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Intelligent transport systems — Curve speed warning systems (CSWS) — Performance requirements and test procedures

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National foreword

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Intelligent transport systems — Curve speed warning systems (CSWS) — Performance requirements and test procedures

Systèmes intelligents de transport — Systèmes d'alerte de vitesse excessive en approche de virage (CSWS) — Exigences de performance et modes opératoires d'essai

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

Introduction

The main function of Curve Speed Warning Systems (CSWS) is to warn the driver against the danger caused by maintaining excessive speed to negotiate an upcoming curved road. The system computes the current location of the vehicle with respect to the upcoming curved road of interest and determines a warning threshold speed, below which the vehicle can safely negotiate the upcoming curves. If the vehicle speed exceeds the warning threshold speed, the system provides a warning to the driver, prompting the driver to react and lower the subject vehicle speed to a level suitable for negotiating the curved road ahead. The CSWS scope does not include automated intervention features or means for controlling the vehicle to match a desired speed.

Intelligent transport systems — Curve speed warning systems (CSWS) — Performance requirements and test procedures

1 Scope

This International Standard contains the basic warning strategy, minimum functionality requirements, basic driver interface elements, minimum requirements for diagnostics and reaction to failure, and performance test procedures for Curve Speed Warning Systems (CSWS). CSWS warns the driver against the danger caused by maintaining excessive speed to negotiate the upcoming curved roads, so that the driver may reduce the speed. The system does not include the means to control the vehicle to meet the desired speed. The responsibility for safe operation of the vehicle always remains with the driver.

This International Standard applies to vehicles with four or more wheels.

2 Terms and definitions

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

2.1
subject vehicle
vehicle equipped with the CSWS and related to the topic of discussion

2.2
subject vehicle speed
longitudinal component of the subject vehicle velocity

2.3
system states
one of several stages or phases of system operation

Note 1 to entry: See Figure 1.

2.3.1
CSWS off state
state in which CSWS is off

Note 1 to entry: This state has one of the following three causes: the driver has selected the off condition, the ignition is off, or the CSWS is in failure.

2.3.2
CSWS on state
state in which CSWS is on

Note 1 to entry: This state is either in unavailable state or in available state.

2.3.3
CSWS unavailable state
system is in on state and the system has inadequate information

Note 1 to entry: The system cannot make a decision whether the warning criteria are met or not because of fault in GNSS device, lack of map data, or other reasons.

2.3.4
CSWS available state
system is in on state and the system has sufficient information to make decisions on whether the warning criteria are fulfilled or not

2.3.5
CSWS warning state
system is in available state and the warning criteria are all met

Note 1 to entry: The CSWS starts warning(s) or is operating the warning(s). The system periodically judges whether the criteria are met in order to transition to the non-warning state.

2.3.6
CSWS non-warning state
system is in available state and the warning criteria are not all met

Note 1 to entry: The system periodically judges whether the criteria are met in order to transition to the warning state.

2.4
curved road
section where the radius of curvature is less than or equal to R_C

Note 1 to entry: R_C denotes the maximum radius of curvature to be regarded as a curvature point of interest for potential warning for CSWS (see 5.2.2).

2.5
curvature point
arbitrary points on the curved road that has associated location and value of curvature

2.6
curvature point of interest
point of the curved road ahead where the distances from the subject vehicle to the curved roads are less than the look ahead distance, S_{LAD}

2.7
curve start point
location where the radius of curvature of the curved roadway ahead becomes less than R_C

Note 1 to entry: See 5.2.3.

2.8
curve end point
location where the radius of curvature of the curved roadway ahead becomes $\geq R_C$

Note 1 to entry: See 5.2.3.

2.9
target curvature point of interest
particular curvature point of interest on the roadway of the subject vehicle that CSWS is about to provide the warning to the driver

Note 1 to entry: CSWS selects the target curvature point of interest among the curvature points of interest and the curvature point of interest may vary depending upon the distance from the current location of the subject vehicle to the curvature point of interest and the current speed of the subject vehicle. If a section of the curved road has a constant radius of the curvature, the curve start point becomes the target point of interest. See 5.2.2.

2.10
distance to curvature point of interest
$S_{current}$
distance from the current position of the subject vehicle to the curvature point of interest

2.11
time to curvature point of interest
t_{TC}
travel time from the current position of the subject vehicle to the curvature point of interest and defined as follows

$$t_{TC} = S_{current} / V_{current}$$

where

$V_{current}$ is the current speed of the subject vehicle

2.12
warning threshold speed
V_{WT}
vehicle speed threshold that is used to determine if the CSWS warning is required

Note 1 to entry: If the vehicle speed measurement is greater than this threshold value, the CSWS provides the warning to the driver. This threshold is below the maximum speed that is defined by designed lateral acceleration to negotiate the upcoming curve.

2.13
warning end speed
V_{WT_end}
vehicle speed at which the CSWS transitions from CSWS warning state to CSWS non-warning so that the CSWS ends the warning

2.14
warning distance
S_{warn}
distance from the location where the warning starts to the target curvature point of interest

2.15
driver response time
t_{resp}
reaction time of the driver which is the time from start of the speed changing event to the time that the driver starts applying brake

2.16
minimum required deceleration
a_{d_req}
deceleration that, if constant, would enable the subject vehicle to match the warning threshold speed for the target curvature point of interest

$$a_{d\_req} = \frac{V_{current}^2 - V_{WT}^2}{2 \times (S_{current} - t_{resp} \times V_{current})}$$

2.17
curve speed warning time
t_{csw}
time when the curve speed warning starts which is greater than or equal to the minimum allowed curve speed warning time

$$t_{csw} \geq t_{csw\_min}$$

Note 1 to entry: The t_{CSW}, S_{warn}, and $V_{current}$ has the following relationship:

$$t_{csw} = S_{warn} / V_{current}$$

Note 2 to entry: The value of t_{CSW} is selected by the manufacturer.

2.18
minimum allowed curve speed warning time
t_{csw_min}
lower threshold of the curve speed warning time

Note 1 to entry: The value of minimum allowed curve speed warning time is decided considering the amount of overspeed of the subject vehicle and the reaction delay of drivers.

2.19
minimum operating speed
V_{min}
minimum subject vehicle speed at which the CSWS shall operate

2.20
maximum operating speed
V_{max}
maximum subject vehicle speed at which the CSWS shall operate

2.21
look ahead distance
S_{LAD}
curve detection range of the CSWS

Note 1 to entry: For the curvature points that have radius of curvature $\leq R_C$ and the distances from the subject vehicle to the curved roads are $< S_{LAD}$, the curvature point is considered to be a curvature point of interest.

2.22
single curve
simple curved road with a constant radius of curvature separated from other curved roads

Note 1 to entry: The clothoid can be included.

2.23
multiple curve
curved road which is a combination of two or more closely located curved roads where the curved roads are constant radius curvatures

Note 1 to entry: The clothoid can be included.

Note 2 to entry: See Table A.1.

2.24
variable radius curve
curved road with two or more radii of curvature in the same direction

Note 1 to entry: See Table A.1.

2.25
angle of curved road
AOC
central angle between the curve start point and the curve end point

Note 1 to entry: See 5.2.3 for illustrative description.

2.26
road shape points
points that is composing roads in digital map

Note 1 to entry: Roads are composed of points and links which reflect the shape and position of the road in the digital map.

3 Symbols

a_{d_req} minimum required deceleration (m/s^2)

a_{d_max} maximum braking deceleration (m/s^2)

$a_{lateral\_max}$ maximum value of the lateral acceleration threshold from which vehicles may deviate on a curved roadway (m/s^2)

d_{max} on the section of a curved road, the maximum distance from the point on the line consisting of two neighbouring road shape points to the point on the arc of the section (m)

G gravitational acceleration (m/s^2)

R radius of curvature at a point along a curved roadway (m)

R_C threshold radius of curvature to define a curvature point of interest; the curvature point of interest is reached if the radius of the curvature of the particular location is less than R_C (m)

R_{max} upper threshold of the operational range in terms of the radius of curvature (m)

R_{min} lower threshold of the operational range in terms of the radius of curvature (m)

$S_{current}$ distance to the curvature point of interest (m)

S_{LAD} look ahead distance (m)

S_{warn} warning threshold distance considering $V_{current}$ and t_{CSW} (m)

S_{warn_min} minimum of warning threshold distance considering $V_{current}$ and t_{CSW_min} (m)

V_{add} additional speed considering the tolerance for the test (m/s)

$V_{current}$ current speed of the subject vehicle (m/s)

V_{min} minimum operating speed of CSWS (m/s)

V_{max} maximum operating speed of CSWS (m/s)

V_{test} test vehicle speed (m/s)

V_{WT} warning threshold speed (m/s)

V_{WT_end} warning end speed (m/s)

V_{WT_max} upper threshold of the warning threshold speed (m/s)

t_{CSW} curve speed warning time (s)

t_{CSW_min} minimum allowed curve speed warning time (s)

t_{d_min} minimum reaction delay (s)

t_{TC} time to curvature point of interest (s)

t_{resp} driver response time (s)

θ angle of curved road (AOC) (deg)

θ_{min} minimum AOC (deg)

4 Classification

The CSWS subject to this International Standard only has a single type.

