Federal Highway Administration
Vulnerable Road User Research Plan

July 2023

U.S. Department of Transportation

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Section 1. Introduction

Walking, biking, and other sustainable modes of transportation are critical options in communities throughout the United States, particularly for economically disadvantaged communities. However, fatalities among pedestrians and bicyclists have been increasing even faster than the overall fatalities among all road users,[1] which has drawn a focus on the safety of vulnerable road users (defined below). In addition, there are opportunities to improve access and mobility for people walking, biking, or rolling. The FHWA research described in this and other plans is needed to address these areas.

Disparate Impacts: Safety & Equity. According to the National Highway Traffic Safety Administration (NHTSA),[2] Indian and Alaskan Native persons have the highest rate of pedestrian fatalities from traffic crashes. Black pedestrians also experience disproportionately high pedestrian fatality rates from traffic crashes. Fatality rates for Black and Hispanic or Latino pedestrians increased relative to white pedestrians between 2014 and 2018, highlighting how inequities in pedestrian fatalities are accelerating.

The U.S. Department of Transportation's (DOT or the Department) National Roadway Safety Strategy (NRSS) specifies that zero is the only acceptable number of deaths and serious injuries on our roadways, and the Department is committed to taking substantial, comprehensive action to achieve this goal.[3] The Federal Highway Administration (FHWA) is committed to this goal. Through the six strategic goals established in the DOT Strategic Plan for Fiscal Year (FY) 2022 – 2026, the Department aims to increase not only the safety of vulnerable road users, but also the availability of, access to, and use of walking, biking, and rolling options. Increasing walking, biking, and rolling trips can improve safety for travelers of all ages and abilities, mobility for all people and businesses, access to jobs and essential services for all, and resilience for all communities, especially underserved communities.

The Infrastructure Investment and Jobs Act (IIJA) (Public Law 117-58, also known as the "Bipartisan Infrastructure Law" (BIL)) emphasizes walking, biking, and other non-vehicular modes of transportation. The BIL includes provisions that significantly increase funding available for vulnerable road user safety, including the Safe Streets and Roads for All discretionary grant programs, an annual $1 billion grant program dedicated to safety planning and investments by regional, local, and Tribal governments;[4] a special rule that requires many States to use more safety dollars on vulnerable road user projects;[5] and a requirement to spend planning funds on Complete Streets policies.[6]

[1] DOT National Roadway Safety Strategy
[2] DOT Learning Agenda
[3] DOT National Roadway Safety Strategy
[4] *See* Section 24112 of BIL; Division J, Title VIII, Safe Streets and Roads for All Grants heading.
[5] *See* 23 U.S.C. 148(g)(3).
[6] *See* Section 11206 of BIL.

This report addresses Section 11122(b) of BIL, which requires the Administrator of the FHWA to develop a vulnerable road user research plan. Specifically, the statutory language states:

> *ESTABLISHMENT OF RESEARCH PLAN. The Administrator shall establish a research plan to prioritize research on roadway designs, the development of safety countermeasures to minimize fatalities and serious injuries to vulnerable road users, and the promotion of bicycling and walking, including research relating to—*
> 1) *roadway safety improvements, including traffic calming techniques and vulnerable road user accommodations appropriate in a suburban arterial context;*
> 2) *the impacts of traffic speeds, and access to low-traffic stress corridors, on safety and rates of bicycling and walking;*
> 3) *tools to evaluate the impact of transportation improvements on projected rates and safety of bicycling and walking; and*
> 4) *other research areas to be determined by the Administrator.*

Section 11122(a)(2) states the definition of vulnerable road user is provided in 23 U.S. Code (U.S.C.) 148(a)(15), as follows:

> *A nonmotorist-*
>
> a. *with a fatality analysis reporting system [FARS] person attribute code[7] that is included in the definition of the term "number of non-motorized fatalities" in section 490.205 of title 23, Code of Federal Regulations (or successor regulations); or*
> b. *described in the term "number of non-motorized serious injuries" in that section.*

This definition includes people walking, bicycling, using mobility aids (such as wheelchairs), or using most micromobility[8] devices (whether motorized or not), but does not include motorcyclists. Throughout this plan, the phrase "people walking, biking, or rolling" is used to generally refer to vulnerable road users.

The research within this plan aligns with eligibilities under the FHWA Research, Development, and Technology (RD&T) Program. The RD&T Program is largely governed and shaped by Chapter 5 of Title 23 of the United States Code (U.S.C.); it includes all activities within the innovation lifecycle leading to technology development and transfer, as well as the introduction of new and innovative ideas, practices, and approaches, through such mechanisms as field applications, education and training, communications, impact analysis, and technical support.

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[7] The relevant person attribute codes include Pedestrian, Bicyclist, Other Cyclist, and Person on Personal Conveyance. The 2020 FARS Manual defines personal conveyances and provides examples of devices within this category, including scooters, self-balancing personal conveyances, and wheelchairs.

