

USDOT Vehicle-to-Pedestrian Research White Paper

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Executive Summary

Walking and bicycling offer an appealing, active, and affordable travel alternative for many Americans. Bicycling and walking make up a substantial proportion of local trips that people take for non-work purposes, particularly in urban areas. Together, they account for approximately one half of all trips taken under one mile and more than 10 percent of all trips of any length. As people bicycle and walk more frequently, pedestrian and bicyclist safety will become a greater issue for policymakers, particularly in urban areas.¹

While safety for bicyclists and pedestrians has improved significantly over the past several decades, safety for the most vulnerable users of our transportation systems remains a persistent problem. Overall numbers of deaths among pedestrians and bicyclists have been steadily climbing since 2009, with the vast majority occurring in urban areas, where these modes are increasing in popularity.² In 2015, the most recent year of released data, the National Highway Traffic Safety Administration (NHTSA) reported that the number of pedestrian fatalities in the United States was 5,376 and that “on average, a pedestrian was killed every two hours and injured every seven minutes in traffic crashes.” The current data available on the NHTSA Fatality Analysis Reporting System (FARS) shows that in 2014, fifteen percent of all traffic fatalities and an estimated 3 percent of those injured in traffic crashes were pedestrians, and those numbers have been slowly increasing each year.³

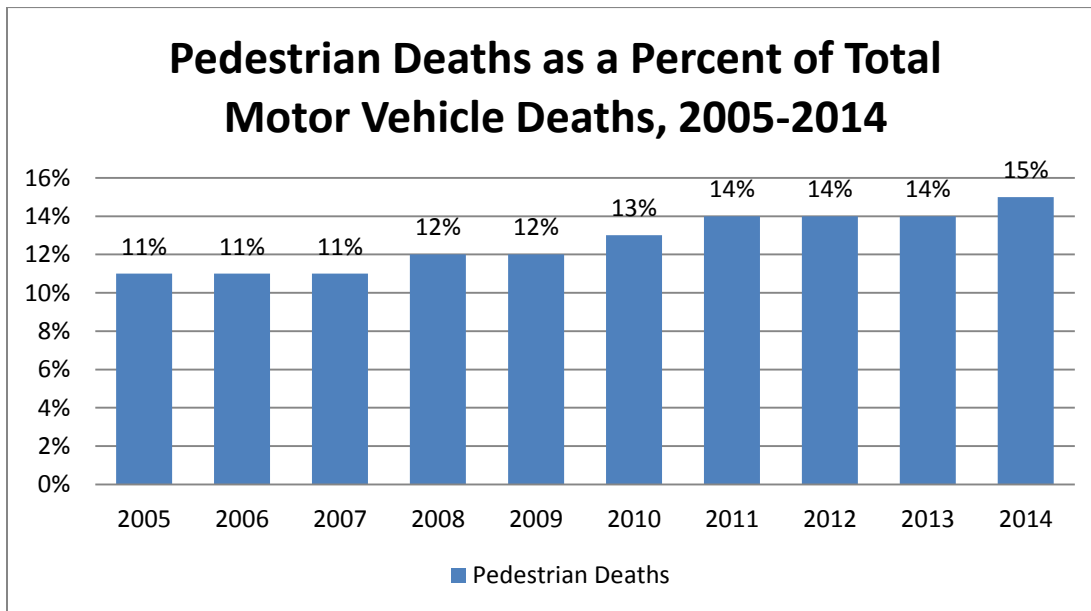


Figure 1: Pedestrian Deaths as a Percent of Total Motor Vehicle Deaths, 2005-2014 (Source: NHTSA FARS)

1 Beyond Traffic: https://cms.dot.gov/sites/dot.gov/files/docs/Draft_Beyond_Traffic_Framework.pdf

2 Beyond Traffic

3 NHTSA Pedestrian Safety: <https://www.nhtsa.gov/road-safety/pedestrian-safety>

1 Vehicle-to-Pedestrian Research

Connecting vehicles with the surrounding infrastructure through Vehicle-to-Pedestrian (V2P) technology offers promise for addressing pedestrian safety. For the past decade, the USDOT has been researching and testing a connected vehicle (CV) system where vehicles can sense the environment around them and communicate that information to other vehicles, infrastructure, and personal mobile devices. This connected vehicle communication will enable safety, mobility, and environmental advancements that current technologies are unable to provide. The technology has the potential to reduce unimpaired vehicle crashes by 80 percent.⁴

