INTERNATIONAL STANDARD

ISO 4272

First edition
2022-09

Intelligent transport systems — Truck platooning systems (TPS) — Functional and operational requirements

Systèmes de transport intelligents — Systèmes de convois de camions (TPS) — Exigences fonctionnelles et opérationnelles

Reference number
ISO 4272:2022(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

A truck platoon is a vehicle string in which multiple vehicles are driving under coordinated longitudinal and possible lateral control.

Truck platooning is beneficial for the transportation industry because it can improve the operational efficiency of motorway transportation, improve safety and reduce the energy consumption of truck operation, as well as improving drivers' working environment and reducing workload. In addition, truck platooning improves the road capacity and efficiency for overall traffic.

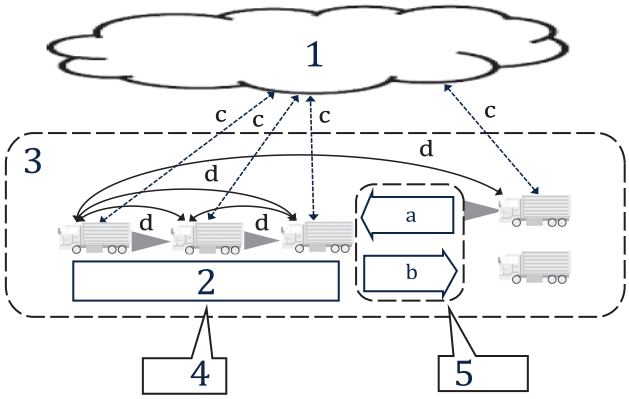
The truck platooning system consists of a platooning control system and optionally a back office (BO) as shown in Figure 1. Information from the back office can be helpful and effective for planning platoon operations.

The platooning control system controls the processes by which vehicles join or leave the platoon and the manoeuvring of the platoon under coordinated longitudinal vehicle control strategies such as cooperative adaptive cruise control (CACC). Each vehicle has vehicle-to-vehicle (V2V) over-the-air communication to exchange information with the other vehicles in the platoon and recognizes its participation in a platoon. Each vehicle controls its own motions in a platoon based on the data obtained from sensors such as radar, lidar and camera, and the data received from the over-the-air communication.

The truck platooning system may include a back office infrastructure system to support the platooning control system. BO functions can include platooning demand matching, and platooning formation and operation management. Platooning demand matching covers forming requests, matching requests, route management and charge/payment of platoon from operators such as shippers and fleet operators. Platooning formation and operation management may issue notifications about the acceptance/refusal of platooning requests, truck sequence in platoon, route selection/permission/recommendation, and geographical limitations on the platooning.

The platooning operational control function controls changes in the membership of platoon; the platooning manoeuvre control function controls interactions within the platoon.

This document provides the common base needed for platooning system development. It also supports market introduction of the platooning system and assists in accelerating the deployment of truck platooning.



Key

1	back office	a	Join.
2	platoon (steady state)	b	Leave.
3	platooning control system	c	Vehicle to infrastructure (V2I) communication.
4	platooning manoeuvre control function	d	Vehicle to vehicle (V2V) communication.
5	platooning operation control function		

Figure 1 — Overall architecture of the truck platooning system (TPS)

Intelligent transport systems — Truck platooning systems (TPS) — Functional and operational requirements

1 Scope

This document defines the terms and definitions related to truck platooning systems (TPS), and the mode transitions in the platooning control system (PCS). The PCS is comprised of two main functions: the platooning operation control function (POCF) and the platooning manoeuvre control function (PMCF).

This document specifies:

— POCF and PMCF governing how vehicles join and leave platoons;

— PMCF governing longitudinal and lateral control of each vehicle;

NOTE PMCF makes reference to current International Standards, such as ISO 20035, ISO 11270 and ISO 21717, where appropriate.

— functional evaluation test methods for POCF and PMCF.

This document also describes:

— the data to be communicated for POCF and PMCF in vehicle to vehicle (V2V) messages and optionally in vehicle to infrastructure (V2I) messages, including local roadside and broader network and cloud;

— strategies for forming platoons, such as ad-hoc or planned formation, and types of truck platooning systems, such as top-down management and peer-to-peer.

This document covers:

— platooning of heavy goods vehicles of multiple brands and fleets, operated by on-board drivers. Light trucks, buses and passenger cars are excluded;

— level 1 and 2 driving automation systems, which provide driver support and operate under the continuous supervision of the drivers.

The functions and operations of the back office (BO) are out of scope of this document.

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 21202, *Intelligent transport systems — Partially automated lane change systems (PALS) — Functional/operational requirements and test procedures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

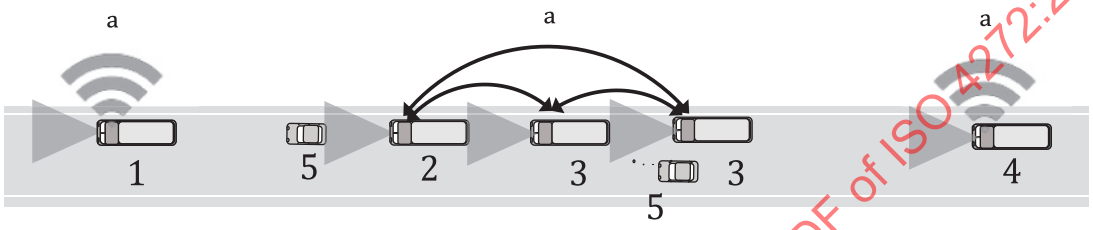
— ISO Online browsing platform: available at https://www.iso.org/obp

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

3.1
platoon
vehicle formation with a common platoon ID and sequence of participants

3.2
platooning
operation of a platoon in which multiple vehicles are driving under coordinated longitudinal control and possibly lateral control

Note 1 to entry: Each vehicle uses forward-vehicle detection by on-board sensors and vehicle to vehicle (V2V) over-the-air communication to exchange information needed to execute the coordinated longitudinal control with the other vehicles in the platoon (see Figure 2).



Key

Key

a	Vehicle to vehicle (V2V) communication.	3	following vehicle (FV)
1	potential leading vehicle (PLV)	4	potential following vehicle (PFV)
2	leading vehicle (LV)	5	other vehicle (OV)

Figure 2 — Platooning formation

3.3
leading vehicle
first vehicle in a platoon

3.4
following vehicle
vehicle operating in a platoon behind the leading vehicle and connected using vehicle to vehicle communication

3.5
other vehicle
vehicle that does not participate in the platoon but can potentially affect platoon operations, by performing emergency braking or a cut-in manoeuvre, for example

3.6
potential leading vehicle
vehicle that is not currently in a platoon but is in a position enabling it to potentially become the leading vehicle in the future or a former leading vehicle after leaving the platoon

3.7
potential following vehicle
vehicle that is not currently in a platoon but is in a position enabling it to potentially become the following vehicle in the future or a former following vehicle after leaving the platoon

3.8
join
transition by which one or more vehicle(s) become(s) member(s) of a platoon

3.9
leave
transition by which one or more vehicle(s) separate(s) from its current platoon

3.10
platooning control system
system for operating the platooning operation control function and the platooning manoeuvre control function in a platoon, including the potential leading vehicle and potential following vehicle

3.11
platooning operation control function
function to manage the transitions of vehicles in and out of platoon membership

3.12
platoon management message
vehicle to vehicle communication or vehicle to infrastructure communication message that transmits information relevant to the platooning operation control function

3.13
platooning manoeuvre control function
function to manage the continuous operations of platoon vehicles, including responses to situations such as cut-in and cut-out

3.14
platoon control message
vehicle to vehicle communication message that transmits information relevant to the platooning manoeuvre control function

3.15
vehicle to infrastructure communication
communication between vehicle and devices such as a roadside unit of infrastructure or mobile phone base station, but excluding vehicles

3.16
back office
infrastructure system to support platoon operation, such as platoon planning and demand matching to start the platoon, and route management and the charge/payment process from the operators, such as shippers and fleet operators

3.17
time gap
time needed to travel a distance equal to the clearance gap between the rear surface of the preceding vehicle and the forward surface of the following vehicle at the current vehicle speed

Note 1 to entry: This value is calculated as c/v , where v is the vehicle speed of the following vehicle and c is the clearance between the head of the following vehicle and the tail of the leading vehicle.

3.18
heavy goods vehicle
truck with a gross combination mass (GCM) over 3 500 kg. which is considered as a vehicle according to categories N2 and N3 of WP.29 TRANS/WP.29/78/Rev.6

Note 1 to entry: See Reference [14].

4 Symbols and abbreviated terms

4.1 Abbreviated terms

ACC	adaptive cruise control
BO	back office
CC	cruise control
CACC	cooperative adaptive cruise control
FV	following vehicle
GCM	gross combination mass
LKAS	lane keeping assistance systems
LV	leading vehicle
OV	other vehicle
PADS	partially automated in-lane driving systems
PALS	partially automated lane change systems
PCM	platoon control message
PCS	platooning control system
PFV	potential following vehicle
PLV	potential leading vehicle
PMCF	platooning manoeuvre control function
PMM	platoon management message
POCF	platooning operation control function
V2I	vehicle to infrastructure/infrastructure to vehicle
V2V	vehicle to vehicle

5 Types of truck platooning systems

5.1 Top-down-managed platooning

The top-down managed platooning type is managed by the LV via V2V communication or optionally is managed by the BO via V2I communication to optimize platoon operations and recommend vehicle sequence, platooning speed, time gap, etc.

5.1.1 LV-managed platooning

The LV-managed platooning type is managed by the LV. The LV or its driver selects the speed and maximum number of vehicles in the platoon. The LV or its driver may inform the FV drivers about the recommended minimum time gap for FVs.

POCF such as "join" and "leave" may be triggered by FV drivers. Final permission to join is provided by the LV.

5.1.2 BO- and LV-managed platooning

The BO and LV perform the platoon management. Under management by the BO, the LV or its driver selects the speed and number of vehicles in the platoon. The LV or its driver may inform the FV drivers about the recommended minimum time gap for FVs and may make lane changing decisions under the management by the BO.

POCF such as "join" and "leave" may be triggered by FV drivers. Final permission to join is provided by the LV based on BO planning. The LV or BO may provide instructions for the "leave" operation.

5.2 Peer-to-peer platooning

Peer-to-peer platooning management operates based on peer-to-peer relationships among all of the vehicles in a platoon. All vehicles have equal status and none of them are governing other vehicles. All FVs individually control their speed (and optionally steering) to follow the LV or preceding FV and all drivers may choose their preferred gap settings.

6 Types of truck platoon formation

6.1 Overview

When a platoon is formed, different locations and types of formation are applied based on one of the strategies described in the following subclauses.