[8] The FHWA defines micromobility as "any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles (e-bikes), electric scooters (e-scooters), and other small, lightweight, wheeled conveyances." While the definition of vulnerable road user does not currently include e-bike riders, this group will likely benefit from the vulnerable road user research identified in this plan.

To develop this plan, FHWA convened a team with subject matter experts from across FHWA and the Department. The team identified and reviewed existing relevant plans and strategy documents, as well as outputs of stakeholder engagement efforts to identify vulnerable road user research priorities, gaps, needs, and FHWA's specific project commitments. Source material reviewed is listed in Appendix A. The review also captured outreach efforts that were performed in the production of those documents demonstrating prior broad stakeholder engagement efforts (see Appendix B).

Background

The FHWA has a long history of supporting pedestrian and bicycle transportation through research, funding, guidance, program management, resource development, and collaboration with external partners. The document review included assessment of the coordinated plans and policies that have motivated past, ongoing, and future vulnerable road user research efforts (for more information, see Appendix C for relevant DOT strategies and plans and Appendix D for relevant external research activities). These plans and policies include:

- The FHWA Strategic Agenda for Pedestrian and Bicycle Transportation ("2016 Strategic Agenda"),[9] which is a research and deployment plan articulating goals and identifying 98 supporting actions organized under 4 goal areas: networks, safety, equity, and trips. A 2021 review of the status of actions identified in the 2016 Strategic Agenda identified that the majority of actions (53) identified in the agenda are in progress and 13 actions are not yet started.

- The Pedestrian and Bicycle Safety Program Plan ("2021 Program Plan"), which is a comprehensive, internal planning and management document for FHWA's Pedestrian and Bicyclist Safety Program. The plan proposes 30 projects that FHWA could undertake over a 10-year implementation horizon to improve active transportation safety under the 5 categories of research, guidance development, awareness and outreach, implementation assistance, and mainstreaming.

- A July 2021 research review performed for the American Association of State Highway and Transportation Officials (AASHTO) Council on Active Transportation (CAT) in partnership with FHWA as part of the National Cooperative Highway Research Program (NCHRP) Project 20-123, which summarizes existing and ongoing research organized around 22 active transportation topics, focusing on research published after 2015 in North America and with findings relevant to practice. The research review informed development of a research roadmap that outlines 110 prioritized research needs, including 6 highest priority research problem statements.

[9] The 2016 Strategic Agenda is available publicly.

Highest Priority Research Problem Statements from the AASHTO CAT Roadmap

- Applying and integrating active transportation data into planning and operations
- Using minimum accommodations vs. alternative approaches to increase active transportation
- Determining context-driven optimal spacing between marked crosswalks
- Addressing barriers to integrating active transportation throughout planning and engineering practice
- Racial and economic disparities in pedestrian and bicyclist safety
- Speed management solutions and strategies to improve pedestrian and bicyclist safety on arterial roadways

Vulnerable Road User Research Plan

Based on findings from the document review and the statutory language of Section 11122(b) of BIL, this Vulnerable Road User Research Plan goes beyond the safety aspects of walking, bicycling, and rolling and describes efforts related to mobility, networks, access, data, and analysis. It emphasizes the connection between walking, biking, and rolling and the goals of the DOT and FHWA Strategic Plans, including improving public health outcomes, coordinating transportation and land use decisions, addressing climate change, advancing equity, addressing accessibility for people with disabilities, fostering transformation, and providing for workforce development. The Vulnerable Road User Research Plan continues and builds on efforts that have been underway for years, such as the successful research and development of connected vehicle technology to protect vulnerable road users, as well as new areas of emphasis and other requirements and programs within BIL.

Given the extensive benefits of increasing vulnerable road user trips, DOT and FHWA will continue to leverage opportunities to simultaneously address safety, equity, and climate change and sustainability priorities through vulnerable road user research activities.

Cross-Cutting Opportunities: Climate Change and Sustainability & Equity

The Vulnerable Road User Research Plan aligns with policy established through Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, to secure environmental justice for disadvantaged communities that have been historically marginalized and overburdened by pollution and underinvestment in transportation.

This plan provides for research that will support practitioners implementing new BIL programs targeted at mitigating the impacts of climate change and increasing the resilience of the surface transportation system, such as the Carbon Reduction Program and the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program.

In addition, the Vulnerable Road User Research Plan aligns with the *America the Beautiful* initiative, which produces simultaneous benefits across multiple priority areas. One premise of the *America the Beautiful* initiative is that improving *access* to nature can help transform historically marginalized and overburdened communities into healthy, thriving communities that are better able to withstand the effects of climate change.

The plan includes more detail about research that is on-going or planned in FY 2023 and 2024. However, specific activities identified in this plan could change due to shifting priorities, funding, safety and mobility trends, and advances in technology.

