

MAT v1.2

Task 6 Multimodal for All Travelers (MAT) White Paper



Multimodal for All Travelers White Paper on Safety



Multimodal for All Travelers Standards Support Project

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1 Introduction

1.1 Scope

This document provides a brief, non-exhaustive reference on road user safety standards and technology developments for all road user types. It includes summaries of selected industry standards and emerging technologies relevant to various road users, including passenger vehicles, trucks and freight, transit vehicles, emergency vehicles, micromobility, and work zone workers. This reference aims to provide an overview of current standards and technological developments.

1.2 Background

Standardization efforts in road safety technology are often fragmented, resulting in overlapping or inconsistent standards. Various industry groups independently develop standards, highlighting the need for ongoing coordination.

This document is intended as a timely reference, specifically focusing on currently applicable standards and technologies. Its primary value lies in providing background information to support coordination among stakeholders in road user safety.

1.3 Research Methodology

This document summarizes selected standards and technologies based on available and current industry publications, standard development organization outputs, and recent technology development updates. It does not employ a specific methodology beyond identifying relevant and recent developments.

1.4 Organization of This Document

This document is organized into 3 sections:

- 1. Introduction.** Provides the scope, background, and approach of this white paper.
- 2. Summary of Standards and Technologies.** Provides brief descriptions of selected topics related to road safety for all travelers.
- 3. Discussion of Potential Stakeholders.** Suggested stakeholder groups for future coordination in road user safety standardization and technological advancements.

2 Summary of Standards and Technologies

This section discusses topics related to road user safety: policy and planning, road user classifications and architectures, technologies for detection and communication, safety alerting and prediction technologies, and specialized safety considerations. Relevant standards listed include a short summary description published by the associated standards development organization (SDO).

2.1 Policy and Planning

This section outlines key policy frameworks and planning considerations that influence the development and application of road user safety standards.

2.1.1 Complete Streets

The USDOT describes complete streets as "streets designed and operated to enable safe use and support mobility for all users. Those include people of all ages and abilities, regardless of whether they are travelling as drivers, pedestrians, bicyclists, or public transportation riders. The concept of Complete Streets encompasses many approaches to planning, designing, and operating roadways and rights of way with all users in mind to make the transportation network safer and more efficient. Complete Street policies are set at the state, regional, and local levels and are frequently supported by roadway design guidelines.¹"

Other related topics: the Safe System Approach², the National Roadway Safety Strategy³, Vision Zero⁴, and grade separation.

2.1.2 Public Right of Way (PROW)

Another aspect of safety is policy issues relating to Public Right of Way (PROW). There is a need for unified policies and enforcement regarding Micromobility Vehicles (MMV).

PeopleForBikes, a national bicycle advocacy group, promotes a three-class system to categorize electric bicycles based on maximum assisted speed. As of January 2023, 39 states have laws using this system.⁵ This system allows municipalities flexibility in governing where each class may travel. However, this classification system only applies to electric bicycles, and not to other MMVs such as e-scooters. PeopleForBikes explicitly stated their opposition to altering the classification or including other MMVs in the system.⁶

There is a lack of similar advocacy groups for other MMVs. With this absence, there is no group promoting laws for a similar categorization system for these other MMVs. This results in a lack of coordinated rules for other MMV users, as cities are moving forward with their own approaches to

¹ <https://www.transportation.gov/mission/health/complete-streets>

² <https://www.transportation.gov/NRSS/SafeSystem>

³ <https://www.transportation.gov/NRSS>

⁴ <https://highways.dot.gov/safety/zero-deaths>

⁵ https://peopleforbikes.cdn.prismic.io/peopleforbikes/d1ebb612-69a8-4791-93a2-c8e4fcf17aa_ebikeFAQ_January+2023.pdf

⁶ https://peopleforbikes.cdn.prismic.io/peopleforbikes/22cafb3e-7284-456d-9a7d-5dfa4208d935_PeopleForBikes+Statement+on+Electrically+Powered+Devices+032621.pdf

handle them. Different types of MMVs may have different rules for riding on bike paths, and the rules may change after crossing into another municipality. MMV users may need education on MMV use.

2.2 Road User Classifications and Architectures

This section highlights standards related to the classification of road users and the architectural frameworks needed to support safe, coordinated interactions across all transportation modes.

2.2.1 Relevant Standards

This section lists standards for the following categories: general road user standards, standards for road user taxonomy, other standards for MMVs, and architecture standards.

