## MAT v1.1

Task 6 Multimodal and Accessible Travel (MAT) White Paper

# Multimodal and Accessible White Paper on VRU

Multimodal and Accessible Travel Standards and Vulnerable Road User Cybersecurity Support Project

July 2023

This document is produced by the MAT and Cybersecurity Subject Matter Experts (SMEs).

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# 1 Introduction

## 1.1 Scope

This white paper reviews existing research, standards, specifications and projects related to Vulnerable Road Users (VRU). The review builds upon the Multimodal and Accessible Travel Standards Assessment (MATSA) project Outreach and Standards Inventory Update outputs. Gaps in standards and specifications and additional stakeholders identified will provide an input for the Multimodal and Accessible Travel (MAT) Standards and Vulnerable Road User Cybersecurity Support Coordination Plan (Task 4).

## 1.2 Background

The MAT area suffers from a lack of coordination in standardization efforts. Because standards are being developed by multiple industry groups, efforts are often duplicated, standards may be incompatible, inconsistent, or conflict and gaps may arise.

The MATSA project, performed from 2018 - 2020, identified current standards related to MAT, determined standards gaps, and developed a roadmap for MAT standardization work. It achieved this through the creation of a survey of existing standards and standards under development and then outreach to stakeholders to collect input regarding industry priorities for standardization development. Two MATSA deliverables are of relevance to this white paper:

1. **Outreach Report[1] (OR),** a document that summarizes standards needs and gaps gathered through outreach to relevant stakeholders; safety of VRUs in the context of the Vehicle-to-Everything (V2X) environment is one of the standards areas covered. This information provides the starting point for the standard gap analysis in this white paper.

2. **Standards Inventory Update** (SIU), a document compiled by the MATSA project team listing related standards and specifications grouped by topic. The standards and specifications listed in the SIU provided the starting point for the related standards listed in this white paper.

s MAT Standards and Vulnerable Road User Cybersecurity Support Project is a continuation of the MATSA effort. The project objective is to continue the work of harmonizing the standardization efforts around VRUs and cybersecurity. The project aims to achieve this by identifying standards gaps and relevant stakeholders to include in upcoming MAT standardization work. Gathering all of the relevant stakeholders to close the gaps will ensure that standardization efforts will be harmonious and minimize incompatibility and duplication of efforts.

This document is a deliverable for the MAT Standards and VRU Cybersecurity Support Project Task 6: Develop MAT, MOD, and VRU Whitepapers. The white papers are documents to support the coordination plan deliverable for Task 4: Addressing MAT Standards and VRU Cybersecurity Support Coordination. The Task 4 deliverable details a plan to coordinate the participation of relevant stakeholders in future standardization efforts in several areas, including VRUs in a V2X environment. However, this white paper examining the topic of VRUs in a V2X environment may be read independent of the other project elements.

[1] https://rosap.ntl.bts.gov/view/dot/55242

## 1.3 Research Methodology

This white paper was created using the MATSA OR and SIU as a starting point. A summary of the OR and SIU and relevant details are provided in

MATSA Outreach R. Interviews and
web-based research were the main sources of further information gathered. A major web-based source, the USDOT Request for Information: Enhancing the Safety of Vulnerable Road Users at Intersections[2] (USDOT RFI) comments page, was valuable in collecting an overview of the current state of VRU safety technology and strongly influences the topics discussed in this document. Interviews were used to fill in additional details that the web-based research was unable to provide. More information about the USDOT RFI and interviews is detailed below.

### 1.3.1 USDOT RFI: Enhancing the Safety of Vulnerable Road Users at Intersections

In September 2022, the USDOT requested information on "the possibility of adapting existing and emerging automation technologies to accelerate the development of real-time roadway intersection safety and warning systems for both drivers and VRUs in a cost-effective manner that will facilitate deployment at scale." Responses from government agencies, private companies, standards development organizations (SDOs), research bodies, advocacy groups, disability organizations, and private individuals provided useful information and directions for further research. Comments illuminated which standards, technologies, efforts, and ideas industry stakeholders are aware of, referencing, and developing. For example, government agencies tended to mention their participation in pilot projects related to VRU safety and technology, private companies took the opportunity to advertise their technologies, SDOs provided related standards both developed and in development, and disability organizations requested careful attention towards the use of AI for disabled VRUs. Responses reflect the most up-to-date aspects of the VRU safety technology realm; for this reason, this white paper heavily relies on the responses from the USDOT RFI to outline relevant topics to discuss.

Included in the supplementary information text, the section on "System Components and Hardware and Software Technologies-A Conceptual Design" lists the following potential system design elements, some of which this white paper discusses throughout the document:

- Sensing and perception
- Sensor fusion, image, and data analysis
- Path planning and prediction
- Data handling and storage
- Communications and networking
- Warning systems
- Other intersection safety system considerations

In addition to these elements, other topics are explored in this white paper, such as considerations for VRUs with disabilities, pilot projects related to VRUs, and work zone safety.

It is important to note that although the contents of this white paper are heavily influenced by the comments from the USDOT RFI, this document is not a summary report. The main purpose of this white paper is to provide an overview of the state of VRU safety technology (Section 3) in order to determine gaps in standards (Section 4) and ultimately identify working groups that will work on the coordination of standards development. The discussion of gaps in this white paper frames questions that the working group may want to address and organize around their work scope.

[2] https://www.regulations.gov/document/DOT-OST-2022-0096-0001

### 1.3.2 Interviews

In addition to the MATSA deliverables and USDOT RFI comments, the following individuals contributed information for this white paper:

- Chris Cherry, Co-Chair of the SAE Powered Micromobility Vehicle Committee (TC)
- Serge Beaudry, Vice President of Research and Development at Ver-Mac

Cherry provided information about micromobility standard works in progress under the TC. Beaudry provided information about safety technologies being developed for work zone workers at Ver-Mac. These interviewees provided additional context to their respective fields.