Platoon formation is the process in which it is determined if vehicles may become part of a platoon.

Platoon formation is the coordination of candidate vehicles which form the platoon in a defined structure.

Platoon formation may be done on the motorway during driving or at the staging area before entering the motorway.

Platoon formation may be done on an ad-hoc basis (that is, not planned) or planned in advance.

Platoon formation is completed to become a cruising operation after the join manoeuvre.

6.2 Formation on the motorway

6.2.1 General

In case of formation on the motorway, V2V and optionally V2I are used to search for other candidate vehicles.

6.2.2 Ad-hoc platoon formation on the motorway

Any vehicle or platoon which is capable of platooning searches for other similarly capable vehicles or platoons via V2V communications, and starts the join operation to form a new platoon. Optionally, V2I communications may be used to identify the availability of other eligible vehicles to join the ad-hoc platoon within the available effective communication range. The communication range covers the same motorway as well as the access ramps and at the interchanges.

6.2.3 Planned platoon formation on the motorway

In case of planned formation on the motorway, the BO coordinates potential platooning participants via V2I communication and manages speeds and routes to the meeting point of vehicles.

Platoon candidates (PLV and PFV) communicate with each other via V2V communications and join the platoon on the motorway.

Platoon candidates can receive instructions from the BO via V2I communications for platoon formation to allow the start of the "join" procedure with the platoon.

6.3 Formation at the staging area

6.3.1 Ad-hoc platoon formation at the staging area

Any vehicle or platoon which is capable of platooning searches for other similarly capable vehicles or platoons via V2V and optionally V2I communications within the available communication range and an ad-hoc platoon "join" operation is started at the staging area before entering the motorway. Each vehicle may start in sequence of platoon when they enter the motorway, or may move to the staging area in advance and park in sequence of platoon before entering motorway.

6.3.2 Planned platoon formation at the staging area

In case of planned formation at the staging area, the BO coordinates potential platooning participants via V2I communication.

Platoon candidates can receive instructions from the BO for platoon formation to allow the start of the "join" procedure with the platoon at the staging area.

Platoon candidates communicate via V2V communications and the "join" operation is implemented at the staging area.

Platoon formation may be achieved and completed at the staging area before initiating the drive. Vehicles can configure the sequence in platoon at the staging area based on the instructions from the BO.

7 Operation state diagram

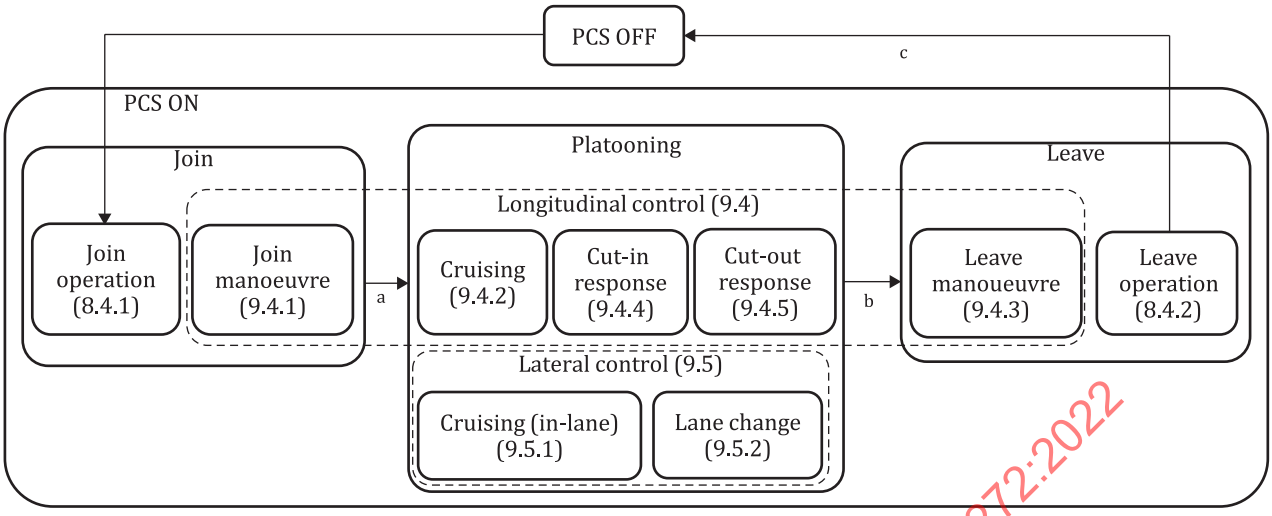
7.1 General

The truck platooning system is under operation when the PCS turns on (PCS ON). When the vehicle turns on the PCS, the "join" operation can be implemented as a POCF. After the "join" manoeuvre is completed, the platooning state is implemented and continues under various manoeuvre controls. When the "leave" notification is transmitted, the "leave" operation is implemented and the vehicle leaves the platoon and turns off the PCS (PCS OFF).

7.2 Operation state diagram of platooning operations

A state diagram of platooning operations is shown in Figure 3.

POCF and PMCF operations are described in Clauses 8 and 9.



a Join complete.

b Leave notification.

c Leave complete.

Figure 3 — Operation state diagram

8 Platooning operation control function (POCF)

8.1 General

In the PCS, there are two modes of transition: "join" and "leave". Both transition modes are operated by the POCF which controls the change in membership status of the platoon.

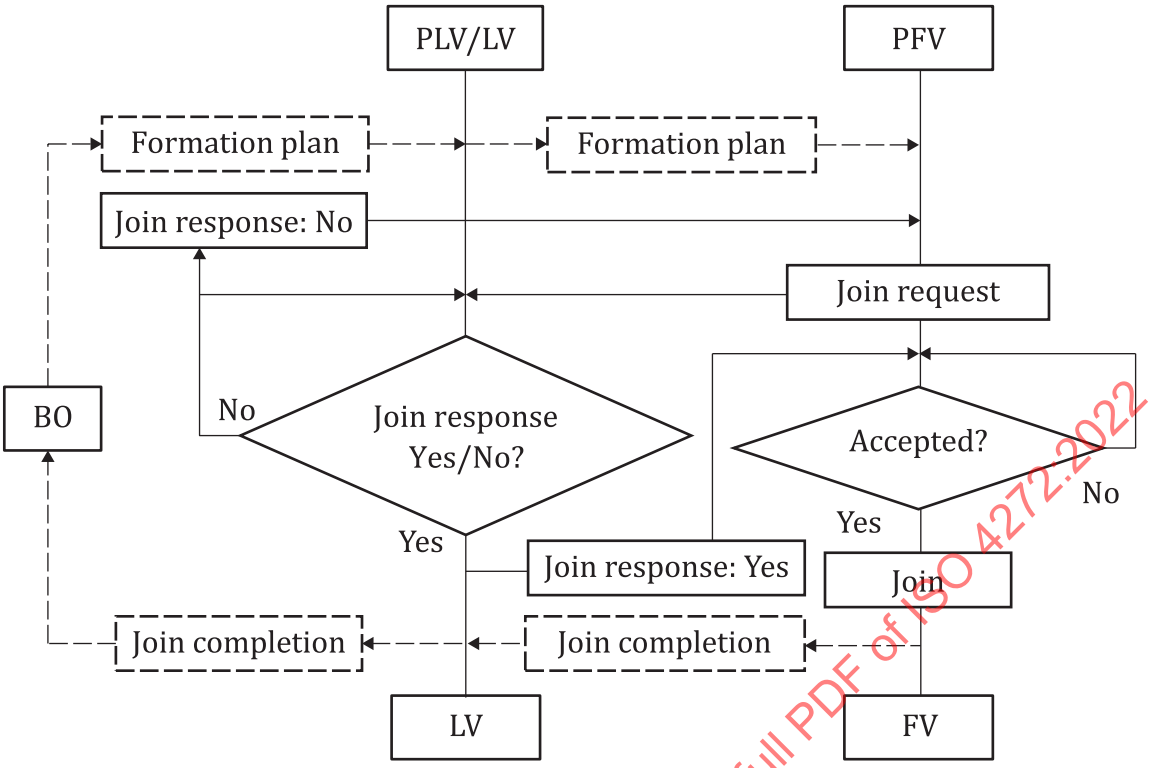
8.2 Join

In the platooning operation, a platoon ID is provided for a new platoon and a sequential number of participant vehicles are confirmed to be a platoon. Joins may be achieved between any combination of individual vehicles and platoons in the leading and following positions. The join transition can be made within a lane during driving or at a staging area, such as a parking site.

Normally, the PLV becomes LV and the PFV becomes FV in a platoon. In some situations, V2V communication and/or V2I communication with BO may adjust the sequence of PLV and PFV to make a suitable platoon during this transition.

Use case examples of "join" transitions are shown in Annex A.

The typical operation flow of "join" transitions is shown in Figure 4.



— Join request: Request for platoon formation or addition to an existing platoon.
— Join response: Response to the request for platoon formation or addition to the existing platoon.
— Dotted boxes and lines represent the optional operations and information flows.

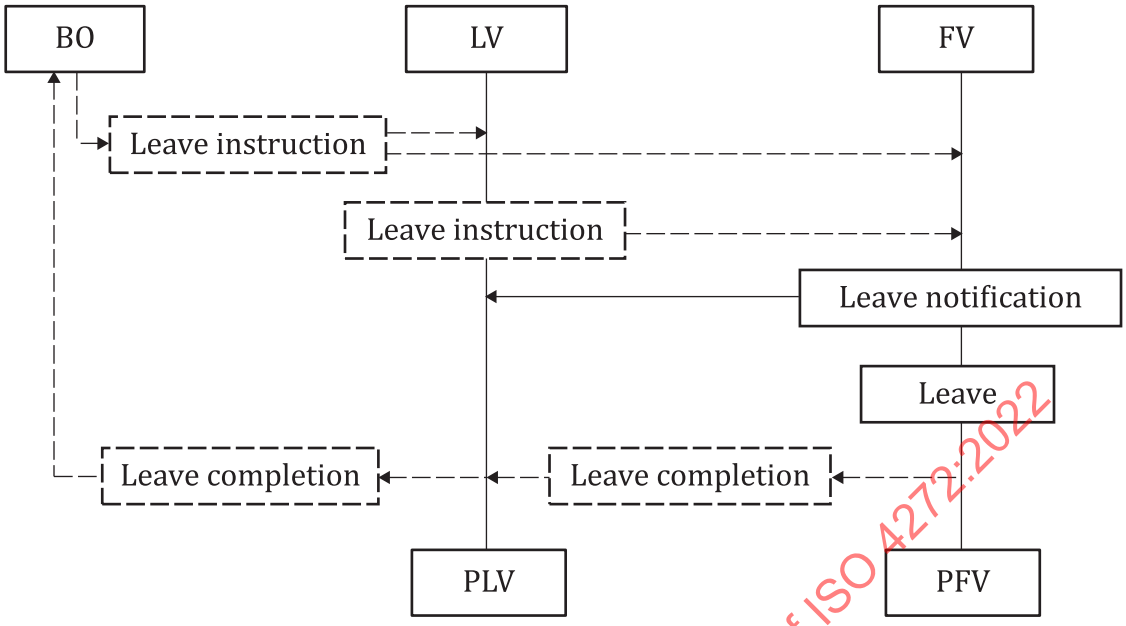
Figure 4 — Typical operation flow diagram of the "join" transition

8.3 Leave

In the platooning operation, the most basic "leave" transition is achieved when the LV and FV(s) separate from each other and become PLV and PFV. In multiple-vehicle platoons, any individual vehicle or group of vehicles may leave. The leave transition can be made while driving or at a staging area, such as a parking site.

