acceleration.
8) Vehicle yaw rate.
9) Brake status: For example: Brake on/off, brake pedal position.
10) Acceleration pedal position.
11) Steering angle.
12) Event flag. Example: hard braking event, ABS, Traction loss, Stability control engaged, Hazard light, Hazard material, flat tire.
13) GNSS data accuracy.

6.1.6.2 The following may be the additional V2V data required if the vehicle is equipped with CACC system.

1) CACC Mode.
2) The followed target vehicle (TV) data (it is the data of the target vehicle that the CACC subject vehicle is following): range from Subject vehicle to target vehicle, azimuth angle of target vehicle with respect to subject vehicle heading, speed of target vehicle, time gap setting and estimated longitudinal acceleration of the target vehicle.
3) CACC requested acceleration/deceleration or equivalent commands.

6.1.6.3 The V2V data shall have a minimum update rate according to the following table.

Table 3 — V2V data minimum update rate

Data	Update rate
Temporarily Vehicle ID/Mac address	1 Hz, and at every change in Device Mac Address
On board unit device type (Aftermarket versus on board).	1 Hz, and at every change in Device Mac Address
Vehicle data: type, dimensions, braking system performance limits, and total vehicle mass	1 Hz, and at every change in Device Mac Address
3D positions (latitude, longitude and elevation).	10 Hz
Heading angle measured from north.	10 Hz
Vehicle speed.	10 Hz
Vehicle longitudinal acceleration.	10 Hz
Vehicle yaw rate.	10 Hz

Table 3 *(continued)*

Data	Update rate
Brake status.	10 Hz
Throttle position.	10 Hz
Steering Angle	10 Hz
Event Flag.	10 Hz
GNSS data accuracy	10 Hz
CACC data in 6.1.6.2	10 Hz

6.1.6.4 The received over the air data shall not be delayed by more than one and a half of the transmission update time interval.

6.1.6.5 V2V data packets shall have the required security credential provision.

6.1.6.6 Path prediction and path history data will be also useful to better track the TV path and assist in smoother control, but it is not required to be sent over the air.

6.1.6.7 Positioning data shall have a 2D lane level position accuracy: 1,5 m or less (1 sigma value).

6.2 I2V CACC

6.2.1 Control Operation Strategy

I2V CACC system reacts to I2V over the air data in addition to the active sensing data.

6.2.1.1 Table 4 specifies the I2V CACC control requirements for some examples of the I2V data.

Table 4 — I2V CACC control requirements

I2V data	Alternative set speed	Alternative time gap	Informing the driver	Driver confirmation	Minimum CACC control action
Recommended speed from infrastructure equipment	yes	no	Driver shall be informed	Driver confirmation is required to accept the recommended speed if the recommended speed is higher than the current set speed). If the recommended speed is lower than the current set speed, driver confirmation is not required.	Current set speed shall be replaced by the recommended speed if driver accepts the recommended speed.
Recommended time gap from infrastructure equipment	no	yes	Driver shall be informed	Driver confirmation is required if the recommended time gap is shorter than the current set time gap. If the recommended time gap is longer than the current set time gap, driver confirmation is not required.	Current time gap shall be replaced by the recommended time gap if driver accepts the recommended time gap. The final operated time gap value shall never go below the requirements in Table 2
Curve safe speed from infrastructure equipment	yes	no	Informing the driver is not required	Driver confirmation is not required.	Current set speed shall be replaced by the curve safe speed
Speed limit from infrastructure equipment	yes	no	Driver shall be informed	Driver confirmation is required when the speed limit is higher than the current set speed. Driver confirmation is not required when the speed limit is lower than the current set speed.	Current set speed shall be replaced by the speed limit if driver accepts the speed limit

Table 4 *(continued)*

I2V data	Alternative set speed	Alternative time gap	Informing the driver	Driver confirmation	Minimum CACC control action
Hazard road condition from infrastructure equipment. Example: Road side alert message such as : bridge icing ahead, Traffic Jam, Work Zone, …	no	yes	Driver shall be informed	No	Depending on the I2V data content, time gap may be increased, max deceleration limit may be reduced, resume to cruise control may be inhibited, acceleration may be limited or inhibited,.

6.2.1.2 Once the above I2V data in Table 4 is no longer of interest to the subject vehicle, the subject vehicle control shall go back to the original control mode which existed before the effect of this data. The control transition between the I2V mode and the original control mode that existed before the effect of the I2V data is up to the manufacturer. Example: subject vehicle still receiving the curve safe speed data after passing the curve of interest.