## 1.4 Organization of This Document

This document is organized into 4 sections:

1. **Introduction.** Provides the scope, background, and methodology of this white paper.
2. **MATSA Outreach Report and Standards Inventory Update.** Provides a summary of the relevant MATSA deliverables and key takeaways relevant to the gap analysis.
3. **Summary of Topics.** Provides a summary of these topics related to VRU safety: ideas, taxonomy, policy issues, incident data, technologies, research, and pilot projects.
4. **Discussion of Gaps and Stakeholders.** Using information from Sections 2 and 3, provides an analysis of standards gaps and stakeholders that may be included in working groups to fill the gaps as well as the methodology of gap identification.

# 2 MATSA Outreach Report and Standards Inventory Update

This white paper anchors its discussion of MAT standards gaps around the MATSA OR and SIU. This section provides a summary of these MATSA deliverables and details key takeaways relevant to this document.

## 2.1 Summaries

This section describes the contents of the OR and SIU.

### 2.1.1 MATSA Outreach Report

The OR summarizes input from an extensive selection of "stakeholders such as advocacy groups, associations, government and vendors, and standard organizations to provide insight, identify gaps, and provide feedback on priorities for standard development activities" for the MAT Standards Roadmap. One of the four areas of study is safety, related to VRUs in a V2X environment. The OR identifies standards end-user needs, related standards and standard development activities, gaps in standards and standard development, industry priorities, and recommendations for filling gaps.

The subsequent sections of this chapter summarize or reproduce the OR takeaways relevant to this white paper for completeness and ease of reading.

### 2.1.2 MATSA Standards Inventory Update

The SIU provides a summary of standards related to MAT both existing and in development, updated in this white paper with new information identified during the project outreach. The MATSA SIU V2 was created in October 2020, but has not been publicly released.

For this white paper, standards related to VRU safety were extracted then examined for updates since the writing of the SIU. The standards are spread throughout this white paper and discussed in more detail in their relevant sections.

## 2.2 Standards End-User Needs

The OR identified the following needs for standards for end VRU-users (text reproduced with minor editorial changes):

- The education and licensure of users, deterrence and prevention of unwanted behaviors (e.g., micromobility devices on high-speed highways, operating under the influence), and the current and future usages of infrastructure and its safety standards in light of competing interests.
- Cross-discipline development of standards. Safety will be achieved from coordination across committees that have expertise in all aspects of vehicle design and deployment.
- Standards for passenger vehicle accessibility. High priority as these are necessary to realize the full benefits of AVs.
- V2V and V2I for non-line-of-sight object detection.
- Incorporation of Vision Zero and the 5 Es (engineering, education, enforcement, engagement, and evaluation) and complete streets as safety should not only be about vehicle detection.
- Many immediate safety data needs, especially with the quality, timeliness, and format of crash

data. On the automotive side, acceleration of the implementation of safety features to protect both occupants and VRUs.

- Ongoing and structured information exchange for each of the areas where safety standards are being developed to ensure repetition is not occurring.
- Complete and safe trip scenarios that include vulnerable populations (e.g., people in wheelchairs, people with visual disabilities, adults with children) and people crossing an intersection at different rates of speed.

## 2.3 Gap Assessment

The MATSA OR heavily referenced the **International Organization for Standardization** (**ISO) Working Draft 24317 Intelligent Transportation Systems— Mobility Integration — C-ITS for light mode conveyances and accessibility travel standards gap assessment** (ISO Gap Assessment). Since the MATSA effort, work on the technical report has advanced. At the time of the writing of this white paper, the technical report has a status of 30.99 Committee Draft (CD) approved for registration as Draft International Standard (DIS)[3]; it reached this step of the process on June 1, 2022. It is currently in editing (with only minor changes since the version used for this paper) and is expected to be published later this year. Any further reference to this document in this white paper uses the draft version 20210415 for further cross referencing.

### 2.3.1 Outreach Report Experts Gaps

Other than the gaps identified in the ISO Gap Assessment, the MATSA OR identified the following gaps, produced with experts' inputs (text reproduced):

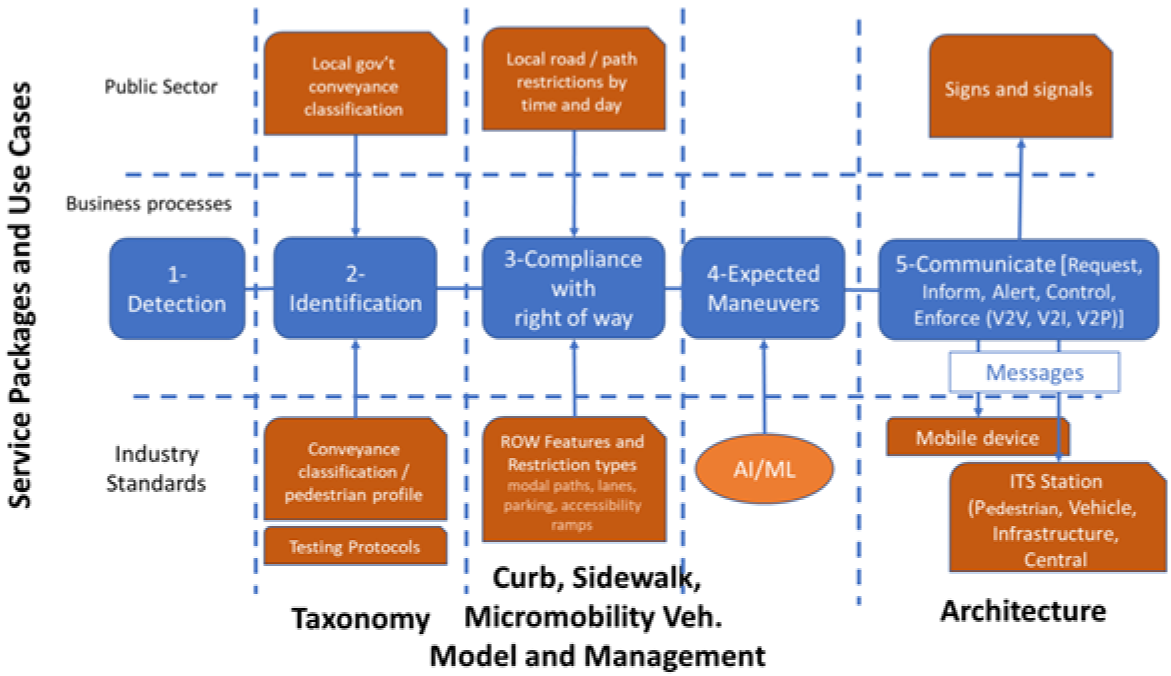
- Standards for passenger vehicle accessibility, including those related to ingress/egress, wheelchair securement, and human-machine interfaces, are a high priority as these are necessary to realize the full benefits of automated vehicles.
- For automated vehicles, detection and alerts are the two highest since these are the key inputs to realizing the technology.
- A holistic approach to standards development where expertise is pulled from various sectors, geographies, and SDOs. For example, “safety” should be more encompassing than just vehicle safety to include other aspects of road safety including infrastructure, enforcement, etc.

