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Intelligent transport systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures

Systèmes intelligents de transport — Systèmes de détection des piétons et de prévention des collisions (PDCMS) — Exigences de performance et modes opératoires 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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

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

Introduction

The fatality and severe injury rates of traffic accidents involving pedestrians are significantly high, resulting in the loss of many lives.

Pedestrian Detection and Collision Mitigation Systems (PDCMS) reduce the severity of pedestrian collisions that cannot be avoided, and may reduce the likelihood of fatality. By a collision warning (CW) and automatically activating EB, PDCMS assist in slowing a vehicle when a collision is likely.

Functional elements of PDCMS are shown in Figure 1.

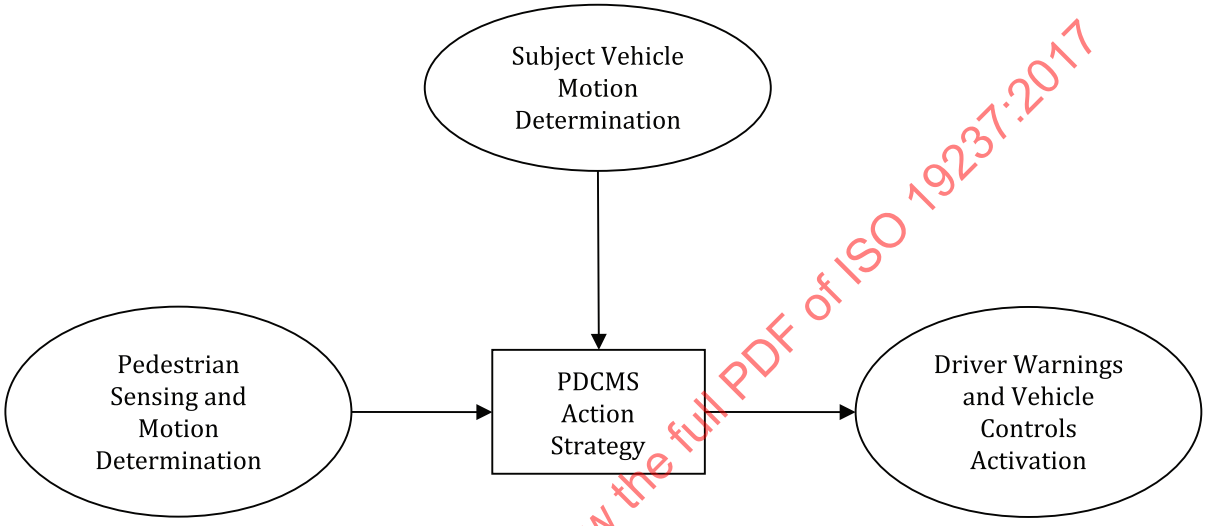


Figure 1 — Pedestrian Detection and Collision Mitigation Systems (PDCMS) functional elements

System designers and other users of this document may apply it to stand-alone PDCMS or to the integration of the PDCMS functions into other driving assistance and support systems.

Intelligent transport systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures

1 Scope

This document specifies the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for Pedestrian Detection and Collision Mitigation Systems (PDCMS). It specifies the behaviours that are required for PDCMS, and the system test criteria necessary to verify that a given implementation meets the requirements of this document. Implementation choices are left to system designers wherever possible.

PDCMS reduce the severity of pedestrian collisions that cannot be avoided, and may reduce the likelihood of fatality and severity of injury. PDCMS require information about range to pedestrians, motion of pedestrians, motion of the subject vehicle (SV), driver commands and driver actions. PDCMS detect pedestrians ahead of time, determine if detected pedestrians represent a hazardous condition, and warn the driver if a hazard exists. PDCMS estimate if the driver has an adequate opportunity to respond to the hazard. If there is inadequate time available for the driver to respond, and if appropriate criteria are met, PDCMS determine that a collision is imminent. Based upon this assessment, PDCMS will activate CWs and vehicle brakes to mitigate collision severity. This document, while not a collision avoidance standard, does not preclude a manufacturer from implementing collision avoidance with PDCMS.

Systems that include other countermeasures such as evasive steering are not within the scope of this document.

Responsibility for the safe operation of the vehicle remains with the driver.

This document applies to light duty passenger vehicles (see 3.6). It does not apply to other vehicle categories such as heavy vehicles or motorcycles. PDCMS are not intended for off-road use.

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 1176, *Road vehicles — Masses — Vocabulary and codes*

ISO 19206-2, *Road vehicles — Test devices for target vehicles, vulnerable road users and other objects, for assessment of active safety functions — Part 2: Requirements for pedestrian targets*[1)]

ISO 19476:2014, *Characterization of the performance of illuminance meter and luminance meter*

United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations. (WP.29) TRANS/WP.29/78/Rev.2

United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations. (WP.29) TRANS/WP.29/1045

No FMVSS 105; Hydraulic and electric brake systems

1) To be published.

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:

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

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

3.1
collision warning
CW
warning system that alerts the driver of a potential collision with a pedestrian in the forward path of the subject vehicle

3.2
driver override
driver initiated suppression of an EB or CW countermeasure

3.3
emergency braking
EB
PDCMS countermeasure that responds to the detection of an imminent pedestrian collision by automatically activating braking to quickly reduce the relative velocity

3.4
heavy vehicle
any single vehicle or combination of vehicles defined as Category 1-2 or Category 2 in the United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations (WP.29) TRANS/WP.29/1045

3.5
impact position
lateral contact position from the SV point of view or expected lateral contact position at the front of the SV when the SV collides with a pedestrian or when a collision is expected

3.6
light duty passenger vehicle
vehicle according to category M1 (≦8 passenger seats except driver seat) in the United Nations Economic and Social Council World Forum for Harmonization of Vehicle Regulations (WP.29) TRANS/WP.29/78/Rev.2.