The FHWA will carry out the Vulnerable Road User Research Plan over the next 5 years, from FY 2023-2027. Doing so effectively will involve leveraging previous work and innovations and collaboration among many technical specialties within FHWA, including those represented in the team that developed this plan. In addition, FHWA's vulnerable road user research will be coordinated with related activities of other modal agencies and partnering organizations, such as AASHTO's research program through the NCHRP. Coordination can include collaboration on research statements, co-funding projects, participation on project teams, and scaling research findings through pilots and implementation outreach. The FHWA actively considers and acknowledges that practitioner implementation of research and guidance is just as important as FHWA's conduct of research and development of guidance. The FHWA research supports State, Tribal, regional, and local agencies as they implement more projects to improve vulnerable road user safety, access, and mobility.

Since 1999, FHWA has also cooperatively funded an information clearinghouse that conducts research, outreach, and technical assistance on pedestrian and bicycle transportation. A new five-year cooperative agreement to operate the Pedestrian and Bicycle Information Center (PBIC) was awarded in September 2022. The PBIC will conduct activities to be determined in coordination with the lead partner, the University of North Carolina's Highway Safety Research Center, that cut across all four of the Vulnerable Road User Research Plan strategic goal areas.

Activities identified in this plan will be integrated into FHWA's broader standard research planning and prioritization process. The FHWA's RD&T efforts are captured in FHWA's Annual Modal Research Plan (AMRP), a two-year plan and outlook document. Research can be conducted and implemented through studies under relevant transportation pooled fund programs.

The FHWA also utilizes roadmaps and plans, such as the 2016 Strategic Agenda, to guide research activities. The FHWA will prepare, as a follow-on to this Vulnerable Road User Research Plan, an ***FY 2024-2028 Strategic Agenda for Pedestrian and Bicycle Transportation***. This successor to the 2016 Strategic Agenda will build upon this Vulnerable Road User Research Plan and the 2021 review of the status of actions identified in the 2016 Strategic Agenda. It will conduct new public outreach, formalize, and publish a new Strategic Agenda outlining in detail vulnerable road user research and complementary outreach, policy, and other research-to-practice activities that FHWA will pursue in support of the goals defined in this Vulnerable Road User Research Plan. It will also investigate research needs on a longer time horizon and will seek to identify activities that help fill possible research gaps within this Vulnerable Road User Research Plan's strategic goal areas where the goals of the DOT Strategic Plan may not be fully addressed.

Section 2. Emerging & Elevated Priorities

Based on the review of higher-level Departmental strategies and priorities, foundational plans addressing vulnerable road user research, and the broader vulnerable road user research ecosystem, the team identified several major themes that inform research priorities identified in this Vulnerable Road User Research Plan.

- ***Consider the nexus of emerging technologies and vulnerable road users, including implications for underserved communities***. Technologies such as vehicle-to-everything (V2X) communication, artificial intelligence and machine learning, automated driving system (ADS), and cooperative driving automation (CDA) present opportunities to improve safety and mobility for vulnerable road users, as well as challenges. Connected vehicle technology allows for communication between vehicles, infrastructure, and vulnerable road users which is proven to protect vulnerable road users by increasing their detection and driver awareness of their presence. Connected vehicle technology can also aid vulnerable road users by alerting them to and increasing their awareness of traffic scenarios and hazards. Advanced artificial intelligence and machine learning techniques can assist in understanding road user intent. Combining connected vehicles with automated driving systems, creates cooperative driving automation, which may further extend opportunities to improve safety and operations.
  Micromobility also presents opportunities to improve safety and mobility for vulnerable road users, as well as challenges. More research is needed in the field of micromobility, including research related to user safety and street design, its role in meeting unmet travel demand for underserved populations, its impact on traveler behavior and mode choice, connections with resilience planning, and parking management implications for vulnerable road users.
- ***Fill data gaps and develop mature methods and performance measures related to walking, biking, and rolling***. While information is readily available on vehicle counts and mileage to discern crash risk rates in multiple units of analysis, including segment- and corridor-level analysis, exposure and count information for vulnerable road users is limited. Data and analysis of active transportation modes lag behind other modes in terms of raw data collection (e.g., volume counts and vulnerable road user facility inventory information, including facility quality factors impacting perceptions of safety) and data utilization (for forecasting; informing better project selection; and assessing climate, public health, and other benefits). It is therefore difficult to establish safety risk rates for pedestrians and cyclists comparable to vehicle exposure. This may result in safety investments being focused on where the data are available as opposed to where the risk is. There is a need to measure how improved active transportation network connectivity (including on- and off-road facilities) impacts participation in biking, walking, and rolling over time. Data unavailability, a lack of consistent definitions for network quality, and the lack of national requirements to analyze walking and bicycling networks all are areas of opportunity for technology transfer and other research activities.
- ***Continue incorporating the Safe System Approach and systemic safety into technology transfer, education, and other research activities***. A systemic approach to safety involves identifying locations most at risk for future crashes involving fatalities and

serious injuries to vulnerable road users and widely implementing treatments to effectively address them. Utilizing both approaches is integral to achieving the overall goal of reducing fatalities and severe injury crashes for vulnerable road users.