5 Requirements

5.1 Basic operation principle

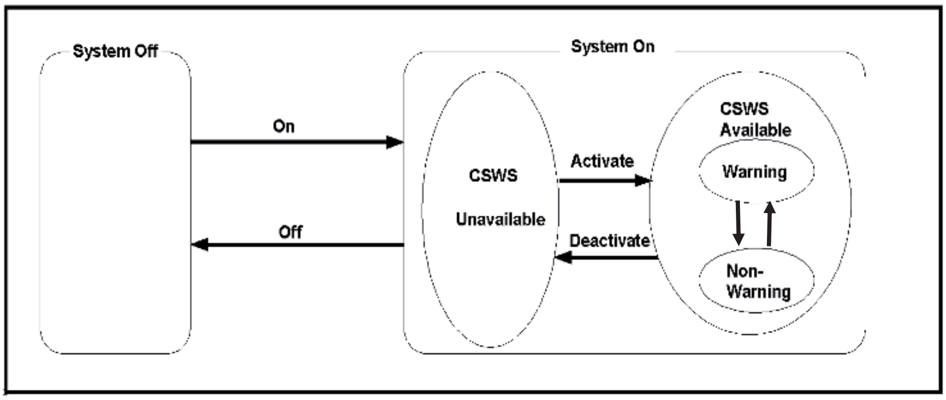


Figure 1 — CSWS states and transitions

The pattern of the transition conditions are as follows.

— The condition that CSWS transitions from system OFF state to system ON state are as follows.

a) For CSWS ON/OFF control equipped vehicles, both the vehicle ignition and the ON/OFF control are on.

b) For CSWS ON/OFF control not equipped vehicles, the vehicle ignition is on.

c) The transition from CSWS OFF to CSWS ON can be performed by the driver or automatically.

— The condition that CSWS transitions from system ON state to system OFF state are as follows.

a) For CSWS ON/OFF control equipped vehicles, either the vehicle ignition or the ON/OFF control are off.

b) For CSWS ON/OFF control not equipped vehicles, the vehicle ignition is off.

c) If the system is in on state and a system failure occurs.

CSWS shall, as a minimum, provide the following operations and state transitions. The following constitutes the fundamental behaviour of CSWS. The warning criteria are described in 5.2.1.

— In CSWS available state, the system judges the warning criteria to determine whether the warning should be issued. If the system judges to warn, the CSWS starts warning(s) immediately.

— In CSWS unavailable state, the warning judgment is not made because the warning criteria such as subject vehicle position are being monitored by CSWS but not confirmed in this state.

— In CSWS non-warning state, the system shall evaluate the activation criteria. CSWS shall not perform any warning actions.

— If the activation criteria are met, the system shall transition from CSWS non-warning state to CSWS warning state. This transition shall be automatic.

— If the activation criteria are not met, the system shall transition from CSWS warning state to CSWS non-warning state.

— The system may be fitted with a system ON/OFF control that can be operated by the driver at all times.

5.2 Functionality

CSWS consists of means to determine the radius of curvature of the road, means to acquire relative position of the subject vehicle from the curvature point of interest, means to acquire the vehicle speed, means to judge the critical speed of the curvature point of interest, and means to provide warning to the driver.

The functional requirements of CSWS are described as follows.

5.2.1 Basic system operation

The basic system operation of CSWS is described in this subclause.

— When the CSWS is in the CSWS available state, the system acquires the warning threshold speed, V_{WT}, the current speed of the subject vehicle, $V_{current}$, the distance to the curvature point of interest, $S_{current}$, and the distance where the warning shall be started, S_{warn}. If $V_{current}$ exceeds V_{WT} and $S_{current}$ is less than S_{warn}, the system regards the curvature point of interest as a target curvature point of interest and transitions from non-warning state to CSWS warning state.

$V_{current} > V_{WT}$ and $S_{current} < S_{warn}$: CSWS non-warning state to warning state

— When the CSWS is in the CSWS warning state, the system provides warning to the driver so that the driver may reduce the vehicle speed. When $V_{current}$ becomes less than V_{WT_end} or $S_{current}$ becomes greater than S_{warn}, the system automatically transitions from warning state to non-warning state.

$V_{current} < V_{WT\_end}$ or $S_{current} > S_{warn}$: CSWS warning state to non-warning state

where V_{WT_end} can be adopted to avoid possible chattering of the CSWS and is selected by manufacturers according to the following formula.

NOTE The value of the V_{WT_end} can be same as V_{WT}.

$$V_{WT} \geq V_{WT\_end}$$

S_{warn} and S_{warn_min} can be defined as follows for better understanding.

$$S_{warn} = V_{current} \times t_{csw}$$

$$S_{warn\_min} = V_{current} \times t_{csw\_min}$$

— The CSWS may suppress the warning when the driver is braking.

5.2.2 Determination of the target curvature point of interest

The conditions to meet in order to be the curved road, the curvature point of interest, and the target curvature points of interest are described as follows. Detail descriptions and figures can be found in A.1.

— Non-curvature point: location on a road with a radius of curvature greater than R_C. This location of the road has no potential to be a curvature point of interest and regarded as a non-curvature point as shown in Figure A.1.

$R > R_C$: Non-curvature point

— Curvature point of interest: location on a road with the radius of curvature less than or equal to R_C and the distance from the current location of the subject vehicle to a curve start point is less than the look ahead distance, S_{LAD}, as shown in Figure A.1 and Figure A.3.

$R \leq R_C$ and $S_{current} < S_{LAD}$: Curvature point of interest

— Target curvature point of interest: particular curvature points of interest on the roadway of the subject vehicle that CSWS is about to provide the warning to the driver. CSWS selects the target curvature points of interest among the curvature points of interest and the target curvature point of interest may vary depending upon the distance from the current location of the subject vehicle to the curvature point of interest and the vehicle speed. If a section of the curved road has a constant radius of the curvature, the curve start point becomes the target curvature point of interest.

$V_{current} > V_{WT}$ and $S_{current} < S_{warn}$: Target curvature point of interest

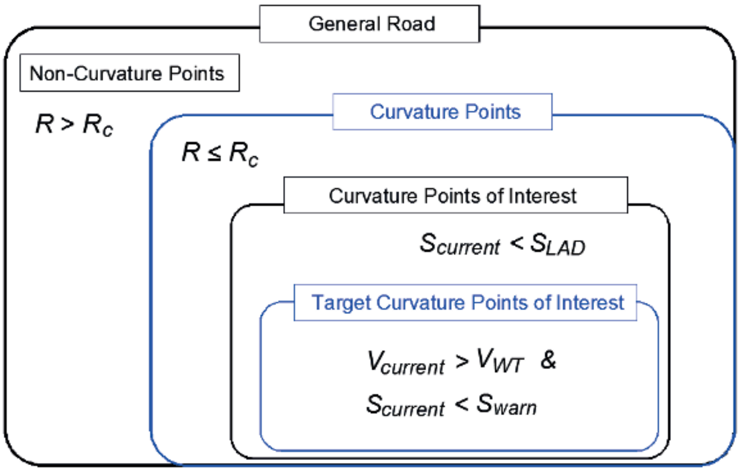


Figure 2 — Definitions of curvature points of interest and the target curvature points of interest

5.2.3 Basic shape of a curved road

The basic shape of a curved road is described in this subclause for defining the curved road in the perspective of CSWS.

— A single curve with constant radius is shown in Figure 3 as an example of a simple curved road. The curved road described here starts from clothoid curve and it has a curve with constant radius.