2.2.1.1 General

- 1) **ISO 13111-1:2017, Intelligent transport systems (ITS) — The use of personal ITS station to support ITS service provision for travellers — Part 1: General information and use case definitions**

Defines the general information and use cases of the applications based on the personal ITS station to provide and maintain ITS services to travelers including drivers, passengers, and pedestrians.

- 2) **ISO 13111-2:2022 Intelligent transport systems (ITS) — The use of personal ITS stations to support ITS service provision for travellers — Part 2: General requirements for data exchange between ITS stations**

Defines the data exchange protocol used to implement use cases for applications based on the personal ITS station defined in ISO 13111-1, which provides and maintains ITS services to travelers, including drivers, passengers and pedestrians.

2.2.1.2 Standards for Taxonomy

- 1) **FHWA Traffic Monitoring Guide**

Provides guidance to State highway agencies about the policies, standards, procedures, reporting, and equipment utilized in a traffic monitoring program. The scope of State traffic monitoring programs encompasses volume, classification, speed, and weight data.

- 2) **SAE J3194 Taxonomy and Classification of Powered Micromobility Vehicles**

Provides a taxonomy and classification of powered micromobility vehicles. These vehicles may be privately owned or be available via shared- or rental-fleet operations. This technical report does not provide specifications or otherwise impose minimum safety design requirements for powered micromobility vehicles.

- 3) **SAE J3272 (WIP) Powered Micromobility Vehicle Identification**

Proposes to provide a means of identification of Powered Micromobility Vehicle classes and characteristics through use of an alpha-numeric identifier. This document will apply primarily to the device classes identified in SAE J3194 and proposes a schema for utilizing alpha-numeric values to represent the manufacturer, year of manufacture, model, device type, weight, width, speed, power, and production number. It also addresses location for placement of these identifiers on the device, type of label, permanence, and visibility.

4) ISO 7176-5:2008 Wheelchairs - Part 5: Determination of Dimensions, Mass and Maneuvering Space

Specifies methods for the determination of wheelchair dimensions and mass. This includes specific methods for the determination of outside dimensions when the wheelchair is occupied by a reference occupant and the required maneuvering space needed for wheelchair maneuvers commonly carried out in daily life.

5) ISO 7176-26:2007 Wheelchairs - Part 26: Vocabulary

Specifies a vocabulary consisting of terms and definitions used in the field of manual and electrically powered wheelchairs (including scooters) and associated seating systems.

6) CEN 17128:2020 Light motorized vehicles for the transportation of persons and goods and related facilities and not subject to type-approval for on-road use - Personal light electric vehicles (PLEV) - Requirements and test methods (withdrawn standard)

Applies to personal light electric vehicles totally or partially electrically powered from self-contained power sources with or without self-balancing system, with exception of vehicles intended for hire from unattended station. This document applies to personal light electric vehicles with or without self-balancing system totally or partially electrically powered from self-contained power sources having battery voltages up to 100 VDC, with or without an integrated battery charger with up to a 240 VAC input. This document specifies safety requirements, test methods, marking, and information relating to personal light electric vehicles to reduce the risk of injuries to both third parties and the user during intended use, i.e., when used as intended and under conditions of misuse that are reasonably foreseeable by the manufacturer.

2.2.1.3 Other Standards for MMVs

1) SAE J3274 (WIP) Minimum Sound Requirements for Powered Standing and Seated Scooters

Establishes performance requirements for pedestrian alert sounds for powered standing and seated scooters as defined in SAE J3194. This standard establishes a set range of sound characteristics for sound frequency and sound pressure levels for select vehicle operation scenarios. Testing procedures are prescribed for each scenario.

2) SAE J3230/1 Kinematic Performance Metrics for Powered Standing Scooters

Provides normalized kinematic performance metrics for powered standing scooters, recognizing that such metrics (e.g., top speed, acceleration, deceleration) are important classification criteria for these vehicles. Standardizing these metrics serves several purposes, including: provide practicable vehicle-level, performance-based metrics; provide standardized test methods and conditions for the above metrics; and provide meaningful metrics for industry, consumers, and public agencies to evaluate safety and performance of powered standing scooters.

3) SAE JA3163_202106 Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine

SAE Recommended Practice provides a taxonomy of terms related to local and regional on-demand and shared mobility services (including ground, aviation, and maritime) and their enabling technologies. Functional definitions for shared modes (both fleet sharing and ride services), services, business models, and mobility applications are defined in this SAE Recommended Practice. This SAE Recommended Practice also provides a taxonomy of related terms and definitions. Though public transport is part of shared mobility, it is not included in this

SAE Recommended Practice because its definition is well-established and documented. This document does not provide specifications or otherwise impose requirements on on-demand and shared mobility.