### 2.3.2 ISO Gap Assessment Gaps

This section reproduces parts of the OR that reference the ISO Gap Assessment, with minor edits for readability.

The ISO Gap Assessment, currently under development by the ISO TC 204 WG 19, identifies general safety processes associated with VRUs communicating with vehicles, infrastructure and other VRUs, and vice versa. In Figure 1, public sector regulations and services (such as road and curb restrictions, signs and signals) are shown in brown boxes on the top; types of standards and specifications are listed in brown boxes/ovals on the bottom. The blue boxes describe the core processes for either the VRU personal (P, where P indicates pedestrian), infrastructure (I), or vehicle (V) point of view. This model identifies where standards are needed to implement this safety process.

[3] https://www.iso.org/standard/78410.html




**Key**

| | |
|---|---|
| AI | Artificial Intelligence |
| ML | Machine Learning |
| ROW | Right of way |

**Figure 1. General Process related to Detection and Communications of VRUs.** *Source: ISO WD 24317*
Where V2V = vehicle to vehicle; V2I = vehicle to infrastructure; V2P = vehicle to pedestrian.

For the holistic review of VRU Safety, the ISO Gap Assessment identified five major gaps in standards with respect to V2X and VRU based on a review of national and international standards. Figure 1 shows a generic process. A key research result from the assessment identified that the differences among VRUs will impact the safety of the VRU. This includes who they are (person – adult, child, older adult, person with disability), what type of conveyance they use (e.g., wheelchair, tram), or micromobility vehicle (MMV) they use, and the connectivity of a mobile device either on their person or docked with their conveyance/MMV. Detection of the VRU profile is a critical factor in determining the avoidance behavior needed to ensure their safety.

The list of standard gaps identified by the assessment includes the following:

**Gap 1: Inconsistent or missing VRU type taxonomies**

- Missing taxonomies for VRU and VRU vehicle types (including devices or vehicles used for people with disabilities)
- Need clear and consistent type definitions for VRU types

**Gap 2: VRU concept model (role-based architecture) that includes roles and responsibilities**

- Ambiguous relationship between VRU, VRU Device (personal ITS station or connected device) VRU conveyance (e.g., wheelchair) and VRU vehicle (MMV)

- Building blocks to describe different configurations and VRU profiles
- Role of technologies – wearables (relationship with mobile devices/personal ITS station)
- Transition between road user and vulnerable road user roles and types (e.g., traveler alighting from a bus or car)

**Gap 3: Missing Use Cases for VRU scenarios**

- Extend and Add Use Cases for VRUs
  - Extend current use cases to differentiate between VRU types and actors
  - Extend Use Cases for detecting and notifying different VRU profiles
  - Extend Use Cases for additional clustering scenarios
- Develop VRU viewpoint use cases
  - Use Cases targeted for VRU with Public Right of Way (PROW) compliance
  - Use Cases for safe journey planning and travel
  - Use Cases where VRUs provide trajectory prediction information (by VRU profile)

**Gap 4: PROW data models and condition measures for VRUs**

- Missing micromobility vehicle and pedestrian PROW data models (e.g., bicycle lanes, cycle tracks, walkways)
- Missing PROW attributes on obstacles and performance metrics on condition (i.e., for travel by wheelchairs, e-scooter, etc.)
- Missing journey planning criteria for safe, cooperative intersections

**Gap 5: Extend and develop messages and performance measures to the support of additional Use Cases**

- Extend and develop messages, data elements, and additional performance measures to meet requirements emerging from the use cases and PROW models

## 2.4 Industry Priorities

The outreach project distributed a questionnaire to stakeholders that identified the following standard development priorities, starting with highest priority (text reproduced, text bolded for this white paper):

- **Connected Vehicle Standards** to advance safety for all users and in particular, vulnerable road users (e.g., vehicle to vehicle, vehicle to pedestrian, vehicle to bicyclist, etc.)
- **Automated Vehicle Standards** to advance safety for all users and in particular vulnerable, road users (e.g., accessibility to the automated controls for persons with disabilities, safety for external persons with disabilities)
- **Shared Use and Micromobility Standards** to advance safety for all users and in particular, vulnerable road/bike lane/sidewalk users (e.g., accessibility issues for persons with disabilities, minimum operator safety requirements for scooter share, bike share, etc.)
- Detection, **alerts** and haptic sensory information **to VRUs** of near collision and avoidance
- **Detection** by vehicles and infrastructure of different types of **profiles** for VRU (e.g., for CAVs)

Questionnaire respondents identified SDOs and Government as the key stakeholders that should lead the standards efforts and trade, advocacy groups, private sector, and research organizations as other participants in the standards development effort. Legal and health professionals were other stakeholders identified to consider.

## 2.5 Other Relevant Information

This section is a catch-all for other information in the OR relevant to this white paper. Subsection text reproduced.

### 2.5.1 Definition of VRU in the V2X domain

A type of traveler who is more vulnerable than people who are in a traditional surface vehicle such as a truck, train, bus, or car. The “vulnerability” occurs as persons transition between modes (e.g., boarding a bus, exiting a ride-hailing service), or take more active transportation modes such as walking, biking, micromobility vehicles, and using mobility and assistive aids such as wheelchairs.

### 2.5.2 Recommendations for Filling Gaps

Experts highlighted the importance of collaboration and coordination within and across disciplines as well as across SDOs and geographies. To realize the safety benefits of advanced mobility technologies for all travelers, stakeholders need to work collaboratively across industries, including private sector developers, public agencies, non-governmental organizations (NGOs), and academia. Furthermore, there is a pressing need for coordination across various areas of expertise and SDOs as safety standards must evolve together. There is a need for ongoing and structured information exchange for each of the areas where safety standards are being developed to ensure repetition is not occurring.