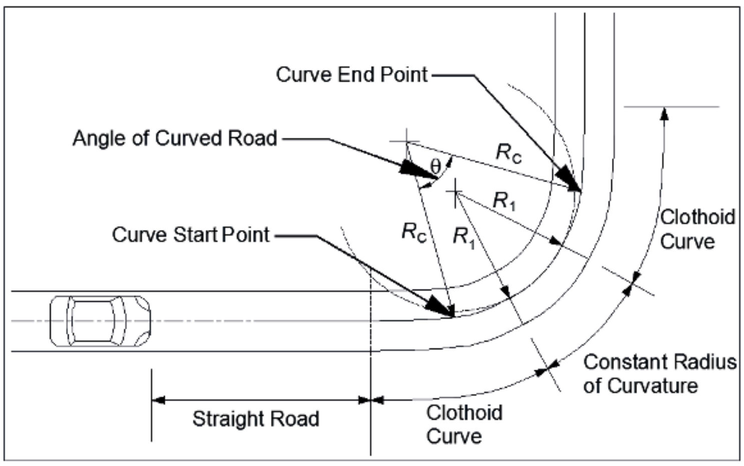


Figure 3 — Basic shape of a single curve with constant radius

— The curved road starts from the point that the radius of curvature becomes less than or equal to the threshold radius of curvature, R_C. This point is defined as a curve start point. On a curve of interest, there can be many curvature points of interest as shown in Figure 4 and Figure 5.

— The curved road ends at the point where the radius of curvature becomes greater than the threshold radius of curvature, R_C.

— For curves with a constant radius, the curve start point can be a potential target curvature point. For the curves with multiple radii of curvature, the target curvature point is defined depending upon the warning distance and warning threshold speed of each curvature point of interest. Determination of target curvature point on curves with multiple radius of curvature is described in A.1.

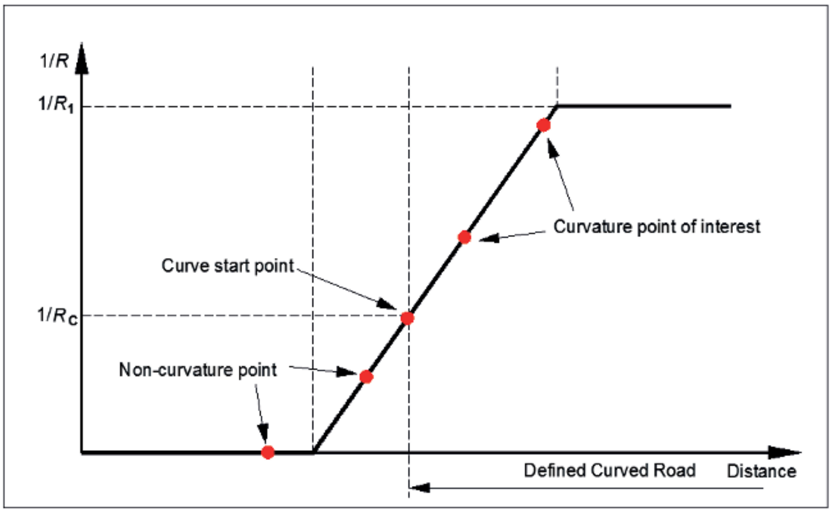


Figure 4 — Basic shape of a curved road in terms of *1/R*

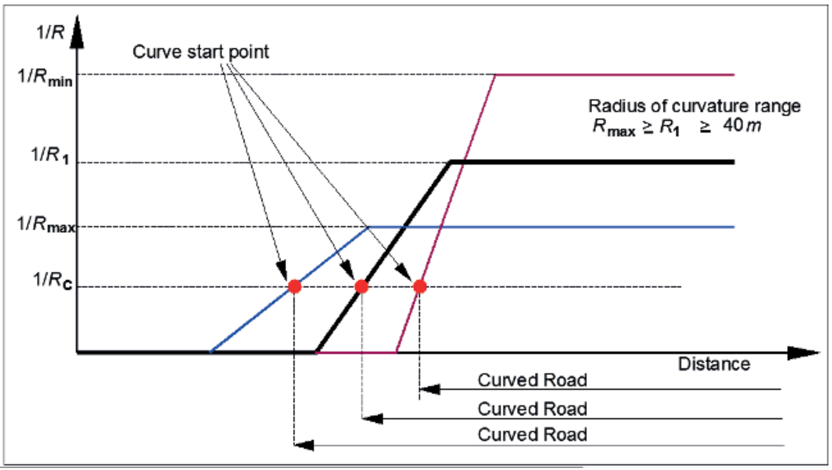


Figure 5 — Curve start point for different curved roads

5.2.4 Radius of curvature requirement for available state

The radius of curvature for available state has the following requirements.

— The calculating method of the radius of curvature lies in the responsibility of manufacturers.

— The operational range of the CSWS in terms of the radius of curvature of the upcoming curved roads is from R_{min} to R_{max}.

$R_{max} \geq R \geq R_{min}$: CSWS shall be able to be in the available state

where R_{max} is selected by the manufacturers and R_{max} shall be ≥200 m, while R_{min} is ≤40 m.

NOTE CSWS recognizes R_{max} as R_C ($R_{max} = R_C$). See B.3 for detailed description.

5.2.5 Determination of the warning threshold speed

The warning threshold speed can be determined as follows.

— The warning threshold speed in this International Standard is based on the general considerations on horizontal alignment design of roads. The specific value of V_{WT} of the CSWS is in the responsibility of manufacturer. Manufacturers select the appropriate V_{WT} considering the safety of the vehicle and the marketability of the system.

— The value of V_{WT} shall be less than the upper threshold of the warning threshold speed, V_{WT_max}.

$V_{WT} < V_{WT\_max}$

— The upper threshold of the warning threshold speed, V_{WT_max}, is the speed when the lateral acceleration of the subject vehicle is $a_{lateral\_max}$.

NOTE The lateral acceleration values for warning threshold speed calculation presented in this International Standard is based on the dry road condition.

— After substituting lateral acceleration limits, the following formula is obtained. For convenience, the following formula can be used for determining V_{WT_max}.

$$V_{WT\_max} = \sqrt{a_{lateral\_max} \times R} \quad \text{(m/s)} \tag{1}$$

where

$a_{lateral\_max}$ is 5,9 m/s^2 (0,6 g).

— The warning threshold speed may be varied depending upon the superelevation, road surface condition, vehicle load distribution, and other factors.

— Manufacturers may set the upper limit of the warning threshold speed considering the vehicle type.

5.2.6 Curve speed warning time requirements

The requirements of determining the curve speed warning time is described in this subclause.

— When $V_{current}$ exceeds V_{WT} and $S_{current}$ is less than S_{warn}, CSWS shall issue a warning or warnings.

The curve speed warning time, t_{csw}, shall exceed the t_{csw_min} calculated by the following formula. The derivation of the t_{csw_min} calculation formula is presented in Annex B. Note that the t_{csw_min} is valid only when $V_{current} \geq V_{WT\_max}$.

$$t_{csw\_min} = t_{d\_min} + \frac{(V_{current}{}^2 - V_{WT\_max}{}^2)}{2 \times a_{d\_max} \cdot V_{current}} \quad \text{(valid for } V_{current} \geq V_{WT\_max}\text{)} \tag{2}$$

where

a_{d_max} is the maximum breaking deceleration, 4,9 m/s^2 (0,5 g);

t_{d_min} is the minimum driver reaction delay, 0,8 s.

$t_{csw\_min} \leq t_{csw}$

— The value of t_{CSW} is selected by the manufacturer considering the safety and the marketability of the system.

— Note that the warning distance, S_{warn}, is computed based on t_{CSW} as follows.

$$S_{warn} = V_{current} \times t_{csw}$$

5.2.7 Look ahead distance requirement

The look ahead distance has the following requirements:

— look ahead distance of the CSWS, S_{LAD}, shall be longer than the warning distance of the CSWS;

— CSWS shall transition to unavailable state when S_{LAD} is undetermined due to map unavailability.

5.2.8 Appropriate warning for multiple curve

The multiple curvature is an important case for CSWS. The appropriate warning for multiple curve is described as follows.

— In order to provide a warning for the curvature point with most danger, it is important for the CSWS to warn for the appropriate target curvature point at a multiple curve or a variable radius curve.

— In some cases, the system shall warn for a curvature point of interest which is located further than the closest curvature point of interest although the closest curvature point of interest is usually selected as a target curvature point.

— When warning is simultaneously required for two or more target curvature points of interest, the warning should operate to one of the target curvature points of interest at least before the minimum warning distance, S_{warn_min}, for the nearest target curvature point of interest.

— Note that it is important to mention that it is difficult for a third party to judge in the test whether the warning is started by the closest curve or the next curve because the manufacturers can select t_{CSW} for their own preference, as well as their warning algorithms. There are two cases to be considered in order to confirm that warning starts before both S_{warn_min1} and S_{warn_min2}, as shown in Figure 7 and Figure 8.