V2P detection systems can be implemented in vehicles, in the infrastructure, or with pedestrians themselves to provide warnings to drivers, pedestrians, or both:

- In-Vehicle Systems: In-vehicle warning systems are becoming more and more commonplace (e.g., blind spot warning, forward collision warning). The current field of V2V communications is providing the development of even more advanced warning systems (e.g., intersection movement assist, left turn assist). In-vehicle warnings to the presence of a pedestrian in the roadway might be the logical next step.
- Handheld Devices (for pedestrians): Perhaps the simplest and most apparent warning system for pedestrians is a handheld device.⁴

The Vehicle-to-Pedestrian (V2P) approach encompasses a broad set of road users including pedestrians, children being pushed in strollers, people using wheelchairs and other mobility devices, passengers embarking and disembarking buses and trains, and people riding bicycles.⁵

The USDOT's research into V2P solutions includes:

- Pedestrians and bicyclists
- Various vehicle types, including passenger vehicles, transit (buses and trains), and commercial vehicles
- Technologies that notify drivers and/or non-motorists
- Domestic and international approaches
- Technologies specifically intended for V2P, and others that may be innovatively applied

The V2P efforts represent just one part of a larger connected vehicle environment that includes Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) connectivity. The USDOT's Connected Vehicle Program works with state and local transportation agencies, vehicle and device manufacturers, and the public to test and evaluate technology that will enable cars, buses, trucks, trains, roads and other infrastructure, and our smartphones and other devices to "talk" to one another.⁶

4 V2P Fact Sheet: http://www.its.dot.gov/factsheets/pdf/cv_v2pcomms.pdf

5 V2P Fact Sheet: http://www.its.dot.gov/factsheets/pdf/cv_v2pcomms.pdf

6 Connected Vehicles Fact Sheet: http://www.its.dot.gov/factsheets/pdf/FactSheet_ConnectedVehicles.pdf

In January 2016, NHTSA released a Notice of Proposed Rule Making (NPRM) to mandate V2V communication technology for new light vehicles in the United States. The proposed mandate would require all new vehicles to come equipped with communication technology enabling communication amongst vehicles. This technology would also further connectivity between connected pedestrians who are equipped with this technology through mobile devices or other means.⁷ As discussed below, demonstration deployments of connected vehicle technology have been ongoing and continue to be conducted both by the federal government and by non-federal organizations. The USDOT's CV Pilots Program in New York City, NY, Tampa, FL and Wyoming, and the Smart City Challenge Program in Columbus, Ohio are deploying various CV and V2P technologies. Specific domestic V2P projects are described in detail in the following sections of this document.

1.1 State of Current Technology

Traditional countermeasures for improving pedestrian safety include reducing speed limits, increasing lighting, building more pedestrian infrastructure, educating pedestrians on measures they can take to improve their own safety (such as wearing brightly colored or high visibility clothing), and basic in-vehicle technologies (such as night-vision and LIDAR/radar based systems).⁸

Over the past decades the USDOT has been actively involved in working to increase the safety of pedestrians on U.S. roadways. Modal administrations such as NHTSA, the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) have undertaken research projects as well as developed policies and strategic plans that emphasize pedestrian safety. Examples of pedestrian initiatives include the USDOT's 2015 "Safer People, Safer Streets Initiative," which worked to provide communities with resources and tools to increase non-motorized safety issues for both pedestrians and bicyclists. During this initiative, the USDOT worked with various stakeholders and local officials to engage in discussions on strategies, resources and available tools to increase safety.⁹ In 2008 and 2012 the FHWA released its original and updated version of "Guidance on the Consideration and Implementation of Proven Safety Countermeasures" which provided FHWA suggested processes, design techniques and safety countermeasures to be implemented by States.¹⁰ The FTA has established a Safety Research and Demonstration (SRD) Program that provides both technical and financial support for transit agencies to pursue innovative approaches to mitigate or eliminate safety hazards.¹¹

