



SURFACE VEHICLE INFORMATION REPORT

J3251™

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Cooperative Driving Automation (CDA) Feature:
Perception Status Sharing for Occluded
Pedestrian Collision Avoidance

RATIONALE

Although still some years from being realized as a commercial product, automated driving system (ADS)-operated vehicles are expected to eventually become a common participant in road traffic. To help prepare for such a future, this document describes a cooperative driving automation (CDA) Feature and test procedure. The focus of the document is on producing a proof-of-concept-level perception-sharing CDA Feature and associated test procedures suitable for testing in both distributed virtual testing environments, as well as on test tracks, at the proof-of-concept level. (Note: This test procedure may also be suitable for testing on-road.)

TABLE OF CONTENTS

1.	SCOPE.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents	3
2.1.1	SAE Publications.....	3
2.1.2	IEEE Publications.....	3
2.1.3	ISO Publications.....	4
2.1.4	NIST Publications.....	4
2.1.5	Other Publications.....	4
3.	DEFINITIONS	5
4.	ABBREVIATIONS AND ACRONYMS.....	10
5.	CONCEPT OF OPERATIONS	11
5.1	Tutorial	11
5.2	Use Case and Feature Description.....	12
5.3	Current Situation and Problem Statement (Informative).....	12
5.4	Reference Architecture	12
5.4.1	Vehicles.....	16
5.4.2	Pre-Conditions	17
5.5	Architectural Needs.....	17
5.5.1	Fundamental Needs for Connected Vehicles Deployment.....	17
5.5.2	Operational Environment	17
5.6	Features	18
5.6.1	Provide Vehicle-Related Information to Other Road Users or Infrastructure.....	18

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Documents

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5.6.2	Vehicle-Level Sensing, Planning, and Maneuver Execution Data Features	18
5.6.3	Receive CADS-Related Data Features.....	18
5.7	Security Needs	18
5.7.1	Data Source Authenticity.....	18
5.7.2	Data Integrity	18
5.7.3	User Privacy	19
5.8	Operational Policies and Constraints	19
5.9	Relationship to the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) (Informative)	19
5.10	Operational Scenarios.....	20
5.10.1	Functional Scenario (Informative)	20
5.10.2	Logical Scenario.....	24
5.10.3	Concrete Scenario	28
6.	NOTES	31
6.1	Revision Indicator	31
APPENDIX A	TEST PROCEDURE	32
Figure 1	Occluded pedestrian crossing a roadway (V2V) use case	12
Figure 2	Class A status-sharing cooperation high-level architecture.....	13
Figure 3	CADS functional reference architecture for Class A status-sharing cooperation (adapted from SAE J3131)	16
Figure 4	CADS core interface and subsystem breakdown as UML component diagram (example CARMA software platform architecture)	17
Figure 5	CARMA platform software plugin layers	21
Figure 6	Class A status-sharing cooperation notional sequence of events for functional scenario.....	24
Table 1	Mapping information flows to ITS service packages.....	19
Table 2	Occluded pedestrian (V2V).....	23
Table 3	Logical scenario overview	25
Table 4	Logical scenario road user parameters.....	26
Table 5	Logical scenario VRU parameters	26
Table 6	Logical scenario road environment parameters.....	27
Table 7	Concrete scenario overview.....	28
Table 8	Concrete scenario road user parameters	29
Table 9	Concrete scenario VRU parameters	29
Table 10	Concrete scenario road environment parameters	30

1. SCOPE

This SAE Information Report develops a concept of operations (ConOps) to evaluate a cooperative driving automation (CDA) Feature for occluded pedestrian collision avoidance using perception status sharing. It provides a test procedure to evaluate this CDA Feature, which is suitable for proof-of-concept testing in both virtual and test track settings.

NOTE 1: This report was developed prior to SAE J3252. Future revisions of this report will align with the framework described in SAE J3252.