3.7
minimum PDCMS speed reduction
minimum speed reduction achieved PDCMS shall achieve

3.8
minimum velocity
V_{min}
minimum SV speed for which PDCMS shall be capable of activating a countermeasure

3.9
pedestrian
human being on the road or near the road

3.10
pedestrian collision
collision between the SV and a pedestrian

3.11
subject vehicle
SV
vehicle equipped with PDCMS as defined herein

3.12
target pedestrian
TP
pedestrian that is positioned within the field of view of the sensor and that may be impacted by SV

4 Symbols and abbreviated terms

ABS	Anti-lock Brake System
CW	Collision Warning
ESC	Electronic Stability Control
EB	Emergency Braking
SV	Subject Vehicle
TP	Target Pedestrian
V_{min}	Minimum velocity for PDCMS operation
v_{sv}	Subject vehicle velocity
vtpL	Target pedestrian lateral velocity
V_{max}	Maximum SV velocity for PDCMS operation
Ld	(Lateral) distance between the vehicle pass and TP
xc	(Longitudinal) distance between SV and TP

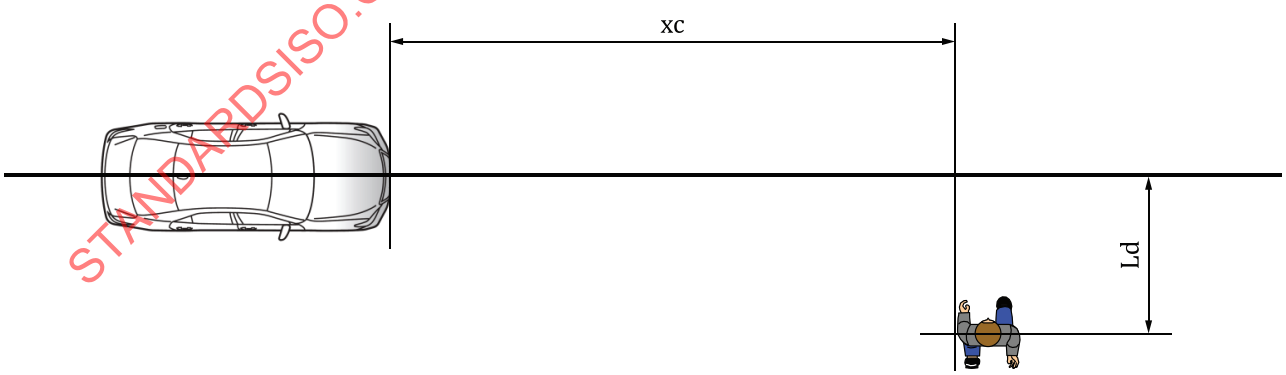


Figure 2

5 Requirements

5.1 Minimum enabling capabilities

Light duty passenger vehicles equipped with PDCMS shall be capable of providing the following characteristics:

— detect the presence of pedestrian(s).

— determine the direction of the detected pedestrian from the SV, distance and relative velocity between the SV and the detected forward pedestrian.

— determine the subject vehicle velocity.

— initiate appropriate PDCMS countermeasures.

— provide CWs.

— activate and modulate the brakes whether or not the driver is already braking.

— control the brake lights.

— enhance driver control based on brakes with a yaw stability capability and a capability to manage longitudinal wheel slip, by utilizing an ESC system.

— generate at least the minimum required PDCMS speed reduction in the defined pass criteria in 6.2.3.1 or 6.3.6.

— after EB has been initiated, permit the driver to increase the deceleration to any higher value up to the maximum possible vehicle deceleration.

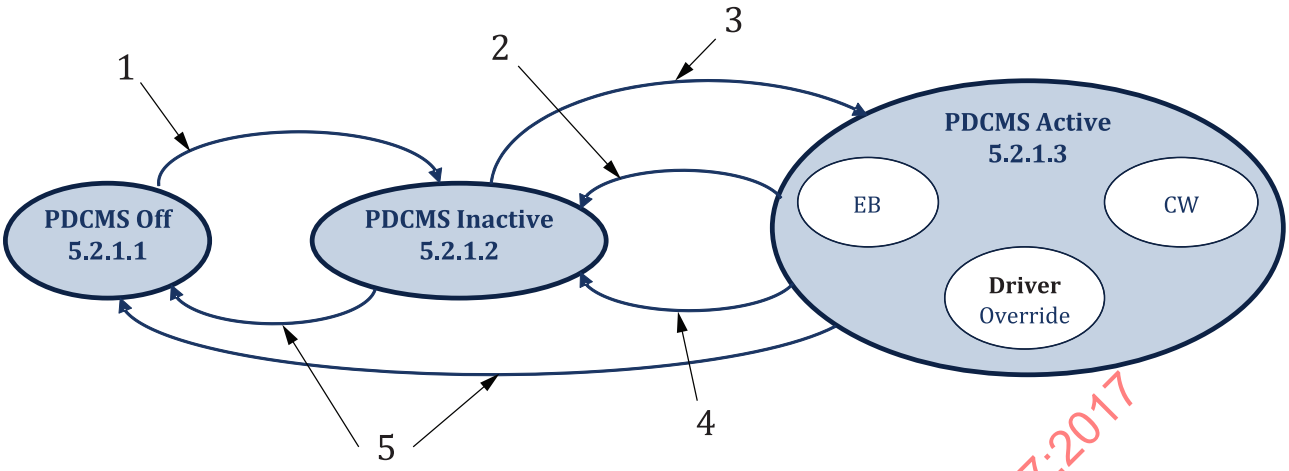
— permit driver override at any time.