Intelligent Transportation Systems (ITS) have also been a source for pedestrian safety improvements. These measures include portable and fixed changeable message speed limit signs, pedestrian detectors, pedestrian countdown timers, accessible pedestrian signals, rectangular rapid flash beacons, ITS video pedestrian detection, high-intensity activation crosswalks (HAWK signals), and automated adapted signals.¹² The theme connecting these strategies is a technology component, whereas V2P technologies require a communication component between vehicles and pedestrians.

7 NHTSA V2V NPRM Fact Sheet: https://icsw.nhtsa.gov/safercar/v2v/pdf/V2V_NPRM_Fact_Sheet_121316_v1.pdf

8 Walking and Talking: How Talking Cars Will Improve Safety for Pedestrians, presented by Karen Timpone and Stacy Balk at the National Safety Council Congress and Expo, Anaheim, CA, October 2016

9 Safer People, Safer Streets Initiative <https://www.transportation.gov/safer-people-safer-streets>

10 FHWA Pedestrian & Bicycle Safety http://safety.fhwa.dot.gov/ped_bike/

11 FTA Safety Research and Demonstration Program <https://www.transit.dot.gov/research-innovation/safety-research-and-demonstration-program>

12 Improving Highway Safety with ITS: 2016 Update

2 The Next Wave of Pedestrian Safety Technologies at the USDOT

The USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) has partnered with universities, small businesses, industry, and cities for over a decade to research and identify the potential safety benefits of applying V2P technologies to increase pedestrian safety. Some of the most promising research includes using smart connected traffic signals and sensors at intersections to alert vehicles to the presence of pedestrians crossing, warn pedestrians of incoming vehicles at cross walks, or even adjust traffic signal wait times and give signal priority to pedestrians. Using existing communications technologies, such as personal mobile devices, to alert those who are visually impaired or blind on when to cross or if a vehicle is approaching has also shown promise.

V2P research continues under USDOT programs in cities across the United States. These cities include the Smart City Challenge winner, Columbus, OH, and the cities of Los Angeles and San Francisco, and Marysville and Dublin, OH, under the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grants. V2P deployment is also taking place in the cities of New York, NY, Tampa, FL, and in the state of Wyoming through the Connected Vehicle Pilot (CV Pilots) program.

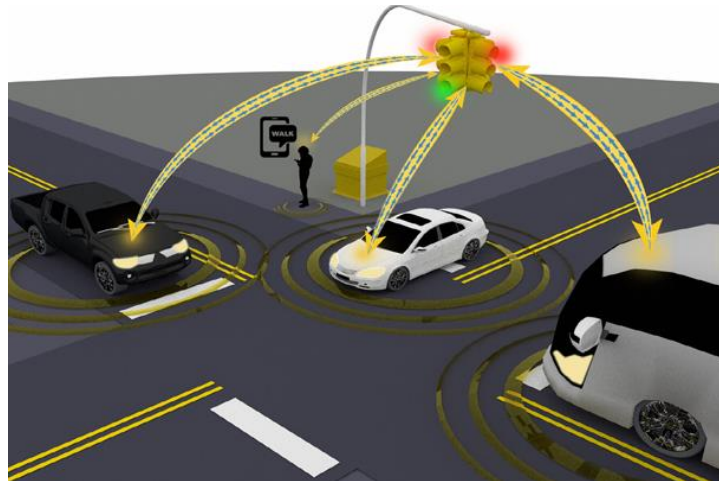


Figure 2: Connected Environment (Source: USDOT)

2.1 USDOT: Research to Deployment

The USDOT has made a significant investment in expanding connected vehicle and mobile technology to promote a coordinated approach to vehicle to pedestrian messaging, application development, and mobility. This research was initiated through the Dynamic Mobility Applications and Vehicle-to-Infrastructure (V2I) Safety Program for Transit and is now being deployed in New York City and Tampa, FL.