The DOT and FHWA have adopted the ***Safe System Approach***, which addresses the safety of all road users, including vulnerable road users. It aims to improve safety culture, increase collaboration across all safety stakeholders, and refocus transportation system design and operation on anticipating human mistakes and lessening impact forces to reduce crash severity and save lives. The Safe System Approach has six principles, including that death and serious injuries are unacceptable, humans make mistakes, humans are vulnerable, responsibility is shared, safety is proactive, and redundancy is crucial. It also has five elements, including safer people, safer vehicles, safer speeds, safer roads, and post-crash care. Objectives under the Safety goal of the Vulnerable Road User Research Plan incorporate many of the principles and align with and support many of the elements of the Safe System Approach.

- ***Further integrate equity considerations***. There is a need to better understand disparities in safety, mobility, and personal comfort (including issues of harassment and environmental comfort such as protection from excessive heat) for vulnerable road users by race, gender, disability status, and other demographic categories (e.g., rural communities), and seek opportunities to reduce those disparities. It remains difficult to assess vulnerable road user safety and access to essential destinations using active transportation networks across racial and ethnic groups due to a lack of data. There is also a need to identify methods and data to better assess equity impacts.
- ***Support climate and sustainability goals***. Data are needed to demonstrate the extent to which mode-shift from driving to walking, biking, or rolling trips contributes to climate change mitigation. In addition, understanding how improvements to both the safety of vulnerable road users and the connectivity of vulnerable road user infrastructure can help address the disproportionate negative environmental impacts of transportation on underserved communities is key to supporting DOT's climate change/resilience and equity priorities.
- ***Integrate Complete Streets concepts, including personal comfort***. Generally, safety outcomes are measured through crash modification factors (CMFs), which isolate the effectiveness of individual countermeasures, instead of assessing the multiple interventions that together make a street complete. Methods are needed to measure safety at a corridor or system level to better guide investment decisions. Research on the extent to which the implementation of Complete Streets practices contributes to vulnerable road user safety, comfort, and mobility is needed. In assessing safety and access for all users, personal comfort for people walking, biking, or rolling is broadly construed to include perceptions of safety and personal security.

Complete Streets. The FHWA established a Complete Streets initiative that seeks to work with State, Tribal and local transportation agencies to implement a Complete Streets design model as they plan, develop, and operate streets and networks that prioritize safety, comfort, and connectivity to destinations for everyone who uses the street network. Complete Streets policies prioritize the safety of all users, including vulnerable road users, in transportation network planning, design, construction and operations. Section 11206 of BIL defines Complete Streets standards or policies as those which "ensure the safe and adequate accommodation of all users of the transportation system, including pedestrians, bicyclists, public transportation users, children, older individuals, individuals with disabilities, motorists, and freight vehicles." Section 11206(b) requires that States use 2.5 percent of their research funds under 23 U.S.C. 505 and MPOs use 2.5 percent of their planning funds under 23 U.S.C. 104(d) for Complete Streets activities that will increase safe and accessible transportation options. A Complete Street is safe, and feels safe, for everyone using the street.

The Vulnerable Road User Research Plan relates to efforts within the *FHWA Moving to a Complete Streets Design Model: A Report to Congress on Opportunities and Challenges* in that vulnerable road user safety is a key part of providing safety for all road users, and Complete Streets are one way to improve vulnerable road user safety and increase participation in biking, walking, and rolling. The report identified areas of opportunity for FHWA relevant to vulnerable road users, including improving data collection and analysis to advance safety for all users; accelerating adoption of standards and guidance that promote safety and accessibility for all users; and reinforcing the primacy of safety for all users in the interpretation of design standards, guidelines, and project review processes.

Section 3. Research Priorities

Research priorities are organized around four strategic goals:

- ***Safety***. Improve safety for people walking, biking, or rolling.
- ***Equity***. Promote equity throughout the transportation planning, design, funding, implementation, and evaluation process.
- ***Networks***. Achieve safe, accessible, comfortable, and connected multimodal networks in communities throughout the U.S.
- ***Trips***. Get more people walking, bicycling, and rolling.

Each goal includes specific objectives that FHWA plans to pursue in FY 2023-2027, along with example research activities that advance these objectives. These example activities do not encompass all the vulnerable road user research FHWA is doing and plans to do; rather, they highlight key actions FHWA is taking towards meeting its vulnerable road user-related goals.

Each objective is aligned with one or more of the statutorily required research areas or other research areas as determined by the Administrator per Section 11122(b)(4) of BIL. The other research areas include:

- ***Equity***. This area considers disparate impacts on various demographic groups (e.g., people with disabilities, Black, Latino, and Indigenous and Native American persons,

Asian Americans and Pacific Islanders and other persons of color, older and younger individuals; and rural communities) and interventions to address these disparities.