# 3 VRU Safety Topics

This section discusses topics related to VRU safety: USDOT RFI, taxonomy, policy issues, incident data reporting, technologies, research, and pilot projects. Relevant standards listed include a short summary description provided by the owner SDO. When applicable, a subsection will state a connection to the MATSA documents to prepare for the gap analysis in Section 4.

## 3.1 USDOT RFI Discussion

Some of the key concepts from the USDOT RFI are summarized in this section, along with general standards relating to VRU safety.

### 3.1.1 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.[4]"

Many USDOT RFI submissions expressed the opinion that the USDOT should be prioritizing low tech Complete Streets[5] interventions such as grade separation and curb extensions before, in addition to, and instead of attempting to implement automation technologies for VRU safety. Other related topics mentioned: the Safe System Approach[6], the National Roadway Safety Strategy[7], Vision Zero[8], and grade separation.

### 3.1.2 Burden of Collision Avoidance

The USDOT RFI states that "the use of smart electronic devices by VRUs should not be a requirement for the efficacy of an intersection safety system." The burden of collision avoidance falls on the vehicle. Therefore, in-vehicle collision avoidance technologies should be the primary method of ensuring VRU safety in this system; this has the additional benefit of covering all roadways, not just intersections[9].
In the area of V2X safety, VRUs without a connected device brings about the concept of proxy personal safety messages (PSMs). More information on the PSM is available in Section 3.5.4.

### 3.1.3 Vulnerable Populations – People with Disabilities

USDOT RFI submissions brought up the following considerations for people with disabilities in the V2X environment: accessibility, including the need for haptic alerts and images for

[4] https://www.transportation.gov/mission/health/complete-streets
[5] https://highways.dot.gov/complete-streets
[6] https://www.transportation.gov/NRSS/SafeSystem
[7] https://www.transportation.gov/NRSS
[8] https://highways.dot.gov/safety/zero-deaths
[9] https://downloads.regulations.gov/DOT-OST-2022-0096-0035/attachment_1.pdf

intellectual/developmental disabilities; the importance of community engagement when making safety decisions; issues with lack of disability representation within datasets; and algorithmic bias.

USDOT leads the Accessible Transportation Technologies Research Initiative (ATTRI), a project that leads "efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities."[10]

### 3.1.4 Accessibility Standards

The following accessibility standards are mentioned in the MATSA SIU and summarized here.

#### 3.1.4.1 ADA Standards for Transportation Facilities

**DOT ADA standards (2006)**

Apply to facilities used by state and local governments to provide designated public transportation services, including bus stops and stations, and rail stations. They include unique provisions concerning:

- Location of Accessible Routes (206.3)
- Detectable Warnings on Curb Ramps (406.8)
- Bus Boarding and Alighting Areas (810.2.2)
- Rail Station Platforms (810.5.3)

#### 3.1.4.2 Accessible Traveler Information

**1) ISO/IEC TS 20071-21:2015 Information technology — User interface component accessibility — Part 21: Guidance on audio descriptions**

Provides recommendations for describing audiovisual content in an auditory modality for use in recorded video presentations, broadcast television, cinema, live or recorded drama, museum, and art gallery exhibits, heritage tours, news, and comedies, regardless of the language and technology being used to transmit and present the recorded or live audiovisual content.

**2) ISO/IEC 20071-23:2018 Information technology — User interface component accessibility — Part 23: Visual presentation of audio information (including captions and subtitles)**

Provides guidance for producers, exhibitors, and distributors on the visual presentation of alternatives to audio information in audiovisual content, such as captions/subtitles.

**3) ISO/IEC TS 20071-25:2017 Information technology — User interface component accessibility — Part 25: Guidance on the audio presentation of text in videos, including captions, subtitles and other on-screen text**

Provides recommendations on the audio presentation of captions/subtitles and other on-screen text for use in all type of videos regardless of the language and technology being used to transmit and present the recorded or live video.

#### 3.1.4.3 Telecommunications Accessibility

**1) F.921 : Audio-based indoor and outdoor network navigation system for persons with vision impairment (08/18)**

Specifies how audio-based network navigation systems can be designed to ensure that they are inclusive and meet the needs of persons with visual impairments.
*Minor revisions since the MATSA SIU version.*

[10] https://www.its.dot.gov/research_archives/attri/index.htm

### 3.1.5 USDOT Direction

Many USDOT RFI comments pointed to USDOT to lead the safety efforts. One recommended that USDOT should rely on pilots, best practices, and information sharing from these successful deployments to guide further deployments[11].

## 3.2 Taxonomy

This section provides summaries of the information provided in the ISO Gap Assessment and includes additional relevant standards that have been published and new standards development efforts since the MATSA project.

### 3.2.1 Relevant Standards

This section lists standards for the following categories: general VRU standards, standards for VRU taxonomy, other standards for MMVs, and architecture standards. Standards not previously included in the ISO Gap Assessment are indicated with "New:" before the name.

#### 3.2.1.1 General

1) **ETSI TR 103 300-1 V2.3.1, Vulnerable Road Users (VRU) awareness; Part 1: Use Cases definition; Release 2. (2022-11)**

Describes the VRU system and the use cases related to Vulnerable Road Users such as pedestrians, bicyclists and road workers.
*Minor updates since ISO Gap Assessment. Added VRU Profile 4 to include animals. Added Use Case E3 protection via a central system.*

2) **ETSI TS 103 300-2 V2.2.1, Vulnerable Road Users (VRU) awareness; Part 2: Functional Architecture and Requirements definition; Release 2. (2021-04)**

Specifies the VRU related requirements; as well as the functional architecture of the VRU system. In addition, it analyses the impact on existing standards.
*Minor updates since ISO Gap Assessment.*

3) **ETSI TS 103 300-3 V2.1.2, Vulnerable Road Users (VRU) awareness; Part 3: Specification of VRU awareness basic service. Release 2. (2021-04)**

Specifies the communication protocols, message format, semantics, and syntax as well as key interfaces and protocol operation for the VRU awareness service.
*Minor updates since ISO Gap Assessment. An update is in preparation.*

4) **SAE J2945/9 Vulnerable Road User Safety Message Minimum Performance Requirements**

Provides recommendations of safety message minimum performance requirements between a VRU and a vehicle. It addresses the transmission of PSM from road user devices carried by pedestrians, bicycle riders, and public safety personnel, to provide driver and vehicle system awareness and potentially offer safety alerts to VRUs. An update with more use cases and data contents to accommodate more VRU types and safety needs is under development.