2.2.1.4 Architecture Standards

1) **ISO TR 22085-1:2019, Intelligent transport systems (ITS) — Nomadic device service platform for micromobility — Part 1: General information and use case definitions**

Provides the service framework to identify the connectivity between nomadic devices, cloud servers, and micromobility in pre-trip, en-route, and post-trip. The service framework can promote micromobility as a new type of urban and rural transport mode and increase the possibility to be included in an integrated mobility system.

2) **ISO 22085-2:2021 Intelligent transport systems (ITS) — Nomadic device service platform for micro mobility — Part 2: Functional requirements and dataset definitions**

Provides definitions of functional requirements for connectivity among nomadic devices, cloud servers and micro mobility during pre-trip, post-trip and while driving, which is defined in ISO/TR 22085-1, and datasets for providing seamless mobility service.

3) **ISO 22085-3:2022 Intelligent transport systems (ITS) — Nomadic device service platform for micro mobility — Part 3: Data structure and data exchange procedures**

Specifies the data structure and data exchange procedure related to micro mobility service applications utilizing a P-ITS-S (i.e., nomadic devices), including car sharing, parcel delivery and first-mile and last-mile connections. In addition, this document delivers related requirements for the development and operation of the service platform between nomadic devices and micro mobility with intelligent transport systems (ITS) technologies.

4) **ISO 17427-1:2018 Intelligent transport systems — Cooperative ITS — Part 1: Roles and responsibilities in the context of co-operative ITS architecture(s)**

Contains a detailed description of the (actor invariant) roles and responsibilities required to deploy and operate Cooperative-ITS (C-ITS). The organization of actors / roles described in this document are designed to be appropriate for any fully operational system that uses the C-ITS concepts and techniques in order to achieve its service provision. This document is presented in terms of an organizational or enterprise viewpoint as defined in ISO/IEC 10746-1.

5) **ISO 24102 Series — Intelligent transport systems — Communications access for land mobiles (CALM) — ITS station management a. Part 1: Local management b. Part 2: Remote management of ITS-SCUs c. Part 3: Service access points d. Part 4: Station-internal management communications e. Part 6: Path and flow management**

The set of CALM International Standards is designed to allow interoperable instantiations of ITS stations which are based on the concept of abstracting applications and services from the underlying communication layers of the ITS station.

6) **ISO/DIS 21217:2020 Intelligent transport systems — Station and communication architecture**

Describes the communications reference architecture of nodes called "ITS station units" designed for deployment in intelligent transport systems (ITS) communication networks. The ITS station reference architecture is described in an abstract manner.

2.2.2 Discussion

Classification of road users into profiles means categorizing users based on common characteristics such as size, type, and mobility mode. This is important for determining the road user's behavior which is necessary for safety in the V2X environment. The SAE J2735 standard which defines the messages broadcast in the V2X environment uses the FHWA 13 Vehicle Category Classification to classify vehicles based on size, and the standard classifies pedestrian and non-vehicular users as "pedestrian," "pedalcyclist," "public safety worker," and "animal" with further information such as propulsion type (e.g., wheelchair, scooter).

2.2.3 Architectures

Architectures are frameworks that describe the relationships and functions of its elements. For example, in standards for connected vehicle technologies, architectures typically define interactions among components such as roadside units, vehicles, personal devices, and traffic management systems. Most existing architectures need additional standards to include non-motorized road users as actors in order to get a complete picture of the road for better safety in real life. ETSI TS 103 300-2 is one standard that has done this. Non-motorized road users pose additional requirements compared to vehicles, as the differences between the road user, the road user's device and the road user's vehicle necessitate additional considerations.

2.3 Technologies for Detection and Communication

This section describes technologies for detection and communication of road users for safety.

2.3.1 Sensors/Perception

This section includes relevant sensor/perception standards/references and discussion.

2.3.1.1 Standards/References

1) ISO 18682:2016 Intelligent transport systems — External hazard detection and notification systems — Basic requirements

Specifies basic requirements for systems to execute notifications such as warning and awareness messages to provide hazard information to a driver. Requirements include principle of notifying, timing of notification, distance of notification, and information elements that should be included in messages.

2) ISO 19237:2017 Intelligent transport systems — Pedestrian detection and collision mitigation systems (PDCMS) — Performance requirements and test procedures

Specifies the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for Pedestrian Detection and Collision Mitigation Systems (PDCMS).