NOTE 2: The term “CDA Feature” as used in this report is defined in SAE J3216 as follows: “The design-specific functionality supported or enabled by M2M cooperation among CDA devices communicating with a C-ADS engaging in CDA.” Thus, the word “feature” here varies from its common English definition. To emphasize this variance and to avoid confusion, “Feature” is capitalized when modified by the adjective “CDA” or “CADS.”

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AVSC00006202103	AVSC Best Practice for Metrics and Methods for Assessing Safety Performance of Automated Driving Systems (ADS)
SAE J2735	V2X Communications Message Set Dictionary
SAE J2945	Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts™
SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
SAE J3131	Definitions for Terms Related to Automated Driving Systems Reference Architecture
SAE J3216	Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles
SAE J3224	V2X Sensor-Sharing for Cooperative and Automated Driving

2.1.2 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE 1362-1998	IEEE Guide for Information Technology - System Definition - Concept of Operations (ConOps) Document
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2.1.3 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 19206-2:2018	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
ISO/SAE PAS 22736:2021	Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles

2.1.4 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NISTIR 6910 4D/RCS Version 2.0: A Reference Model Architecture for Unmanned Vehicle Systems

2.1.5 Other Publications

5GAA. (2019). *C-V2X use cases methodology, examples and service level requirements* [White paper]. 5GAA Automotive Association. Available at https://5gaa.org/content/uploads/2019/07/5GAA_191906_WP_CV2X_UCs_v1-3-1.pdf.

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3. DEFINITIONS

3.1 AUTOMATED DRIVING SYSTEM (ADS) [ISO/SAE PAS 22736:2021/SAE J3016]

The hardware and software that are collectively capable of performing the entire dynamic driving task (DDT) on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system. (For up-to-date definitions, notes, and examples, refer to the latest version of SAE J3016.)

3.2 COOPERATIVE DRIVING AUTOMATION (CDA) [SAE J3216]

Automation that uses machine-to-machine (M2M) communication to enable cooperation among two or more entities with capable communications technology and is intended to facilitate the safer, more efficient movement of road users, including enhancing performance of the DDT for a vehicle with driving automation feature(s) engaged.

NOTE 1: For CADS-equipped vehicles (see 3.4) engaged in cooperative automation, the M2M communications may enhance the performance of the DDT for the subject vehicle (e.g., object and event detection [OEDR] and response, operational, and tactical maneuvers).

NOTE 2: For road operators engaged in cooperative automation, the M2M communications may provide situational awareness and influence performance of traffic management (e.g., signal phase and timing [SPaT], dynamic speed limits, and emergency response).

3.3 COOPERATIVE AUTOMATED DRIVING SYSTEM (CADS) [SAE J3216]

An ADS capable of utilizing CDA.

3.4 COOPERATIVE AUTOMATED DRIVING SYSTEM (CADS)-EQUIPPED VEHICLE [SAE J3216]

A vehicle equipped with Level 3, 4, or 5 driving automation and capable of utilizing CDA. Note that Level 3 systems require human driver intervention upon ADS request. (Refer to SAE J3016 for additional information about driving automation systems.)

3.5 COOPERATIVE AUTOMATED DRIVING SYSTEM (CADS)-OPERATED VEHICLE

A CADS-equipped vehicle in which a CADS Feature is actively engaged in performance of the DDT.

NOTE 1: Additional ADS functions that are not specifically part of the CADS Feature function may also be actively engaged on a CADS-operated vehicle.

NOTE 2: A CADS-equipped vehicle may be operated by the ADS while the CADS Feature is disengaged (i.e., it can also be an ADS-operated vehicle).

3.6 CDA COOPERATION CLASSES [SAE J3216]

Classes of cooperation facilitated by M2M communications among CDA devices that may influence DDT performance and traffic operations, defined as Classes A through D based on the increasing amount of cooperation entailed in each successive class.

NOTE: The use of CDA information to influence DDT performance by one or more CADS-equipped vehicle in any given situation depends upon the type of message provided, as well as other information used by the CADS-equipped vehicle(s).