**5) 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**

[11] https://downloads.regulations.gov/DOT-OST-2022-0096-0218/attachment_1.pdf

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.

**6) New: 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.

#### 3.2.1.2 Standards for Taxonomy

1) **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.

2) **New: 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.

**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.

1) **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.

2) **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.

#### 3.2.1.3 Other Standards for MMVs

1) **New: 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) **New: 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) **New: 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.

#### 3.2.1.4 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) **New: 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) **New: 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.

### 3.2.2 VRU Type Taxonomies

The ISO Gap Assessment identified gaps in VRU type taxonomies. Classification of VRUs into profiles is important for determining the VRU's behavior which is necessary for safety in the V2X environment. Existing standards define what types of road users fall under the VRU definition but do not classify the road users into profiles beyond basic categories such as "pedestrian" and "bicyclist." ETSI TS 103 300-2 includes the following four VRU profiles: pedestrian, light vehicle, motorcyclist and animals that may create a risk to road traffic. The ISO Gap Assessment determined that these profiles are too broad for the purpose of classifying a VRU for determining its possible behavior. The ISO Gap Assessment gave the example of a runner and a person using a walker as pedestrians that cross an intersection at different speeds.

Most VRU types have an existing standard taxonomy. But the ISO Gap Assessment also recognized that "[n]o one taxonomy covers all the categories needed to describe the people and devices representing VRUs, and certainly not the variety of footprints, expected manoeuvres and combinations." The ISO Gap Assessment mentions that the footprint "becomes more important for passive detection systems when the vehicle or infrastructure needs to detect and identify the VRU, compliance and expected manoeuver."

The ISO Gap Assessment summarized the state of taxonomy for different VRU classes (reproduced with minor edits):

- **People, animals (VRU)**
    - Pedestrians (stationary, walking, running, older adults, children, adults with children,

persons with disabilities, person pushing carts/carriages, pets/animals, persons with service animals, wild animals, service workers including road, safety, enforcement, and horse/buggy)
    - No standard describes non-powered VRUs, particularly differences in speed, dimensions, abilities
- **People using human-powered conveyances (VRV)**
    - SAE J3194:2019 Taxonomy and Classification of Powered Micromobility Vehicles
        - Human powered vehicles such as bicycles, tricycles, skateboards
        - This taxonomy does not include MMV with trailer combinations
    - TCRP Report 171 for Mobility Devices for People with Disabilities
        - This is a research report, not a specification or standard
- **People using powered MMV designed to be used on paved roads and paths (VRV)**
    - Powered bikes, powered boards, powered skates, seated/standing scooter (fully or partially powered)
    - "A category of powered vehicles that have a curb weight of less than or equal to 500 pounds (227 kg) and a top speed of 30 mph (48 km/h) or less."
- **People using powered wheelchair and mobility scooters (VRV)**
    - TCRP Report 171 for Mobility Devices for People with Disabilities
- **People using "low-speed vehicles"**[12]
    - Defined in regional ROW regulations such as U.S. Code of Federal Regulations Title 49 CFR § 571.3 and EU regulation 168/2013
- **People using motorcycles, mopeds and motor-driven cycles**
    - Vehicles exceed a curb weight of 500 pounds (227 kg) and/or a top speed of 30 mph (48 km/h)
    - Similar to "low speed vehicles," defined in regional regulations and codes

This summary is still accurate. Since the ISO Gap Assessment, not much additional work has been done in the area of VRU taxonomy. However, development of SAE J3272 has started. Currently still a work in progress, it intends to provide a means of identification of powered MMV classes and characteristics through use of an alpha-numeric identifier to represent manufacturer, year of manufacture, model, device type, weight, width, speed, power, and production number and applies primarily to the device classes identified in SAE J3194.

### 3.2.3 Architectures

Architectures are frameworks that describe the relationships and functions of its elements. The ISO Gap Assessment discussed the role of VRUs in architectures. The key point is that existing architectures need additional standards to include VRUs as actors. ETSI TS 103 300-2 is one standard that has done this. VRUs pose additional requirements compared to vehicles, as the differences between the VRU, the VRU's device and the VRU's vehicle necessitate additional considerations.

Since the ISO Gap Assessment, the following has occurred: ISO 22085 Parts 2 and 3 were published and the US National ITS Architecture proposes to provide additional support for multimodal mobility, including VRUs, in a future 2023 update of ARC-IT.

[12] Low-speed vehicles may include small utility work trucks, security vehicles, 6-person shuttles, farm equipment, and golf carts (when regulated).

### 3.2.4 Use Cases

This section provides a list of updates relevant to VRU use cases since the ISO Gap Assessment.

1. **SAE J2945/9** is currently being updated to include more use cases and data contents to accommodate more VRU types and safety needs. The current version (J2945/9_201703) only describes walking pedestrians. Changes include the following:
   - addition of cyclists to use cases
   - addition of use cases for generalized VRUs (including VRU-VRU interactions and vehicle moving from private ground to public ground crossing through VRU path)
   - addition of the ASN.1 definition of the PSM
   - addition of functional and performance requirements corresponding to some PSM data frames and data elements
2. **ETSI TR 103 300-1** made several changes from V2.1.1 (2019-09) to V2.2.1 (2021-04) to V2.3.1 (2022-1).
   - Added the following info to Class E description: The third party central system equipped with Central ITS-S can also assess the collision risk, alert and / or trigger a collision avoidance action by VRU/vehicles based on received information from other VRU/vehicles. Edge computing is part of this category.
   - Added UCE3 VRU protection via a central system
   - Added a fourth profile to include animals that may pose a danger to other road users
3. **ISO 13111-2:2022** has been published. A description is provided above in section 3.2.1.1.