3) ISO 22078:2020 Intelligent transport systems — Bicyclist detection and collision mitigation systems (BDCMS) — Performance requirements and test procedures

Specifies the concept of operation, minimum functionality, system requirements, system interfaces, and test procedures for bicyclist detection and collision mitigation systems (BDCMS).

4) SAE J2945/3 Requirements for Road Weather Applications

Specifies interface requirements between vehicles and infrastructure for weather applications, including detailed systems engineering documentation (needs and requirements mapped to appropriate message exchanges). The purpose of this SAE Standard is to enable interoperability supporting these weather applications over a communications technology agnostic interface.

5) SAE J3116-202301 Active Safety Pedestrian Test Mannequin Recommendations

Standard specifications/requirements for pedestrian test mannequins (1 adult and 1 child) that are representative of real pedestrians to the sensors used in Pedestrian Detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions.

6) SAE J3157201902 Active Safety Bicycle Test Target Recommendations

Standard specifications/requirements for bicyclist test mannequins (one adult and one child) that are representative of real bicyclists to the sensors used in Bicyclist Detection systems and can be used for performance assessment of such in-vehicle systems (including warning and/or braking) in real world test scenarios/conditions.

7) Synthesis of Automated Pedestrian Data Collection Technologies⁷ (Sensor Survey)

Surveys new roadside technologies that can assist in efforts for detecting pedestrians. Traditional technologies and many new product offerings are identified. Results of surveys and interviews show that most practitioners use video-based technologies, but thermal imaging, LiDAR, and combinations of these technologies with video are gaining attention. The expense of technologies and their suitability for use in specific environments are important considerations in choosing products. Details about ongoing cost structure and data ownership are also important to analyze, including products that require a recurring subscription to a cloud-based data processing service. This project delivers a simple decision support framework that assists in identifying products and technologies most appropriate for a set of requirements.

2.3.1.2 Discussion

Detection of road users is vital to their safety. Cameras, LIDAR, and radar are a few of the sensors integral in the perception of road users by infrastructure and other road users. Technology is improving over time, often including the use of artificial intelligence.

Different sensors have different advantages and disadvantages. The Sensor Survey discusses them in detail. Using a combination of sensors allows for system redundancy. But which sensors, in what combination, in what placement, are questions that may be answered with standardization. The Sensor Survey attempts to answer these questions with the creation of a simple decision support framework. The framework uses a binary scoring scheme for compliance of sensor technologies to inputted agency criteria.

When dealing with proxy personal safety messages (PSMs) (described more in Section 2.3.2.2) generated by infrastructure or other sensors, there may be an artificial intelligence (AI) / machine learning (ML) component to the determination of the type of road user sensed and confidence in the determination. For example, cameras with edge computing capabilities to classify objects in view (such as vehicles and different types of non-motorized road users) currently exist. However, the classification scheme that the camera uses may not be standardized, and there might not currently be an existing

⁷ <https://rosap.ntl.bts.gov/view/dot/64694>

standardized classification scheme that can be used at all. For example, the camera may have difficulty classifying an e-bike into the common three-class system.

In addition, there are some issues with the Artificial Intelligence (AI)/ Machine Learning (ML) determination of non-motorized road user types, especially with certain populations such as people in wheelchairs.⁸ Road users that act in a manner unfamiliar to the AI may possibly be classified incorrectly and left unprotected in a connected intersection. A classification scheme that sensors may need to be able to follow appears to be a prerequisite for standardization of the sensing/perception area.

2.3.2 Vehicle to Everything (V2X)

This section includes relevant V2X standards, discussion, technologies, and pilots.

2.3.2.1 Standards

1) SAE J2735 V2X Communications Message Set Dictionary (J2735_202211)

Specifies a message set, and its data frames and data elements, specifically for use by applications that use vehicle-to-everything (V2X) communications systems.

2) SAE J3224 V2X Sensor-Sharing for Cooperative and Automated Driving

Describes the concept of operation, use cases, and message flows to create a Sensor Sharing Service (SSS). This service enables RSUs and V2X vehicles to share information about their localized driving environment. This work defines message structure, V2X entity requirements, and information elements to describe detected objects to facilitate sensor sharing.

3) SAE J3295 Cooperative Perception Services Concept of Operations (WIP)

This information report is a cooperative perception services concept of operations. Included is a description of cooperative perception systems and a description of the data potentially shared between its participants. The participants are the actors within the cooperative perception system, such as vehicles, bicycles, pedestrians and infrastructure. The types of data that can be shared among the actors are presented, and the types of features and applications that can be satisfied based on the types and precision of information shared are classified into categories. This report supports a wide variety of potential cooperative perception use cases ranging from connected-vehicle enabled driver-assistance applications to connected automation.