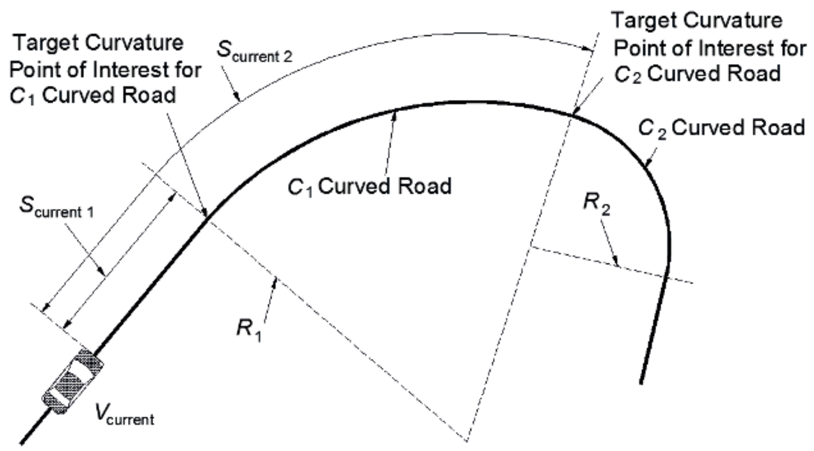


Figure 6 — Selection of the target curvature point of interest for multiple curve

Case 1: Target curvature point of interest of C1 curved road is the nearest.

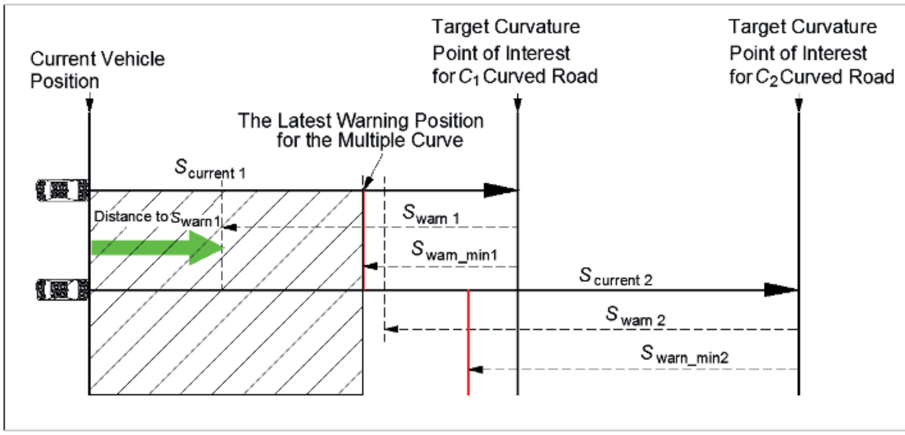


Figure 7 — Description of Case 1

Case 2: Target curvature point of interest of C2 curved road is the nearest

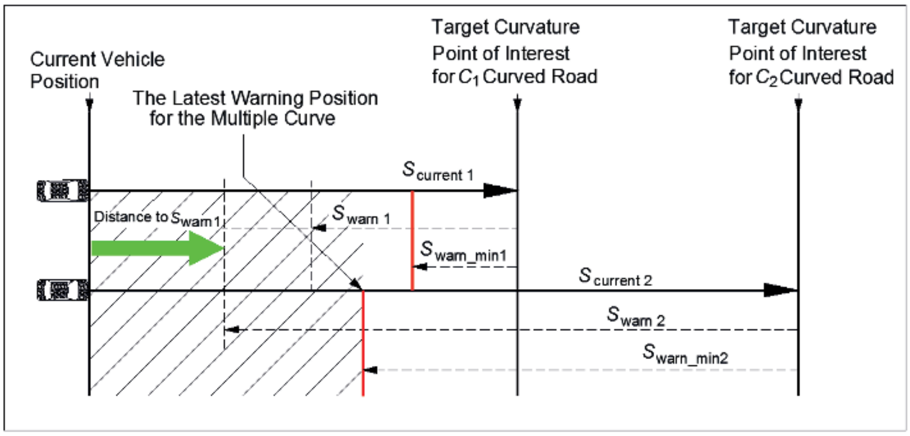


Figure 8 — Description of Case 2

— In case of multiple curve, the warning shall start before the S_{warn} closest to the current vehicle position not the nearest curvature point of interest. Note that in practice, since the determination logic for S_{warn} is dependent upon the CSWS manufacturer, it is possible that the S_{warn} is not directly proportional to the radius of curvature.

5.2.9 Optional functions of CSWS

The following are several optional functions which the manufacturers can consider.

— The operation of CSWS on unpaved road is optional.

— The operation of the CSWS may be calibrated by the manufacturer based upon the type and capability of the subject vehicle such as sedan, truck, and bus.

— The system may detect the suppression request to minimize nuisance warnings. The suppression request is issued, e.g. if the driver is engaged in other high-priority braking manoeuvres such as crash-avoidance manoeuvres.

— The system may suppress additional warnings to avoid repetitive warnings.

— The system may suppress warnings when the driver is applying the brake.

— The system may suppress warnings when a driver action that indicates change of path is detected.

— The warning threshold may be adjustable within the range allowed by the manufacturers.

— If any of these optional features is included, it shall be described in the vehicle owner's manual.

5.3 Basic driver interface capabilities

5.3.1 Operation elements and system reactions

The operation elements and system reactions for basic driver interface are described in this subclause.

— The driver shall be warned when the system is transferred to the CSWS warning state by independent or combined use of visual, audible, and/or haptic elements.

— Drivers shall be informed of the conditions that result in CSWS activation and deactivation and of the limitations of the system performance by the vehicle owner's manual.

— If CSWS is not available due to a failure, the driver shall be informed and the description of the notice shall be stated in the vehicle owner's manual.

5.3.2 Haptic elements

The requirements for haptic interface elements are described in this subclause.

— Haptic warning(s) may be used for CSWS. Haptic warning including vehicle speed changes is optional. The haptic warning(s) can include the change of subject vehicle speed using transmission gear downshift, seat belt vibration, accelerator pedal vibration, and accelerator pedal reaction force change.

— For speed-related haptic warning system equipped vehicles, it is recommended that warning braking modality not be used if the subject vehicle driver is applying the brakes.

— Warning braking shall be applied for a duration that is less than 1 s. It shall result in a deceleration less than 0,5 g and a speed reduction not to exceed 2 m/s. To ensure the effectiveness of the warning braking, a minimum average deceleration of 0,1 g for a minimum duration of 100 m/s shall be fulfilled.

5.4 Operational limits

The operational limits requirements are as follows.

— The system shall be operational at all speeds above V_{min}. The value of V_{min} can be selected by the manufacturers.

— The means for computing the position of the vehicle such as Global Navigation Satellite Systems (GNSS) module might not be fully functional, depending upon the terrain and building conditions. This should also be stated in the vehicle owner's manual.

6 Performance evaluation test methods

6.1 Test environmental conditions

a) Test location shall be on a flat, dry, and clean asphalt or concrete surface.

b) Temperature range shall be between −20 °C and 40 °C.

c) Horizontal visibility range shall be greater than 1 000 m.

6.2 Test course conditions

The test conditions are as follows.

— During the test, the test course shall be separated from the road traffic. If the map database can be prepared, the test course can be a part of existing proving ground. A section of public road can also be used as test course for CSWS as long as the test course is separated from the road traffic at the time of the test.

— Note that if the CSWS under test is using vision-based sensing, the test course should have clear lane markings for the following three test cases.

— Test Course 1 for Test A1

The test curved road shall be single curves with constant radius without clothoid curve and the radius of the curvature of the test course shall be as follows.

Test Course 1: a single curve

R_1 = 36 m ~ 40 m

$\theta 1 > \theta_{min1}$

NOTE 1 If the system is designed to operate at a curve radius below R_{min}, then the test can be carried out at a radius of curvature that is less than R_{min}. θ_{min1} represents AOC of C_1 curved road. Refer to Figure 9.

The minimum AOC of the curved road is calculated from the following formula:

$$\theta_{min} = 2\cos^{-1}\left(\frac{R - d_{max}}{R}\right), \text{(deg)} \tag{3}$$

where

θ_{min} is the minimum AOC;

d_{max} is 2,5 m.

Calculation of the minimum AOC is described in Annex C.

— Test Course 2 for Test A2

Test Course 2: a single curve

R_2 = 200 m ~ 220 m

$\theta 2 > \theta_{min2}$

NOTE 2 θ_{min1} represents AOC of C_1 curved road. Refer to Figure 9.