## 3.3 Policy Issues - PROW

This section addresses another aspect of VRU safety- policy issues relating to Public Right of Way (PROW). There is a need for unified policies and enforcement regarding MMVs.

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.[13] 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. PeopleForBikes explicitly stated their opposition to altering the classification or including other MMVs in the system.[14]

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 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.

The OR identified the need for considerations concerning the education of users.

[13] https://peopleforbikes.cdn.prismic.io/peopleforbikes/d1ebb612-69a8-4791-93a2-c8e4fcaf17aa_ebikeFAQ_January+2023.pdf

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

## 3.4 Incident Data Reporting

This section covers a key manual defining incident data reporting standards and discussion of how Incident Data Reporting relates to VRU safety.

### 3.4.1 Key Guidance

**Fatality Analysis Reporting System (FARS) / Crash Report Sampling System (CRSS) Coding and Validation Manual**

Provides guidance for coding data elements for the following incident reporting systems:

- **CRSS -** a sample of police-reported crashes involving all types of motor vehicles, pedestrians, and cyclists, ranging from property-damage-only crashes to those that result in fatalities. CRSS is used to estimate the overall crash picture, identify highway safety problem areas, measure trends, drive consumer information initiatives, and form the basis for cost and benefit analyses of highway safety initiatives and regulations.
- **FARS -** a nationwide census providing NHTSA, Congress, and the American public yearly data regarding fatal injuries suffered in motor vehicle traffic crashes.

### 3.4.2 Discussion

One of the major decision-making inputs for determining which intersections or road locations to prioritize safety improvement work is incident data. The Vulnerable Road User Safety Assessment requires each state to use a data-driven process to identify high-risk areas for VRUs.

The two major federal incident reporting systems are the CRSS and FARS. The 2020 FARS/CRSS Coding and Validation Manual updated the Person Type element on the Not a Motor Vehicle Occupant level to expand on the specific types of non-motorists on motorized or non-motorized personal conveyances. However, the Person Type does not include further detail. This lack of detail makes comparison of incidents throughout the country difficult, as different states and municipalities will have different data and levels of detail.

In the EU, the Micro-Mobility for Europe (MMfE) association of shared micromobility providers released a fact sheet[15] of incident data involving shared e-scooters. It provided statistics on risk of injuries requiring medical treatment (5.1 injuries per million kilometers), fatality risks (0.015 fatal injuries per million kilometers), and incident trends over time for shared e-scooters across several European countries and six micromobility providers in 2021. It also expressed interest in a standardized incident reporting framework; reporting issues mentioned included different definitions of injury severity levels, taxonomies, methods of collecting and reporting e-scooter incident data and lack of separation of private and shared e-scooter incident data. Other recommendations include investment in safe infrastructure such as protected bike lanes, city acknowledgement of e-scooter users as VRUs, and encouragement of authorities to enforce road safety rules.

The OR identified the need for quality, timeliness, and format of crash data.

## 3.5 Technologies

This section describes areas of technology mentioned in the USDOT RFI comments. Subsections present a list of related standards, discussion, and examples of each technology where relevant.

[15] https://micromobilityforeurope.eu/industry-alliance-publishes-first-of-its-kind-incident-data-involving-shared-e-scooters/

### 3.5.1 Sensors/Perception

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

#### 3.5.1.1 Standards/References

ISO Gap Assessment

**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 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.
*This standard has been reaffirmed.*

**5) 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.

Other

**1) 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.

**2) Synthesis of Automated Pedestrian Data Collection Technologies**[16] **(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

[16] https://rosap.ntl.bts.gov/view/dot/64694

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.

#### 3.5.1.2 Discussion

Detection of VRUs is vital to their safety. Cameras, LIDAR, and radar are a few of the sensors integral in the perception of VRUs by infrastructure and 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 PSMs (described more in Section 3.5.2.2) generated by infrastructure or other sensors, there may be an artificial intelligence (AI) / machine learning (ML) component to the determination of the type of VRU 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 VRUs) currently exist. However, the classification scheme that the camera uses may not be standardized, and there might not currently be an existing 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, some USDOT RFI comments mentioned current issues with the AI/ML determination of VRU types, especially with certain vulnerable populations such as people in wheelchairs.[17] VRUs 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.
The OR identified automated vehicle detection as a standard **gap**.

### 3.5.2 V2X

The OR identified the **need** for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) for non-line-of-sight object detection and the standards **gaps** of extended messages, data element and additional performance measures to support additional use cases. This section includes relevant standards, discussion, and technologies.

#### 3.5.2.1 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.

[17] https://downloads.regulations.gov/DOT-OST-2022-0096-0218/attachment_1.pdf

**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.

### 3.5.2.2 Discussion

This section describes two of the key messages in the V2X environment which support VRU safety are described below.

**PSM**

Defined in SAE J2735. Provides information on the VRU such as position, speed, acceleration, heading, path prediction, propulsion, and attachments, if any.

**Proxy-PSM**

V2X technology can enhance VRU safety. However, a VRU does not require a personal OBU (on-board unit) to benefit from a V2X environment. Through infrastructure-based sensors and a roadside unit (RSU), the V2X environment can generate a proxy PSM for the VRU (i.e., the RSU generates and broadcasts a PSM for a VRU detected by an infrastructure-based sensor).  This concept of the proxy PSM is covered in the SAE J3224 standard.

A USDOT RFI submission[18] commented on the lack of a method to describe accuracies of VRU object 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 VRU type (such as from cyclist to pedestrian after parking a shared bike) or status (such as a VRU to non-VRU when a pedestrian boards a bus).

### 3.5.2.3 Technologies

This section describes a few key technologies that support VRU safety.

<u>**OBU for Bikes**</u>

- **Spoke Safety**[19] (with Qualcomm, Commsignia, and Audi) developed a Cellular-Vehicle To Everything (C-V2X) OBU for bicycles.
- **Autotalks ZooZ**[20] is a handlebar-mounted OBU with both Dedicated Short-Range Communications (DSRC) and C-V2X radios.

<u>**Bluetooth Low Energy (Bluetooth LE)**</u>

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[18] https://downloads.regulations.gov/DOT-OST-2022-0096-0163/attachment_1.pdf

[19] https://www.spokesafety.com/

[20] https://auto-talks.com/products/zooz/

**Tome**[21] (and Ford Motor Co.) is researching the feasibility of sending and receiving VRU safety messages to vehicles using Bluetooth LE.