3.6.1 STATUS-SHARING COOPERATION (CLASS A) [SAE J3216]

Perception information about the traffic environment and information about the sending entity provided by the sending entity for potential utilization by receiving entities. ("Here I am, and here is what I see.")

NOTE 1: Status-sharing cooperation does not require the ability or consent of transmitting entities to employ the information provided via M2M communication, which may originate from any nearby traffic participant.

NOTE 2: Status-sharing cooperation may be used to enhance an entity's situational awareness.

NOTE 3: CDA devices that do not have direct control over the actions of the CDA device agent (e.g., pedestrians or conventional vehicles in which a human directly controls actions) may engage in status-sharing cooperation.

3.6.2 INTENT-SHARING COOPERATION (CLASS B) [SAE J3216]

Information about planned future actions of the sending entity provided by that entity for potential utilization by receiving entities. ("This is what I plan to do.")

NOTE 1: Intent-sharing cooperation does not require the ability or consent of receiving entities to employ the information provided via M2M communication, which may originate from any nearby traffic participant. Receiving entities do not necessarily need to act on the shared intent, and all entities are expected to conduct competent operations regardless of others' actions.

NOTE 2: Intent-sharing cooperation may be used to augment prediction of future states to enhance models of the planned future actions of the sending entity.

NOTE 3: Intent-sharing cooperation may augment status-sharing cooperation by providing information that relates to a future state (rather than just the current state) of a sending entity.

NOTE 4: In some cases, intent information may be shared without M2M communication (e.g., turn signals), but in many cases (e.g., occlusion of taillights), this information could not otherwise be determined at all or as soon by a receiving entity that is not participating in CDA. These non-CDA forms of intent sharing (e.g., turn signals, human gestures, etc.) are beyond the scope of this document.

NOTE 5: CDA devices that do not have direct control over the actions of the CDA device agent (e.g., pedestrians or conventional vehicles in which a human directly controls actions) may engage in intent-sharing communication.

3.6.3 AGREEMENT-SEEKING COOPERATION [AMONG CDA DEVICE AGENTS] (CLASS C) [SAE J3216]

A sequence of collaborative messages among specific CDA devices intended to influence local planning of specific DDT-related actions. ("Let's do this together.")

NOTE 1: Agreement-seeking cooperation requires the ability and authority of the CDA device agents involved to cooperate and agree on plan(s) based on the information provided via M2M communication, which may originate from any nearby traffic participant.

NOTE 2: Agreement-seeking cooperation includes an interactive exchange of messages that may include plans, acceptance or rejection of plans, or considerations for arriving at consensus on a proposed plan. Depending on circumstances, CDA device agents may not follow a planned future action, and all entities must conduct competent operations regardless of others' actions.

NOTE 3: Agreement-seeking cooperation may utilize status-sharing and intent sharing cooperation.

NOTE 4: This document does not consider planning for CDA devices that do not have direct control over the actions of the CDA device agent (e.g., pedestrians or conventional vehicles and driver support features in which a human directly controls actions), instead focusing on planning for systems with driving automation.

NOTE 5: Agreement-seeking cooperation includes proposing plans for other traffic participants (i.e., "What I want you to do"). In contrast, intent-sharing includes only sharing a plan for the sending entity (i.e., "What I plan to do").

3.6.4 PRESCRIPTIVE COOPERATION (CLASS D) [SAE J3216]

The direction of specific action(s) to specific traffic participants for imminent performance of the DDT or performance of a particular task by a road operator (e.g., changing traffic signal phase), provided by a prescribing CDA device agent(s) and adhered to by a receiving CDA device agent(s). ("I will do as directed.")

NOTE 1: CDA devices that do not have control over the actions of their corresponding CDA agents (e.g., pedestrians or conventional vehicles and driver support features in which a human directly controls actions) cannot participate in prescriptive cooperation-based CDA Features.

NOTE 2: Prescriptive cooperation does not require the willingness of the affected entities to cooperate. It relies on a pre-existing understanding between parties to adhere to commands, such as a specific aspect of DDT performance, under particular circumstances.