— provide information about system availability to the driver.

5.2 Operating model — State transition diagram

5.2.1 State functional descriptions

The PDCMS shall function according to the state transition diagram in Figure 3. Specific implementation, beyond what is illustrated below, of the state transitions is left to the manufacturer.



Key

1 Ignition On or (optional) Ignition On and driver turn On

2 failure detected (automatic deactivation possible)

3 $v_{sv} \geq v_{min}$ and $v_{sv} \leq v_{max}$

4 $v_{sv} < v_{min}$ or $v_{sv} > v_{max}$
Exception: when the SV speed falls below v_{min} or exceeds v_{max} as long as the command is being issued.

5 fail self-test, ignition Off or (optional) driver turn Off

Figure 3 — PDCMS state transition diagram including optional features

The PDCMS state descriptions address the functional requirements of PDCMS, identifying which functions shall be performed in each state.

5.2.1.1 PDCMS Off

No countermeasures are performed in the PDCMS Off state. Upon turning the ignition to the Off position, PDCMS shall transition to the PDCMS Off state. Whenever the self-test function determines that PDCMS are not able to deliver adequate performance, or when the driver manually turns off the PDCMS (optional), it shall transition to the PDCMS Off state. PDCMS may be in the PDCMS Off state when the vehicle's ignition is on.

5.2.1.2 PDCMS Inactive

In the PDCMS Inactive state, PDCMS shall monitor vehicle speed and determine if it is appropriate to activate the system.

PDCMS shall enter the PDCMS Inactive state from the PDCMS Off state if the ignition on sequence has been completed and the engine is running. PDCMS shall enter Inactive state from the Active state if the conditions for activating are not met, for example, if the vehicle speed drops below *V*min. If a manufacturer defined failure mode is encountered for which an automatic recovery (optional) is possible, the PDCMS shall transition from PDCMS Active state to PDCMS Inactive state. Based on the results of a diagnostic self-test, functions of all or some of the countermeasures may be restored. Once the recovery occurs the system may transition back to PDCMS Active state. Finally, if the driver manually turns on PDCMS (optional), then it shall transit from the PDCMS Off state to the PDCMS Inactive state.

5.2.1.3 PDCMS Active

PDCMS shall enter this state if the vehicle speed is greater than or equal to *V*min and less than or equal to *V*max. In PDCMS Active state, it shall monitor for triggering conditions resulting in the selection of EB or CW and decide to activate or optionally override countermeasures.

If a system failure is detected or there is an inability to perform a countermeasure, PDCMS shall transfer to the PDCMS Inactive state if automatic recovery from the failure is possible. If the system fails a self-test (automatic recovery without driver intervention is not possible) PDCMS shall transfer to the PDCMS Off state. Means of notification of these failures to the driver is left up to the manufacturer.

5.3 Performance requirements

5.3.1 General

PDCMS shall, at a minimum, activate when a pedestrian(s) is crossing a straight road, represented in Figure 6, as collisions with crossing pedestrians are the main contribution to the total number of pedestrian collisions (see A.1). Performance limitations are influenced by weather conditions, e.g. fog, rain, and snow, illumination, e.g. glare by backlighting, occlusions and abnormal shapes of pedestrians, e.g. special clothing, large carried items.

5.3.2 Operating speed

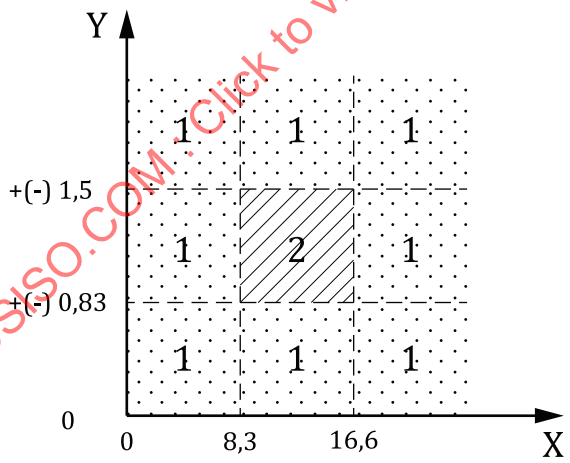
The operating speed and relative speed constraints are shown in Figure 4. The upper and lower speed limits for operation, both for the subject vehicle and the target pedestrian, are left to the manufacturer.

Direction of pedestrian velocity is shown in Figure 5.

5.3.2.1 Minimum subject vehicle velocity (V_{min})

All PDCMS shall have V_{min} of 8,3 m/s (30 km/h) or less.

PDCMS shall enter the Inactive state if the subject vehicle speed drops below V_{min} and EB is not in process.



Key

X initial subject vehicle velocity, in m/s

Y initial target pedestrian lateral velocity, in m/s

1 may operate

2 shall operate (in case of collision at the center of the front of the vehicle)

