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

Systèmes de transport intelligents — Systèmes de changement de voie partiellement automatisés (PALS) — Exigences fonctionnelles et opérationnelles et procédures d'essai

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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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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

In general, driving assist systems and automated driving systems equipped in a vehicle reduce the burden of the drivers and contribute to safe driving. For a lane change operation, there are many drivers who are not good at performing a lane change. To support such drivers, Partially Automated Lane Change Systems (PALS) execute an automatic lane change manoeuvre following the request of the driver and under the supervision of the driver, on a road with visible lane markings, where non-motorized vehicles and pedestrians are prohibited.

PALS acquire information not only on the position of the vehicle within the lane, but also on adjacent lanes and obstacles in the vicinity of the subject vehicle (SV). PALS evaluate whether or not a lane change to an adjacent lane is possible and send commands to the actuators which control lateral movement of the vehicle to perform a lane change. This document specifies how PALS support drivers for a lane change and describes PALS' operations.

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

1 Scope

This document contains the basic control strategy, minimum functionality requirements, basic driver interface elements, minimum requirements for reaction to failure, and performance test procedures for PALS.

PALS perform part or all of lane change tasks under the driver's initiation and supervision. PALS are intended to function on roads with visible lane markings, where non-motorized vehicles and pedestrians are prohibited (e.g. access controlled highway), and to perform a lane change into a lane with traffic moving in the same direction. Support on sections of roadway with temporary or irregular lane markings (such as roadwork zones) is not within the scope of this document.

This document does not describe functionalities based on combinations with longitudinal control systems such as those standardized in ISO 22839 (FVCMS) or ISO 15622 (ACC).

The driver always assumes responsibility for this system and the driver's decisions and operations take priority at all times.

Use of PALS is intended for light-duty and heavy-duty vehicles (heavy trucks and buses).

This document does not address any functional or performance requirements for detection sensors, nor any communication links for co-operative solutions.

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 15037-1, *Road vehicles — Vehicle dynamics test methods — Part 1: General conditions for passenger cars*

ISO 15037-2, *Road vehicles — Vehicle dynamics test methods — Part 2: General conditions for heavy vehicles and buses*

ISO 17387, *Intelligent transport systems — Lane change decision aid systems (LCDAS) — Performance requirements and test procedures*

3 Terms and definitions

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

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

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

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

3.1
subject vehicle
SV
vehicle equipped with the system in question and related to the topic of discussion

3.2
PALS state
one of several stages or phases of the system operation flow

Note 1 to entry: See Figure 1.

3.3
PALS off state
PALS state when the system is switched off

3.4
PALS stand-by state
PALS state when the system is switched on, but the activation criteria are not all met

3.5
PALS active state
PALS state when the system is switched on and the activation criteria are met

3.6
lane
one of the longitudinal strips into which a roadway is divided by *lane markings* (3.7)

3.7
lane marking
delineators, markings, or Botts' dots intentionally placed on the borderline of the *lane* (3.6)

3.8
lane change manoeuvre
lateral movement which the system automatically executes to change *lanes* (3.6) from its initial lane to an adjacent lane

3.9
lane change function
function of the system which includes both gap-searching and *lane change manoeuvre* (3.8)

3.10
time gap
value calculated from vehicle speed, v, and clearance, c, by the Formula: $t_{gap} = c/v$

Note 1 to entry: see Figure 1

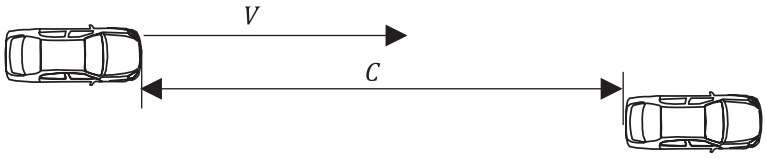


Figure 1 — Time gap

3.11
time to collision
TTC
estimated time that it would take a target vehicle to collide with the SV if the SV were in the target vehicle's path and the target vehicle's current closing speed remains constant

3.12
overtaking speed
difference between the SV's speed and the target vehicle's speed when the SV is overtaking the target vehicle

Note 1 to entry: A positive overtaking speed indicates that the SV is moving faster than the target vehicle.