NOTE 3: Prescriptive cooperation may be performed by transportation authorities and/or fleet operations centers communicating with fleet vehicles under their control.

NOTE 4: Transportation authorities may have the ability to direct prescriptive cooperation to any relevant traffic participants.

NOTE 5: Prescriptive cooperation may utilize status-sharing, intent-sharing, and agreement-seeking cooperation to provide context for the understanding to cede control over actions that relate to the DDT performance.

3.7 CDA DEVICE [SAE J3216]

A device equipped with requisite M2M communication technology that is used by traffic participants to perform CDA Features.

3.8 CDA DEVICE AGENT [SAE J3216]

A traffic participant that authorizes its CDA device to send and receive communications enabling traffic participants to engage in CDA, and authorizes CDA-related actions.

3.9 CDA FEATURE [SAE J3216]

The design-specific functionality supported or enabled by M2M cooperation among CDA devices communicating with a CADS engaging in CDA.

NOTE 1: A given CDA device agent may employ multiple CDA Features simultaneously, where each Feature is associated with a particular data exchange, CDA device(s), and usage specification.

NOTE 2: CDA Features may be referred to by generic names (e.g., cooperative merging) or manufacturer-specific names.

3.10 DYNAMIC DRIVING TASK (DDT) [ISO/SAE PAS 22736:2021/SAE J3016]

All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints. (For up-to-date definitions, notes, and examples, refer to the latest version of SAE J3016.)

3.11 [DRIVING AUTOMATION SYSTEM] FEATURE [SAE J3016]¹

A Level 1-5 driving automation system's design-specific functionality at a given level of driving automation within a particular ODD, if applicable.

NOTE 1: Because the term "driving automation system" subsumes both driver support features and ADS features, it is also acceptable to refer to them as such.

NOTE 2: A given driving automation system may have multiple features, each associated with a particular level of driving automation and ODD.

NOTE 3: Each feature satisfies a usage specification.

NOTE 4: Features may be referred to by generic names (e.g., automated parking) or by proprietary names.

3.12 MOBILE UNIT (MU) [U.S. DOT, 2021]

A device used to wirelessly communicate with other devices for safety and mobility purposes carried by a pedestrian, bicyclist, work zone worker, or other traveler.

3.13 ON-BOARD UNIT (OBU) [U.S. DOT, 2021]

A device used to wirelessly communicate with other devices for safety and mobility purposes installed in a vehicle as original equipment or as aftermarket equipment; sometimes referred to as an aftermarket safety device (ASD).

3.14 OPERATIONAL DESIGN DOMAIN (ODD) [ISO/SAE PAS 22736:2021/SAE J3016]

Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics. (For up-to-date definitions, notes, and examples, refer to the latest version of SAE J3016.)

¹ SAE J3016 also defines the following three specific types of driving automation system features: (1) maneuver-based, (2) sub-trip, and (3) full-trip.

3.15 [A] PLAN [SAE J3216]

A sequence of tasks defined to achieve or maintain a DDT-relevant goal during a trip.

NOTE 1: Planning may occur at strategic, tactical, and operational timescales. This may include outputs from mission planning (e.g., selected route segments and strategies to achieve a given destination or waypoint given certain goals) and behavior planning (e.g., trajectory—i.e., path and speed—of vehicles to competently perform the DDT given a particular driving situation).

NOTE 2: The terms task, goal, and trip are not further defined here. These concepts are discussed in other documents, such as NISTIR 6910.

3.16 TRAFFIC PARTICIPANT [SAE J3216]

Entities whose actions influence travel in the transportation environment, which may include road users engaged in travel upon or across publicly accessible roadways and road operators.

3.16.1 ROAD USERS [SAE J3216]

A traffic participant on or adjacent to an active roadway for the purpose of travelling from one location to another.

NOTE 1: Road users may include motor vehicles (including emergency vehicles), vehicle occupants, pedestrians, pedalcyclists, and users of motorized and non-motorized personal mobility devices, such as scooters, wheelchairs, and mobility carts.