2.1.1 Dynamic Mobility Applications (DMA) Program

The DMA Program has developed two applications that are expected to improve pedestrian safety using mobile devices and smart infrastructure at signalized intersections. The Mobile Accessible Pedestrian Signal System (PED-SIG) is an application that allows for an automated call from the smartphone from a visually impaired pedestrian to the traffic signal. The application provides audio

cues to the pedestrian to safely navigate the crosswalk and alerts drivers attempting to make a turn to the presence of a visually impaired pedestrian.

2.1.2 Transit V2I Safety Program

The Federal Transit Administration (FTA) developed V2P technology to reduce pedestrian incidents involving transit vehicles. The Pedestrian in Signalized Crosswalk Warning is an application that warns bus operators when pedestrians are in a signalized intersection or crosswalk and are in the path of the bus. The FTA has funded the deployment of the Enhanced Pedestrian in Cross Walk Warning (EPCW), the successor to Pedestrian in Signalized Crosswalk Warning. EPCW will be deployed at four crosswalks in Cleveland, OH, starting in 2017.



**Figure 3: Crosswalk Signal
(Source: USDOT)**

The FTA also provided funding for the initial development of the Transit Bus Stop Pedestrian Warning (TSPW) application

and has approved the funding of its deployment at three bus stops in Cleveland, OH. The application is expected to increase safety by providing warnings to waiting passengers at bus stops, exiting passengers from transit vehicles, and pedestrians if they are at risk of being struck by the bus. The application will utilize an array of sensors to provide warnings to transit drivers on additional pedestrian hazards and potential strike zones. Starting in 2017, a total of 50 buses in Cleveland, OH will be equipped with the TSPW sensor and communication systems.

2.1.3 Connected Vehicle Pilot Sites

The USDOT's ITS JPO is funding regional pilots of connected vehicle technology in New York City, Tampa, and Wyoming. The CV Pilots are deploying technologies developed from other USDOT sponsored programs, such as the Pedestrian Signal System (PED-SIG) from DMA and Pedestrian at Signalized Crosswalk (PED-X) from USDOT's V2I Safety Program in the cities of New York City and Tampa.

PED-SIG is an application that allows for an automated call from the smart phone of a visually impaired pedestrian to the traffic signal and provides audio cues to safely navigate the crosswalk. PED-X is the CV Pilot implementation of the DMA application that warns drivers when pedestrians are within the crosswalk of a signalized intersection, or are in the intended path of the vehicle. Both applications are expected to increase pedestrian safety by deploying innovative technologies that harness previous USDOT research.

2.1.4 Federal Highway Administration (FHWA) Exploratory Advanced Research Program (EAR)

The FHWA EAR Program funded three pedestrian navigation projects such as the "Extended Event Horizon Navigation and Wayfinding for Blind and Visually Impaired Pedestrians in Unstructured Environments," at Auburn University. The system uses Dedicated Short Range Communications (DSRC) to obtain information (i.e., signal status and intersection layout) at equipped intersections, which it communicates to the user. The purpose of the project is to assist blind or visually-impaired pedestrians the ability to traverse large, unstructured environments that they encounter in the course of daily life (e.g., parks, parking lots, airports, sports arenas, intersections, and pedestrian zones) in situations where global positioning system (GPS) navigation may not be sufficient.

2.1.5 Accessible Transportation Technologies Research Initiative (ATTRI)

The ATTRI research program is seeking to fund the development of a safe intersection crossing application. The program currently has a Broad Agency Announcement for application development of several technology areas, including safe intersection crossing. Awards are expected in early 2017. The program envisions an application where pedestrians communicate with traffic signals and get automated intersection crossing assistance and vehicles receive alerts. The application is designed for people with vision, cognitive, and mobility issues.