— Test Course 3 for Test B

Test Course 3: a multiple curve

Test course 3 consists of two curved roads. Each curved road shall be as follows.

R_1 (radius of curvature of the first curved road): 120 m ~ 200 m

R_2 (radius of curvature of the second curved road): 36 m ~ 40 m

AOC of C_1 curved road and AOC of C_2 curved road shall be greater than minimum AOC of C_1 curved road and minimum AOC of C_2 curved road, respectively.

$\theta_1 > \theta_{min1}$

$\theta_2 > \theta_{\min2}$

NOTE 3 An example of the test course 3 is provided in Figure 10. The R_1 and R_2 curves can be in the same or in different direction.

It is allowed to prepare Test Course 3 with a combination of a physically existing single curved road (real C_1 curved road) and a virtually existing curved road (virtual C_2 curved road). If the CSWS is conducting Test B with a virtually existing curved road, the virtual curved road shall be loaded in the map database of the CSWS under test. This is because Test B can actually end before the curve start point of C_2 curved road after the curve start point of the C_1 curved road.-

6.3 Test vehicle conditions

The test vehicle conditions shall be as follows.

The test vehicle mass shall be between complete vehicle kerb mass (includes lubricant, coolant, washer fluid, fuel, spare wheel, fire extinguisher, standard spare parts, chocks, and standard tool-kit) plus driver and test equipment (combined mass of driver and test equipment shall not exceed 150 kg) and maximum authorized total mass (determined as a maximum by the administrative authority). No alterations shall be made once the test procedure has begun.

6.4 Test system installation and configuration

The requirements for the test system installation and configuration are as follows.

— The CSWS shall be installed and configured in accordance with the instructions provided by the manufacturer. For the CSWS that requires a digital map for its operation, a section of the digital map which imitates (or reflects) the test course can be installed to the system for the CSWS test. The system shall be in the available state during the test.

— The test course shall be located in an open place so that the GNSS receiver of CSWS functions properly.

— CSWS that learns the driving route through experience of the past driving may load the route information in advance to use it for computing the radius of curvature.

— The road level map database of the test course may be used to perform this test.

— If the CSWS is conducting Test B with a virtually existing curved road, the CSWS shall be inspected to prove that the corresponding virtual map database is loaded.

6.5 Test procedure

6.5.1 Parameters recoverable from data record

The parameters which shall be recorded and recovered are described as follows.

— The following parameters shall be recorded and shall be recoverable from the tested subject vehicle:

a) warning time;

b) warning location;

c) subject vehicle speed at the warning start.

— All warning that occurs during the test shall be recorded. The data shall be recovered by a device other than the CSWS. The precision of the test device shall be noted in the test report.

— The actual shape of the test course shall be provided along with the recorded data. The actual shape of the test course contains the radius of curvature of the test curve and position of target curvature point of interest.

6.5.2 Detail test procedure

The detail test procedures are described as follows.

The following two types of tests shall be carried out:

a) single curve test: tests for warning generation at a constant radius curve;

b) multiple curve test: tests for warning generation at a multiple radius of curvature.

NOTE 1 If the CSWS of the subject vehicle is calibrated by the manufacturer due to the type and capability as described in 5.2.9, the manufacturer can select the V_{WT_max} different from the value described above.

— Test a): Warning generation test for a single curve

The distance from the target curvature point of interest to the vehicle start location shall be long enough for the vehicle to reach to the intended test speed before the warning distance of the curvature point.

The subject vehicle speed before warning distance shall be 0,83 m/s ~ 3,6 m/s (3 km/h ~ 13 km/h) greater than V_{WT_max}.

$3{,}6 > V_{current} - V_{WT\_max} > 0{,}83$ m/s

where $V_{WT\_max} = \sqrt{a_{lateral\_max} \times R}$ and $a_{lateral\_max}$ is 5,9 m/s^2 (0,6 g).

The vehicle shall pass the target curvature point of interest once in either a right or left curve.

(Test A1) For test course 1, the subject vehicle speed before the warning distance shall be ≥15,3 m/s (55 km/h). The subject vehicle maintains the speed until the distance to the curvature point of interest becomes less than the warning distance.

(Test A2) For test course 2, the subject vehicle speed before the warning distance shall be $\geq V_{WT\_max}$. The subject vehicle maintains the speed until the distance to the curvature point of interest becomes less than the warning distance.

The CSWS passes the warning generation test if the system successfully generates the warning when the distance to the curvature point of interest becomes less than the warning distance.

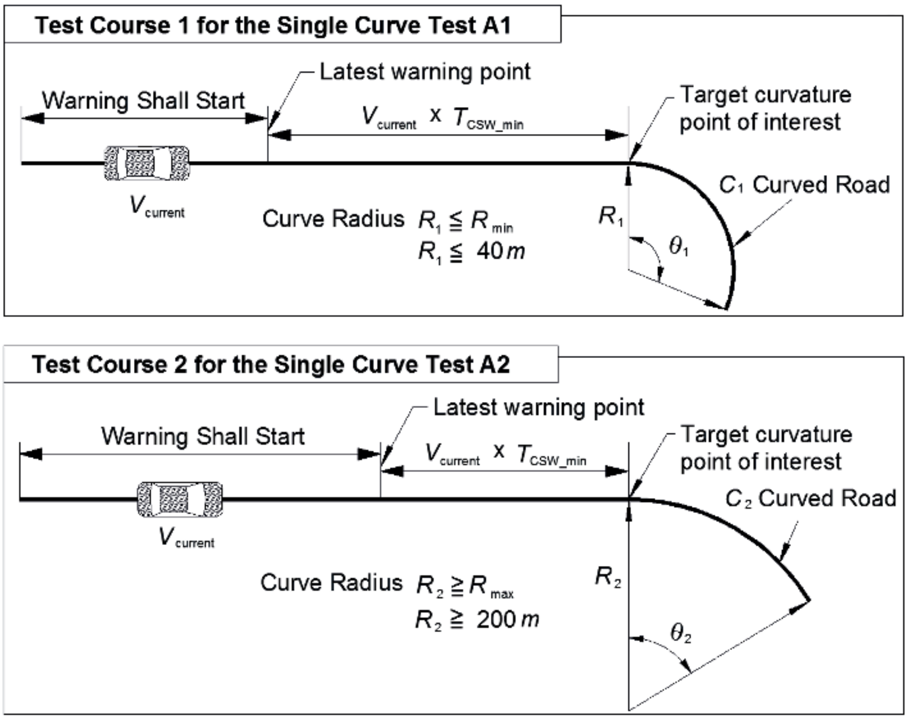


Figure 9 — Test course 1 and test course 2 for single curve test A1 and test A2

— Test b): Tests for warning generation at a multiple curve. The distance from the target curvature point of interest to the start location shall be long enough for the vehicle to reach the intended speed at least 50 m before the warning distance of the nearest target curvature point of interest of C1 curved road.

Test B consists of two tests with different test speeds. In test 1, both C1 and C2 curved roads are target curvature points of interest. The purpose of test B1 is to confirm the CSWS to warn at the multiple curve case. In test B2, only C2 curved roads is the target curvature points of interest. The purpose of test B2 is to confirm the CSWS to have ability to take account of the next curve.

(Test B1) The subject vehicle speed at 50 m before the warning distance of the nearest target curvature point of interest of C1 curved road, V_{test}, shall be 0,83 m/s ~ 3,6 m/s (3 km/h ~ 13 km/h) greater than one of greater value of V_{WT_max1}.

$$V_{test} > V_{WT\_max} + V_{add}$$

Where the value of V_{add},

$0{,}83 < V_{add} < 3{,}6$ m/s

$V_{WT\_max1} > V_{WT\_max2}$

where

V_{WT_max1} is the V_{WT_max} of C_1 curved road;

V_{WT_max2} is the V_{WT_max} of C_2 curved road.

The subject vehicle maintains the speed and the subject vehicle passes the target curvature point of interest once in either a right or left curve.

The CSWS passes the warning generation test if the system successfully generates the warning before the warning zone for both C_1 and C_2 curved road.

(Test B2) The subject vehicle speed at 50 m before the warning distance of the nearest target curvature point of interest of C1 curved road, V_{test}, shall be greater than one of greater value of V_{WT_max2} and less than V_{WT_max1}.

$V_{WT\_max1} > V_{test} > V_{WT\_max2} + V_{add}$

Where the value of V_{add} is same as in Test B1.

The subject vehicle maintains the speed and the subject vehicle passes the target curvature point of interest once in either a right or left curve.

The CSWS passes the warning generation test if the system successfully generates the warning before the warning zone of C_2 curved road.