Use case examples of "leave" transitions are shown in Annex A.

The typical operation flow of "leave" transitions is shown in Figure 5.



— Leave instruction: Instruction to leave the platoon or of platoon dissolution.
— Leave notification: Notification of intention to leave the platoon.
— Dotted boxes and lines represent the optional operations and information flows.

Figure 5 — Typical operation flow diagram of leave

8.4 Operation

8.4.1 Join operation

The "join" operation is achieved when PFV searches PLV or LV to form a platoon and finally the PLV becomes LV and the PFV becomes FV in a platoon. A "join" operation may also be achieved between any combination of individual vehicles and platoons in the leading or following positions.

The "join" operation may also be achieved based on information such as a formation plan provided from BO or it may be achieved by ad-hoc actions of the PLV and PFV and their drivers. The following steps describe the "join" operation.

1) A PFV which intends to join and to become a platoon member transmits "join request" to the PLV (or LV if the platoon already exists). In case of formation on the motorway, the PFV is travelling in the same direction on the same motorway and is behind the PLV or LV.

2) The PLV or LV which receives the "join request" judges whether the PFV is eligible to join (i.e. platoon has not reached its maximum size and PFV is properly equipped).

3) If the PFV is eligible to join, the PLV or LV transmits "join response: yes" to the PFV.

4) When the PFV receives "join response: yes", it starts the join manoeuvre to the PLV or last FV in existing platoon and becomes a platoon member.

5) If the PFV is not eligible to join, "join response: yes" is not transmitted and “join response: no” is transmitted by the PLV, LV or last FV. In this case, the PFV is not accepted to join and does not start the join manoeuvre.

6) If the PLV or LV refuses to accept a join request from an eligible PFV based on reasons such as the PLV or LV is leaving motorway soon, the PLV or LV transmits "join response: no" to notify the PFV that the join is not possible.

7) After completion of the join manoeuvre, the PFV notifies the PLV or LV of the join completion and the PLV or LV may also inform the BO of the join completion.

8.4.2 Leave operation

The "leave" operation is achieved when the LV and FV separate from each other and become PLV and PFV. In platoons with three or more vehicles, any individual vehicle or group of vehicles can leave and becomes a PLV, PFV or a shorter platoon. The following steps describe the "leave" operation.

1) The FV which intends to leave from a platoon transmits "leave notification" to the LV.

2) After the transmission of "leave notification", the FV starts the leave manoeuvre and separates from a platoon, becoming a PFV.

3) When the FV needs to be separated from a top-down managed platoon, "leave instructions" may be sent from the LV to FV, or from the BO to LV and/or FV.

4) When the FV or LV receives "leave instructions" or the FV intends to leave a top-down managed platoon, the FV transmits "leave notification" and starts the leave manoeuvre.

5) After completion of the leave manoeuvre, when the LV receives a "leave completion" notification from the FV of a top-down managed platoon, it may inform the BO of the leave completion.

8.5 Requirements

8.5.1 Join requirements

8.5.1.1 General

The following are the requirements for the vehicles in the join process.

8.5.1.2 Join request

1) A vehicle that intends to join with another vehicle or another platoon shall transmit a "join request".

2) In the case of a top-down managed platooning type, the "join request" shall contain vehicle performance information, which is described in 10.3.1, about the vehicle(s) that intend(s) to join.

8.5.1.3 Join response

1) The vehicle or platoon which accepts the join request shall transmit "join response: yes". In case of refusal to accept a join request, "join response: no" shall be transmitted.

2) The "join response" shall contain "platoon management information" which is needed to operate platooning.

   NOTE "Platoon management information" includes platoon ID, maximum number of vehicles in the platoon, vehicle sequence in platoon, etc. See 10.3.1.

3) The "join response" shall contain the vehicle performance information of the platoon member which is just in front of the joined vehicle.

8.5.1.4 Join completion

After completion of the "join" manoeuvre, the new FV or LV of the platoon may report the join completion to the BO.

8.5.2 Leave requirements

8.5.2.1 General

The following are the requirements for the vehicles in the leave process.

8.5.2.2 Leave notification

1) A platoon member or a part of platoon who intend(s) to leave the platoon shall transmit "leave notification". "Leave notification" may be initiated automatically by the driver's take-over of manual driving operation or may also be initiated by another driver action (e.g. platooning mode on/off switch).

2) The driver or PCS of the vehicle that intends to leave may implement the leave operation in the following situations. However, the specific periods and distances mentioned below are not specified in this document.

   — OV cut-in situation continues longer than a certain time.

   — The distance to the preceding vehicle in the platoon becomes longer than a certain distance.

   — V2V communication with preceding platoon member is interrupted for longer than a certain time.

   — The intended destination of the vehicle is approaching.

   — The driver prefers to drive separately for any other reason.

8.5.2.3 Leave instruction

1) In case of top-down managed platooning type, the LV or BO may instruct platoon member(s) to leave.

2) A platoon member who receives a "leave instruction" shall transmit "leave notification" and perform the leave manoeuvre.

8.5.2.4 Leave completion

1) After the completion of the leave operation, in the case of top-down managed platooning type, the PFV or PLV of the platoon shall report the leave completion to the LV or BO that issued the leave instruction.

2) The PFV or PLV of a platoon which completed the leave operation shall delete their platoon management information. If a platoon remains after the LV, FV or a part of platoon leaves, members of the platoon that completed the leave operation and/or remain shall update all or part of their platoon management information and share it.

9 Platooning manoeuvre control function (PMCF)

9.1 General

In the PCS, longitudinal control and optionally lateral control are applied to the platoon and its vehicles to manage the platooning by platooning manoeuvre control function (PMCF).

9.2 Longitudinal control

A vehicle which receives "join response: yes" in POCF starts the join manoeuvre and completes the formation of platoon. The LV or its driver controls its speed based on the traffic and road conditions and maintaining separation from vehicles ahead of it.

When a platoon is driving in-lane, CACC is used to control the distances between vehicles. CACC control may be the constant time gap with respect to speed (time-gap-based control; ISO 20035) or may be the constant clearance with respect to speed (clearance-based control).

When an OV cuts in front of the FV, the FV should increase its following distance to maintain an appropriate gap behind the OV. In this case, FV CACC mode makes a transition from close-follow mode to CACC follow mode, or suspends CACC control with reference to the preceding LV or FV in the platoon, and needs to change to ACC mode behind the OV.

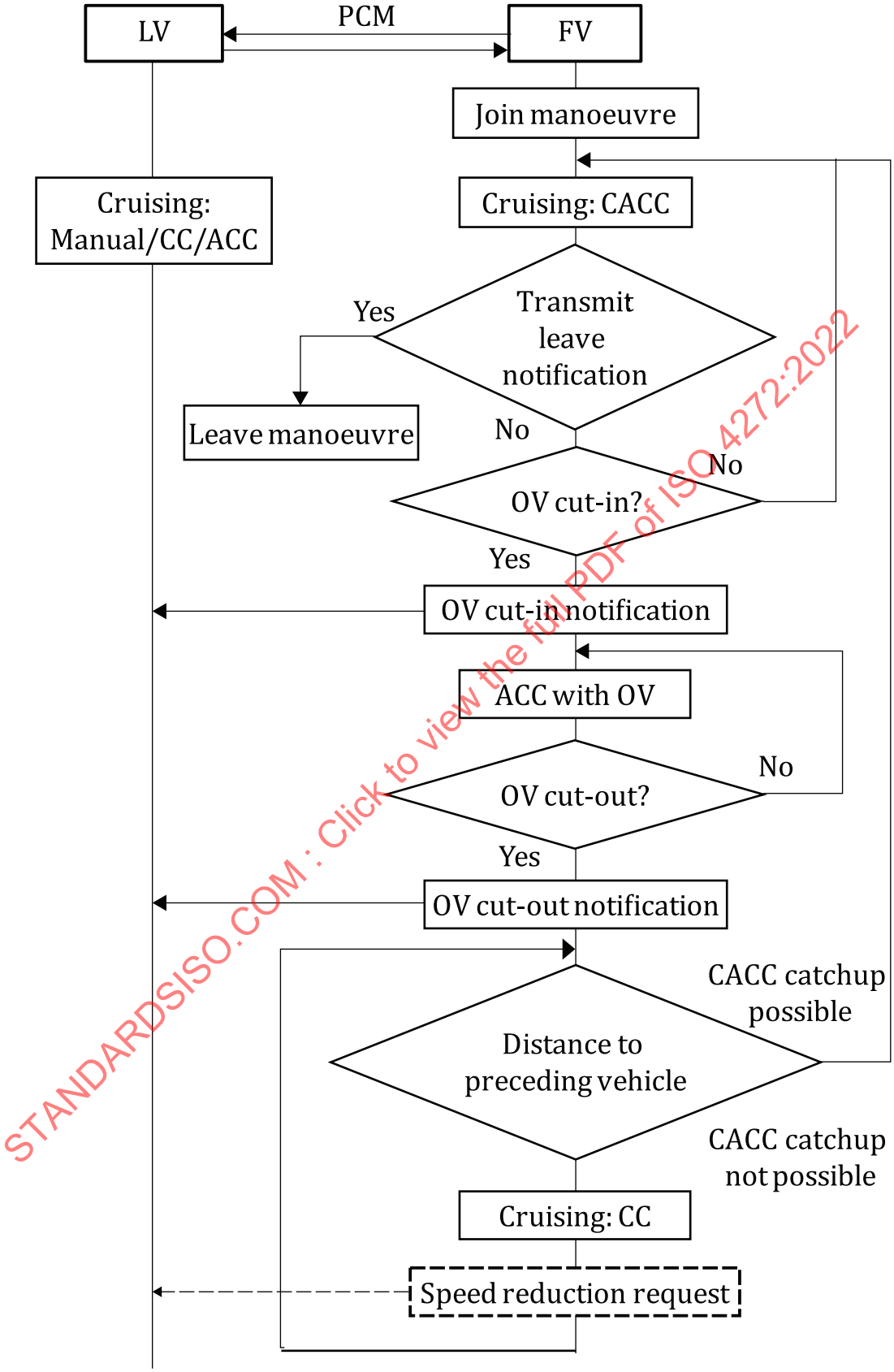
NOTE The definition of an appropriate gap is left for manufactures and/or operators of platoon.