Figure 4 — Operation range of PDCMS

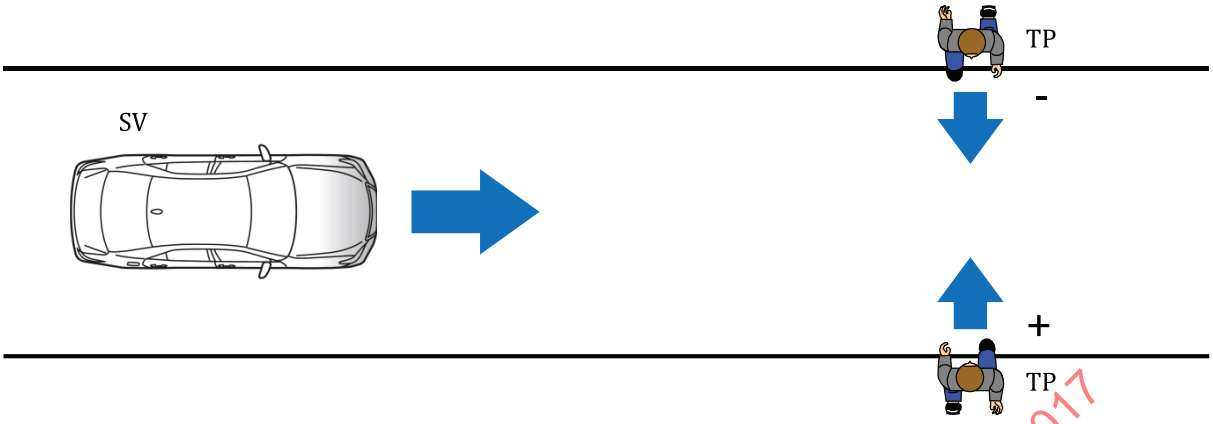


Figure 5 — Definition of positive and negative values of crossing pedestrian velocity

5.3.2.2 Maximum subject vehicle velocity (V_{max})

All PDCMS shall have a minimum value of V_{max} as 16,6 m/s (60 km/h).

5.3.3 Countermeasure requirements

5.3.3.1 Provision of EB

All PDCMS shall provide EB.

5.3.3.2 Brake light control

If PDCMS applies automatic service braking, the brake lights shall be illuminated.

5.3.3.3 EB requirements

5.3.3.3.1 Minimum speed reduction in EB

PDCMS shall be capable to achieve a speed reduction of at least 5,6 m/s (20 km/h) from the time EB has been activated to before a collision occurs while EB was continuously on. The minimum speed reduction shall be verified in the defined test scenario.

5.3.3.3.1.1 Driver-commanded enhancement of EB

PDCMS shall allow a driver-initiated increase in braking force unless the SV is already braking at its maximum capability.

5.3.3.4 Driver initiated override of EB

PDCMS may optionally permit the driver to override EB by driver actions in a manner to be defined by the manufacturer. After EB has been activated and the driver has overridden it, EB may again activate after driver override has ended.

5.3.3.5 Braking with reduced traction

EB shall not lead to locked wheels for periods longer than anti-lock or stability control devices (ABS/ESC) would allow.

5.3.4 Driver controls and human interface

5.3.4.1 System limitation information

The driver shall at least be informed of PDCMS operating limitations by means of the owner's manual or equivalent alternative.

5.3.4.2 PDCMS fault indication

The driver shall be provided with an indication of system failure. Specific implementation of the indication is left to the manufacturer.

5.3.4.2.1 PDCMS state indication

The driver shall be provided with an indication of PDCMS off-state. Specific implementation of the indication is left to the manufacturer.

5.4 Types of PDCMS

Type 1: PDCMS capable of daytime activation.

Type 2: PDCMS capable of daytime, twilight and nighttime activation.

6 Test procedures

6.1 General requirements

The following subclauses describe general requirements that shall be fulfilled when the functionalities described in this document are tested. To avoid incorrect measurements, these tests shall be performed in an environment where no objects or structures are interfering with the sensor systems. These specific environmental conditions are not meant to be exhaustive or restrictive in assessing the overall system performance. This test specification does not preclude manufacturers from testing during additional conditions.

6.1.1 Pedestrian test target specification

Test targets shall provide a surface profile and reflectivity representative of a pedestrian. For detailed specifications for pedestrian test targets, refer to ISO 19206-2. An adult pedestrian target shall be used for testing.

6.1.2 Driving surface

Tests shall be conducted on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 1 %. The test surface shall have a minimal peak braking coefficient (PBC) of 0,9.

6.1.3 Ambient air temperature

Ambient temperature range during test execution shall be above 0 ° C and below 40 ° C.

6.1.4 Horizontal visibility

Horizontal visibility shall be greater than 1 km.

6.1.5 Vehicle pre-conditioning

The vehicle used for testing shall be adequately conditioned to ensure proper sensor performance and braking capability. If requested by the vehicle manufacturer, drive a maximum of 100 km on a mixture of urban and rural roads with other traffic and roadside furniture to calibrate the sensor system. Avoid harsh acceleration and braking. The conditions for adequately warming up brake systems/tyres for the test vehicle shall be equivalent to FMVSS 105 S7.4.1.1.

6.1.6 Vehicle mass

The test vehicle mass shall be between complete vehicle kerb mass (refer to ISO 1176), and complete vehicle kerb mass plus test operator(s) and test equipment loaded to the test vehicle (combined mass of test operator(s) and test equipment shall not exceed 200 kg).

6.2 Test requirements for Type 1 systems

6.2.1 Ambient illumination

Testing for Type 1 systems shall be performed in bright conditions. For bright conditions, illumination shall be higher than 2000 lx.