NOTE 2: Road users are governed by local traffic laws.

3.16.2 ROAD OPERATOR [SAE J3216]

A traffic participant who provides, operates and maintains the roadways and supporting infrastructure that enable and support the mobility needs of road users.

NOTE: Road operators may include infrastructure owner operators as public, public-private, or private sector entities that operate in accordance with applicable laws at the federal, state, and/or local level.

3.16.3 CERTIFICATE AUTHORITY [SAE J3216]

An entity that issues digital certificates that confirm authenticity of the certificate owner.

3.16.4 COMMUNICATIONS SERVICE PROVIDER (CSP) [SAE J3216]

A traffic participant who provides and maintains the hardware and software necessary to support secure, low-latency communication M2M between and among traffic participants.

NOTE: CSPs may include public, public-private, or private sector entities that operate in accordance with applicable laws at the federal, state, and/or local level.

3.17 VULNERABLE ROAD USER (VRU) TEST SURROGATE

A device designed to mimic a human road user who is not a vehicle occupant, such as a pedestrian, pedal cyclist, or wheelchair user, which is used in dynamic vehicle testing scenarios involving such road users.

NOTE: Additional specificity regarding the type of VRU represented should be added using common terms, such as “child pedestrian VRU test surrogate” or “adult pedal cyclist VRU test surrogate.”

4. ABBREVIATIONS AND ACRONYMS

ADS	Automated Driving System
AEB	Automatic Emergency Braking
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
BSM	Basic Safety Message
CADS	Cooperative-Automated Driving System
CACC	Cooperative Adaptive Cruise Control
CARMA	Cooperative Automation Research Mobility Applications
CDA	Cooperative Driving Automation
ConOps	Concept of Operations
CSP	Communications Service Provider
C-V2X	Cellular V2X
DDT	Dynamic Driving Task
DSRC	Dedicated Short Range Communications
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HMI	Human-Machine Interface
ID	Identification
INS	Inertial Navigation System
ITS	Intelligent Transportation System
LiDAR	Light Detection and Ranging
M2M	Machine-to-Machine
MUTCD	Manual on Uniform Traffic Control Devices
N/A	Not Applicable
OBD	Onboard Diagnostics
OBE	On-Board Equipment
OBU	On-Board Unit
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response

QoS	Quality of Service
RSE	Roadside Equipment
SDSM	Sensor Data Sharing Message
SPaT	Signal Phase and Timing
TSMO	Transportation Systems Management and Operations
TTC	Time-to-Collision
UML	Unified Modeling Language
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VOBE	Vehicle On-Board Equipment
VRU	Vulnerable Road User
VUT	Vehicle Under Test

5. CONCEPT OF OPERATIONS

5.1 Tutorial

A concept of operations (ConOps) describes a proposed system from the users' perspective. Typically, a ConOps is used on a project to ensure that the system developers understand the users' needs. In this document, the concept of operations describes a specific CDA use case in sufficient operational detail to enable exploratory testing during development of a CDA Feature that fulfils the use case. As such, this document stops short of developing requirements for a specific CDA Feature and instead supports the exploratory testing needed to develop such requirements. This exploratory testing and development requires cooperation among distinct entities, whose participation is necessary for the CDA Feature in question to function.

The ConOps starts with a discussion of the current situation and problem statement that have led to the need to deploy the CDA Feature. This discussion permits both potential users and system developers to understand the situation.

The ConOps then documents key aspects of the proposed system, including:

- Reference Architecture (see [5.4](#)): The reference physical architecture defines the overall context of the proposed system and defines which specific interfaces are addressed.
- Architectural Needs (see [5.5](#)): The architectural needs discuss issues and needs relative to the system architecture.
- Features (see [5.6](#)): The features identify and describe the various functions that users may want the system to perform. These features are derived from the high-level user needs identified in the problem statement, but are refined and organized into a more manageable structure that forms the basis of the traceability table that would otherwise be included in a "Functional Requirements" section. However, this document defines a CDA Feature ConOps only, and therefore does not establish functional requirements.