If an FV in a platoon is temporarily in ACC mode due to the OV in front, when the OV departs the lane of the platoon, the FV needs to resume CACC control operation and starts CACC close-follow. In this case, the FV increases speed to catch up with the preceding vehicle or communicates with the LV to request it to reduce its speed so that the gap can be reduced.

The vehicle which transmits “leave notification” starts the leave manoeuvre and separates from the platoon.

Use case examples of longitudinal control are shown in Annex B.

The typical operation flow of longitudinal manoeuvre control such as cut-in and cut-out is shown in Figure 6.



— Dotted box and line represent the optional operation and information flow

Figure 6 — Typical operation flow diagram of longitudinal manoeuvre control

9.3 Lateral control

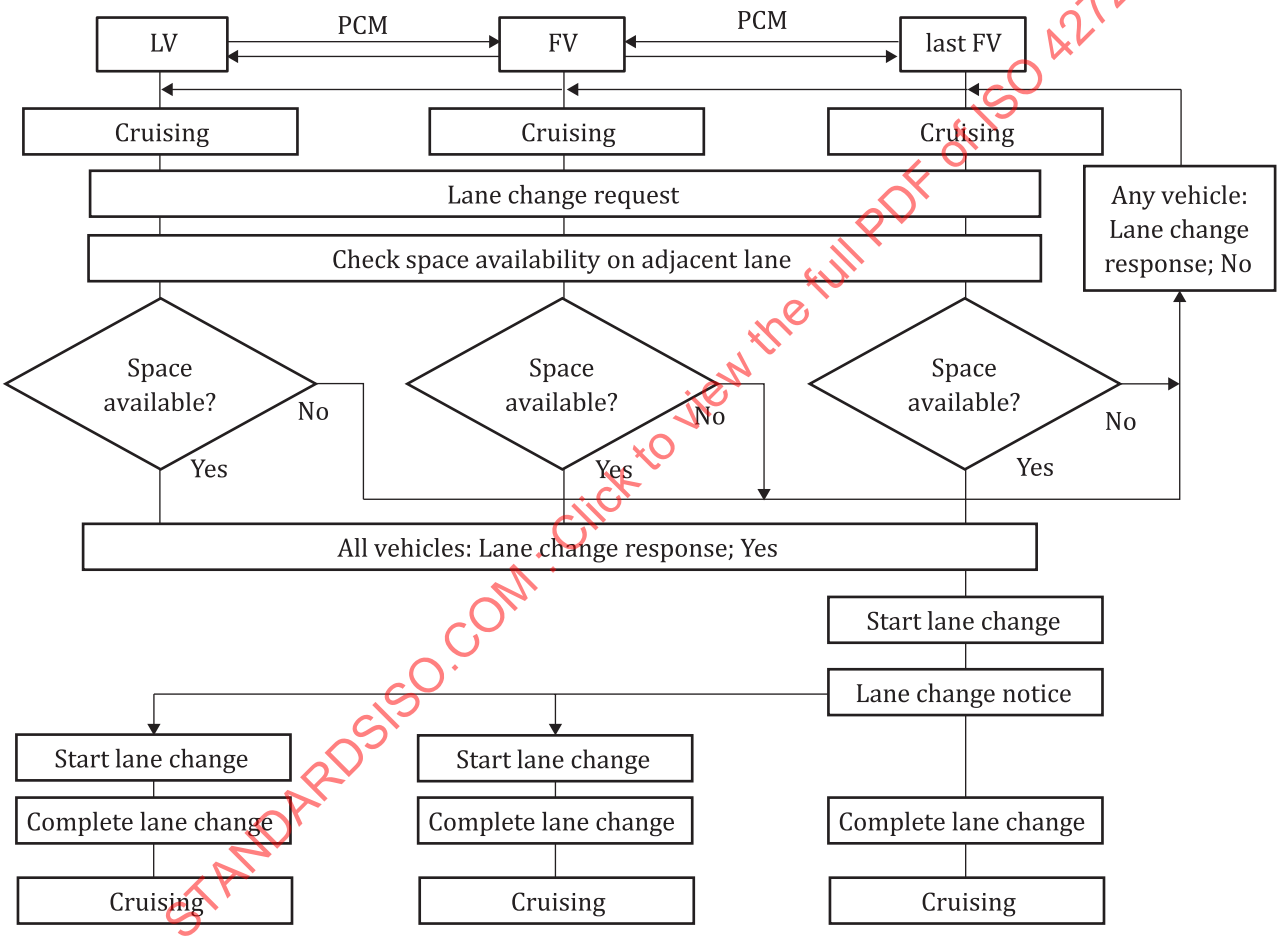
When a platoon is driving in lane, the drivers may steer the vehicles manually or lateral control system may be used to maintain the in-lane position of each vehicle.

Vehicles in a platoon may use lane-keeping assistance system (LKAS) to stay in-lane.

Vehicles in a platoon may perform the lane change manually or may use PALS to change the lane. It is recommended that the last vehicle in the platoon be the first to change lane to block the lane from vehicles overtaking from behind, so that the rest of the platoon can complete the lane change with less risk of interference. The lane change may be requested by the driver of any of the vehicles, but shall be approved by the drivers of all of the vehicles, using V2V communication.

Use case examples of lateral control are shown in Annex B.

The typical operation flow of lateral manoeuvre control such as lane change is shown in Figure 7.



— Lane change request: Request to change the lane as a platoon.

— Lane change response: Response to the lane change request. If space in rear and side is available to change the lane, response is yes, and if not available, response is no.

Figure 7 — Typical operation flow diagram of lateral manoeuvre control

9.4 Longitudinal control operations

9.4.1 Join manoeuvre

An FV which becomes a member of platoon after receiving "join response: yes" in POCF, implements the join manoeuvre and completes platoon formation.

If the PLV joins in front of a platoon (use case J3 in Annex A), the new FV which was formerly the LV of platoon implements the join manoeuvre behind the new LV as described in the following steps.

1) The joining FV detects the preceding FV or LV by the comparison of its own on-board sensors and V2V communication data (see ISO 20035: 2019, 6.1.5.4, for example), and follows the other FV or LV to drive behind it in the same lane with adequate forward clearance.

2) After the confirmation that the preceding vehicle in the same lane is the other FV or LV to follow, the driver of the FV turns on CACC and the clearance is automatically adjusted by CACC to reach the time gap set by PMCF or by the driver.

3) The join process is completed and cruising operation begins when the set time gap is reached.

9.4.2 Cruising operation

Vehicles in a platoon normally drive at constant speed using their vehicle control systems. An LV can use ACC to follow the preceding vehicle or CC, or drive manually. FVs use CACC to follow the preceding FV or LV in order to maintain the speed and time gap to remain with the platoon. The operation is described in the following steps.

1) The speed of platoon is set by the LV and shared with platoon members as a target speed.

2) The minimum time gap for safe driving in a platoon may be recommended to FVs by the LV.

3) If an FV falls behind the preceding vehicle, the FV may communicate with the LV to request it to reduce its speed, or it may leave the platoon and become the PFV or the LV of a new platoon.

9.4.3 Leave manoeuvre

The vehicle which transmits a "leave notification" in POCF implements the leave manoeuvre and completes the separation from platoon formation. The manoeuvre is described with the following steps.

1) If the FV transmits "leave notification" with driver's take-over or another driver action (e.g. platooning mode on/off SW), the PCS turns off and the FV switches to ACC control behind the preceding vehicle.

2) If the LV transmits "leave notification", the FV immediately behind the LV switches to ACC control.

9.4.4 Cut-in operation

A cut-in operation is achieved when an OV changes lane and enters between FVs or the LV and FV from the adjacent lane (cut-in). If an additional OV cuts in between the OV and the FV, a new cut-in response may not be generated. The operation is described with the following steps.

1) When an OV enters in front of an FV, the FV detects the existence of the cut-in OV.

2) The FV increases its following distance to keep an adequate gap behind the OV.

3) The FV starts ACC mode with respect to OV.

4) The FV may terminate CACC control with reference to the preceding LV or FV in the platoon if the cut-in continues beyond a certain duration or it causes the FV to fall more than certain distance behind the preceding LV or FV in the platoon.

5) When an FV recognizes an OV as cut-in vehicle, the FV transmits "OV cut-in notification" to the other members in the platoon.

9.4.5 Cut-out operation

A cut-out operation is achieved when a platoon of LV and FV are cruising with an OV cut-in situation and the OV in front of the FV changes lane to the adjacent lane and leaves (cut-out). After cut-out, if another OV is driving in front of the FV as its preceding vehicle, the cut-in condition continues. The operation is described in the following steps.

1) When the OV in front of the FV changes lane, the FV detects its departure from the lane of platoon.

2) The FV reduces the distance to the preceding LV or FV and returns to CACC control with reference to the preceding LV or FV.

3) In this case, the FV increases speed to catch up with the preceding LV or FV. If the FV cannot catch up with the preceding vehicle, the FV uses CC for speed control and may communicate with the LV to request it to reduce its speed.

4) When an FV recognizes an OV cut-out, the FV transmits an "OV cut-out notification" to the other members in the platoon (if any).

9.5 Lateral control operations

9.5.1 Cruising (in-lane) operation

Platoon members normally stay in the same driving lane as the platoon. Each vehicle may use lane-keeping systems such as LKAS or PADS, or drive with manual steering and keep the lane.

9.5.2 Lane change operation

1) Lane change operation is achieved when a platoon is driving in lane and needs to change the lane. In the lane change, lateral control can be done automatically or by the human driver(s).

2) A "lane change request" is transmitted by the LV or any FVs to the other platoon members.

3) Each platoon member checks availability of space on the lane change intended side and notifies the result to other platoon members.

4) If any of platoon member does not have space available, it transmits "lane change response: no" to the other members. In this case, the lane change operation is judged not feasible and all platoon members continue cruising as a platoon in the original lane.

5) If space is available, each platoon member transmits "lane change response: yes" to the other members.

6) After reception of "lane change response: yes" from all platoon members, the last vehicle of the platoon starts the lane change to the adjacent lane and transmits "lane change notice" to the other platoon members.

7) When other platoon members receive "lane change notice", they start the lane change and complete the lane change. They need to change the lane with adequate clearance. After the lane change of the last vehicle, the order of lane change implementation of other platoon members is not specified in this document.

8) After all members complete the lane change, all vehicles return to cruising.