3.13
gap searching
system function to search for sufficient gap between the SV and the other vehicle(s) in the adjacent target lane

4 Symbols and abbreviated terms

4.1 Symbols

See Table 1.

Table 1 — Symbols

Symbol	Definition
$A_{PALS,l,max}$	Maximum lateral acceleration which is allowed to be induced by a lane change manoeuvre
$J_{PALS,l,max}$	Maximum lateral jerk which is allowed to be induced by a lane change manoeuvre
V_{max}	Maximum SV speed which PALS is required to function
V_{min}	Minimum SV speed which PALS is required to function
V_{sv}	Velocity of SV
V_{rv}	Velocity of the rearward vehicle
V_{fv}	Velocity of the forward vehicle
D_r	Distance between the front edge of the rearward vehicle and the rear edge of the SV
D_f	Distance between the rear edge of the forward vehicle and the forward edge of the SV. The distance is equivalent to $V_{sv} \times T_{f.}$
T_f	Time gap between the forward vehicle and the SV
$T_{col,r}$	TTC between the rearward vehicle and the SV
$T_{l,S}$	Time from the initiation of the lane change function to the start of the lane change manoeuvre itself, in a free gap available condition

4.2 Abbreviated term

ACC Adaptive cruise control

HMI Human-machine interface

LCDAS Lane Change Decision Aid Systems

SV Subject vehicle

TTC Time to collision

5 Classification

5.1 General

PALS are classified into two types by different tasks split between system and driver as shown in 5.1.1, and 5.1.2, and by a modified sequence of operations. In both types, the lane change manoeuvre is initiated and supervised by the driver and is terminated when the SV is brought totally inside the target lane.

In Type I systems, the driver intends to promptly change the lane as the driver evaluates the target lane to be free and the PALS receive a driver command to perform the lane change manoeuvre. The system performs the lane change unless it detects an adjacent vehicle that obstructs the lane change.

In Type II systems, the driver intends to change the lane as soon as a sufficient gap in the target lane becomes available. The driver authorizes the system to search for a sufficient gap and then to perform a lane change manoeuvre.

In both types, a lane change manoeuvre is only started when no hazardous obstacle is detected in the relevant range for Type I or Type II, respectively (see 5.1.1 and 5.1.2).

For both types, the point in time when the SV leaves the current lane is specified as the point in time when the preceding wheel of the SV crosses the inner edge of the lane marking.

Type I and II systems can be offered separately, or as a combined system with both types in one system.

Both types may be combined with a longitudinal control system such as ISO 15622 (ACC) to maintain an appropriate time gap behind a forward vehicle.

5.1.1 Type I systems

Type I systems perform a lane change corresponding to the driver's initiation by controlling the lateral manoeuvre of the vehicle when there is no obstacle detected at least in the blind spot area. Means to detect the blind spot area shall conform to the requirements of LCDAS Type I specified in ISO 17387.

The following actions shall be performed.

a) The driver monitors the target lane and initiates a lane change manoeuvre (e.g. by indicator or specific HMI) if he or she believes that there is no hazardous obstacle in the target lane.

b) The system monitors the traffic situation at least in the blind spot area, (see ISO 17387:2008, LCDAS Type I) and if there is no interfering vehicle, the requested lane change manoeuvre can be executed. The system performs the lane change unless it detects an adjacent vehicle that obstructs the lane change. If a vehicle is detected in the adjacent lane, the PALS lane change function is cancelled and an additional driver initiation may be applied to start the lane change manoeuvre at a later time.

c) The turn signal shall be activated no later than at the beginning of the lane change manoeuvre. The SV should not leave the current lane earlier than 3 s and shall not leave earlier than 1 s after activation of the turn signal.

d) The driver shall be informed when the lane change manoeuvre starts.

e) The system performs a lane change manoeuvre when the necessary activation conditions have been met.

5.1.2 Type II systems

If the driver initiates a lane change, Type II systems search the gap in the adjacent lane at least in the blind spot and closing range and automatically perform the lane change. Means to detect the blind spot and closing range shall conform to the requirements of LCDAS Type III C specified in ISO 17387.