An example of test course 3 for test B1 is described below.

The radius of curvature of R_1 and R_2 are 120 m and 40 m, respectively. The current vehicle speed at 50 m before the warning distance of the curvature point for C_1 curved road is 27 m/s and the angle of curved road for C_1 curved road is 24 deg.

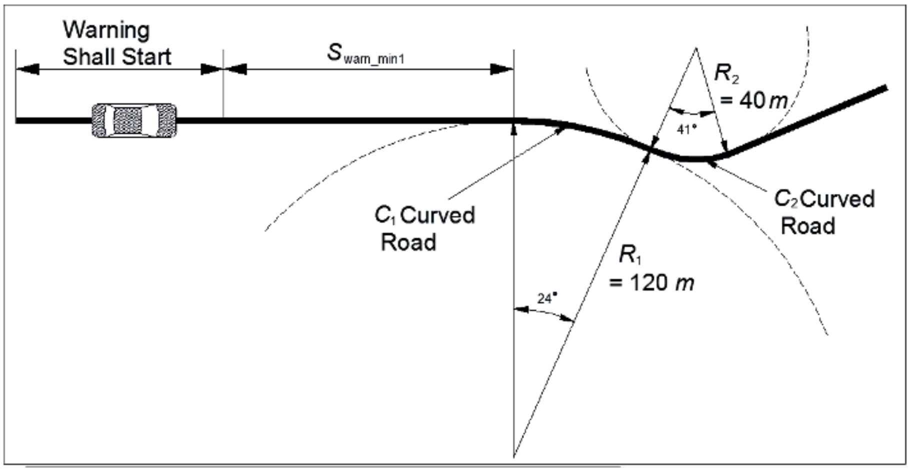


Figure 10 — Example of a test course 3 for multiple curve test B1

Annex A
(informative)

Definition of curves

A.1 Graphical descriptions for the curved road, the curvature point of interest, and target curvature point of interest

The following figures are added to avoid possible confusion on terminology, curved road, curvature point of interest, and target points. Detailed explanations of each terms can be found in 5.2.2.

— For example, Figure A.1,

Location A: Curvature point of interest ($R \leq R_C$ and $S_{current} < S_{LAD}$)

Location B: Non-curvature point ($R > R_C$)

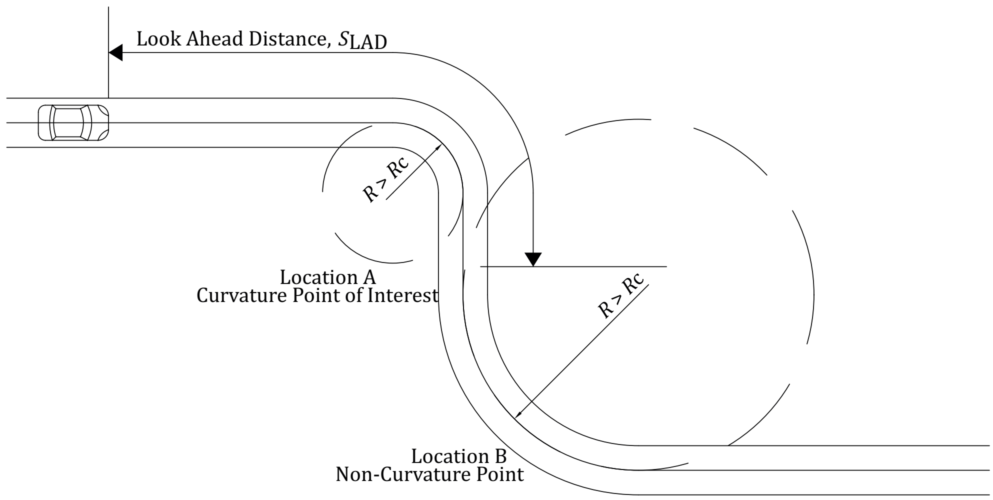


Figure A.1 — Curvature point of interest (location A) and non-curvature point (location B) for R_C

— For example, Figure A.2,

Location E1: Target curvature point of interest

($R \leq R_C$ and $S_{current} < S_{LAD}$, $V_{current} > V_{WT}$ and $S_{current} < S_{warn}$)

Location E2: Curvature point of interest ($R \leq R_C$ and $S_{current} < S_{LAD}$)

Location E3: Curvature point ($R \leq R_C$)

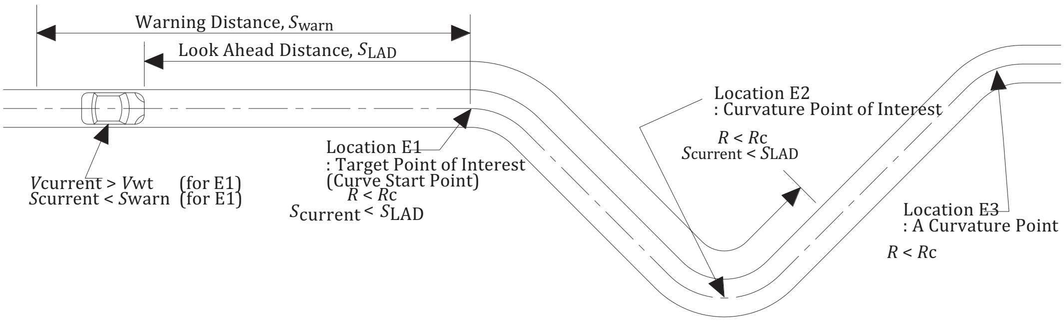


Figure A.2 — Target curvature point of interest (location E1) and curvature point of interest (location E2)

— The difference among distance to target curvature point of interest, distance to curvature point of interest, and look ahead distance is described in Figure A.3.

NOTE Both location F1 and F2 are qualified as curvature point of interest, while only the location F1 is qualified as a target curvature point of interest.

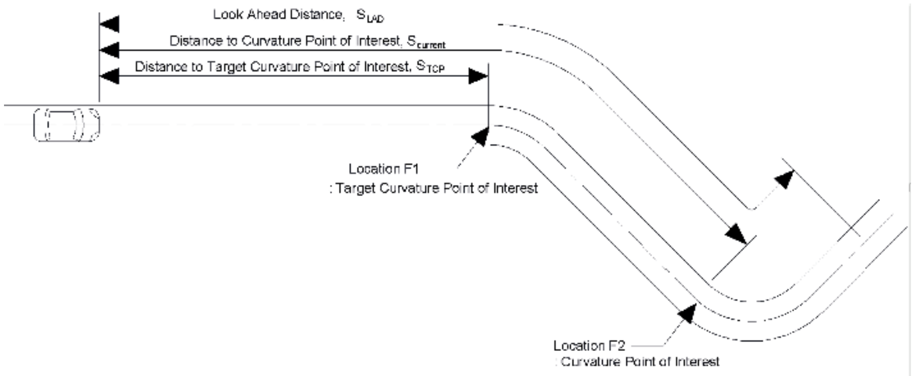
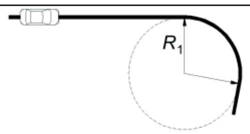
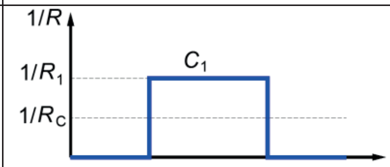
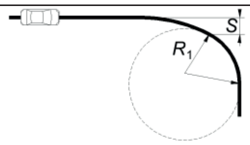
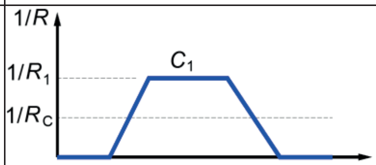
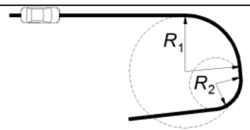
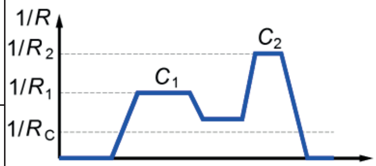
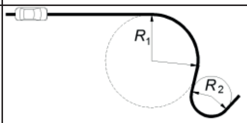
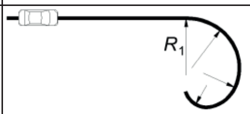
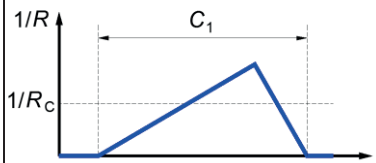


Figure A.3 — Target curvature point of interest (location E1) and curvature point of interest (location E2)

A.2 Types of curved roads

The curved roads can be sorted into five categories. The types of curved roads are described in Table A.1.