- ***Technology and Innovation***. This topic covers emerging vehicle and infrastructure technologies and includes novel communications technologies and micromobility devices.
- ***Planning and Policy Development***. This area includes institutionalization of research into practice, project prioritization and selection, and workforce development.
- ***Data and Methods***. This topic considers data collection and analytical techniques for measuring and forecasting bicycling and walking activity and infrastructure.
- ***Benefits of Promoting Biking and Walking***. This area covers the relationship between the role of bicycling and walking and climate change, sustainability, public health, economic development, and access to transit.
- ***Personal Comfort***. This topic includes vulnerable road users' sense of safety from motorized traffic, personal security, and environmental comfort.

Safety Goal: Improve safety for people walking, bicycling, and rolling

The DOT Strategic Plan establishes a strategy to "improve travel safety for vulnerable road users." The FHWA has a goal to reduce the number of non-motorized fatalities and serious injuries. In approaching safety for vulnerable road users, FHWA focuses on the Safer Roads and Safer Speeds objectives defined in the NRSS.

This Vulnerable Road User Research Plan Safety goal includes research activities that develop countermeasures, reduce the prevalence of vulnerable road user injuries and fatalities, better integrate vulnerable road user safety into planning and project development, enhance the availability and quality of safety data related to vulnerable road users, and, in partnership with NHTSA, identify safety education interventions to reduce harm to vulnerable road users on roadways. Objectives supporting this goal include:

- Increase vulnerable road user safety through roadway design and operations improvements;
- Manage vehicle speeds to improve vulnerable road user safety;
- Develop tools and methods to assess potential safety impacts to vulnerable road users; and
- Increase vulnerable road user safety through emerging technologies.

Beyond the Vulnerable Road User Research Plan, BIL contains other provisions supporting vulnerable road user safety, requiring:

- States to conduct Vulnerable Road User Safety Assessments as part of their State Strategic Highway Safety Plan under the Highway Safety Improvement Program (HSIP) (*see* 23 U.S.C. 148(l));
- States where the total annual fatalities of vulnerable road users represents not less than 15 percent of the total annual crash fatalities in the State to obligate not less than 15 percent of the amounts apportioned to the State under the HSIP in the following fiscal year for highway safety improvement projects to address the safety of vulnerable road users (23 U.S.C. 148(g)(3)); and

- Compilation of best practices and lessons learned for preventing transportation-related fatalities and serious injuries based on data submitted by Safe Streets and Roads for All grant recipients (Section 24112(i) of BIL).

In addition, the House Report[10] accompanying the Departments of Transportation, and Housing and Urban Development, and Related Agencies Appropriations Bill, 2022[11] requires development of noteworthy practices of local agencies accessing HSIP funding for pedestrian safety improvements.

Safety Objective 1: Increase vulnerable road user safety through roadway design and operations improvements

Roadway design impacts safety for both vulnerable road users and motorists and strongly influences how people use roads. Many public roads also support a growing mix of diverse users – including people who take public transportation, walk, bike, and roll. This objective describes research needed to identify, analyze the efficacy of, and implement roadway design elements that offer layers of protection to prevent vulnerable road user serious injuries and fatalities and mitigate the severity of harm to vulnerable road users when crashes do occur. It covers research related to active transportation infrastructure (e.g., the safety benefits of crosswalk retroreflectivity for vulnerable road users); crash modification factors; Complete Streets performance measures; safe access for people walking, biking, or rolling to transit stations; and quantifying the safety benefits to vulnerable road users of roadway features, such as street trees.

Increasing vulnerable road user safety through roadway design improvements responds directly to Section 11122(b)(1) of BIL, which requires this plan to prioritize research relating to *roadway safety improvements, including traffic calming techniques and vulnerable road user accommodations appropriate in a suburban arterial context* by focusing on physical design elements proven to enhance the safety of vulnerable road users. Research initiatives under this objective are aligned with several research areas determined by the Administrator pursuant to Section 11122(b)(4) of BIL, including equity considerations across various categories of vulnerable road users, technology and innovation, data and methods (for determining roadway design safety improvements), and physical comfort. This objective also aligns with the NRSS Safer Roads objective to design roadway environments to mitigate human mistakes and account for injury tolerances, to encourage safer behaviors, and to facilitate safe travel by the most vulnerable road users. This objective will also facilitate evidence gathering related to road configurations associated with the highest risk of pedestrian and cyclist crashes, as identified in the DOT Learning Agenda.

