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Intelligent transport systems (ITS) — Cooperative intersection signal information and violation warning systems (CIWS) — Performance requirements and test procedures

Systèmes intelligents de transport (ITS) — Systèmes d'avertissement d'information et de violation du signal d'intersection coopérative (CIWS) — Exigences de performance et modes opératoires d'essai

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Foreword

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

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

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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 system function of cooperative intersection signal information and violation warning systems (CIWS) is to warn drivers who are about to violate an intersection's traffic signal to stop at the prescribed location. The CIWS is intended to provide a cooperative vehicle and infrastructure system that reduces the likelihood and severity of crashes at signalized intersections by providing the signal phase information and/or by warning the driver that an intersection signal violation is about to occur. The system uses information communicated from the roadside infrastructure to determine if a warning should be given to a driver.

The purpose of implementing CIWS is to reduce violations of traffic signals at signalized intersections to: (a) reduce fatalities, (b) reduce the number and/or severity of injuries, and (c) reduce property damage associated with collisions.

This International Standard addresses CIWS for use in road vehicles approaching signalized intersections.

This International Standard may be used as a system level standard by other standards, which extend the CIWS to a more detailed standard utilizing wireless communication technologies. Issues such as the specific requirements for the function and performance of communication technology or traffic control facilities (including traffic signal controllers) will not be considered in this International Standard.

Intelligent transport systems (ITS) — Cooperative intersection signal information and violation warning systems (CIWS) — Performance requirements and test procedures

1 Scope

This International Standard specifies the concept of operation, system requirements, and test methods for cooperative intersection signal information and violation warning systems (CIWS) at signalized intersections. CIWS are intended to reduce the likelihood of crash injury, damage, and fatality by enhancing the capability of drivers to avoid crash situations at signalized intersections.

The scope of CIWS standardization includes basic functions, functional requirements, performance requirements, information contents, and test methods.

The characteristics of the technologies used to communicate between the signal controller and the vehicles are not addressed by this International Standard nor are the behavioural responses by drivers, the various capabilities of vehicles on the road, or the multitude of combinations of these two characteristics.

2 Normative references

There are no normative references cited in this document.

3 Terms and definitions

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

3.1
stopping distance
distance, X_v, travelled by a vehicle with the speed of v, from the time the driver receives CIWS warning until the vehicle comes to a complete stop

Note 1 to entry: This includes the distance travelled during the driver perception and reaction time.

3.2
speed of vehicle
speed of the subject vehicle, v

3.3
time to arrive at stop line of intersection
TTAI
time needed for a vehicle approaching the intersection at a speed of v to travel the distance, X, from its current location to the stop line

$$TTAI = \frac{X}{v}$$

3.4
traffic signal phase
green, yellow, and red intervals within a cycle that are assigned to an independent traffic movement or combination of movements

3.5
stop line
pavement marking line extending across approach lanes to indicate the point at which a stop is intended or required to be made

3.6
road side equipment
RSE
roadside device that can supply traffic signal information to the approaching subject vehicle and may also support determination of vehicle position and heading

3.7
onboard equipment
OBE
in-vehicle equipment that can provide drivers with information and/or warnings based on the information received from the RSE and the vehicle

3.8
spot communication media
wireless communication system between roadside and vehicles that operates only within such a small zone that the availability of the communication link can serve as a definitive indicator of the vehicle's location in support of the intended application

4 Symbols

d deceleration rate of subject vehicle for stopping on level pavement (m/s^2), assumed for the purpose of designing CIWS (could be specific for the vehicle type, weather conditions, and road gradient)

G duration of green time (s)

G_r remaining green time (s)

t_D total time of information delay (s)

t_{OBE} the time between when the OBE receives information from the RSE and when it displays a warning

$$t_{\mathrm{OBE}} = t_{\mathrm{OBE1}} + t_{\mathrm{OBE2}}$$

where t_{OBE1} includes communication delay and judgement processing in OBE and t_{OBE2} is display delay to driver.

t_{PRT} driver's perception-reaction time (PRT)

t_{RSE} the time between when the RSE receives signal status information and when it broadcasts that information

v approach speed (m/s)