Table A.1 — Types of curved roads

	Name of curve	Type	Shape of curve	Diagram of curvature	Remarks
1	Single curve	Without clothoid			— Constant radius of curvature — No clothoid curvature
2		With clothoid			— Constant radius of curvature —With clothoid curvature
3	Multiple curve	Same direction			— Two or more constant radius of curvature in the same direction — With/without clothoid curvature
4		Opposite direction			—Two or more constant radius of curvature in opposite direction — With/without clothoid curvature
5	Variable curve	N/A			— Variable radius of curvature in the same direction — Any point of the variable radius curve satisfies the curve criteria, i.e., less than or equal to R_C — With/without clothoid curvature

Annex B
(informative)

Operation principles

B.1 Operation principles

The operation principles of CSWS are described in this Annex. The operating process is as follows.

a) When the subject vehicle is driven, the CSWS checks the curvature of the upcoming road within the range of look ahead distance. The conditions of the curvatures are checked and the curvature points of interest are selected.

b) If the activation criteria are met, the CSWS transitions to CSWS available state. The system judges whether the warning should be issued or not. If the system judges to warn, the CSWS starts warning(s).

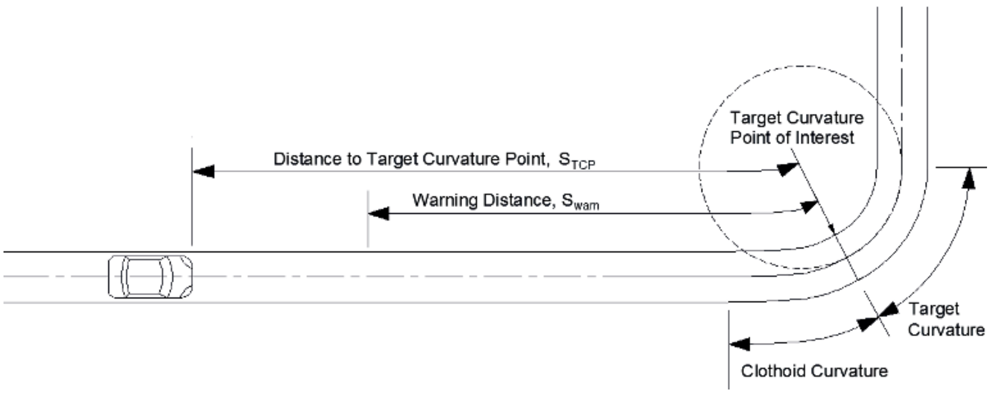


Figure B.1 — CSWS operation principle

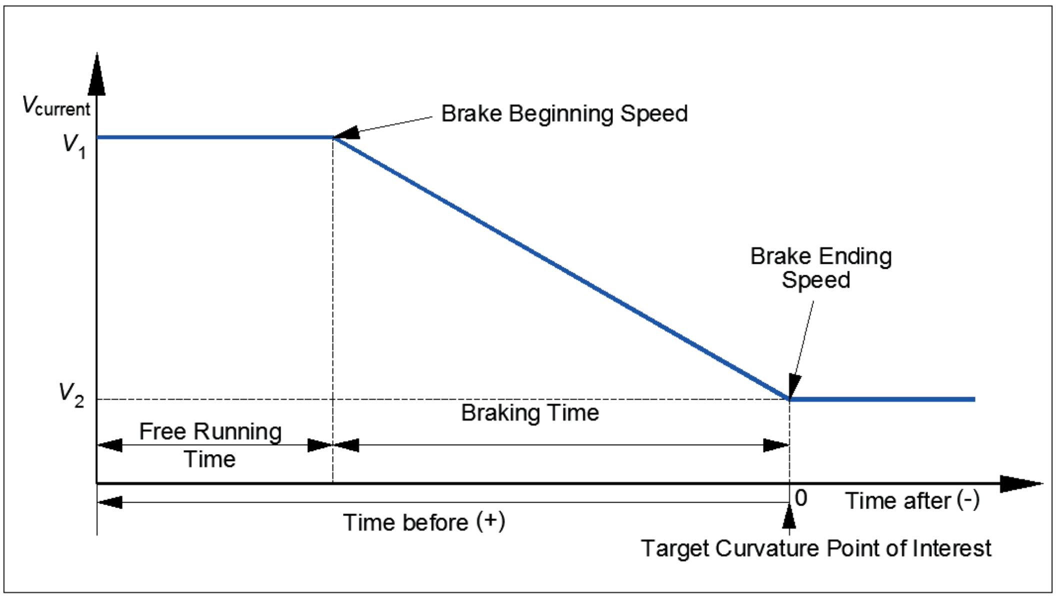


Figure B.2 — CSWS operation principle regarding the subject vehicle speed and distance

— The required warning distance, S_{warn}, is obtained from Formula (B.1):

$$S_{warn} = S_{free} + S_{braking} \tag{B.1}$$

where

S_{warn}	is the warning distance;
S_{free}	is the free running distance;
$S_{braking}$	is the braking distance.

— The free running distance is computed assuming that the subject vehicle speed is constant during free running. The free running is mainly caused by the driver reaction delay; therefore, the free running time is denoted as the driver response time, t_{resp}. Note that the driver response time shall be a minimum of 0,8 s, as described in 5.2.5.

$$S_{free} = V_{current} \times t_{resp}$$

— The minimum required braking distance, $S_{braking}$, is obtained from Formula (B.2):

$$S_{braking} = \frac{V_{current}^2 - V_{WT}^2}{2 \times a_{d\_req}} \tag{B.2}$$

where

$V_{current}$	is the subject vehicle speed;
V_{WT}	is the warning threshold speed;
a_{d_req}	is the required deceleration;
$S_{braking}$	is the braking distance.

— The minimum allowed curve speed warning time, t_{csw_min}, is obtained from $S_{braking}$ as Formula (B.3).

$$t_{csw\_min} = \frac{S_{free}}{V_{current}} + \frac{S_{braking}}{V_{current}} = t_{d\_min} + \frac{\left(V_{current}^2 - V_{WT}^2\right)}{\left(2 \times a_{d\_max}\right) \times V_{current}} \tag{B.3}$$

B.2 Basic system operation

Basic system operation is described in Figure B.3. The black solid line indicates the warning distance change relative to the subject vehicle speed, $V_{current}$, and the distance to the target curvature point, $S_{current}$. The blue solid line indicates the distance to the target curvature point, $S_{current}$, at the minimum allowed curve speed warning time, t_{CSW_min}.

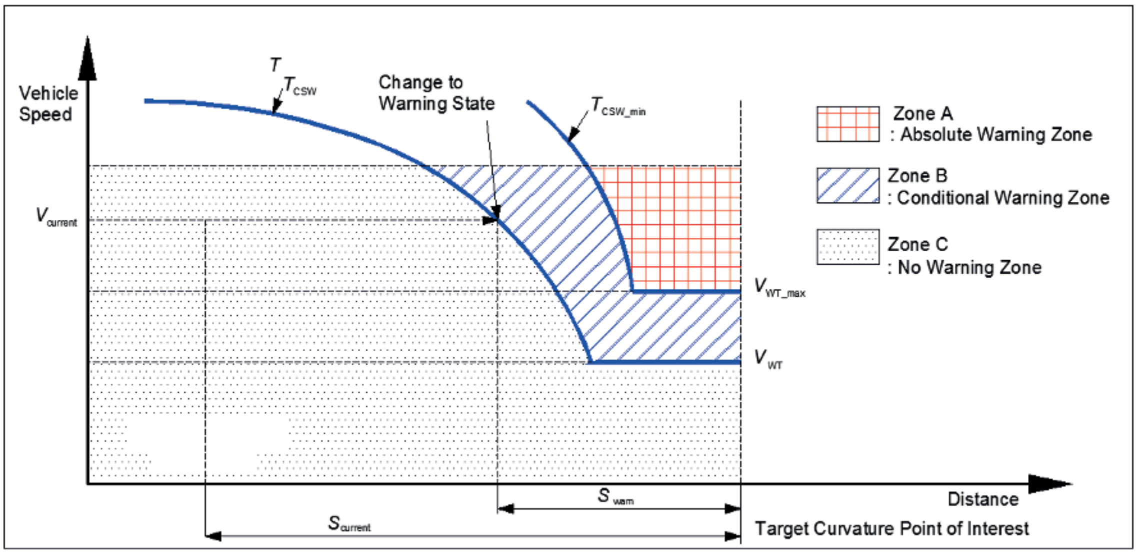


Figure B.3 — Basic CSWS operation

There are three zones hatched on Figure B.3. The meanings of three zones are as follows.

a) Zone A: absolute warning zone

b) Zone B: conditional warning zone

c) Zone C: no warning zone

The system shall warn at Zone A while the system shall not warn at Zone C. In Zone B, the warning conditions are described in 5.2.1.