The following actions shall be performed:

a) The driver initiates the PALS lane change function (e.g. by indicator or specific HMI).

   Optionally, Type II systems may propose a lane change first without the driver's initiation of a lane change, e.g. when a slower vehicle is detected ahead or when an exit or junction in the routing is being approached. In this optional case, the system requires driver confirmation before the lane change manoeuvre is initiated, e.g. by switch or by steering wheel input.

b) The system continuously monitors the traffic situation and determines whether there is a sufficient gap which allows the lane change manoeuvre to be executed (gap searching). This should include detecting whether the target lane for the lane change is still available for the lane change manoeuvre (e.g. lane still exists, or lane markings and road signs still allow lane change).

c) The system informs the driver by an appropriate HMI that a sufficient gap exists, and the lane change manoeuvre can be started.

d) If a sufficient gap is not detected for longer than 10 s after the driver's lane change initiation request, an additional driver confirmation is necessary to continue gap searching. However, if the same vehicle has been obstructing the lane change since the driver initiated the lane change, gap searching may continue without additional confirmation. It is up to the manufacturer to determine how the gap searching is terminated if the driver doesn't confirm after a certain time period.

e) The turn signal shall be activated no later than at the beginning of the lane change manoeuvre. The SV should not leave the current lane earlier than 3 s and shall not leave earlier than 1 s after activation of the turn signal.

f) The driver shall be informed when the lane change manoeuvre starts and is expected to monitor that there is no hazardous obstacle in the target lane.

g) The system performs the lane change manoeuvre.

6 Requirements

6.1 General

PALS do not perform automated driving and only provide a lane change manoeuvre under the driver's initiation and supervision.

When the driver overrides the system, PALS shall allow the driver to take control. In that case, the lane change manoeuvre by the system shall be terminated.

In the following subclauses, the minimum requirements of functionalities and state transitions which PALS provide are specified.

6.2 Functionality

PALS shall have the means to detect visible lane markings and detect other vehicles and obstacles in the vicinity of the SV.

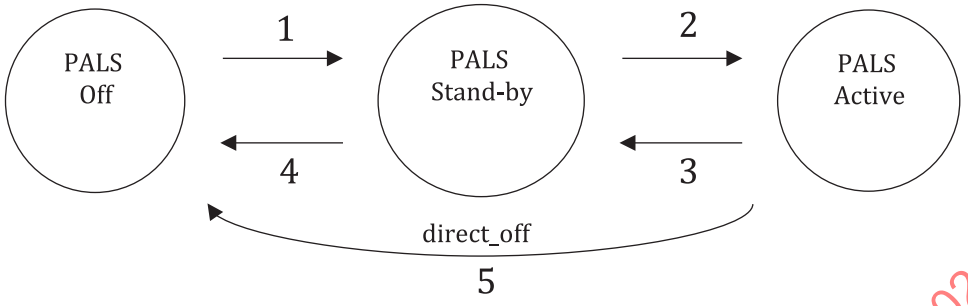
PALS shall have the means to move the SV in a lateral direction in order to perform a lane change manoeuvre.

PALS may have the capability of conducting longitudinal control relative to a vehicle in the adjacent lane. In this case, the functionality should be executed according to other control systems, such as ISO 21717 (PADS).

6.3 State transitions

6.3.1 General

PALS shall, at a minimum, provide operations and state transitions as described in Figure 2 below.



Key

1 - Ignition on
- And no system failure
- And PALS switch on

2 - All criteria for lane change are met
- And lane change initiation by the driver

3 - Any of criteria for lane change are not met
- Or lane change completed
- Or override by the driver is detected

4 - Ignition off
- Or system failure
- Or PALS switch off

5 - System failure
- Or PALS switch off

Figure 2 — PALS state transition diagram

The following constitutes the fundamental behaviours of PALS.

6.3.2 PALS off state

No functions are performed in the PALS off state.

6.3.3 Transition from PALS off state to PALS stand-by state

Transition from PALS off state to PALS stand-by state shall be executed when PALS is switched on and there is no functional failure after ignition on.

6.3.4 Transition from PALS stand-by state to PALS off state

Transition from PALS stand-by state to PALS off state shall be executed if a system fault is detected, after ignition off, or manually by the driver.