2.3.2.2 Discussion

This section describes two of the key messages in the V2X environment which support road user safety.

Basic Safety Message (BSM)

Defined in SAE J2735. Provides information on vehicles such as position, speed, heading, brake status, and size.

Personal Safety Message (PSM)

Defined in SAE J2735. Provides information on a non-motorized road user such as position, speed, acceleration, heading, path prediction, propulsion, and attachments, if any.

Proxy-PSM

V2X technology can enhance road user safety. However, a road user does not require a personal OBU (on-board unit) to benefit from a V2X environment. Through infrastructure-based sensors and a

⁸ https://downloads.regulations.gov/DOT-OST-2022-0096-0218/attachment_1.pdf

roadside unit (RSU), the V2X environment can generate a proxy PSM for a road user (i.e., the RSU generates and broadcasts a PSM for a road user detected by an infrastructure-based sensor). This concept of the proxy PSM is covered in the SAE J3224 standard.

There is a lack of a method to describe accuracies of non-motorized road user detection and confidences about classification and existence. In addition, there is currently no standard that defines how to manage the cases where a person with a mobile unit that transmits PSMs changes mode (such as from cyclist to pedestrian after parking a shared bike) or status (such as a non-motorized user to motorized user when a pedestrian boards a bus).

2.3.2.3 Technologies

This section describes a few key technologies that support road user safety.

Vehicle OBU

These are devices equipped by a vehicle that broadcast BSM information to other equipped cars and the V2X infrastructure. They may be from Original Equipment Manufacturer (OEM) or aftermarket.

OBU for Bikes

- **Spoke Safety**⁹ (with Qualcomm, Commsignia, and Audi) developed a Cellular-Vehicle To Everything (C-V2X) OBU for bicycles.
- **Autotalks ZooZ**¹⁰ is a handlebar-mounted OBU with both Dedicated Short-Range Communications (DSRC) and C-V2X radios.

Bluetooth Low Energy (Bluetooth LE)

- **Tomé**¹¹ (and Ford Motor Co.) is researching the feasibility of sending and receiving non-motorized road user safety messages to vehicles using Bluetooth LE.

Ultra-Wideband (UWB) for Pedestrians

- **Commsignia**¹² can use UWB to detect pedestrian personal devices to transmit a proxy PSM via an RSU.

Remote / Handsoff Pedestrian Signal Actuation

- **PedPal Crossing App**¹³ From the Accessible Transportation Technologies Research Initiative (ATTRI) project, CMU application for pedestrians with disabilities to aid in crossing signalized intersections. Supports DSRC and cellular. Communicates with the intersection equipment to give a pedestrian with a disability enough crossing time.
- **ITS4US Pedestrian Actuation Request apps**. Two projects provide automated, remote actuation for pedestrians during their trip plan when they approach an intersection. The Georgia Department of Transportation (GDOT) app requests extra time for people with mobility challenges (<https://georgia-map.com/>) and the Niagara Frontier Transportation Association (NFTA) requests signal priority using their All Access app (<https://bnmc.org/allaccess/>). Both use

⁹ <https://www.spokesafety.com/>

¹⁰ <https://auto-talks.com/products/zooz/>

¹¹ <https://www.tomesoftware.com/>

¹² <https://www.commsignia.com/expertise>

¹³ <https://highways.dot.gov/public-roads/winter-2021/technology-make-signalized-intersections-safer-pedestrians-disabilities>

NTCIP signal control standards from the gateway server to the signal system while each developed their own application programming interface (API) for the center-to-center actuation request.

2.3.2.4 Pilots

The following are V2X pilot projects that are completed or under way.

UMTRI Smart Intersection Project in Ann Arbor, MI¹⁴

The University of Michigan Transportation Institute (UMTRI), along with its many public and private partners, manage over 20 smart intersections throughout Ann Arbor and a fleet of CVs. Iteris is equipping intersections with cooperative perception technology with V2X applications¹⁵.

City of Peachtree Corners¹⁶

Georgia's City of Peachtree Corners, with Jacobs and Qualcomm, implemented C-V2X technology at their Curiosity Lab, showing traffic benefits and safer streets in a real-world setting.

School bus boarding and alighting¹⁷

Applied Information C-V2X RSUs mounted to flashing speed limit signs near a Fulton County school zone in Alpharetta, Georgia communicated to an Audi vehicle equipped with V2X technology to slow down. The RSU also alerted traffic that children may be entering or exiting a school bus when a Blue Bird school bus with V2X technology extended its stop arm.