Figure 4: Connected Pedestrian (Source: USDOT)

2.1.6 ITS JPO Connected Data Systems (CDS) Program

The CDS program is developing and testing core V2P functionality as a means to identify needed V2P data elements and messages. The “Coordination of Mobile Devices for Connected Vehicle Applications” project includes the development and testing of the Pedestrian in Signalized Crosswalk Warning application, Pedestrian-to-Pedestrian (P2P) communication to support the ad hoc formation of travel groups (groups of pedestrians with similar origins and destinations who may choose to travel together), and V2P communication between vehicle equipment and the devices carried on to equipped vehicles by pedestrians.

2.2 Collaborating with Cities for Deployment of Pedestrian Safety Technology

Recent USDOT programs, such as the Smart City Challenge, Operations Congestion Grants, and the Northwest U.S. 33 Smart Mobility Corridor awards have provided the cities of Columbus, OH, Los Angeles and San Francisco, CA, Denver, CO, and Marysville and Union County OH, funding to address pedestrian safety needs with new technologies and communications systems.

2.2.1 Smart Columbus: The Smart City Challenge Winner

As part of Columbus’ winning Smart City Challenge proposal, the Columbus Smart City Plan will utilize traffic signals equipped with traffic detection and sensors using DSRC for pedestrian detection at intersection crossings. Transit vehicles will also be equipped with Mobileye developed driver assistance devices,¹³ and Bus Stop Pedestrian Warning systems will be deployed at bus stops to provide bus drivers with in-vehicle warnings and on transit stop signage if pedestrians or waiting passengers are at risk of being struck at stops or in crosswalks.

¹³ <http://www.mobileye.com/smart-cities-challenge/>

2.2.2 Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grants¹⁴

In 2016, the USDOT selected several cities, including Los Angeles and Marysville, OH to receive grants to implement new technologies to reduce congestion and improve transportation safety. Each program included a pedestrian safety component as part of its overall congestion management plan.

- The *Los Angeles DOT Implementation of Advanced Technologies to Improve Safety and Mobility within the Promise Zone* project focuses on large-scale deployment of technology to allow the traffic signal system to detect red light-violating vehicles and adjusts stoplight timing to allow personal wireless devices to prioritize pedestrian travel and safety at intersections. The adjusted stoplight timing will also assist transit bus drivers to operate safely and efficiently.
- The *Northwest U.S. 33 Smart Mobility Corridor* deploys corridor-focused connected vehicle applications across a wide range of connected fleets – city, county, transit, private fleets, throughout multiple communities and in rural and urban settings in Marysville, Dublin, and Union County in Ohio. The connected vehicle applications include dynamic signal phase and timing with pedestrian warning systems on the local street network.

2.3 Additional USDOT Programs for Pedestrian Safety

The USDOT continues to fund research to expand connected vehicle and mobile technology to promote a coordinated approach to vehicle to pedestrian messaging, application development, and mobility.

Through the University Transportation Centers program (UTC) and Small Business Innovative Research Projects (SBIR), the USDOT provides grants to universities, research institutions, and small businesses to research ways to make the transportation system safer. The programs have explored the applications of new technologies to increase pedestrian and cyclist safety at intersections using V2P technologies, such as short range communication systems and personal mobile devices.

2.3.1 University Transportation Centers (UTC) Program

In 2013 and 2014 the USDOT awarded grants to Minnesota’s Roadway Safety Institute and the University of Iowa to research the use of mobile device alerts for pedestrian safety at signalized intersections.

Minnesota’s Roadway Safety Institute developed a smartphone-based mobile accessible pedestrian signal (MAPS) application to provide “walk” phase information to visually impaired pedestrians at signalized intersections. The application has been successfully tested with many subjects at various sites, and uses a spatial database in the “cloud,” wireless communication, and a text-to-speech interface. Researchers also incorporated routing information into MAPS to alert blind pedestrians as they approach a work zone on the sidewalk.

The University of Iowa’s Safety Research Using Simulation (SAFER-SIM) Center is exploring the use of connected vehicle technology to provide timely warning to pedestrians via their mobile devices. This

¹⁴ <https://www.transportation.gov/Briefing-Room/ATCMTD-Fact-Sheet-2016>

study focused on improving pedestrian safety and reducing impairment from distraction while crossing intersections.