Architectural needs and features are collectively called "user needs."

The ConOps concludes by:

- Identifying security needs for the CDA Feature under development (see [5.7](#)).
- Describing the extent to which policies or constraints relative to the operational environment have a direct impact on the implementation of the CDA Feature under test (see [5.8](#)).
- Providing a description of how the CDA Feature under test relates to the national ITS architecture (see [5.9](#)).
- Describing the process for deriving operational scenarios that facilitate the development of this CDA Feature (see [5.10](#)).

5.2 Use Case and Feature Description

The use case for this document is: Cooperative Driving Automation (CDA) Feature—Occluded Pedestrian. It describes a situation in which a pedestrian has begun to cross a two-lane road without crosswalk markings in which both lanes carry approaching vehicles, and where one of the approaching vehicles blocks the “view” of the pedestrian by the other vehicle, as shown in [Figure 1](#). The occluding vehicle (CADS-operated vehicle 1, a heavy truck) shares its perception information on the pedestrian via wireless message with the vehicle in the adjacent lane (CADS-operated vehicle 2, a passenger car), whose “view” of the pedestrian is occluded by CADS-operated vehicle 1, so that it can stop in time to avoid striking the pedestrian. The roadway environment is unmarked (except for lane markings) and unsignalized location. The relative speeds and distances of CADS-operated vehicle 1 and CADS-operated vehicle 2 are such that the pedestrian can be avoided with braking, only. In this use case, CDA Class A status-sharing cooperation (refer to SAE J3216) is demonstrated. The wireless message sent by CADS-operated vehicle 1 to CADS-operated vehicle 2 may be broadcast or subscription-based, depending on application configuration.

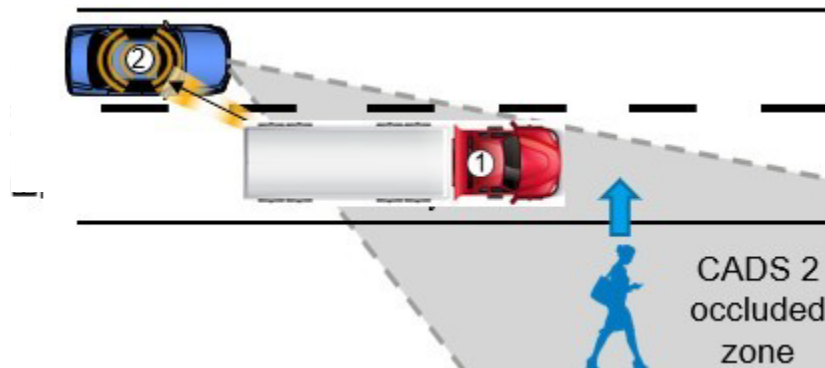


Figure 1 - Occluded pedestrian crossing a roadway (V2V) use case

5.3 Current Situation and Problem Statement (Informative)

The National Highway Traffic Safety Administration (NHTSA) reported that in 2020, 6516 pedestrians died in traffic crashes occurring on public roads and another ~55000 people were injured. Most pedestrian traffic deaths occurred in urban settings (82%) and on open roads (75%), versus occurring at intersections (15%), and most occurred during darkness (77%) (refer to NHTSA, 2022). Connected and automated Class A status-sharing cooperation (refer to SAE J3216) applications, such as the one described in this document, can be expected to reduce the incident rate of pedestrian crashes.

This particular use case was also selected based on its ability to challenge a distributed virtual test platform by having high criticality and low latency needs, while still being simple enough to recreate and validate in a test track setting without undertaking a large development effort.

5.4 Reference Architecture

In this use case, CADS-operated vehicle 1 (V1) perceives the pedestrian and brakes to a stop in time to avoid it; CADS-operated vehicle 1 transmits relevant information via wireless means to CADS-operated vehicle 2 (V2), whose “view” of the pedestrian is occluded by V1. The information received is acted upon by V2’s planning module, which commands braking in time to avoid collision with the pedestrian.