Tampa Hillsborough Expressway Authority (THEA) CV Pilot¹⁸

THEA piloted CV applications such as pedestrian collision warning to demonstrate the technology's safety and mobility benefits.

Gainesville Bike and Pedestrian Safety Project¹⁹

The Florida Department of Transportation tested CV pedestrian/bicyclist safety applications at signalized intersections and mid-block crossings at the University of Florida campus using DSRC technology.

2.4 Safety Alerting and Prediction Technologies

Road user safety may rely on alerting and prediction technologies.

2.4.1 Alerting

This section provides standards, research, and a discussion on alerting research.

¹⁴ <https://sip.umtri.umich.edu/>

¹⁵ <https://www.iteris.com/news/iteris-selected-university-michigan-transportation-research-institute-smart-mobility-and>

¹⁶ https://www.curiositylabptc.com/press_release/jacobs-peachtree-corners-and-qualcomm-collaborate-to-deploy-cellular-vehicle-to-everything-technology-in-georgia-smart-city/

¹⁷ <https://media.audiusa.com/en-us/releases/477>

¹⁸ https://www.its.dot.gov/pilots/pilots_the.a.htm

¹⁹ <https://teo.fdot.gov/architecture/architectures/d2/html/projects/projarch47.html>

2.4.1.1 Standards and Research

Standards

- 1) ISO/TR 10992-2:2017 Intelligent transport systems — Use of nomadic and portable devices to support ITS service and multimedia provision in vehicles — Part 2: Definition and use cases for mobile service convergence

Specifies the introduction of multimedia and telematics nomadic devices in the public transport and automotive world to support intelligent transport systems (ITS) service provisions and multimedia use such as passenger information, automotive information, driver advisory and warning systems, and entertainment system interfaces to ITS service providers and motor vehicle communication networks.

Research

- 1) Lerner, N., Singer, J., Huey, R., Brown, T., Marshall, D., Chrysler, S., ... & Chiang, D. P. (2015, November). **Driver-vehicle interfaces for advanced crash warning systems: Research on evaluation methods and warning signals**. (Report No. DOT HS 812 208). Washington, DC: National Highway Traffic Safety Administration.
- 2) **Smartphone-Based In-Vehicle Driver Warnings for Pedestrian Midblock Crossings**²⁰ (Midblock Warning)
Develop a smartphone-based application to warn drivers of pedestrians using midblock crosswalks. Conduct test subject experiments of the application at the Turner-Fairbank Highway Research Center (TFHRC) midblock crosswalk. Upload the application to the open source portal.
- 3) **Smartphone-Based Mid-Block Pedestrian Crossing In-Vehicle Warning – Phase 2 Final Project Report**²¹
Project evaluated pedestrians' perceptions and use of an FHWA smartphone application to signal their intent to cross at a marked midblock crossing

2.4.1.2 Discussion

Many decisions need to be made regarding safety alerts: timing, method (visual, audio, haptic), combinations, frequency, priority, direction, etc. Research for this topic requires studies on cognition, human factors, user experience, and human machine interface. This is important to avoid alert fatigue and users ignoring warnings due to high rates of false alerts. It is imperative that alerting is well-researched before implementation; otherwise, drivers will become desensitized to alerts, rendering the whole alerting system useless. The following sections will look at two viewpoints: drivers versus pedestrians.

2.4.1.2.1 Driver

This section describes two key USDOT-funded studies related to driver alerting.

²⁰ <https://highways.dot.gov/research/projects/hrdo-fy17-03-smartphone-based-vehicle-driver-warnings-pedestrian-midblock-crossings>

²¹ https://www.its.dot.gov/research_archives/safety/pdf/SmartphoneMidblock_Report.pdf

The Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals²² work showed that further study is needed to test different combinations of alert systems in a variety of situations for effective responses.

The **Midblock Warning project**²³ determined that drivers who received an alert on a dashboard-mounted smartphone indicating a pedestrian at a midblock crosswalk slowed down earlier and were more likely to stop for the pedestrian.

2.4.1.2.2 Pedestrian

The following relates to pedestrian alerting.

*Phase 2*²⁴ of the **Midblock Warning project** studied pedestrians' perceptions and use of the smartphone application to signal their intent to cross at a marked midblock crossing. Results showed that "participants used the application as intended without significant changes in crossing behavior relative to a nonconnected smartphone-based alternative."

2.4.2 Road User Path Prediction

This section provides relevant standards and references as well as a discussion on road user path prediction in the context of V2X.