This objective supports activities related to Equity Objective 1: Understand and reduce disparities in safety, comfort, and mobility across demographic groups; Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity; and Trips Objective 2: Encourage more vulnerable road user trips. Designing for safer roadway

[10] House Report 117–99, Departments of Transportation, and Housing and Urban Development, and Related Agencies Appropriations Bill, 2022. July 2021.
[11] The Departments of Transportation, and Housing and Urban Development, and Related Agencies Appropriations Bill, 2022 is Division L of the Consolidated Appropriations Act, 2022 (Pub. L. 117-103).

infrastructure encourages greater comfort in the use of that infrastructure by vulnerable road users, which may result in an increase in the diversity of users and vulnerable road user trips taken. Work under this objective may use data on demographics, volume, perception of facility safety by vulnerable road users, and natural and built environment conditions to understand the infrastructure design needs of safer roadways for vulnerable road users. This data is particularly important to supporting connections between this objective and the Equity, Networks, and Trips objectives on encouraging connected, safe, and comfortable trips for all vulnerable road users.

The FHWA has completed studies related to roadway design improvements that enhance vulnerable road user safety, including the following:

- ***Research Reports:*** ***Street Lighting for Pedestrian Safety*** ***and*** ***Pedestrian Lighting Primer***: The Street Lighting for Pedestrian Safety report focuses on the visibility needs for pedestrians, including both adults and children. The Pedestrian Lighting Primer offers transportation practitioners guidance on lighting design to promote pedestrian safety and recommended minimum lighting levels per level of pedestrian volume.
- ***Enhancing Conspicuity for Standard Signs and Retroreflective Strips on Posts***: This study, conducted under the Traffic Control Device Consortium Pooled Fund in coordination with FHWA's Manual of Uniform Traffic Control Devices (MUTCD) Team, confirmed the appropriateness of standard sign and retroreflective strips treatments for use by transportation practitioners in considering roadway safety design. Data for the project were collected in New Hampshire, Iowa, and Virginia with the following treatments: red flags, beacons, retroreflective strips on posts, sign enlargements, duplicating signs on both sides of roadway, and adding header panels. Results demonstrate mixed changes in behavior across all treatment sites; however, drivers had an increase in glances at the signs where enhancements were made, demonstrating the effectiveness of enhanced treatments in increasing conspicuity.
- ***Improving Intersections for Pedestrians and Bicyclists – An Informational Guide***: The purpose of this guide is to inform the state of the practice concerning intersection planning and design to implement solutions that help achieve the goal of zero fatalities and serious injuries while improving mobility for bicyclists and pedestrians. The primary intersection types discussed in this guide include traditional signalized intersections, roundabouts, Median U-Turn (MUT) intersections, Reduced Crossing U-Turn (RCUT) intersections, Quadrant Roadway (QR) intersections, Displaced Left Turn (DLT) intersections, and Diverging Diamond Interchanges (DDI). This guide also includes discussion about stop-controlled and uncontrolled intersection crossings for bicyclists and pedestrians.
- ***Improving Safety for Pedestrians and Bicyclists Accessing Transit***: This guide is intended for transit agencies, State, local, and Tribal roadway owners, and regional organizations involved with planning and designing transit stops and the roadway, pedestrian, and bicycle facilities that provide safe access to transit.

Emerging and future research to support increased vulnerable road user safety through roadway design improvements focuses on several areas. The FHWA may further develop research on

roadway lighting, aesthetic treatments, nonmotorized signal timing, pedestrian and bicyclist safety countermeasures, improving safe access to transit for bicyclists and pedestrians, and areas of bicycle and motor vehicle conflict on the road, including bicycle signal conflicts with turning vehicles and counter-flow bike lane placements. Additional research is needed in quantifying safety benefits to vulnerable road users of roadway design features, such as street trees. This research will support enhanced visibility of vulnerable road users on the road; identify specific improvements that are proven to increase safety conditions for vulnerable road users; inform practitioners of roadway design treatments that promote greater equity among the various types of vulnerable road users; promote best practices for multimodal safety; develop safety performance factors; and ensure connectivity to broader transportation networks and access to public transportation. Ongoing and planned projects that support these areas of research include:

- ***Pedestrian Safety on Urban Signalized Arterials: Learning from the Australasian Safe System Approach***: The purpose of this study is to examine noteworthy approaches and innovations used by other countries to achieve reductions in pedestrian fatalities, with a particular focus on urban, signalized arterials. This global benchmarking study featuring a visit to Australia and New Zealand aims to identify proven practices, policies, approaches, and innovations that could be successfully applied in the U.S. to reverse the trend of increasing pedestrian fatalities and serious injuries.
- ***Effective Selection of Crosswalk Design***: This study includes field research to help identify contexts in which high-visibility crosswalk designs may improve safety for pedestrians, with plans to produce a guidebook for practitioners on crosswalk design policies.
- ***Evaluation of Aesthetically Treated Crosswalks***: This study assesses the impact that aesthetically treated crosswalks have on drivers and pedestrians (including pedestrians with low vision), the recognition of crosswalks by all roadway users, and behavior at crosswalks by both drivers and pedestrians.
- ***Complete Streets Safety Analysis***: This study identifies how multiple roadway countermeasures, as measured through CMFs, work in concert to improve safety for vulnerable road users through a Complete Streets treatment, produces case studies, and prepare recommendations for practitioners.
- ***Guide for Maintaining Active Transportation Facilities for Enhanced Safety***: Active transportation facilities require maintenance, similar to highway and roadway facilities, to maintain safe and dependable access. Neglected active transportation facilities discourage use because comfort is a major consideration for people walking or rolling on sidewalks and riding in bike lanes. This work provides information and highlights exemplary and effective practices for maintaining active transportation facilities.
- ***Highway Safety Manual Guidance on Pedestrian and Bicyclist Countermeasures***: This activity involves further research to develop enhancements for CMFs and/or Safety Performance Functions (SPFs) for additional facilities and countermeasure types not addressed by NCHRP Project 17-84.
- ***Development of Pedestrian-Intersection Countermeasure CMFs***: This study includes the development of CMFs for treatments and strategies that could be applied at