6.2.2 Test procedures

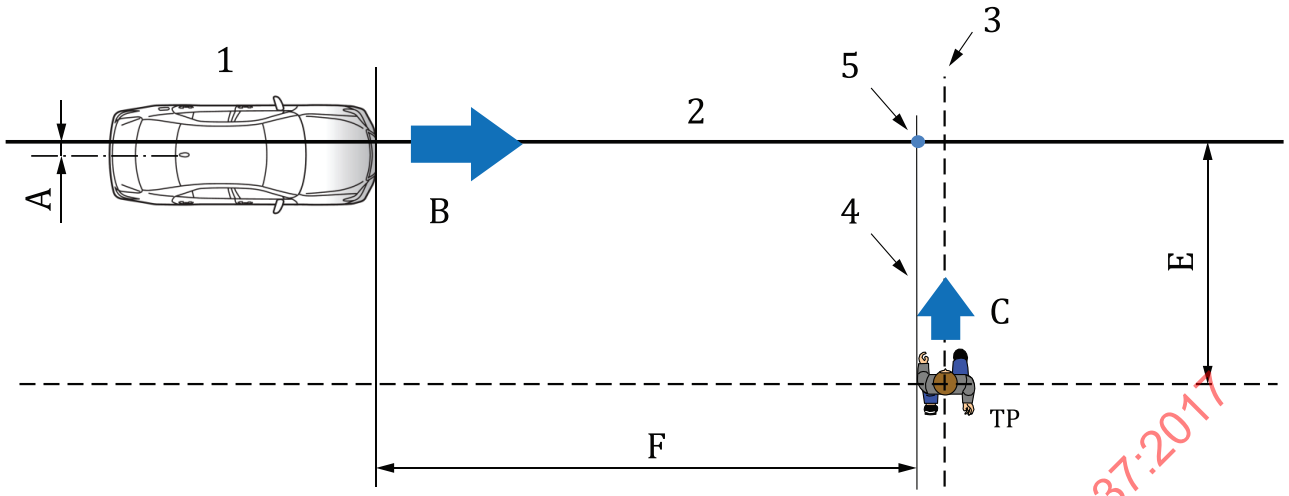
This test shall be carried out on a test course with a setup shown in Figure 6. A vehicle path shall be set up to help maintain the vehicle moving in a straight line (the gradient in the travelling direction shall be ± 1 % or less). In addition, a pedestrian path that crosses the vehicle path perpendicularly shall be set up. The vehicle shall travel along the vehicle path at a constant velocity of v_{sv}. TP shall travel along the pedestrian path at a constant velocity of vtpL. SV and TP shall reach the specified speed based on the positional relationship E and F shown in Figure 6. The position of the TP (either starting from the left or right side of the vehicle path) may be switched depending on the major countries or regions for which the SV is bound.

6.2.3 Pass criteria

6.2.3.1 Pass criteria

— the speed of the vehicle passing the collision point is less than 10,0 km/h according to a speed reduction of at least 20 km/h, or

— a collision (see 6.2.3.2 for the definition of a collision) between pedestrian and vehicle is avoided.



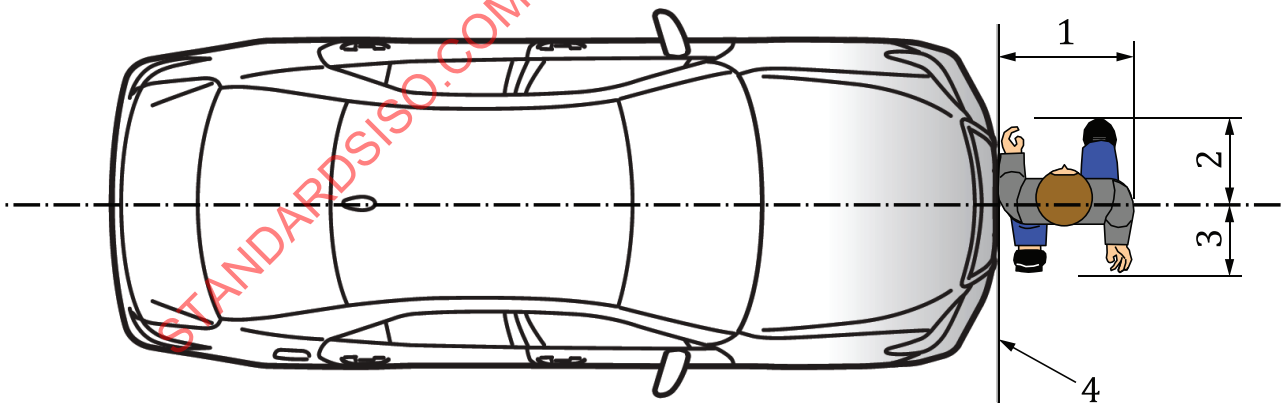
Key

1	SV	A	= 0,0 m (± 0,05 m)
2	vehicle path	B	= v_{sv}= 30,0 km/h (± 0,25 km/h)
3	pedestrian path	C	= vtpL = 5,0 km/h (± 0,2 km/h)
4	virtual line on the outermost side of the pedestrian	E	= Ld = 3,0 m (± 0,05 m)
5	collision point	F	= xc = 18,0 m (± 0,25 m)

Figure 6 — Diagram of activation test setup

6.2.3.2 Definition of a collision

Collision is when the front most portion of the vehicle touches the virtual line on the outermost side of the pedestrian as described in Figure 7. The pedestrian reference point for forward/backward direction is 360 mm from the front edge of the forefoot of the pedestrian, and for lateral direction, the outermost side which contacts with the vehicle.



Key

1 500 mm (±20 mm)
2 360 mm (±10 mm)
3 240 mm (±10 mm)
4 virtual line on the outermost side of the pedestrian