V_{Design} maximum speed of vehicle, assumed for the purpose of designing CIWS (m/s)

X travel distance from the current position of the vehicle to the stop line (m)

X_{AL} location of downloading information from RSE (m)

$$X_{AL} \geq v_{\mathrm{Design}} \cdot t_D + \frac{v_{\mathrm{Design}}^2}{2 \cdot d}$$

NOTE: Location of the RSE is limited by the physical conditions of the road. If the RSE is located upstream than $v_{Design} \cdot t_D + v^2_{Design}/(2 \cdot d)$, it can communicate the information in the timing required for warning.

$$t_D = t_{PRT} + t_{OBE}$$

X_v stopping distance (m)

$$X_v = v \cdot t_{PRT} + \frac{v^2}{2 \cdot d}$$

Y duration of yellow time (s)

5 Classification

5.1 System configuration

The system configuration should be in accordance with Figure 1.

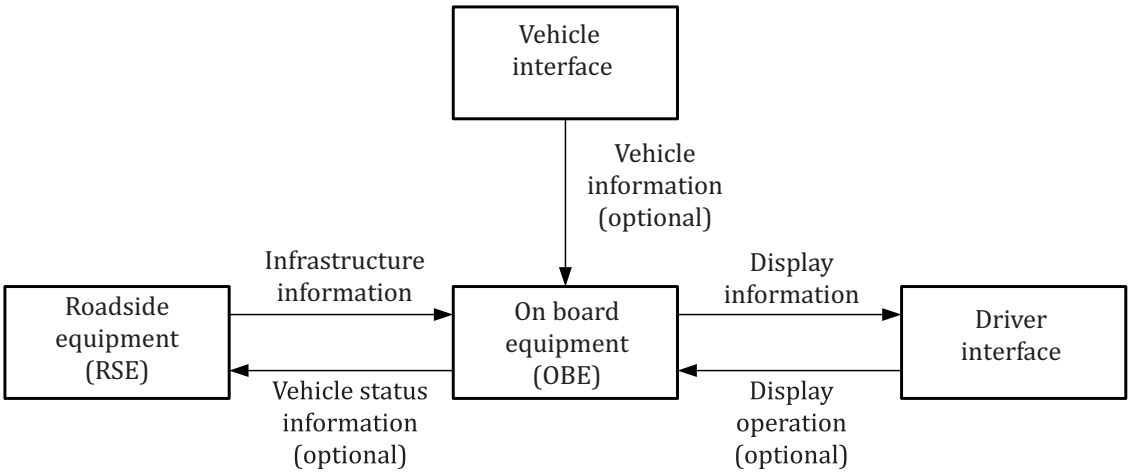

Figure 1 — System configuration

5.2 System configuration

In order to reduce the likelihood of crash injury, damage, and fatality by enhancing the capability of drivers to avoid crash situations at signalized intersections, the CIWS application shall be classified as three types as shown in Table 1. Class I systems are intended to give information about the current phase of the traffic signal for enhancing the driver's awareness of the signal state. Class II systems are intended to provide an in-vehicle warning to the driver of an imminent traffic signal violation for enhancing the opportunity for the driver to avoid the signal violation.

Class III systems address future issues; they are intended to include the function of automatic brake control to reduce red light violations by inattentive drivers.

Table 1 — Classification of CIWS applications

Class	Function	Aims	Driver support	Infrastructure information	Vehicle information	Scope
I	Information	Information provision	Current state of traffic signals	Signal phase: (green/yellow/red) by direction	Direction of travel	Yes
			Timing of signal changes	Signal phase and timing by direction	Direction of travel	Future issue
II	Warning	Avoiding violation	Signal violation warning	Signal phase and timing by direction	Direction of travel, position, speed, *TTAI*	Yes
III	Control	Avoiding violation	Assisted braking or automatic stopping	Signal phase and timing by direction	Direction of travel, position, speed, *TTAI*	Future issue

6 Functional requirements

6.1 CIWS state diagram

CIWS shall, at a minimum, operate according to the state diagrams as shown in Figures 2 and 3.