6.3.5 PALS stand-by state

In PALS stand-by state, the system evaluates the conditions to activate the lane change manoeuvre using information on surroundings which is obtained from sensors installed on the vehicle. The system also evaluates whether or not it can remain in the stand-by state.

6.3.6 PALS active state

In PALS active state, the system is performing a lane change manoeuvre.

6.3.7 Transition from PALS stand-by state to PALS active state

Transition from PALS stand-by state to PALS active state shall be executed upon lane change initiation by the driver when all the following conditions for a lane change are evaluated and satisfied:

— lane markings required for a lane change are detected;

— no obstructing vehicles are detected in the lane into which the SV is moving;

— a sufficient gap is detected (Type II);

— speed of the SV is within the operation speed range.

6.3.8 Transition from PALS active state to PALS stand-by state

Transition from PALS active state to PALS stand-by state shall be executed when any of the following conditions are evaluated and satisfied:

— the phase after completion of a lane change is entered and detected;

— steering override by the driver is detected during the lane change manoeuvre; the vehicle shall be controllable by the driver;

— the system has determined that the lane change cannot be continued due to changes in the surrounding environment (e.g. another vehicle is entering the same target lane) or other reasons; in such cases, the system is allowed to perform an additional manoeuvre (e.g. manoeuvre the vehicle until it is entirely within one lane) before transition to PALS stand-by.

6.3.9 Transition from PALS active state to PALS off state

Transition from PALS active state to PALS off state shall be executed when any of the following conditions are evaluated and satisfied:

— system failure is detected;

— driver turns PALS off.

6.4 Driver interface and override capabilities

6.4.1 System reaction

6.4.1.1 Driver input

The initiation of the lane change function shall be conducted by activating the turn signal or by other means.

The system shall provide the driver with HMI representing the intended start of a lane change manoeuvre by visual means, at a minimum. Haptic (e.g. force on the steering wheel) and/or audible (e.g. click sound accompanied by the turn signal) means are recommended.

6.4.1.2 Driver override

The driver shall be able to override the lane change function by turning the steering wheel at any time and shall be able to deactivate PALS with a force not greater than 50 N.

Driver override may be performed by other means specified by the manufacturer.

In addition to steering override, PALS types I and II may provide other means for the driver to cancel the lane change function.

6.4.2 Display elements

6.4.2.1 PALS state indication

The start of a lane change manoeuvre and whether PALS is in the active state shall be informed to the driver.

The information whether PALS is in the stand-by state or off state shall be accessible to the driver.

6.4.2.2 PALS fault indication

In the case that PALS is not available due to system failure, the driver shall be informed of such a status.

6.5 Minimum performance

6.5.1 Duration of the lane change manoeuvre

PALS shall bring the vehicle totally inside the target lane within 10 s after starting the lane change manoeuvre.

6.5.2 Velocity for PALS operation

PALS, at a minimum, should be active at the minimum speed below. A manufacturer defined value may apply instead.

V_{min} = 20 m/s

PALS, at a minimum, shall be active within the range up to the speed below.

V_{max} = 30 m/s or the maximum possible speed of the vehicle under the national regulation, whichever is less.

The system is allowed to be operational in a wider speed range.

6.5.3 Operational limit

The lateral acceleration of the vehicle during lane change shall not exceed specific values. The values include the lateral acceleration required to follow the lane in curves. Lane change function shall be at least operational on roads with curve radius greater than 500 m. Within the curve radius, the lateral acceleration generated by PALS is sufficient to perform lane change manoeuvres.

The magnitude of the lateral acceleration which is induced by PALS shall not exceed $A_{PALS,l,max}$ and the moving average over half a second of the lateral jerk should be limited to $J_{PALS,l,max}$ as given below.

— For a light-duty vehicle: $A_{PALS,l,max}$ = 4,0 m/s^2; $J_{PALS,l,max}$ = 5 m/s^3.

— For a heavy-duty vehicle: $A_{PALS,l,max}$ = 3,0 m/s^2; $J_{PALS,l,max}$ = 5 m/s^3.