2.4.2.1 Standards and References

1) SAE J2735-2024 V2X Communications Message Set Dictionary

This SAE Standard specifies a message set, and its data frames and data elements, for use by applications that use vehicle-to-everything (V2X) communications systems.

2) IEEE 2846-2022 Standard for Assumptions in Safety-Related Models for Automated Driving Systems

Applies to road vehicles. It defines a minimum set of reasonable assumptions and foreseeable scenarios that shall be considered in the development of safety related models that are part of an automated driving system (ADS).

3) IEEE 2846 White Paper – Literature Review on Kinematic Properties of Road Users for Use on Safety-Related Models for Automated Driving Systems (IEEE 2846 White Paper)

Presents a review of relevant literature (e.g., standards, regulations, and scientific publications) that investigated kinematic behavior of road users. This review is intended to serve as a key contribution to the Automated Driving Systems (ADS) research and industry communities, as well as to current standardization efforts, such as IEEE Std 2846, IEEE Standard for Assumptions in Safety-Related Models for Automated Driving Systems.

2.4.2.2 Discussion

Path prediction for different road user types is essential for V2X systems.

²² <https://www.nhtsa.gov/document/driver-vehicle-interfaces-advanced-crash-warning-systems-research-evaluation-methods-and>

²³ <https://highways.dot.gov/research/projects/hrdo-fy17-03-smartphone-based-vehicle-driver-warnings-pedestrian-midblock-crossings>

²⁴ <https://rosap.ntl.bts.gov/view/dot/64953>

2.4.2.2.1 Vehicle Path Prediction of Other Vehicles

The BSM is used in V2X systems and is defined in SAE J2735. Vehicles periodically broadcast the BSM for other vehicles and the CV infrastructure, providing information such as location, speed, acceleration, heading, and path prediction.

2.4.2.2.2 Vehicle Path Prediction of Other Road User Types

In order for a vehicle computer to make a collision avoidance decision, it needs to determine other road users' set of possible paths and their probabilities. To determine this, the vehicle may either detect the profile with its own sensors or receive profile information from the road user or a proxy PSM from infrastructure.

2.4.2.2.3 Non-motorized Road User Path Prediction of Vehicles

Non-motorized road users, such as pedestrians or cyclists, typically rely on direct observation of vehicles' speed, signaling, lane positioning, and acceleration to predict vehicle paths. Enhancements provided by V2X infrastructure could improve the accuracy and reliability of these predictions.

2.4.2.2.4 Non-motorized Road User Path Prediction of Other Non-motorized Road Users

Path prediction of road users outside of vehicles depends on the profile of the road user. For example, the unpredictable path of a small child that can run in any direction or stop at any time differ greatly from a cyclist on a bike lane with a more predictable path.

The IEEE 2846 White Paper provides a review of standards, regulations, and research regarding the kinematic behavior of road users, particularly pedestrians and bicyclists.

Although there are many methods for predicting road user paths, there are still several issues to solve. For example, the concept of confidence levels for a road user's future location may depend so highly on the road user (especially if it is a small child), the model and external factors that the value becomes meaningless. Subsequently, the path prediction becomes useless.

2.5 Specialized Safety Considerations

Some specialized safety considerations include work zone workers.

2.5.1 Work Zones

The standards and technologies in this section impact work zone worker safety.

2.5.1.1 Standards

1) Work Zone Data Exchange (WZDx) Specification

Enables infrastructure owners and operators (IOOs) to generate harmonized work zone data available for third party use. The objective is to make travel on public roads safer and more efficient through ubiquitous access to data on work zone activity. Specifically, the project aims to get data on work zones into vehicles to help automated driving systems (ADS) and human drivers navigate more safely.

2) Connected Work Zones Standard Implementation (CWZ Standard) (2025)

Defines the data elements, capabilities, and interfaces a connected work zone must support to ensure interoperability for state/local infrastructure owner/operators and vehicle operators. A

connected work zone is defined as a set of technologies that generates or collects work zone information (whether automatically or manually) as well as the infrastructure that broadcasts/distributes this information to the public and to vehicles.

2.5.1.2 Technologies

This section discusses two of the technologies that can support safety in work zones.

Worker Presence Vests: Safety vests equipped with alerting modes and a GPS that transmit location to the work zone management system. Virginia Tech Transportation Institute (VTTI)²⁵ and Ver-Mac²⁶ have used this technology in pilot projects.

Smart Cones: Cones with GPS equipment transmit their locations to the work zone management system to define virtual work zones. Changes to the work zone geometry can be made simply by moving the cones. VTTI has piloted this technology.

2.5.1.3 Pilots

The following are work zone projects that are completed or under way.