**Ultra-Wideband (UWB) for Pedestrians**
**Commsignia**[22] can use UWB to detect pedestrian personal devices to transmit a proxy PSM via an RSU.

**PedPal Crossing App**[23]
**ATTRI** 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.

### 3.5.3 Work Zones

Workers in a work zone may be VRUs. The standards and technologies in this section impact worker safety.

#### 3.5.3.1 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) (WIP)**

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.

#### 3.5.3.2 Discussion

USDOT first led the creation of WZDx then launched the CWZ Standard effort to transition the specification to a formal standard. The CWZ Standard is currently a work in progress.

#### 3.5.3.3 Technologies

This section discusses two of the technologies that can support VRU 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)[24] and Ver-Mac[25] have used this technology in pilot projects.

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[21] https://www.tomesoftware.com/
[22] https://www.commsignia.com/expertise/vru-protection/
[23] https://highways.dot.gov/public-roads/winter-2021/technology-make-signalized-intersections-safer-pedestrians-disabilities
[24] https://www.youtube.com/watch?v=FWAtd4fbjGY
[25] https://ver-mac.com/en/news-and-events/file/defining-the-future-of-work-zone-safety-collaboration-with-the-mdot-and-gm/159

**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.

## 3.6 Research

This section discusses research related to VRU safety in the V2X environment.

### 3.6.1 VRU Path Prediction

This section provides relevant standards and references as well as a discussion on VRU path prediction.

#### 3.6.1.1 Standards and References

1) **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).

2) **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.

#### 3.6.1.2 Discussion

VRU path prediction is required for V2X systems.

The OR identified that detection of different types of profiles for VRU is a standardization priority.

##### 3.6.1.2.1 Vehicle-Side VRU Path Prediction

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

##### 3.6.1.2.2 VRU-Side VRU Path Prediction

Path prediction of VRUs depends on the profile of the VRU. The ISO Gap Assessment contrasts the unpredictable path of a small child that can run in any direction or stop at any time to a cyclist on a bike lane with a more predictable path.

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

One approach to studying VRU path prediction is through the use of sensors to gather real live data. Bosch crowdsources their path data through the use of sensors on their bicycles.[26]

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

### 3.6.2 Alerting

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

#### 3.6.2.1 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**

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.

**Smartphone-Based In-Vehicle Driver Warnings for Pedestrian Midblock Crossings**[27] (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.

**Smartphone-Based Mid-Block Pedestrian Crossing In-Vehicle Warning – Phase 2 Final Project Report**[28]
Project evaluated pedestrians' perceptions and use of an FHWA smartphone application to signal their intent to cross at a marked midblock crossing

#### 3.6.2.2 Discussion

The OR identified standard **gaps** for (1) passenger vehicle accessibility, specifically human-machine interfaces and (2) automated vehicle alerts. The OR also identified the **priority** of standardizing alerts and haptic sensory information to VRUs of near collision and avoidance.

Many decisions need to be made regarding safety alerts: timing, method (visual, audio, haptic),

[26] https://downloads.regulations.gov/DOT-OST-2022-0096-0211/attachment_1.pdf
[27] https://highways.dot.gov/research/projects/hrdo-fy17-03-smartphone-based-vehicle-driver-warnings-pedestrian-midblock-crossings
[28] https://www.its.dot.gov/research_archives/safety/pdf/SmartphoneMidblock_Report.pdf

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: the driver and VRU.

###### 3.6.2.2.1 Driver

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

**The Driver-Vehicle Interfaces for Advanced Crash Warning Systems: Research on Evaluation Methods and Warning Signals**[29] 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**[30] 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.

###### 3.6.2.2.2 VRU

The following two efforts relate to VRU alerting.

*Phase 2*[31] 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."

Autotalks mentioned in its USDOT RFI comment that maintaining the sight of the driver or VRU on the risk when being alerted is critical for safety. Vehicles achieve this by displaying alerts on the dashboard. Autotalks changed its bicycle safety device to a simple LED warning instead of a screen showing an elaborate warning so that cyclists do not need to look down on the handlebar while at risk[32].

## 3.7 Implementations/Pilots

Cities, universities, government agencies, and private companies have been partnering to deploy pilot projects related to VRU safety technology. Examples of projects and their descriptions are detailed in this section.

### 3.7.1 V2X

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

**UMTRI Smart Intersection Project in Ann Arbor, MI**[33]

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[29] https://www.nhtsa.gov/document/driver-vehicle-interfaces-advanced-crash-warning-systems-research-evaluation-methods-and

[30] https://highways.dot.gov/research/projects/hrdo-fy17-03-smartphone-based-vehicle-driver-warnings-pedestrian-midblock-crossings

[31] https://rosap.ntl.bts.gov/view/dot/64953

[32] https://downloads.regulations.gov/DOT-OST-2022-0096-0150/attachment_1.pdf

[33] https://sip.umtri.umich.edu/

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 applications[34].

**Intelligent Woodward Corridor Project**

Bosch Building Technologies' video sensors perform "pedestrian detection, prioritization and alerts as well as wrong-way-driver detection and alerts. The goal of this deployment is to improve VRU safety by using video sensors and connected vehicle systems to share the trajectories of VRUs as they move through the intersection environment.[35]" Other technologies used in the project include traffic signal preemption and priority, V2X, and advanced data analytics and computing.[36]

**City of Peachtree Corners[37]**

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 alighting[38]**

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 Pilot[39]**

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

**Gainesville Bike and Pedestrian Safety Project[40]**

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.

### 3.7.2 Work Zones

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

**I-96 Flex Route Construction Project Demo[41]**

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-

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

35 https://downloads.regulations.gov/DOT-OST-2022-0096-0211/attachment_1.pdf

36 https://highways.dot.gov/newsroom/us-department-transportation-awards-55-million-michigans-intelligent-woodward-corridor

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

38 https://media.audiusa.com/en-us/releases/477

39 https://www.its.dot.gov/pilots/pilots_thea.htm

40 https://teo.fdot.gov/architecture/architectures/d2/html/projects/projarch47.html

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

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.