Figure 7 — impact point of the pedestrian

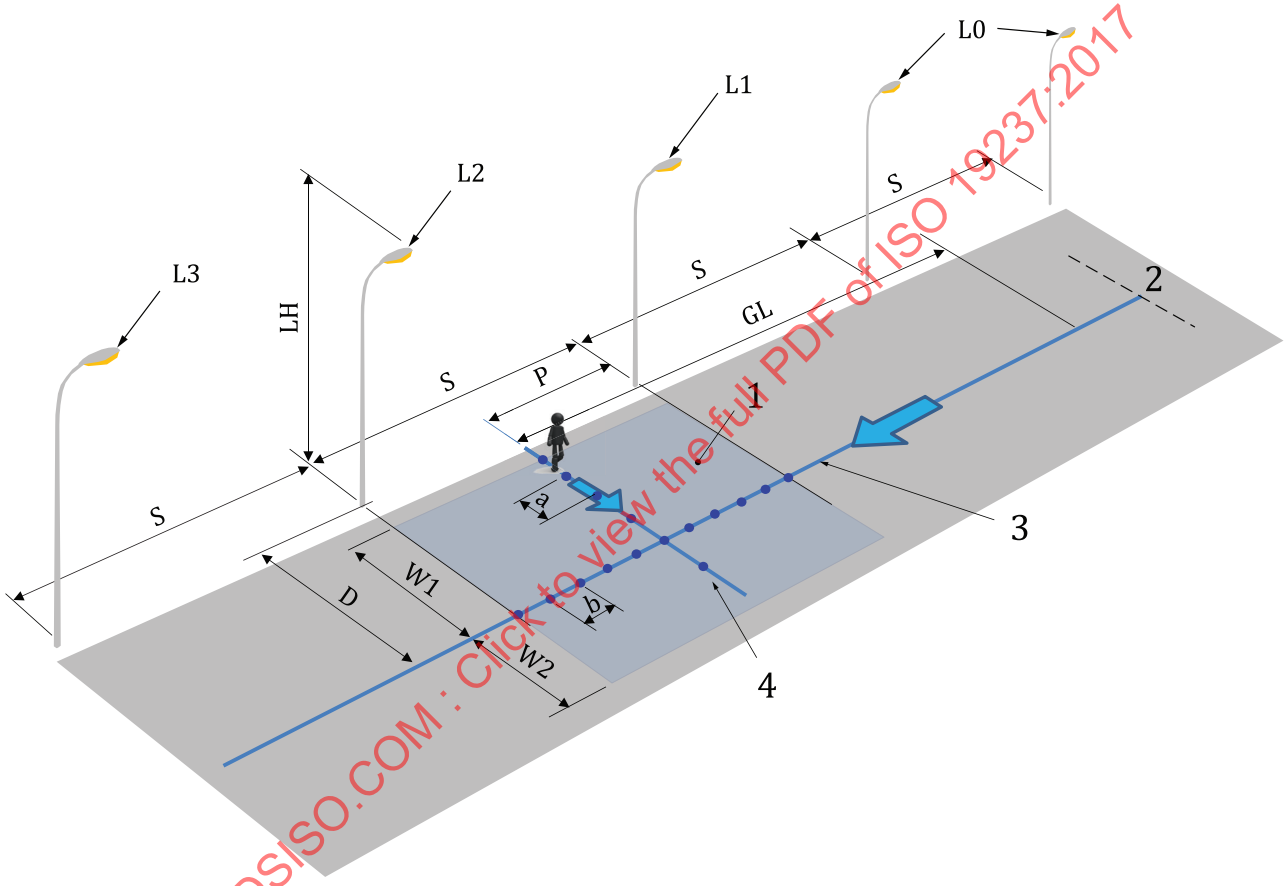
6.3 Test requirements for Type 2 systems

6.3.1 Ambient illumination

Testing for Type 2 systems shall be performed for both bright and dark conditions. For bright conditions, refer to 6.2. Ambient illumination for dark conditions shall be less than 1 lx, when all the lamps of the test vehicle and installed lights for the test are off.

6.3.2 Test setup

Testing under dark conditions shall be set up as specified in Figure 8.



Key

LH	= 4,5 m to 12,0 m	W2	= 3,0 m ± 0,1 m
S	= 20,0 m to 42,0 m	GL	= 60,0 m ± 0,5 m
P	= S/2 (±0,5 m)	1	illuminance measurement area
D	≥ 4,0 m	2	test car start side
a	= 1,0 m ± 0,1 m	3	vehicle path
b	= S/10 (±0,1 m)	4	pedestrian path
W1	= 4,0 m ± 0,1 m	L0 to L3	installed street lamps
•	illuminance measurement points		

Figure 8 — Test set-up for dark conditions

6.3.2.1 Lamp installation requirements

— There shall be a sufficient number of street lamps installed along the test course to ensure the illumination values specified in 6.3.4. The number of street lamps represented by L0 in Figure 8 will change according to the value of S.

— As represented by L3 in Figure 8, there shall be one lamp installed beyond the illuminance measurement area (see 6.3.2.2).

— The installed lamps along the test course shall be the same type, have the same height with a deviation of less than 0,2 m, and be equally spaced with a deviation of less than 1,0 m.

— The position of the centre of the lamps shall be within 2 m from the lamp pole in the direction towards the vehicle path.

— Colour temperature of the lamps shall be between 4 500 K ± 1 000 K.

6.3.2.2 Illuminance measurement area and points

— The illuminance measurement area is defined by the length and width below:

  — Length = the distance between L1 and L2 in Figure 8.

  — Width = W1 + W2 in Figure 8.

— Vehicle path runs parallel to the lamps and at least 4,0 m (D in Figure 8) away from the base of the lamp pole. The distance between the two lamps is divided into 10 sections to define the 11 illuminance measurement points on the vehicle path as shown in Figure 8.

— Pedestrian path runs in the middle of L1 and L2. On the pedestrian path within the illuminance measurement area, 6 illuminance measurement points are defined with 1 m distance between them.