intersections for the convenience and safety of pedestrians. Specifically, this project assesses the geometric design of intersection corner radii to determine and characterize the resulting crash frequency and severity.

- ***Development of CMFs for Separated Bicycle Lanes (SBLs)***: The project considers the safety effectiveness of separated bicycle lanes, sometimes known as a protected bicycle lane, where the bicycle lane is separated from motor vehicle traffic with a spatial buffer or with a vertical barrier such as a flexi-post. The findings from this study support the development of a CMF for converting a traditional bicycle lane to a SBL with flexi-posts. The project is ongoing; however, the completed analysis resulted in a CMF for SBLs that have a blended vertical element located in the buffer area.
- ***Bollard Lighting for Pedestrian Crosswalks***: This study will investigate the feasibility of a bollard-based fluorescent lighting system mounted at the ends of a crosswalk and oriented to provide vertical illumination on pedestrians in the crosswalk as an approach to improving pedestrian visibility with reduced costs. Phase I of this effort will include closed road experiments and Phase II will consist of field validation of the results.
- ***Can Landscaping Reduce Crashes on Lower Speed Urban Roads***: This project will study the effects of landscaping on traffic safety, including on lower speed urban roads. The expected benefit of the project would be consistent information and messaging on landscaping recommendations for safety and environment disciplines.

Safety Objective 2: Manage vehicle speeds to improve vulnerable road user safety

Unsafe motor-vehicle speeds are a well-documented and understood factor in roadway death and injury, especially for vulnerable road users. Speed limits frame expectations for drivers and vulnerable road users, and should be set to provide a safe, consistent, and reasonable speed to protect people walking, biking, or rolling along the roadway. Safer speed is a cross-cutting issue that involves roadway design, infrastructure interventions, speed limit setting, education, and enforcement. This objective describes research needed to directly demonstrate the impacts of speed management efforts for vulnerable road users and speed management implementation approaches.

Research under this objective directly addresses the requirement in Section 11122(b)(2) of BIL to prioritize research on *the impacts of traffic speeds on safety*. Research areas determined by the Administrator pursuant to Section 11122(b)(4) of BIL related to initiatives under this objective include technology and innovation, planning and policy development, and data and methods.

Through the NRSS, the Department has committed to:

- Developing and improving the information available for setting speed limits through Proven Safety Countermeasures and the MUTCD, providing a range of methodologies depending on the context of the roadway;
- Clarifying the applicability and correct use of key criteria used in setting speed limits, such as the 85th percentile method; and

- Providing technical assistance to all sizes of communities to determine appropriate speed limit setting, considering external assistance from leading practitioners and research organizations.

By relating vehicle speed conditions to the design of roadway infrastructure, this objective builds upon the research activities in Safety Objective 1: Increase vulnerable road user safety through roadway design improvements. Additionally, Trips Objective 2: Encourage more vulnerable road user trips, is supported by this work by facilitating more comfortable speed conditions on mixed-use roadways. Facility design data supporting research under this objective also contributes to the other Safety objectives, as well as the Trips objective to encourage more vulnerable road user trips by highlighting the physical infrastructure conditions that promote or hinder safe travel speeds.

The FHWA has completed work in alignment with this objective, including development of a ***Traffic Calming ePrimer***: This guide incorporates noteworthy new practices and research findings concerning traffic calming and addresses specific topics such as mid-block crossings and community connections.