6.2.1.3 The applied control strategy to meet the requirements in Table 4 is left to the manufacturer.

6.2.2 I2V CACC data requirements

I2V CACC data described in Table 4 does not have to be broadcasted at a high rate and low latency. A 1 Hz transmission rate with 750 ms latency should be sufficient.

6.3 General operational control requirements

6.3.1 For Close-Follow mode, the negative jerk shall not exceed 3,5 m/s^3. The positive jerk shall not exceed 2,2 m/s^3.

6.3.2 For all other operating modes or transitions between different modes of operation, the jerk requirements are according to ISO 15622.

7 Performance evaluation test methods

7.1 V2V CACC

7.1.1 Communication range test

The connected vehicle is placed at A, B, C and D corners of Figure 3. The subject vehicle receives the remote connected vehicle over the air data in a very consistent manner with an acceptable error level which is required for intended services.

7.1.2 Accuracy test (lane and range discrimination tests)

7.1.2.1 Lane discrimination test

A lane discrimination test is illustrated in Figure 5. In Figure 5, the subject vehicle is following three remote connected vehicles: one in the subject vehicle lane, one in the left adjacent lane, and one in the right adjacent lane. The down range between the subject and each of the remote vehicles is 40 m. The speed of all vehicles is 15 m/s. Two runs shall be executed at 180 ° angles from each other (i.e. driving in one direction in the first run, and driving in the opposite direction in the second run). Each run is executed for a minimum of 60 s. The run will be successful if the reported cross range for each vehicle indicates its correct lane 95 % of the time of the run.

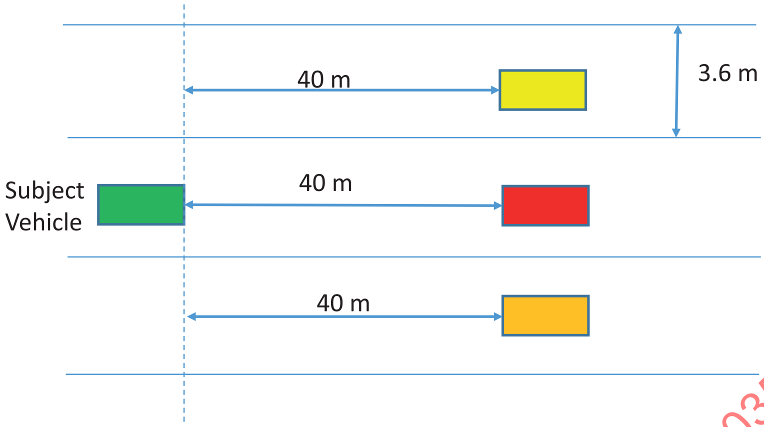

Figure 5 — Lane classification test

7.1.2.2 Range discrimination test

A range discrimination test is illustrated in Figure 6. In Figure 6, the subject vehicle is following two remote connected vehicles: all in subject vehicle lane. All vehicles are traveling at around a 5 m clearance and with a speed of 5 m/s. If system cannot set to 5 m/s, then the recommended clearance will be set to the closest possible value to 5 m. Five runs are executed. Each run is executed for a minimum of 60 s. The run will be successful if for 95 % of the following time, the vehicle E is reported at a positive down range from subject vehicle and if vehicle F is reported ahead of vehicle E.

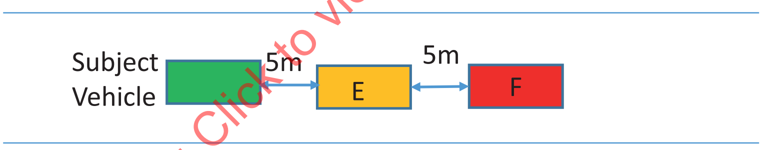

Figure 6 — Range discrimination test

7.1.3 V2V cooperative operating modes/states tests

7.1.3.1 Non-follow mode test

In Figure 7, the subject vehicle is traveling in the main road and on the right most lane. The remote vehicle is driving toward merging into the subject vehicle lane. The subject vehicle is approaching the merging junction at around a 50 m distance and cruising toward a set speed (accelerating) of 27 m/s (20 m/s for trucks). The connected remote vehicle traveling to the right of the subject vehicle is at a speed of 20 m/s (14 m/s for trucks). The test will be successful if the CACC V2V cooperative reports its operating state as *Non-Follow mode* before the remote connected vehicle is about to join the subject vehicle lane.