9) Vehicles in the platoon can use PALS to change lane or the drivers may perform the lane change manually.

10) The lane change procedure which starts from the last vehicle has the advantage that the last vehicle in the platoon blocks the lane from vehicles overtaking from behind, so that the rest of the platoon can complete the lane change without interference.

11) Other lane change use cases are possible. If drivers of the LV and FVs confirm that the side and rear of the adjacent lane of the platoon are clear, the platoon can change lane simultaneously or the LV can start the lane change and FVs follow.

9.6 Longitudinal control requirements

9.6.1 Join manoeuvre requirements

When the FV receives "join response: yes" in POCF, the following join manoeuvres are implemented.

1) The FV shall search for and recognize the LV or other FV of the platoon that accepts its join request using at least its own on-board sensors data and V2V communication data.

2) After the FV confirms that the preceding vehicle in the same lane is the LV or last FV of the platoon to join, the FV shall follow that vehicle manually or using ACC.

3) If CACC turns on when the FV is following the preceding vehicle manually or using ACC, the FV shall start CACC mode and adjust the clearance to the preceding vehicle with CACC being consistent with its time gap setting.

9.6.2 Cruising requirements

1) The target minimum time gap shall not be less than 0,5 s (see ISO 20035: 2019, 6.1.5.2).

2) In case of top-down managed platooning type, the LV or BO may set the target time gap of platoon members to a value greater than the minimum time gap and the setting value is notified to each FV.

3) Each driver of a platoon member vehicle may set a time gap to equal or more than the minimum time gap.

4) If the PCS or the driver of an FV judges that it cannot maintain the speed set by the LV (on a positive grade), or an FV falls too far behind the preceding vehicle, a speed reduction request may be transmitted to the LV.

5) Based on the information from the BO or the other platoon members, or on-board information such as map data, the PCS or driver may change the time gap setting relative to the preceding vehicle.

6) The target speed of platoon and clearance shall be set within the speed and clearance limit of each country or the local highway section and be shared with each platoon member.

7) In case of BO and LV managed platooning type, if the BO specifies the target speed for the platoon, each member of the platoon shall comply accordingly.

9.6.3 Leave manoeuvre requirements

When the FV or LV transmits "leave notification" in the POCF, the following leave manoeuvres are implemented.

1) Separation from the platoon formation is made by speed reduction or lane change for the FV, and by speed acceleration or lane change for the LV.

2) If the FV transmits "leave notification", the FV shall start drive manually or start ACC and the clearance to the preceding vehicle shall be increased to the adequate clearance if the FV stays on the same lane.

3) If the LV transmits "leave notification", the FV which is just behind the LV shall increase the clearance behind the LV and start to drive manually or start ACC if the LV stays in the same lane.

9.6.4 Cut-in requirements

1) During platoon cruising, when an OV enters between two vehicles (cut-in), the FV just behind the OV shall use its on-board sensors to detect cut-in. However, the detection method of cut-in of OV is not specified in this document.

2) In case of OV cut-in, the FV shall use ACC to control its gap behind the OV.

3) In case of OV cut-in, the FV may continue platooning interactions with the other vehicles in the platoon.

4) In case of OV cut-in, the FV shall transmit "OV cut-in notification" to the other vehicles in the platoon.

9.6.5 Cut-out requirements

1) Subsequently to the cut-in situation, when an OV moves to the adjacent lane (cut-out), the FV just behind the OV shall use its on-board sensors to try to detect the cut-out. However, the detection method of cut-out of OV is not specified in this document.

2) Subsequently to the OV cut-out, the FV shall increase its speed to reduce the gap to the LV or preceding FV and transition to CACC to control its gap. If the gap is too large, the FV switches to CC and may (a) request the LV to reduce its speed via V2V communication to enable closing the gap; or (b) continue to drive independently; or (c) become a platoon LV for the CACC vehicles behind it.

3) After detection of OV cut-out, the FV shall transmit "OV cut-out notification" to the other vehicles in the platoon.

9.7 Lateral control requirements

9.7.1 Cruising requirements

Platoon members may use a lane-keeping system that conforms to ISO 11270 and/or ISO 21717.

9.7.2 Lane change requirements

1) A platoon member who wants the platoon to perform a lane change shall transmit a "lane change request" message to all of the vehicles in the platoon.

2) In case of a top-down managed platooning type, the LV or BO shall have the authority to approve the lane change.

3) Every platoon member who receives a "lane change request" shall search for the availability of the space needed to the rear and side in the lane to which the lane change will be made, and shall send the status of availability to the other platoon members. This status shall be updated periodically until the lane change is completed or aborted.

4) The lane change manoeuvre shall not start until after all platoon members have confirmed that the necessary space is available in the destination lane. If the space becomes unavailable because of the intrusion of an OV, the lane change shall be aborted.

5) Lane change of platoon members should start from the last FV and the last FV shall transmit the "lane change notice" when starting the lane change.

   NOTE Automated lane changing of a platoon can only be done in relatively low-density traffic because of the need for a large gap in the destination lane; if a higher-speed vehicle is approaching from behind in that lane, it is better for the last vehicle in the platoon to block it from obstructing the lane change.

6) After LV and FVs receive "lane change notice", they may implement the lane change manoeuvre.

7) Lane changing vehicles may continue platoon control during the lane change manoeuvre.

8) The lane change of each platoon member may be implemented manually or may be operated by PCS.

9) When changing lanes by PCS, PCS shall conform to ISO 21202.

10) After the lane change manoeuvre completion, platoon members start cruising in the new lane.

10 Communication data (V2V/V2I)

10.1 General

This document describes basic requirements for the communication of POCF and PMCF. It also describes required or recommended data items and those general descriptions of platoon management messages (PMM) which are necessary messages for POCF operation and platoon control messages (PCM) which are necessary messages for PMCF operation.

10.2 Requirements of communication

The communication requirements related to POCF or PMCF are as follows. Note that the methods of communication and related protocol are not described in this document.

1) The PCS of platoon member vehicles shall be able to transmit and receive PMMs that operate the platoon and PCMs that control the driving manoeuvres of platoon members via V2V communication.

2) The PCS of platoon member vehicles of top-down managed platooning type shall be able to transmit and receive PMM via V2I communication in order to realize the communication with the BO. Other types may realize PMM transmission and reception via V2I communication.

3) The PCM transmission frequency shall be at least 10 Hz. PMM transmission is event-based.

4) A join request should be transmitted repeatedly for a certain period or until a join response is received. Transmission frequency and transmission period of the join request are not specified in this document.

5) In case of top-down managed platooning type, the leave instruction from an LV or BO should be transmitted until leave completion is received. However, the transmission frequency of the leave instruction is not specified in this document.

6) Each platoon member shall transmit platoon control information when the status of the platoon is changed due to join or leave operations.

7) Each platoon member shall recognize the interruption of PCM communication from other platoon member vehicle(s).

8) V2V and V2I communication in a platoon shall be secured. However, the level of security and the methods for achieving this security are not described in this document.

10.3 Communication data

10.3.1 General

The tables below describe the contents of the data items used for platooning systems but the element, format and structure of data are not specified. Data items shown in this subclause are not mandatory; additional data items can also be communicated up to the design of platooning system.

10.3.2 Communication data for PMM

Data items and the explanations of contents described in PMM are shown in the following tables.

Table 1 lists the common description data in PMM.

Table 1 — Common description data in PMM

Data items	Contents
Message ID	Identification of message to specify that this message is PMM.
Vehicle ID	Unique identification of vehicle or station. For V2I communication, this identifies BO or roadside unit.
Vehicle position	Current vehicle position (longitude, latitude, altitude). Measurement time corresponds to time stamp.
Vehicle heading	Azimuth of vehicle-moving-direction against north. Measurement time corresponds to time stamp.
Time stamp	Time at which position and heading are specified or time to generate the message which includes those data.

Tables 2-5 list the data descriptions for the join operation. Data for the join operation are classified as platoon formation plan (Table 2), join request (Table 3), join response (Table 4) and join completion (Table 5).

Table 2 — Data for platoon formation plan

Data items		Contents
Platoon formation plan		Platoon formation plan which is submitted from BO via V2I communication to potential platoon members. Applied only if that BO is a transmitter.
	Platoon formation planned location	Planned location of platoon formation.
	Platoon formation planned time	Planned time of platoon formation.
	(Platoon management information)	Management information for potential platoon formation members and including following contents.
	Platoon ID	Unique and temporary identification of platoon.
	Platoon max. length	Acceptable maximum number of vehicles in platoon.
	Vehicle sequence number in platoon	Vehicle sequence number and vehicle ID of each vehicle in platoon.
	Desired time gap	Desired time gap of each vehicle in platoon.
	Desired speed	Desired speed of platoon.

Table 3 — Data for join request

Data items		Contents
Join request		Request for platoon forming or participation in an existing platoon. Transmitted via V2V communication.
	Platoon length	Number of vehicles in platoon which requests to join. In case single vehicle requests to join, it is “1”.
	(Vehicle performance information)	Vehicle performance information of possible joining vehicle including following contents. In case of platoon join, repeat up to the number of platoon members.
	Vehicle type	Information to show the classification of vehicle, such as category and type of vehicle.
	Vehicle length	Length of vehicle.
	Vehicle weight	Gross weight of vehicle (estimated weight is possible when loading).
	Max. acceleration	Estimated achievable acceleration and deceleration based on current vehicle loading.

Table 4 — Data for join response

Data items	Contents
Join response	Response for the request for platoon forming or participation in an existing platoon.
Join response status	Accept or refuse (yes or no) to join. When accepting join, it is necessary to transmit platoon management information.
(Platoon management information)	Platoon management information of new platoon after join completion and including following contents.
Platoon ID	Unique and temporary identification of platoon.
Platoon max. length	Acceptable maximum number of vehicles in platoon.
Vehicle sequence number in platoon	Vehicle sequence number and vehicle ID of each vehicle in platoon.
Desired time gap	Desired time gap of each vehicle in platoon.
Desired speed	Desired speed of platoon.
(Vehicle performance information)	Performance information of each platoon member including following contents.
Vehicle type	Information to show the classification of vehicle such as category and type of vehicle.
Vehicle length	Length of vehicle.
Vehicle weight	Gross weight of vehicle (estimated weight is possible when loading).
Max. acceleration	Estimated capable acceleration and deceleration under its current loading.

Table 5 — Data for join completion

Data items	Contents
Join completion	Completion report of new platoon formation. FV reports to LV via V2V communication. LV reports to BO via V2I communication.
(Platoon management information)	Platoon management information of new platoon including following contents.
Platoon ID	Unique and temporary identification of platoon.
Platoon max. length	Acceptable maximum number of vehicles in platoon.
Vehicle sequence number in platoon	Vehicle sequence number and vehicle ID of each vehicle in platoon
Desired time gap	Desired time gap of each vehicle in platoon.
Desired speed	Desired speed of platoon.