B.3 Operational limits

The limit of operation of CSWS is described in Figure B.4. In terms of radius of curvature, the system shall be operated from R_{min} to R_{max}. The detail properties regarding the operational limit in terms of radius of curvature can be found in 5.2.2. The system shall be operated at the speed above V_{min} and the V_{min} can be selected by the manufacturer as stated in 5.4.

In Figure B.4, the system shall be operated at Zone A. On the other hand, the system shall be operated when the conditions are met at the Zone B. Zones are hatched on Figure B.3.

a) Zone A: absolute operating zone

b) Zone B: conditional operating zone

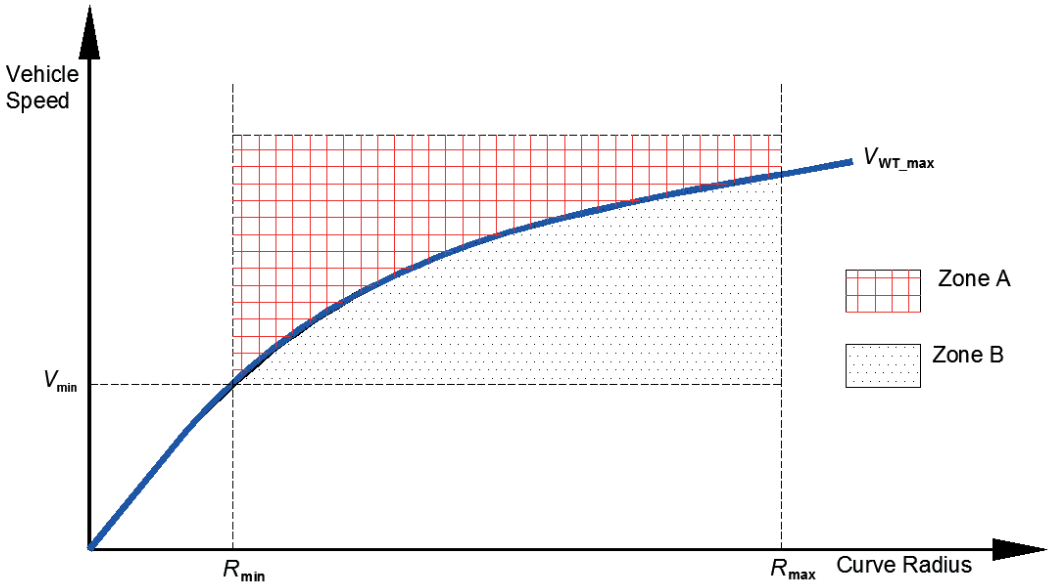


Figure B.4 — Operational limits of CSWS

Annex C
(informative)

Calculation of the minimum AOC

C.1 Influence of the AOC

The CSWS is intended to reduce the danger on the curved roads. With the same radius of curvature of the curved road, there can be less danger when AOC is small, as shown in Figure C.1.

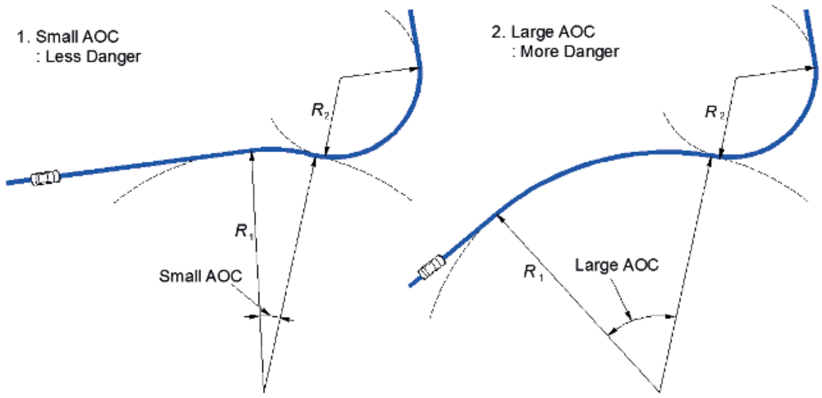


Figure C.1 — Influence of AOC

Although the AOC has influence on CSWS, the AOC cannot be one of the basic requirements because this International Standard is not intended to set the restrictions on sensing method. Also, in practical, it is not possible to measure the accuracy of the road shape points of the digital map used for CSWS.

NOTE The road shape points are actual source of computing the curvature of the road, as well as the AOC of the curved road.

C.2 Calculation of the minimum AOC

In the test conditions, it is necessary to consider the minimum of AOC because this International Standard is not intended to prevent some manufacturers to disregard the curved roads with very small AOC. Also, when CSWS is developed in reality, it is necessary to consider the influence of AOC regarding the general accuracy of the map database suggested by the map providers.

The maximum possible error of the real road position and the expected road position computed from the road shape points can be represented as d_{max}, as shown in Figure C.2

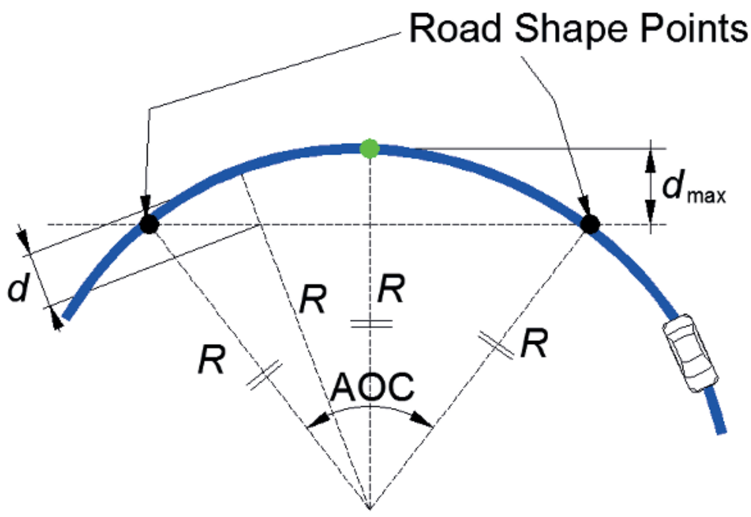


Figure C.2 — Definition of d_{max}

d_{max} can be calculated using Formula (C.1):

$$d_{max} = R - R \times \cos\left(\frac{\theta_{min}}{2}\right) \tag{C.1}$$

From Formula (C.1), the minimum AOC, θ_{min}, can be calculated. When the value of d_{max} is defined as 2,5 m, the calculated value of minimum AOC is shown in Figure C.3.

$$\theta_{min} = 2\cos^{-1}\left(\frac{R - d_{max}}{R}\right)$$

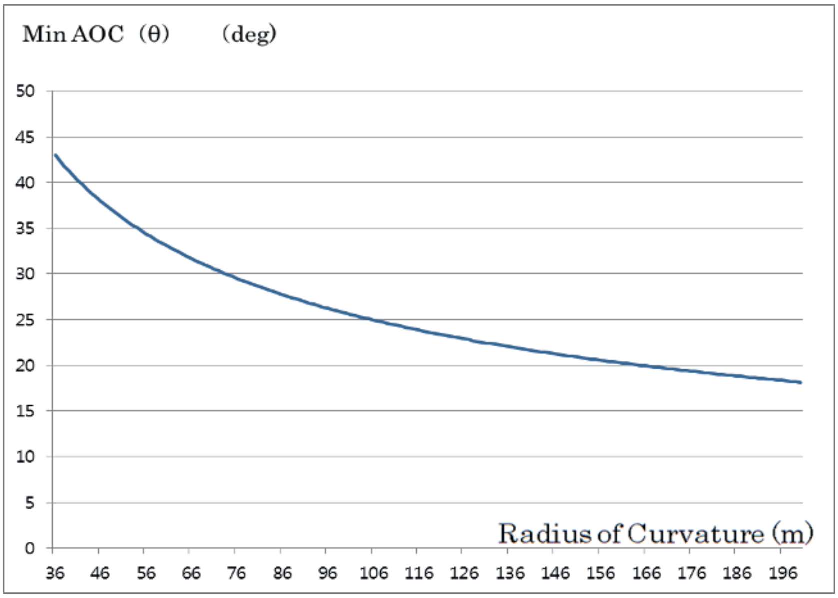


Figure C.3 — Value of minimum AOC with various R when d_{max} is 2,5 m

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