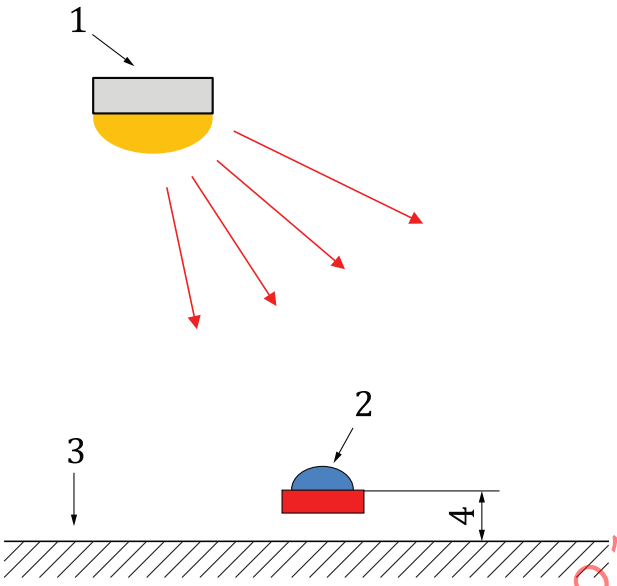
6.3.3 Illuminance measurement methods

To measure illumination, an illuminance meter that meets ISO 19476:2014 (Characterization of the performance of illuminance meter and luminance meter) shall be used.

As shown in Figure 9, the illuminance meter shall be positioned horizontally.

For the measurement points over the vehicle path, height of measurement shall be ≤ 0,2 m.

For the pedestrian path, height of measurement shall be both ≤ 0,2 m and 1,5 ± 0,1 m above the ground.



Key

1 installed lamps along the test course
2 illuminance meter
3 ground surface
4 height of measurement

Figure 9 — Illuminance measurement methods

6.3.4 Illuminance values

Table 1 specifies illuminance requirements for dark condition testing.

Table 1 — Illuminance requirements

Measurement points	≤ 0,2 m above ground	1,5 m ± 0,1 m above ground
Vehicle path	16 lx to 25 lx (average value of the 11 measurement points)	Not required
Pedestrian path	≥ 5 lx (each measurement point)	≥ 5 lx (each measurement point)

The ratio factor (RF) of the illuminance of the brightest and the darkest points of the measurement points at the height of ≤ 0,2 m within the illuminance measurement area shall be less than 10.

Glare on the sensor system shall not occur anywhere on the illuminance measurement area. In particular, the lamps shall not be tilted towards the approaching vehicle as it may create glare that negatively affects sensor performance.

At least for the area within 60 m from the crossing point of the vehicle path and the pedestrian path to the direction of the test vehicle start point, the same level of illuminance, RF and glare avoidance shall be ensured.

6.3.5 Test procedures

This test shall be carried out on a test course with a setup shown in Figure 10. For the performance test under night conditions, headlamps of the test SV shall be on. A low-beam light shall be used for the test. A vehicle path shall be set up to help maintain the vehicle moving in a straight line (the gradient in the

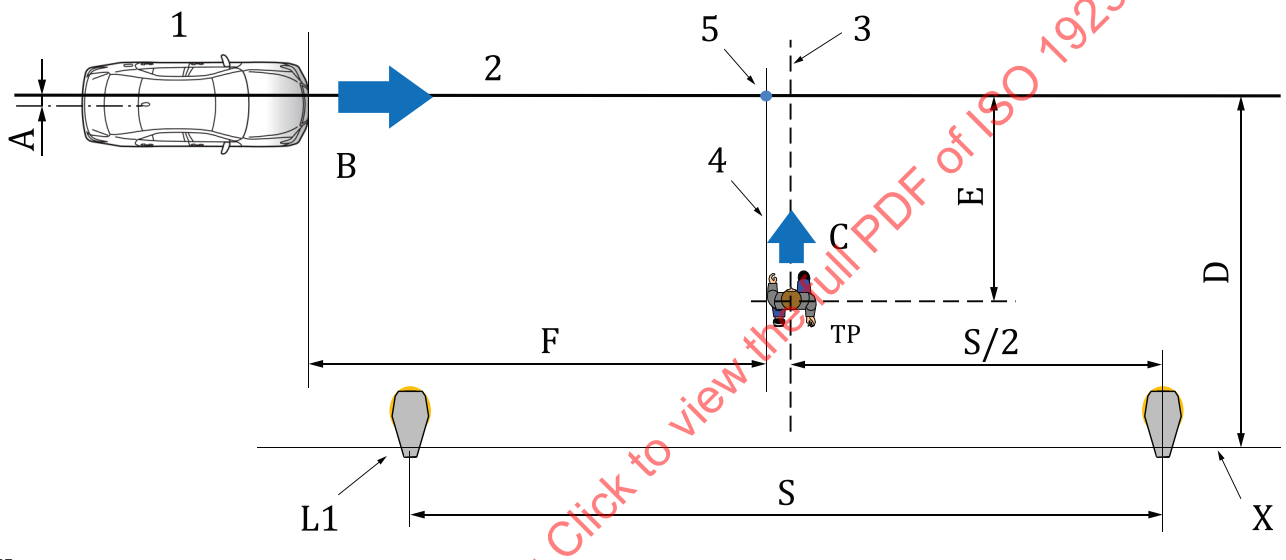
travelling direction shall be ±1 % or less). In addition, a pedestrian path that crosses the vehicle path perpendicularly shall be set up. The vehicle shall travel along the vehicle path at a constant velocity of v_{SV}. TP shall travel along the pedestrian path at a constant velocity of vtpL. The position of the TP (either starting from the left or right side of the vehicle path) may be switched depending on the major countries or regions for which the SV is bound. TP shall always start moving from the side of the lamps.

— For a vehicle driving on the right side of the road, the pedestrian test target shall start from the right side of the vehicle path when viewed from the driver.

— For a vehicle driving on the left side of the road, the pedestrian test target shall start from the left side of the vehicle path when viewed from the driver.

Figure 10 shows the vehicle driving on the right hand side of the road.

SV and TP shall reach the specified velocity based on the positional relationship E and F shown in Figure 10.