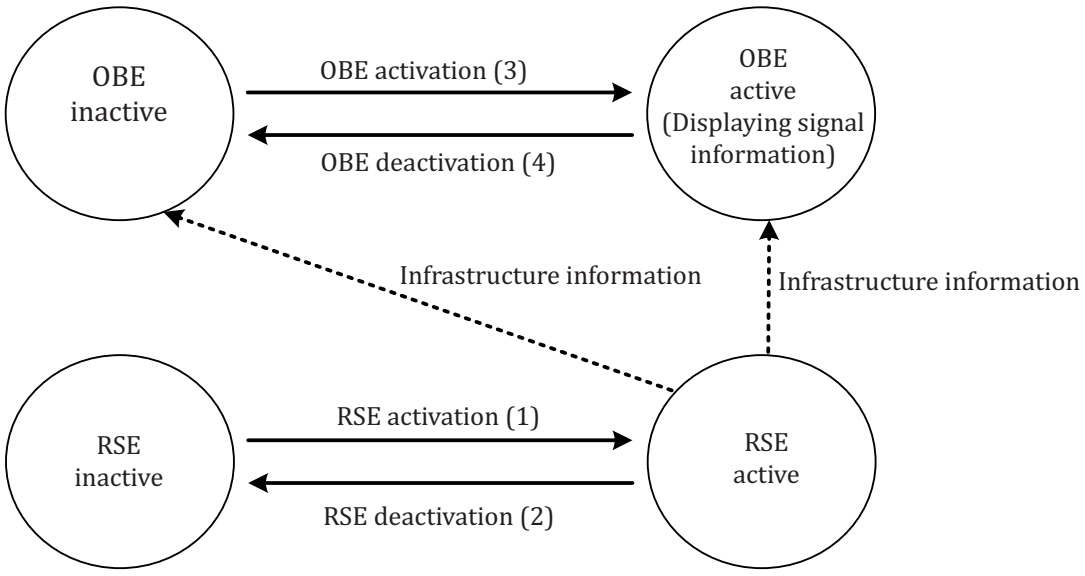

Figure 2 — System state diagram — Class I information

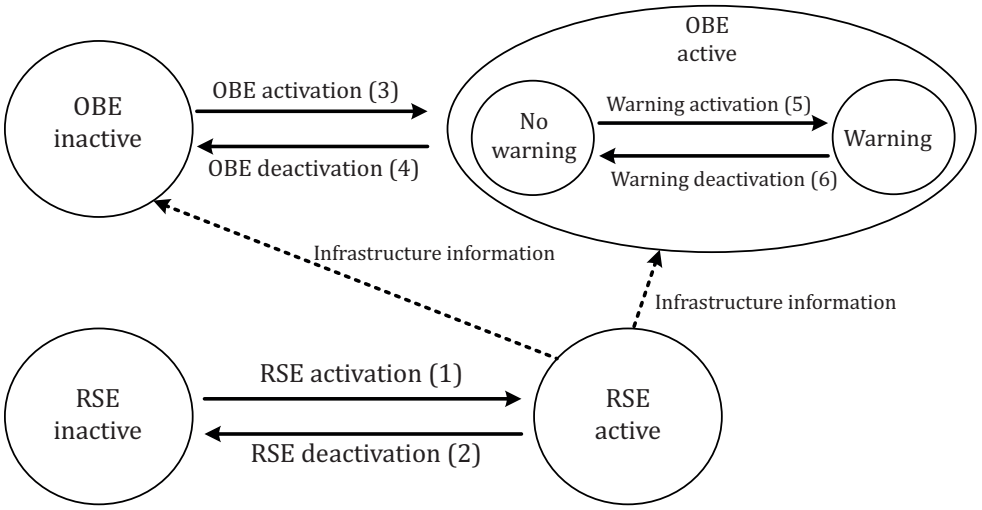

Figure 3 — System state diagram — Class II warning

6.1.1 CIWS states

6.1.1.1 CIWS states

State in which RSE is inactive.

6.1.1.2 RSE active

State in which RSE is active and sends information on signal phase, etc. to OBE.

6.1.1.3 OBE inactive

State in which OBE is inactive.