2.3.2 Small Business Innovative Research (SBIR) Projects

In 2015, an SBIR was awarded to develop an application called SmartCross. The application runs on mobile devices and communicates with traffic signal systems to receive information about the pedestrian signal. In addition to sending alerts to notify pedestrians when they have the signal to cross, SmartCross allows users to request the pedestrian signal, and for users in need of more time, the ability to request an extended pedestrian crosswalk time. For enhanced safety, the application provides audio, visual and haptic (typically vibration) feedback to the user, so pedestrians approaching a crosswalk with their heads down will know to stop at the curb.¹⁵

The application can also provide information on pedestrians in the crosswalk to vehicles equipped with on-board DSRC units. The SBIR-supported SmartCross application has different modes for pedestrians, bicyclists, visually impaired individuals, and people in wheelchairs, and is expected to be of immense help to the elderly and the physically impaired once it is available for iPhone and Android users.

2.4 Additional USDOT V2P Resources

The USDOT has prepared an array of research documents, databases, and fact sheets to encourage the adoption of innovative technologies to improve pedestrian safety. This includes the V2P Database, the V2P Fact Sheet, and the V2P Infographic.

2.4.1 V2P Database

USDOT has prepared a scan of V2P products from the private sector. The database is located [here](#) for download. The scan searched existing databases, peer-reviewed journals, and the internet to identify potential V2P technologies in the United States and abroad. In addition, industry and research professionals were contacted to more fully understand developing V2P technologies. Technologies were not limited to passenger vehicles; the scan also included technologies for other vehicle types such as personal vehicles, commercial vehicles/trucks, transit, and public transportation vehicles including buses, light rail vehicles, etc.

2.4.2 V2P Fact Sheet

The ITS JPO website includes a [fact sheet](#) developed in 2016 related to the USDOT's V2P research.

2.4.3 V2P Infographic

The ITS JPO website includes an [infographic](#) demonstrating the Pedestrian at a Signalized Intersection application.

¹⁵ Fastlane, USDOT Blog, October 23, 2015, <https://www.transportation.gov/fastlane/sbir-program-makes-crossing-street-safer>.

3 The Future of Pedestrian Safety

Vehicle-to-Pedestrian (V2P) technologies offer a promising and potentially cost effective measure for increasing pedestrian safety. However, there is still work to be done in ensuring interoperability, device accessibility, and market penetration of the V2P technologies. A USDOT effort is underway to identify the best methods to utilize the solutions that these technologies can offer. Connected vehicle technology, of which V2P technology is a fundamental part, could address up to 90 percent of pedestrian fatalities and injuries.¹⁶ Work is already in progress to shape how broad deployment of these technologies could work nationwide. As efforts continue, the USDOT is committed to advancing deployment of these technologies in communities.

¹⁶ Walking and Talking: How Talking Cars Will Improve Safety for Pedestrians:
<http://www.congress.nsc.org/NSC2016/Public/SessionDetails.aspx?FromPage=Sessions.aspx&SessionID=1769&SessionDateID=82>

APPENDIX A. List of Acronyms

Acronym	Meaning
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
ATTRI	Accessible Transportation Technologies Research Initiative
CDS	Connected Data Systems
CV	Connected Vehicle
DMA	Dynamic Mobility Applications
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
EAR	Exploratory Advanced Research
EPCW	Enhanced Pedestrian in Cross Walk Warning
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HAWK	High-Intensity Activation Crosswalks
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
MAPS	Mobile Accessible Pedestrian Signal
NHTSA	National Highway Traffic Safety Administration
NPRM	Notice of Proposed Rule Making
PED-SIG	Pedestrian Signal System
PED-X	Pedestrian at Signalized Crosswalk
SAFER-SIM	Safety Research Using Simulation
SBIR	Small Business Innovative Research
SRD	Safety Research and Demonstration
TSPW	Transit Bus Stop Pedestrian Warning
US	United States
USDOT	United States Department of Transportation
UTC	University Transportation Center
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything

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