6.6 Failure reactions

System failure shall result in immediate notification to the driver. If possible, the system may gradually fade out the manoeuvre.

7 Performance evaluation test methods

7.1 Environmental conditions

Environmental conditions for performance evaluation test methods are as given below:

— the test location shall be on a flat, dry, and clean asphalt or concrete surface;

— the temperature range shall be between –20 °C and +40 °C;

— the wind speed shall be less than 3 m/s;

— the horizontal visibility range shall be greater than 1 km;

— the lane markings at the test location should take into consideration the nationally defined visible lane markings of the countries in which the system is intended to operate.

7.2 Test course conditions

The course shall be long enough to maintain a minimum vehicle speed (of at least 20 m/s) while allowing the vehicle to drift out from the lane at a low rate of departure.

The width of the lane marking shall be in the range of 0,1 m to 0,3 m taking into consideration the nationally defined highway-like roads.

The width of the lane relative to the centre of the lane markings shall be in the range of 3,4 m to 3,9 m taking into consideration the nationally defined highway like roads.

7.3 Test vehicle conditions

The test vehicle mass shall be between the complete vehicle kerb mass plus driver and test equipment and maximum authorized total mass (refer to ISO 15037-1 and ISO 15037-2). No alterations shall be made once the test procedures have begun.

7.4 Test system installation and configuration

The PALS shall be installed and configured in accordance with the instructions provided by the manufacturer.

7.5 Test procedures

7.5.1 Parameters recoverable from data record

Parameters recoverable from the data record are described as follows:

a) lateral acceleration of the SV;

b) vehicle speed of the SV;

c) lateral position of the SV;

d) longitudinal distance and relative speed between the SV and other vehicles.

For all lane changing actions by PALS that occur during the test, the data for the above listed parameters given in a) to d) shall be recorded. The data shall be recovered by a device other than PALS The precision of the test device shall be noted in the test report.

7.5.2 Lane change test (types I and II)

7.5.2.1 Lane change test (adjacent lane free)

The SV is travelling with a constant speed, V_{sv}, of 22 m/s (±1 m/s) along a straight test course and no vehicle is in the adjacent lane. A lane change shall be initiated by the driver. If V_{min} is larger than 22 m/s, the manufacturer defined value may be used instead of V_{sv}. $T_{I,S}$ is measured for type II systems for the test specified in 7.5.2.2.

The test is passed when the following conditions are fulfilled.

— The turn indicator is active at the time when the SV leaves the current lane.

— The SV does not leave the current lane before the turn indicator has been active for 1 s.

— The SV is completely within the target lane within a maximum of 10 s after starting the manoeuvre.

7.5.2.2 Lane change test (adjacent lane blocked)

The SV is travelling with a constant speed, V_{sv}, of 22 m/s (±1 m/s) along a straight test course. If the minimum PALS operating speed is greater than 22 m/s, then the minimum operating speed may be used instead of V_{sv}.

The following conditions shall apply for PALS type I.

— In the adjacent lane a vehicle is overtaking with a speed of $V_{rv} = V_{sv}$ + 1,5 m/s (±0,5 m/s) in the same direction.

— When the distance between the front of the approaching vehicle and the rear of the SV is 0 m (±3 m) the driver shall initiate a lane change. The test is passed when the lane change manoeuvre does not start at all or when the SV does not leave the current lane.

The following conditions shall apply for PALS type II.

— In the adjacent lane a vehicle is travelling with a constant speed in the same direction and rearward to the SV. The vehicle has an overtaking speed of 7 m/s (±1 m/s).

— When the $T_{col,r}$ is 3 s + $T_{I,S}$ (–0,5 s, +0 s), the driver shall initiate a lane change. At this point of time, D_r between the front of the approaching vehicle and the rear of the SV is between $T_{I,S}$ × 7 m/s + 21 m and $T_{I,S}$ × 7m/s + 17,5 m.

The test is passed when the following conditions are fulfilled (both types I and II).

— The SV does not leave the current lane until the approaching vehicle is completely ahead of the SV.

— The lane change manoeuvre has started within 10 s of the driver's initiation.

— The lane change is completed within 10 s of the start of the manoeuvre.

Figure 3 below describes the lane change test.