Tables 6-8 list the data descriptions for the leave operation. Data for the leave operation are classified as leave instruction (Table 6), leave notification (Table 7) and leave completion (Table 8).

Table 6 — Data for leave instruction

Data items	Contents
Leave instruction	Instruction for leave operation. In case of top-down managed platooning type, LV transmits via V2V communication or BO transmits via V2I communication as an optional case.
Platoon ID	ID of platoon of the vehicle that is instructed to leave.
Vehicle ID	ID of vehicle which is instructed to leave. If multiple vehicles are instructed, all IDs are enumerated.

Table 7 — Data for leave notification

Data items	Contents
Leave notification	Notification of leave operation from a platoon transmitted by a platoon member who departs. Regardless of own decision or instruction from LV or BO, departure from original platoon is notified via V2V communication.
Platoon ID	ID of platoon of which the leaving vehicle is a member.
Vehicle ID	ID of vehicle which is leaving. If multiple vehicles are leaving, all IDs are enumerated.

Table 8 — Data for leave completion

Data items	Contents
Leave completion	Notification of leave completion from a platoon. Completion of leave from original platoon is notified to the platoon via V2V communication from the vehicle who transmits leave notification and in case of top-down managed platooning type, it may also be notified to BO via V2I communication.
Platoon ID	ID of original platoon of which leaving vehicle was a member.
Vehicle ID	ID of vehicle which has left. If multiple vehicles have left, all IDs are enumerated.

10.3.3 Communication data for PCM

Data items and the explanations of contents described in the PCM are shown in Tables 9-11.

Table 9 — Common description data in PCM

Data items	Contents
Message ID	Identification of message to specify that this message is PCM.
Vehicle ID	Unique and temporary identification of vehicle.
Vehicle position	Current vehicle position (longitude, latitude, altitude).
Vehicle heading	Azimuth of vehicle-moving-direction against north.
Time stamp	Time at which position and heading are specified or time to generate the message which includes those data.

Table 10 — Data describing longitudinal control operation

Data items	Contents
Longitudinal control status	Status of vehicle longitudinal control such as CC, ACC, CACC etc. (transmitted by both LV and FV).
Minimum in-platoon clearance	Minimum vehicle following distance in platoon (transmitted by LV).
Desired clearance	Desired following distance chosen by FV or its driver (transmitted by FV).
Clearance to preceding vehicle	Actual distance to preceding vehicle (transmitted by FV).
Longitudinal acceleration	Longitudinal acceleration (transmitted by both LV and FV).
Speed	Longitudinal speed (transmitted by both LV and FV).
Cut-in event	Transmitted by FV, which detects cut-in of OV.
Cut-in status	Status such as cut-in (OV enters and stays).
Distance cut-in vehicle	Distance to cut-in vehicle (OV).
Speed	Speed of cut-in vehicle (OV) detected by FV sensors.

Table 10 *(continued)*

Data items		Contents
Cut-out event		Transmitted by FV, which detects cut-out of OV.
	Cut-out status	Status such as cut-out (OV leaves).

Table 11 — Data describing lateral control operation

Data items		Contents
Lateral control status		Status of vehicle lateral manoeuvre control such as manual, LKAS, PALS etc. (transmitted by both LV and FV).
Lateral acceleration		Lateral acceleration (transmitted by both LV and FV).
Yaw rate		Yaw rate.
Lane change event		In case of lane change intention, lane change request is transmitted, and lane change response is transmitted from all members of platoon.
	Lane change request	Lane change request with intended direction of lane change (right or left) to the other platoon members.
	Lane change response	Possibility of lane change as yes or no, based on the safety condition of adjacent lane.
	Lane change notice	Status of lane change condition such as start, in-process or finish and the direction of lane change.

11 Functional evaluation test method

11.1 Evaluation test conditions

All tests shall be operated under the following conditions.

— The tests shall be performed outdoors under open sky conditions.

— The test road shall be on a flat, dry asphalt or concrete surface.

— The temperature range shall be –20 °C to 40 °C.

— Horizontal visibility shall be greater than 1 km.

— The tests may occur during daylight conditions.

All figures such as speed, distance and time gap specified in the evaluation test methods allow ±10 % tolerances, if not specified.

11.2 Evaluation test method

11.2.1 General

POCF and PMCF are evaluated in the following tests.

Each test shall be achieved three times and evaluations are confirmed with all tests successfully.

11.2.2 Join evaluation test

1) Test conditions (Figure 8):

— Vehicles A and B are independent vehicles and not in platoon mode.

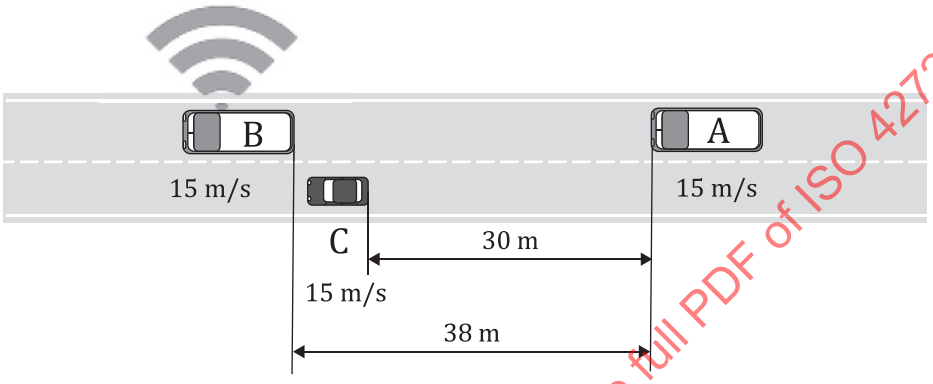
— Vehicle A follows vehicle B.

— Vehicle B turns on PCS and transmits PCM via V2V communication.

— Vehicle C is not equipped with V2V communication.

— Vehicle A is driving with manual mode and vehicle B is driving in front of vehicle A with CC mode on the same lane as vehicle A. Vehicle C is driving ahead of vehicle A on the adjacent lane.

— Vehicles A, B and C move with the speed of 15 m/s. The distance between vehicles A and B is 38 m (equivalent to 2,5 s time gap) and the distance between vehicle A and C is 30 m (equivalent to 2 s time gap).



Key

Vehicle A: manual, PCS_OFF
Vehicle B: CC, PCS_ON
Vehicle C: manual, not equipped PCS

Figure 8 — Test conditions (join)

2) Test procedures (Figure 9):

— Vehicle A turns on PCS and transmits PCM via V2V communication.

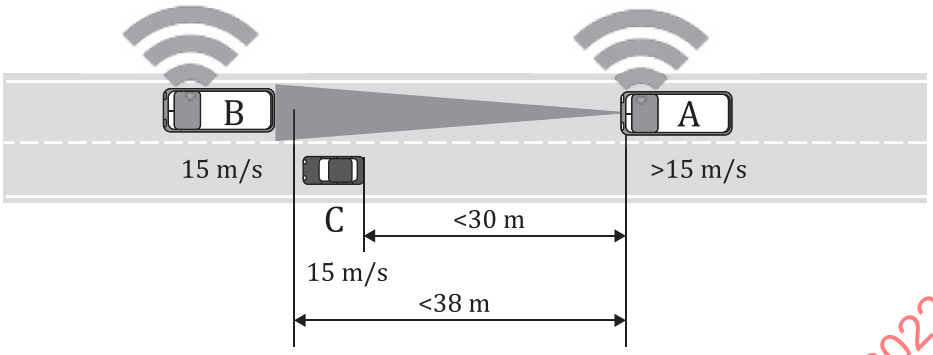
— Vehicle A transmits "join request" with PMM via V2V communication.

— Vehicle B receives "join request" and judges if this request is acceptable.

— If vehicle A is join-capable, vehicle B transmits "join response: yes" with PMM via V2V communication.

— Vehicle A receives "join response: yes".

— Vehicle A sets the time gap as 1,6 s (equivalent to 24 m) and turns on platooning mode switch.



Key

Vehicle A: from Manual to CACC, PCS_ON, transmit & receive; PMM, PCM

Vehicle B: CC, PCS_ON, transmit & receive; PMM, PCM

Vehicle C: manual, not equipped PCS

Figure 9 — Test procedures (join)

3) Evaluation confirmation (Figure 10):

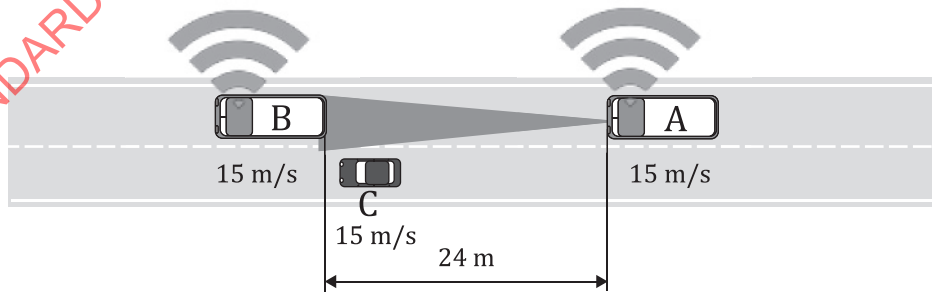
In the join evaluation test, the following shall be confirmed.

— A common Platoon ID has been generated for both vehicles A and B, and vehicle B becomes the LV with platoon sequence number 1 and vehicle A becomes the FV with platoon sequence number 2.

— PCS of vehicles A and B report this situation to each driver for which the platooning control has been activated.

— Vehicles A and B transmit PCM and receive PCM from the other vehicle.

— Vehicle A adjusts speed and clearance to vehicle B. Vehicle A follows vehicle B with a set time gap of 1,6 s and does not follow vehicle C.



Key

Vehicle A: CACC; time gap 1,6 s, transmit & receive; PCM

Vehicle B: CC, transmit & receive; PCM

Vehicle C: manual, not equipped PCS

Figure 10 — Evaluation confirmation (join)

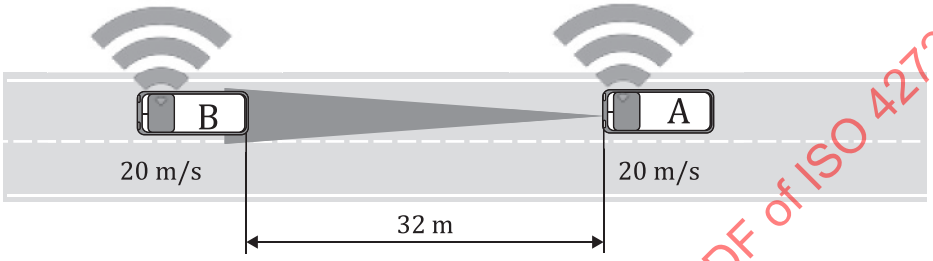
11.2.3 Leave evaluation test

1) Test conditions (Figure 11):

— Vehicles A and B are PCS ON. They transmit PCM via V2V communication and receive PCM from the other vehicle.