I-96 Flex Route Construction Project Demo²⁷

MDOT, General Motors (GM), Mixon Hill, and Ver-Mac partnered to demonstrate the ability of CVs to receive work zone data from MDOT's work zone data platform. Through the use of WZDx, a lane closure due to road work was effectively communicated to a GM vehicle through cellular communications. Ver-Mac work zone equipment collected data such as worker presence and work zone boundaries and transmitted the information to MDOT's work zone management system, developed by Mixon Hill.

Ver-Mac's worker presence technology is currently a prototype. It involves the use of vests that indicate the presence of workers and the transmission of that information and the reduced speed limit for communication to vehicles in order to alert motorists that a work zone is active.

Virginia Tech Transportation Institute Smart Work Zone System Deployments

- Wise County²⁸ – Smart vests transmit worker GPS position and predict potential hazards from passing motorists.
- Albemarle County²⁹ – Sensor fusion technology using radar and cameras detected speeding vehicles that triggered an airhorn to warn workers, in addition to the smart vest alerting system.

2.5.1.4 Discussion

USDOT first led the creation of WZDx then launched the CWZ Standard effort to transition the specification to a formal standard. There are currently no standards for work zones that disrupt public right of ways or alert pedestrians, bicyclists and other MMVs of right of way disruptions.

²⁵ <https://www.youtube.com/watch?v=FWAtd4fbjGY>

²⁶ <https://ver-mac.com/en/news-and-events/file/defining-the-future-of-work-zone-safety-collaboration-with-the-mdot-and-gm/159>

²⁷ <https://ver-mac.com/en/news-and-events/file/defining-the-future-of-work-zone-safety-collaboration-with-the-mdot-and-gm/159>

²⁸ <https://vtx.vt.edu/articles/2022/05/vtt-smart-work-zone.html>

²⁹ <https://vtx.vt.edu/articles/2022/12/vtti-smart-work-zone-albemarle.html>

3 Discussion of Potential Stakeholders

With relevant topics detailed in the previous section, this section continues with the identification of potential stakeholders that should be involved in further standards development.

This list is non-exhaustive and should only be used to provide examples of stakeholder groups that may be included in future standardization efforts.

Example Stakeholders:

Standards Development Organizations

- International Organization for Standardization (ISO)
- European Committee for Standardization (CEN)
- SAE and other SDOs involved in V2X standards

Private Sector Companies

- Vehicle manufacturers
- Spoke Safety and its partners
- Autotalks
- Other vendors of V2X/safety technologies and services

Government

- State, local, territorial and tribal governments
- National Highway Traffic Safety Administration (NHTSA)
- Federal Highway Administration (FHWA)
- Federal Transit Administration (FTA)
- National Transportation Safety Board (NTSB)

Advocacy Groups

- PeopleForBikes
- Disability Rights Education and Defense Fund
- Alliance of People with Disabilities
- Micro-mobility for Europe (MMfE)
- Safety associations
- Other advocacy groups

Other

- Research institutions

Appendix A: Acronyms

Acronym	Description
ADS	Automated Driving Systems
ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
ATTRI	Accessible Transportation Technologies Research Initiative
CAV	Connected and Autonomous Vehicles
CD	Committee Draft
CEN	European Committee for Standardization
C-ITS	Cooperative ITS
CRSS	Crash Report Sampling System
CV	Connected Vehicle
C-V2X	Cellular Vehicle-to-Everything
CWZ	Connected Work Zones
DIS	Draft International Standard
DSRC	Dedicated Short-Range Communication
ETSI	European Telecommunications Standards Institute
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GM	General Motors
IEEE	Institute of Electrical and Electronics Engineers
IOO	Infrastructure Owner and Operator
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
MAT	Multimodal for All Travelers
MMFe	Micro-Mobility for Europe
MMV	Micromobility Vehicle
NGO	Non-Governmental Organizations
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
OBU	On-board Unit
OR	Outreach Report
PROW	Public Right of Way
PSM	Personal Safety Message
RFI	Request for Information
RSU	Roadside Unit
SAE	Society of Automation Engineers
SDO	Standards Development Organization
SIU	Standards Inventory Update

Acronym	Description
SSS	Sensor Sharing Service
THEA	Tampa Hillsborough Expressway Authority
UMTRI	University of Michigan Transportation Institute
USDOT	United States Department of Transportation
UWB	Ultra-Wideband
V2X	Vehicle-to-Everything
VTTI	Virginia Tech Transportation Institute
WIP	Work-in-Progress
WZDx	Work Zone Data Exchange