6.1.1.4 OBE active

State in which the OBE is active, (a) conditions of information provision are met and the system can provide information to driver (Class I) or (b) conditions of warning are met and the system can warn the driver (Class II).

6.1.1.4.1 Warning state

State in which the warning requirements are fulfilled. In this state, a warning shall be issued to human-machine interface (HMI), which might arbitrate priorities relative to other warnings.

6.1.1.4.2 No warning state

State in which the system shall give no warning to the driver because the warning requirements are not met.

6.2 Transition criteria

6.2.1 Criterion (1): RSE activation

When the RSE operator or the automatic system turns RSE on, it becomes active.

6.2.2 Criterion (2): RSE deactivation

When the RSE operator or the automatic system turns RSE off to discontinue the system due to failures and maintenance, etc., it becomes inactive.

6.2.3 Criterion (3): OBE activation

The OBE becomes active when the accessory/ignition switch is turned on. In systems with an optional ON/OFF switch, the OBE becomes active when this switch is turned on.

It might also transition to the active state again when a failure period ends.

6.2.4 Criterion (4): OBE deactivation

The OBE becomes inactive when the accessory/ignition switch is turned off or during failure periods. In systems with an optional ON/OFF switch, the OBE becomes inactive when this switch is turned off.

6.2.5 Class II criterion (5): Warning activation

For the warning in Class II, the warning shall be given when passing the area or time in which warnings are required based on the reception of information from RSE. The warning decision depends on the criteria specified in 6.5.3.

6.2.6 Class II criterion (6): Warning deactivation

The warning shall be ended when passing the stop line or after the warning criteria are no longer met, for example, because the vehicle has decelerated so that it is no longer in danger of violation. The position of the stop line is contained in the message sent by the RSE or stored in the in-vehicle map database.

6.3 Functional requirements of OBE

6.3.1 Acquisition of travel direction

The direction of travel of the vehicle shall be acquired using a position-detection function such as global navigation satellite systems (GNSS) or information provided from the RSE.

6.3.2 Acquisition of vehicle position

The position of the vehicle shall be acquired using a position-detection function such as GNSS or information provided from the RSE.

6.3.3 Acquisition of vehicle speed

The speed of the vehicle shall be acquired by sensors onboard the vehicle.

6.3.4 Identification of traffic signal information

Information about the state of the traffic signal ahead of the vehicle shall be identified from information received from the RSE.

6.3.5 Judgement of warning necessity and warning contents (Class II)

The decision to issue a warning and its contents will be based on the estimated signal phase at the time the subject vehicle arrives at the intersection and on the position and speed of the subject vehicle.

6.3.6 Timing of warning output

The timing and position to trigger the warning should take into account the driver's perception and reaction time.

6.3.7 Timing of warning termination

The warning shall be terminated when judged unnecessary due to driver operation, vehicle position, vehicle speed, traffic signal state, or the like, or when the predetermined warning output time has elapsed.

6.3.8 HMI display contents

The HMI shall display the content of the warning correctly.

6.4 Functional requirements of RSE

The RSE shall be installed in the intersection area according to the type of communication links used by the system. The RSE shall be connected to the signal controller at the intersection for receiving the data of signal timing and status from the controller.

6.4.1 Data sets

Data sets shall be provided with the resolution and accuracy that are sufficient to ensure system performance; for example, signal phase (Class I) and stop line position (Class II), signal phase in the direction travelled by the vehicle, remaining time of signal phase, and next signal phase.

6.4.2 Communication range

The RSE shall have a communication range that is sufficient to ensure system performance with a vehicle driving at the design speed.

6.4.3 Communication delay

Information shall be outputted within the maximum tolerable delay time that is sufficient to ensure the system performance for OBE and RSE, i.e. 200 m/s of t_{OBE1} and 1,0 s of t_{RSE}, respectively.

6.5 CIWS system performance

6.5.1 System capabilities

The OBE in the CIWS will use information transmitted from the RSE to determine if a warning or information should be given. The transmitted information should include traffic signal status and/or timing and traffic signal stopping location or distance information.