Key

1	SV	A	= 0,0m (± 0,05 m)
2	vehicle path	B	= v_{sv} = 30,0 km/h (± 0,25 km/h)
3	pedestrian path	C	= vtpL = 5,0 km/h (± 0,2 km/h)
4	virtual line on the outermost side of the pedestrian	D	≥ 4,0 m
5	collision point	E	= Ld = 3,0 m (± 0,05 m)
L1	installed street lamp	F	= xc = 18,0m (± 0,25 m)
X	from inner edge of the pole or the foundation of the lamp	S	= 20,0 m to 42,0 m

Figure 10 — Diagram of activation test setup (dark conditions)

6.3.6 Pass criteria

— speed of the vehicle passing the collision point is less than 10,0 km/h according to a speed reduction of at least 20 km/h, or

— collision (see 6.2.3.2 for the definition of a collision) between pedestrian and vehicle is avoided.

Annex A
(informative)

A.1 Fatal pedestrian accident patterns

According to traffic accident statistics in Japan, over 80% of fatal pedestrian accidents occur on a straight road. Of these accidents, 74% are defined as occurring on a straight road with good visibility (62% while crossing the road and 12% while playing or working).

(Source: compiled by ITARDA)

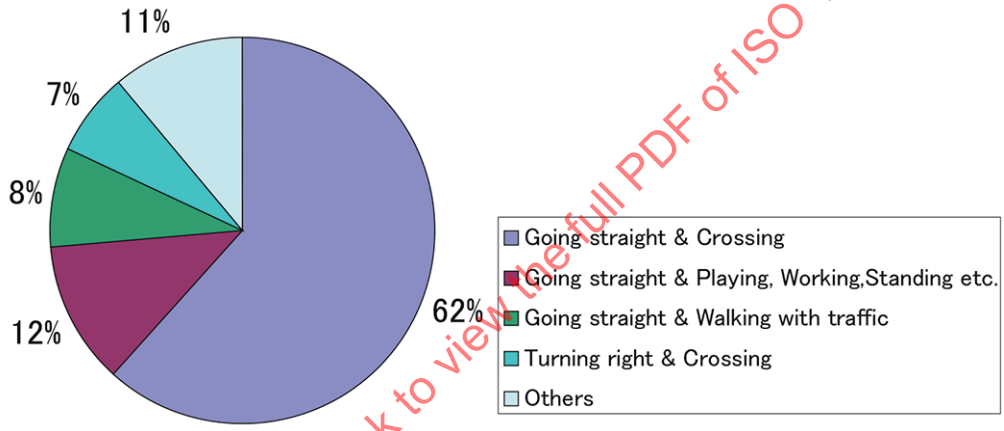
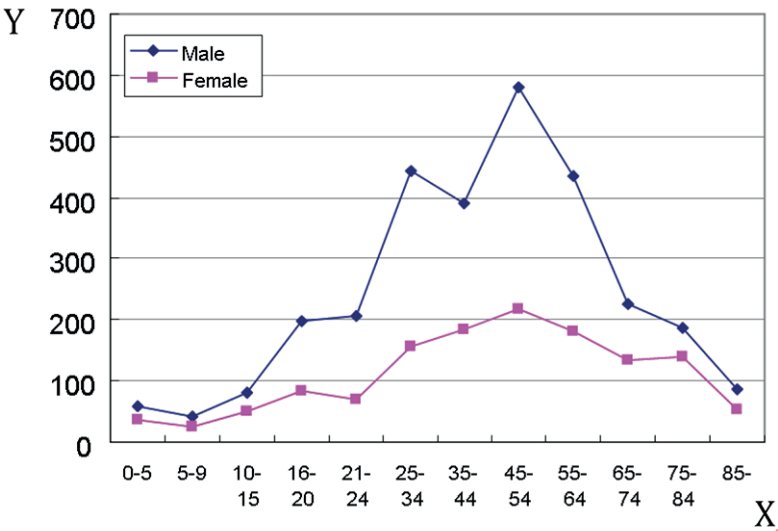


Figure A.1 — Percentage of fatalities for each combination of driver and pedestrian behaviour in Japan.

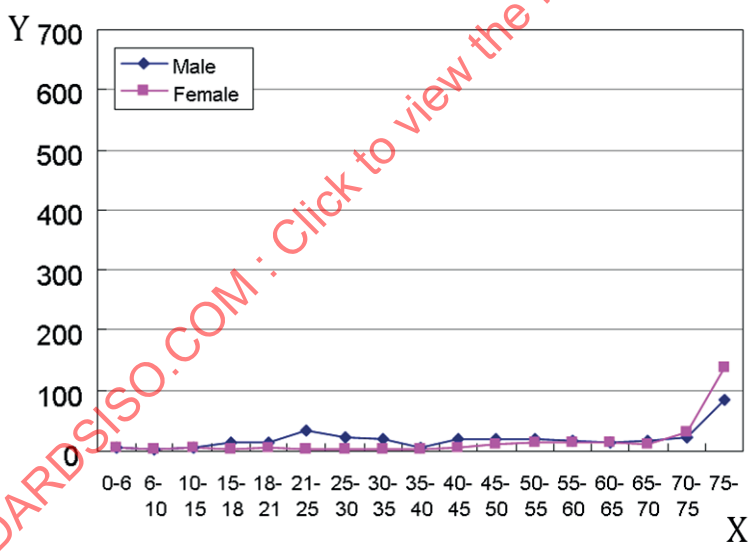


Key

X age

Y fatalities

Figure A.2 — Pedestrian fatalities in US according to age, 2010 (Source: compiled by NHTSA)



Key

X age

Y fatalities

Figure A.3 — Pedestrian fatalities in DE according to age, 2011 (Source: Statistisches Bundesamt, Wiesbaden)

When sorted by age groups, fatalities increase as a function of age, with 75% of all fatalities occurring in the two age groups 65 and over.