**VTTI Smart Work Zone System Deployments**
Wise County[42] – Smart vests transmit worker GPS position and predict potential hazards from passing motorists.
Albemarle County[43] – 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.

[42] https://vtx.vt.edu/articles/2022/05/vtt-smart-work-zone.html
[43] https://vtx.vt.edu/articles/2022/12/vtti-smart-work-zone-albemarle.html

# 4 Discussion of Gaps and Stakeholders

With relevant topics detailed in previous chapters, this section continues with the identification of their standards gaps and discusses stakeholders that should be involved in further standards development. This section first explains the methodology of the gap analysis and then provides the gaps identified and stakeholders to include in further standards efforts.

## 4.1 Methodology of Gap Analysis

This white paper uses the MATSA OR key takeaways in Section 2 to perform the gap analysis. Each topic discussed in Section 3 was linked to relevant bullet points in the Needs, Gaps Assessment, and Priorities subsections, then each subsection of Section 3 was analyzed for possible standardization work in the context of the bullet points.

## 4.2 Gaps

This section is split into two subsections: not ready for standardization and ready for standardization.

### 4.2.1 Not Ready for Standardization

The following topics were determined to not be ready for standardization: sensing and perception, VRU path prediction, and alerting. Currently, research on these topics are not yet mature enough for standardization work to start. Research still has much to explore (e.g., in human cognition and human factors), and some challenges still need to be overcome (e.g., algorithmic bias). These issues are described in their respective sections above. However, the future stakeholder team may disagree with this conclusion and determine that certain areas or parts of areas may be ready for standardization work.

### 4.2.2 Ready for Standardization

The following topics were determined to be mature enough to be ready for standardization consideration: VRU classification/taxonomy, incident data reporting, OBUs for bicycles, PSM confidence intervals.

#### 4.2.2.1 VRU Classification/Taxonomy

**Summary**: Existing VRU taxonomy standards require harmonization of classification, especially taking into consideration the boundary transitions between a VRU, their V2X device, and their MMV/bicycle. In addition, a creation of standardized VRU profiles that are limited in inclusivity and encompass every type of VRU needs to be created.

**Determination of Gap**: This is ISO Gap Assessment Gap 1, and no new work on the harmonization of VRU classification has been done since.

**Justification:** Harmonization of VRU types and the creation of profiles is the foundation of further standardization efforts; creating a complete VRU taxonomy with granular profiles is necessary for ensuring that future standards minimize gaps in coverage of VRUs.

**Recommendations:** The ISO Gap Assessment includes a work plan that addresses their five identified gaps. Before starting work on VRU classification/taxonomy, coordinate with the relevant ISO working groups to avoid duplication of efforts.

#### 4.2.2.2 Incident Data Reporting

**Summary**: A detailed VRU incident data reporting standard is needed.

**Determination of Gap**: MATSA-identified need.

**Justification:** In order to make transportation and policy decisions, including those related to V2X and safety, incident data is needed. However, current incident reporting standards lack sufficient detail (such as specificity of VRU MMV conveyances, e.g., differentiating between motorized wheelchairs and e-scooters in reports) or differ greatly between data collectors.

**Recommendations:** The MMfE has experience dealing with a lack of MMV data detail. See their lessons learned. MMV advocacy groups such as PeopleForBikes and advocacy groups for people with disabilities such as the Disability Rights Education and Defense Fund may also have input on information to include in reporting.

#### 4.2.2.3 Extend the PSM to Include Confidence Levels

**Summary**: The standard for the PSM for VRUs needs to be extended to include elements that describe confidence levels for items such as object detection, classification and existence.

**Determination of Gap**: USDOT RFI comment (MCCity and UMTRI, University of Michigan, Ann Arbor).

**Justification:** The PSM is essential for VRUs in the V2X environment. Proxy PSMs may be generated by the infrastructure or vehicle sensors, and confidence in the VRU detection information is valuable for the intersection actors' decision making. It may also be unclear whether a person with a mobile unit changes VRU type or status, depending on the capabilities of the mobile unit.

**Recommendations:** V2X SDOs, especially SAE which already has standards for V2X messages

#### 4.2.2.4 OBUs for Bicycles

**Summary / Determination of Gap / Justification**: Multiple companies are developing OBUs for bicycles. This technology may be mature enough to consider standardization.

**Recommendations:** Stakeholders for standardization may include: the companies developing the technology (Spoke Safety et al., Autotalks), V2X SDOs.

## 4.3 Stakeholders

With standards gaps identified above, this section lists stakeholders to include in further development of standards related to VRU safety in the V2X environment. 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:**

<u>Standards Development Organizations</u>

- ISO
- CEN
- SAE and other SDOs involved in V2X standards

Private Sector Companies

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

Government

- State, local, territorial and tribal governments
- NHTSA
- FHWA
- FTA
- NTSB

Advocacy Groups

- PeopleForBikes
- Disability Rights Education and Defense Fund
- Alliance of People with Disabilities
- MMfE
- Safety associations
- Other advocacy groups

Other

- Research institutions

# Appendix A: Acronyms

| Acronym | Description |
|---|---|
| ADA | Americans with Disabilities Act |
| 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 |
| 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 and Accessible Travel |
| MATSA | Multimodal and Accessible Travel Standards Assessment |
| MMFe | Micro-Mobility for Europe |
| MMV | Micromobility Vehicle |
| NGO | Non-Governmental Organizations |
| OBU | On-board Unit |
| OR | Outreach Report |
| PSM | Personal Safety Message |
| 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 |
| SSS | Sensor Sharing Service |

| Acronym | Description |
| --- | --- |
| THEA | Tampa Hillsborough Expressway Authority |
| UMTRI | University of Michigan Transportation Institute |
| USDOT | United States Department of Transportation |
| UWB | Ultra-Wideband |
| V2I | Vehicle-to-Infrastructure |
| V2P | Vehicle-to-Pedestrian |
| V2X | Vehicle-to-Everything |
| VRU | Vulnerable Road User |
| VRV | Vulnerable Road Vehicle |
| VTTI | Virginia Tech Transportation Institute |
| WIP | Work-in-Progress |
| WZDx | Work Zone Data Exchange |