The RSE will broadcast a periodic wireless message that identifies the traffic signal and its exact location. The message will indicate the current phase of the signal and the travel direction corresponding to that information. The message could also indicate the next phase for the traffic signal, as well as the time until that phase change.

The OBE will receive the wireless message from the RSE and conduct computations to determine if a warning or information should be generated. In conjunction with information about traffic signal location, phase, and/or timing, the OBE could display signal status information or use information regarding the vehicle's location, heading, speed, and acceleration, to estimate the likelihood of violating the traffic signal phase upon entering the intersection. The calculations could also use information about road conditions, embedded in the message from the traffic signal via RSE or known from any other source, to adjust the operation of the decision algorithm.

6.5.2 Provision of information

6.5.2.1 Provision of information to drivers

The system has many ways to provide drivers with information. However, this International Standard focuses on messages to the OBE that will be used to provide the driver with current state of traffic signals (Class I) or warning signals (Class II).

6.5.2.2 Out-of-order indication

In case of system failure detected by the OBE, the driver shall be informed that the system is not able to provide information.

6.5.3 Warning threshold for signal violation

When a vehicle approaches the intersection, the distance to the intersection where the warning is activated according to the activation conditions, X_v, is based on the global navigation satellite system (GNSS) data and/or on the information about the vehicle location derived from the RSE location. Then, the time to arrive at the intersection (*TTAI*) from the distance, X_v, can be determined as a function of the distance and the speed of vehicle, as follows.

$$TTAI = \frac{X_v}{v} \tag{1}$$

In this case, the requirements for providing warning could be determined by comparing the time of remaining green (G_r) at the approach as shown in the following table.

Any warning shall be terminated when it is judged to be unnecessary in consideration of the position/state of the vehicle.

Table 2 — Warning activation condition with respect to *TTAI*

Time condition	Class II	Meaning of information
$TTAI < G_r$	No warning	Green signal ahead (optional)
$G_r \leq TTAI \leq G_r + Y$	Signal violation warning (optional)	Signal changes – attention and/or reduce speed
$TTAI > G_r + Y$	Signal violation warning	Red light running – stop

When spot communication media is used by the RSE, RSE information is not available continuously. As a consequence, there are two possible system configurations.

6.5.3.1 Systems for which the warning can be activated at any time during the approach

The OBE shall estimate the elapsed time and distance travelled from the point when the vehicle did pass the RSE; it shall update the time green remaining (G_r) and the *TTAI*, taking into account the current vehicle speed. In this case, the provision of warning could be decided during the approach by comparing *TTAI* to thresholds as shown in Table 2.

Any warning shall be terminated when it is judged to be unnecessary in consideration of the position/state of the vehicle.

This system should not be installed in intersections where actuated signal control, with changeable signal timing, is applied.

6.5.3.2 Systems for which the warning can only be activated at the location where the spot communication from the RSE is received

The warning can be activated only at the instant when the vehicle passes the location where information is downloaded from the RSE via a wireless communications link. If the duration of green time is given as G s, the warning threshold will be determined to be $G - t_1$ before the onset of the yellow signal, i.e. the end of the green signal. Thus, a subject vehicle approaching with the speed of v might have sufficient time to reduce its speed until the vehicle reaches the intersection to stop safely. The warning threshold is determined as a function of the speed of the subject vehicle at the location for providing information.

$$t_1 = G - \frac{X_{AL}}{v} \tag{2}$$

When a vehicle is approaching the range of location, $X_{AL,}$ with the speed of v at a specific time, t, the activation conditions for providing warnings are shown in Table 3.

The warning shall be activated according to either Table 2 or Table 3.

Any warning shall be terminated when it is judged to be unnecessary in consideration of the position/state of the vehicle.

Table 3 — Warning activation conditions of OBE with respect to time at X_{AL}

Time, t, at X_{AL}	Class II	Meaning of information
$t_0 < t \leq t_1$	No warning	Green signal ahead (optional)
$t_1 < t \leq t_y$	Signal violation warning (optional)	Signal changes – attention
$t_y < t \leq t_2$	Signal violation warning	Signal changes – stop
$t_2 < t \leq t_3$	Signal violation warning	Red light running – stop

t_0: time when the green signal is initiated (t_0 shall be set as 0,0 s at the beginning of every green phase)

t_1: time when the warning activation conditions are met

t_y: time when the yellow signal is initiated

t_2: time when the red signal is initiated

t_3: time when the red signal is off and the next green signal is initiated

This system should not be installed in intersections where actuated signal control with changeable signal timing is applied.