— Vehicle A follows vehicle B in CACC mode of cruising operation.

— Both vehicles move with a speed of 20 m/s in the same lane with 32 m clearance (equivalent to 1,6 s time gap).



Key

Vehicle A: PCS_ON, CACC; time gap 1,6 s, transmit & receive; PCM

Vehicle B: PCS_ON, CC, transmit & receive; PCM

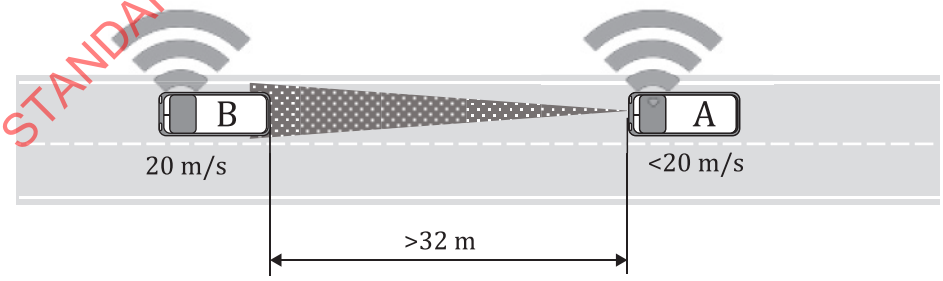
Figure 11 — Test conditions (leave)

2) Test procedures (Figure 12):

— Set time gap of ACC as 2,4 s for vehicle A during CACC mode of cruising.

— Vehicle A transmits “leave notification” with PMM via V2V communication. This is triggered by platooning mode switch off.

— Vehicle B receives “leave notification” from vehicle A via V2V communication.



Key

Vehicle A: from CACC to ACC, transmit; PMM

Vehicle B: CC, receive; PMM

Figure 12 — Test procedures (leave)

3) Evaluation confirmation (Figure 13):

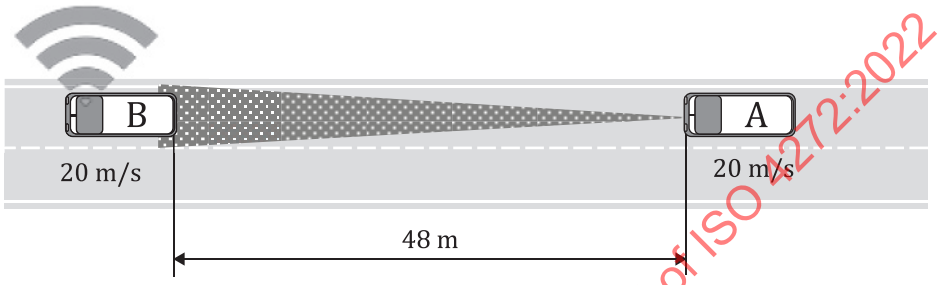
In the leave evaluation test, the following shall be confirmed.

— Platoon ID and platoon sequence numbers are deleted in vehicle A and B.

— PCS of vehicles A and B report to each driver that the platooning control has been deactivated.

— Vehicle A turns off PCS automatically and the leave operation is completed.

— Vehicle A increases the clearance to vehicle B to time gap 2,4 s and follows vehicle B in ACC mode.



Key

Vehicle A: ACC; time gap 2,4 s

Vehicle B: CC

Figure 13 — Evaluation confirmation (leave)

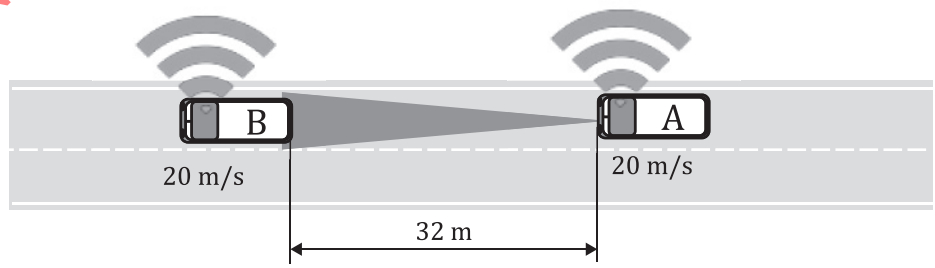
11.2.4 Cruising evaluation test

1) Test conditions (Figure 14):

— Vehicles A and B are PCS ON. They transmit PCM via V2V communication and receive PCM from the other vehicle.

— Vehicles A and B drive in cruising mode in platooning and vehicle A follows vehicle B in CACC mode.

— Both vehicles move with the speed of 20 m/s on the same lane and vehicle A drives with the set time gap 1,6 s (equivalent to 32 m clearance).



Key

Vehicle A: PCS_ON, CACC; time gap 1,6 s, transmit & receive: PCM

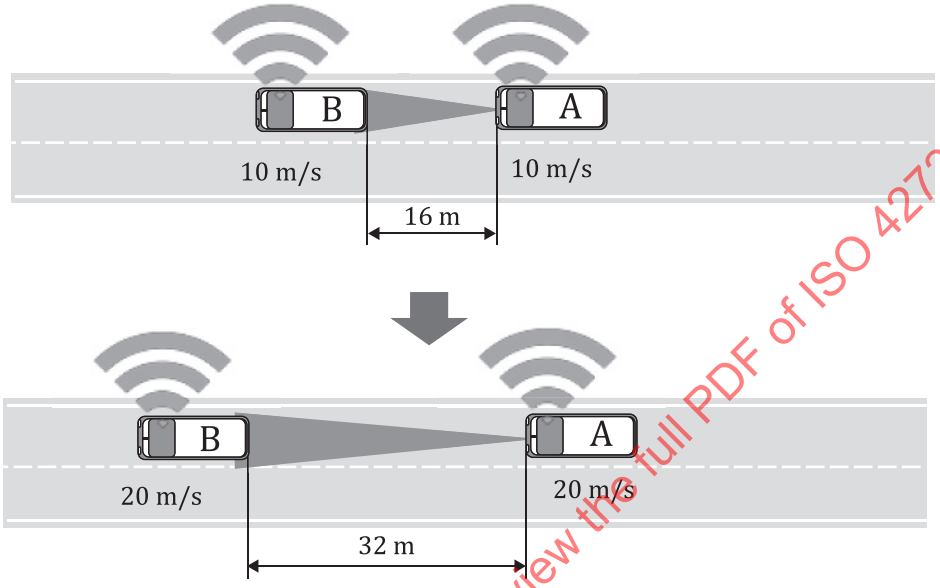
Vehicle B: PCS_ON, manual, transmit & receive: PCM

Figure 14 — Test conditions (cruising)

2) Test procedures (Figure 15):

— Vehicle B reduces speed to 10 m/s. Vehicle A also reduces speed to maintain set time gap 1,6 s (equivalent to 16 m clearance) and keeps clearance and follows.

— Vehicle B increases speed to 20 m/s. Vehicle A also increases speed to maintain set time gap 1,6 s (equivalent to 32 m clearance) and keeps clearance and follows.



Key

Vehicle A: CACC; time gap 1,6 s

Vehicle B: manual

Figure 15 — Test procedures (cruising)

3) Evaluation confirmation:

In the cruising evaluation test, the following shall be confirmed.

— Vehicles A and B transmit PCM and receive PCM from the other vehicle.

— Vehicle A drives to adjust speed and clearance, and maintains own set time gap 1,6 s behind vehicle B when vehicle B changes the speed.

11.2.5 Cut-in evaluation test

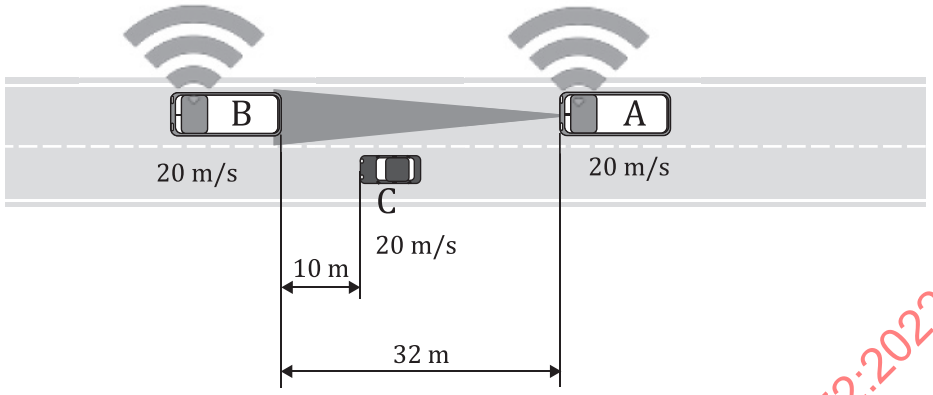
1) Test conditions (Figure 16):

— Vehicles A and B are PCS ON. They transmit PCM via V2V communication and receive PCM from the other vehicle.

— Vehicle A follows vehicle B in CACC mode of cruising operation.

— Both vehicles move with a speed of 20 m/s on the same lane with 32 m clearance (equivalent to 1,6 s time gap).

— Vehicle C is driving between vehicles A and B in the adjacent lane of vehicles A and B. Vehicle C is in manual mode and is 10 m behind vehicle B with a speed of 20 m/s.



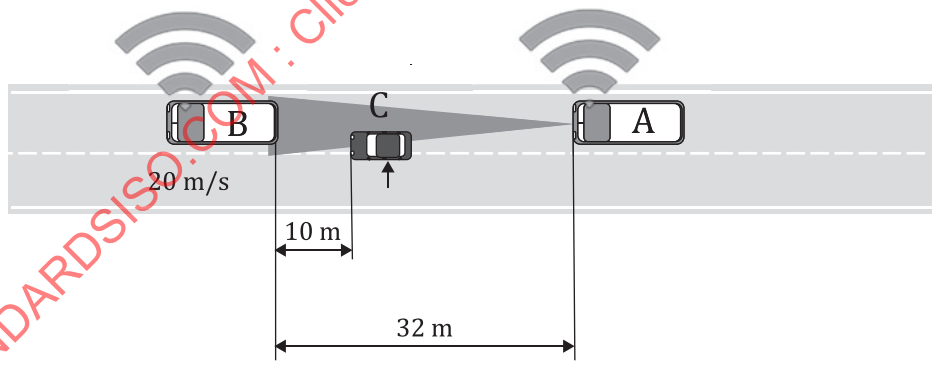
Key

Vehicle A: PCS_ON, CACC; time gap 1,6 s, transmit & receive; PCM
Vehicle B: PCS_ON, CC, transmit & receive; PCM
Vehicle C: manual

Figure 16 — Test conditions (cut-in)

2) Test procedures (Figure 17):

— Vehicle C cuts-in between vehicles A and B from the adjacent lane with 1 m/s lateral speed and follows vehicle B with the same speed.



Key

Vehicle A: CACC; time gap 1,6 s, transmit & receive; PCM
Vehicle B: CC, transmit & receive; PCM
Vehicle C: manual, cut-in (lateral; 1 m/s)

Figure 17 — Test procedures (cut-in)

3) Evaluation confirmation (Figure 18):

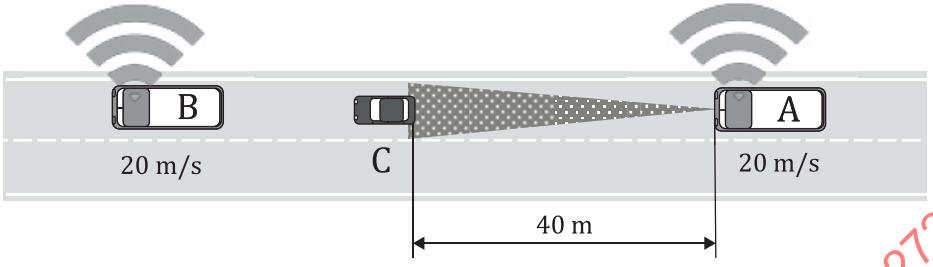
In the cut-in evaluation test, the followings shall be confirmed.

— Vehicle A detects vehicle C cut-in situation with its on-board sensors and transmits “OV cut-in notification” with PCM.

— Vehicle B receives “OV cut-in notification” from vehicle A and report cut-in situation to the driver.

— Vehicle A starts ACC control behind vehicle C.

— Vehicle A increases its time gap behind vehicle C to the ACC desired time gap.



Key

Vehicle A: transmit; OV cut-in notification, ACC; time gap 2 s

Vehicle B: CC, receive; OV cut-in notification

Vehicle C: manual

Figure 18 — Evaluation confirmation (cut-in)

11.2.6 Cut-out evaluation test

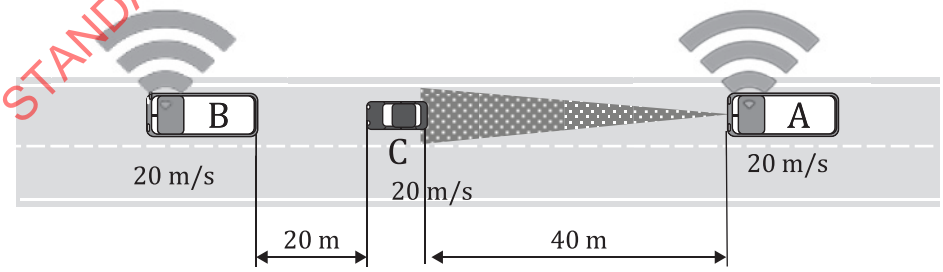
1) Test conditions (Figure 19):

— The cut-out operation evaluation is performed under the cut-in situation and it is recommended to perform this evaluation after the cut-in operation evaluation (11.2.5).

— Vehicles A, B and C move at a speed of 20 m/s on the same lane.

— Vehicle B is driving in CC mode.

— Vehicle C follows vehicle B in manual mode with 20 m clearance, and vehicle A follows vehicle C in ACC mode with time gap 2 s (equivalent to 40 m clearance).



Key

Vehicle A: PCS_ON, ACC; time gap 2 s

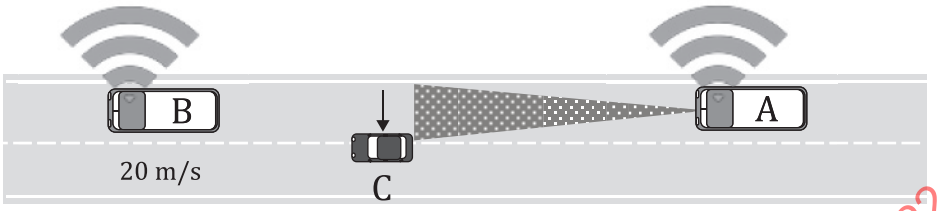
Vehicle B: PCS_ON, CC

Vehicle C: manual

Figure 19 — Test conditions (cut-out)

2) Test procedures (Figure 20):

— Vehicle C moves out to the adjacent lane with 1 m/s lateral speed.



Key

Vehicle A: ACC
Vehicle B: CC
Vehicle C: manual, cut-out (lateral: 1 m/s)

Figure 20 — Test procedures (cut-out)

3) Evaluation confirmation (Figure 21):

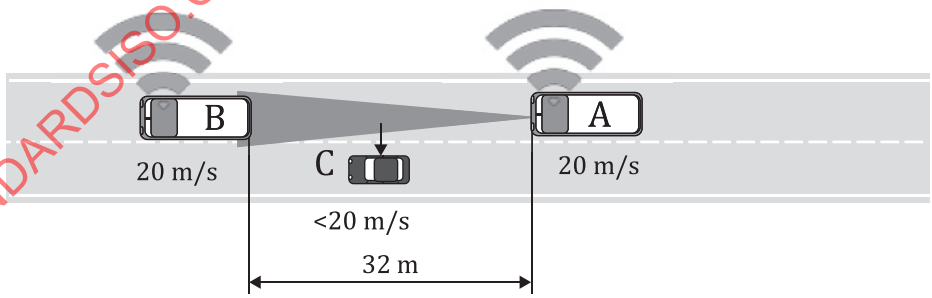
In the cut-out evaluation test, the following shall be confirmed.

— Vehicle A detects the cut-out situation of vehicle C with its on-board sensors and transmits "OV cut-out notification" with PCM.

— Vehicle B receives "OV cut-out notification" from vehicle A and reports cut-out situation to the driver.

— Vehicle A terminates ACC control behind vehicle C and starts CACC control behind vehicle B.

— Vehicle A reduces the gap and reaches time gap 1,6 s behind vehicle B.



Key

Vehicle A: transmit; OV cut-out notification, CACC; time gap 1,6 s
Vehicle B: CC, receive: OV cut-out notification
Vehicle C: manual

Figure 21 — Evaluation confirmation (cut-out operation)

Annex A
(informative)

Use cases of POCF

A.1 Join

A.1.1 General

In the platooning operation, the following use cases are expected with the "join" transition (Figures A.1 to A.5).

A.1.2 Use case J1

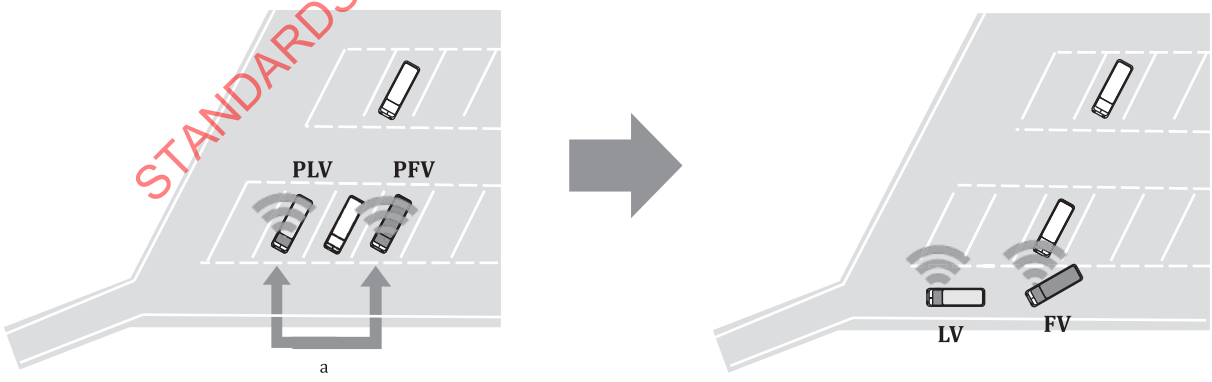
Use case J1 is achieved when the PFV joins the PLV from behind. This transition can be made on the same lane during driving, as shown in Figure A.1a), or at a staging area such as a parking site, as shown in Figure A.1b).

Normally, the preceding PLV becomes the LV and the following PFV becomes the FV. In some case, V2V communication and/or V2I communication with the BO can adjust the sequence of the PLV and the PFV to make a suitable platoon during this transition.

Key

a Join.

Figure A.1 a) Use case J1 (on the motorway)



Key

a Join.

Figure A.1 b) Use case J1 (at the staging area)

A.1.3 Use case J2

Use case J2 is achieved when a PFV joins a preceding platoon from behind (Figure A.2). This transition can be made on the same lane during driving or at a staging area such as a parking site.

Key

a Join.

Figure A.2 — Use case J2

A.1.4 Use case J3

Use case J3 is achieved when a PLV joins the platoon as the new leader in front of the current LV (Figure A.3). This transition can be made on the same lane during driving or at a staging area such as a parking site.

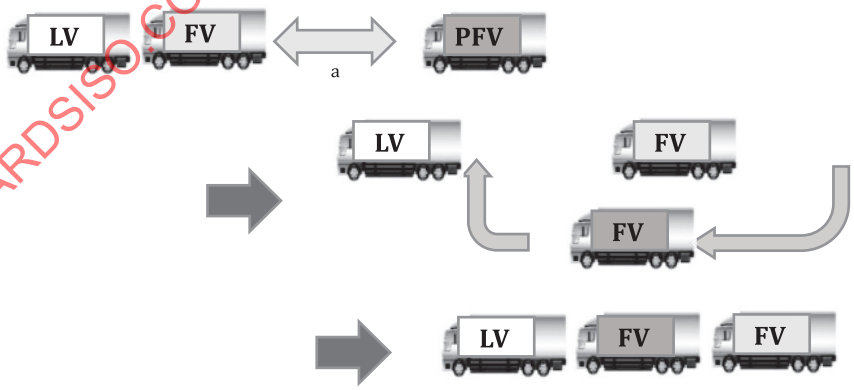
Key

a Join.

Figure A.3 — Use case J3

A.1.5 Use case J4 (not supported by functionalities defined in this document)

Use case J4 is achieved when a PFV joins the middle of a platoon from the adjacent lane (Figure A.4). This transition can be made during driving or at a staging area such as a parking site.



Key

a Join.

Figure A.4 — Use case J4

A.1.6 Use case J5

Use case J5 is achieved when a platoon joins a preceding platoon from behind (Figure A.5). This transition can be made on the same lane during driving or at a staging area such as a parking site.