7 Test requirements

7.1 Test vehicle

The test vehicle shall be equipped with a device to record the CIWS outputs as a function of time and position of the vehicle.

7.2 Test site

7.2.1 Environmental conditions

The test intersection shall be on a flat, dry asphalt, or concrete surface. The ambient temperature during testing shall be within the range of 10 °C ± 30 °C.

7.2.2 Geometric conditions

The test site shall be installed at a signalized intersection which need not be on a public road.

7.2.3 RSE location for the systems providing communication only at X_{AL}

If the CIWS system has the function of warning the location of downloading information from RSE, X_{AL} can be determined for providing sufficient range where the drivers can make a safe decision for stopping regardless of approaching speed. For this, a maximum speed value for CIWS operation, v_{Design}, can be utilized as follows in determining the minimum distance for providing information to vehicles over all speed ranges.

$$X_{AL} \geq v_{\text{Design}} \cdot t_D + \frac{v_{\text{Design}}^2}{2 \cdot d} \tag{3}$$

where

t_D = $t_{\text{PRT}} + t_{\text{OBE}}$

7.3 Test procedure

The following sections describe the minimum test requirements for a signal information and violation warning system (Class I and II).

7.3.1 Test method

For example, X_{AL} is calculated as the distance of 125 m from the intersection if the following parameters are given; v_{Design} = 90 km/h (25 m/s), d = 3,1 m/s^2, and t_D = 1,0 s.

7.3.1.1 Warning tests

7.3.1.1.1 Setting the warning threshold according to the subject vehicle approaching speed

The purpose of this test is to check that the CIWS in vehicles gives both information for Class I and warning for Class II when required as the subject vehicle approaches the intersection. The test shall be conducted as follows.

The subject vehicle shall be driven in the test approach zone at a steady speed of v (where $v \leq v_{\text{Design}}$). The warning threshold shall be set as described in 6.5.3.

For example, if a subject vehicle approaches the intersection with the speed of 65 km/h (18 m/s) and the green interval of 30,0 s, the warning threshold, t_1, becomes 23,0 s after the beginning of green signal, t_0.

7.3.1.1.2 Warning issued based on Table 3

As the subject vehicle approaches the range of location, X_{AL}, in this case with the speed of v at a specific time, t, the system shall issue the warning based on the activation conditions for providing information with the type of warnings as shown in the Table 3.

7.3.1.1.3 Warning issued based on Table 2

As the subject vehicle approaches the intersection, the time to arrive at the intersection ($TTAI$) will be continuously updated at the position of vehicle, X_v. Then, the system shall issue the warning based on the activation condition with $TTAI$ as the function of X_v and the speed of vehicle, as shown in the Table 2.

7.3.1.2 Test run

This test shall be fulfilled according to the conditions shown in Table 4.

Table 4 — Test run conditions

Speed of subject vehicle	Class I: Information	Class II: Warning
$v \leq v_{Design}$	one run (Pass or Fail by information)	two runs: one of warning activation condition and one of non-activation condition. (Pass or Fail by warning)

Bibliography

[1] CAMP. Vehicle Safety Communications 2, *Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V),* Interim Release v1.03, June 2007

[2] Moon Y. J.System Integration and Field Tests for Developing In-Vehicle Dilemma Zone Warning System. *Transportation Research Record 1826*, Transportation Research Board (TRB), Washington D.C., 2003

[3] Kobayashi M. Vehicle Positioning Using an Infrared Beacon and Driver Behavior Analysis for Signal, *Proceedings in Transportation Research Board Annual Meeting 08-0838*, Washington, D.C., 2008

[4] Maile M., Neale V., Ahmed-Zaid F., Basnyake C., Caminiti L., Doerzaph Z. Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V). Phase I Final Reports, Washington, D.C., 2010

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