Emerging and future research supporting management of vehicle speeds to improve vulnerable road user safety is consistent with the Safe System Approach. Because of the role of speed in fatal crashes, FHWA is providing new resources on the setting of speed limits and on re-engineering roadways to help "self-enforce" speed limits. The FHWA will work with NHTSA to study and develop resources on slowing streets for pedestrian safety in high pedestrian traffic areas. Additional future research under this objective deals with speed-related technologies and enforcement measures; specifically, the enforcement of speed limits and the use of technology, like speed safety cameras or vehicle speed controls. While there is speed safety camera guidance under development, additional research related to this technology is necessary for equitably achieving comfortable, safe roadway conditions for vulnerable road users. The following list reflects ongoing and planned projects that support this research direction:

- ***Safe System Approach for Speed Management***: This informational report aims to help practitioners understand the impacts of speed on traffic safety and explore linkages between speed management and the Safe System Approach by introducing a five-tiered Safe System Approach for Speed Management Framework, including key illustrative examples in the form of domestic and international case studies.
- ***Update to USLIMITS2***: This web-based tool helps practitioners set reasonable, safe, and consistent speed limits for specific segments of roads and takes pedestrians and bicyclists into consideration. This tool is applicable to all types of roads. The FHWA is currently developing additional resources related to this tool and is updating the tool under NCHRP 03-139 "Next Generation of the USLIMITS2 Speed Limit Setting Expert System."
- ***Methods and Practices for Setting Appropriate Speed Limits for All Roads and Streets***: The purpose of this project is to provide a single, comprehensive source of information on a variety of different approaches to determining appropriate posted speed limits that are safe for all road users, covering the advantages and disadvantages of different approaches.

Safety Objective 3: Develop tools and methods to assess safety impacts to vulnerable road users

Many agencies struggle with having little to no multimodal exposure data, and no well-accepted national method exists for estimating vulnerable road user demand. Tools and methods to assess safety impacts to vulnerable road users are needed when assessing these data to make planning decisions for vulnerable road users. Additional tools and methods to assess vulnerable road user safety may include emerging technologies and effective collaboration processes for data sharing. The FHWA is working to gather and analyze additional information on vulnerable road user risk to inform decision making on infrastructure and other safety interventions. Assessing risk requires accurate data on the locations and volume of people walking, biking, or rolling (i.e., exposure data), which in turn requires volume counts and an inventory of the active transportation network. These data may also be relevant in accomplishing Trips and Networks objectives that relate to improved data collection processes to measure vulnerable road user trips.

Research initiatives relevant to developing tools and methods to evaluate vulnerable road user safety impacts address Section 11122(b)(3) of BIL, which requires this plan to prioritize research relating to *tools to evaluate the impact of transportation improvements on projected safety of bicycling and walking*. Research activities under this objective will also support several research areas determined by the Administrator pursuant to Section 11122(b)(4) of BIL, including equity, data and methods, planning and policy development, and technology and innovation. This objective will also facilitate evidence gathering related to road configurations associated with the highest risk of pedestrian and cyclist crashes, as identified in the DOT Learning Agenda.

Initiatives for developing tools and methods to assess safety impacts to vulnerable road users under this objective are aligned with the research initiatives for Trips Objective 1: Improve data collection and measurement of vulnerable road user trips. Particularly, the Trips project "Enhancing Vulnerable Road User Detection and Volume Data Through Advanced Imaging Techniques" supports this safety objective by evaluating emerging technologies for their appropriate usage in collecting vulnerable road user exposure data. This safety objective is also strengthened by the Networks Objective 1: Enhance vulnerable road user data collection; while this safety objective focuses on the individual vulnerable road user experience and the networks objective emphasizes impacts for vulnerable road users within the full network, these research areas combined can contribute to a comprehensive understanding of safer conditions for vulnerable road users.

As part of the Safety Data Initiative, the Department will continue exploring ways to integrate existing data and new "big data" sources to conduct predictive analysis on vulnerable road user safety.[12] The Department will continue collaboration across its Operating Administrations to leverage new and existing data sources (including, for example, the Fatality Analysis Reporting System (FARS), Crash Investigation Sampling System (CISS), Crash Report Sampling System (CRSS), Centers for Disease Control and Prevention (CDC) Vulnerable Populations Tool, National Emergency Medical Services Information System (NEMSIS), NHTSA Electronic Data Transfer program, Highway Performance Monitoring System (HPMS), Highway Safety

[12] The DOT Learning Agenda identifies this among other evidence-building activities related to pedestrian and cyclist safety.

Information System (HSIS), and the Applications of Enterprise Geographic Information Systems for Transportation (AEGIST) Pooled Fund Study).

The FHWA has completed work relevant to this objective, including the following sample projects:

- ***Update to the Pedestrian and Bicyclist Safety Crash Analysis Tool (PBCAT) Version 3.0***: The PBCAT is an open-access software application designed to assist State and local pedestrian and bicycle coordinators, planners, and engineers in addressing pedestrian and bicyclist crash problems.
- ***Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists and Areawide Exposure Tool***: This guide describes scalable risk assessment methods for pedestrians and bicyclists, wherein risk is a measure of the probability of a crash to occur given exposure to potential crash events. This guide outlines eight sequential steps to develop risk values at various desired geographic scales and describes the scope and nature of each step, including guiding principles. The Areawide Exposure Tool supplements the guide, making it easy for practitioners to obtain and summarize nationwide travel survey data to estimate pedestrian and bicyclist exposure to risk at Statewide and Metropolitan Planning Organization (MPO) area scales.

Emerging and future areas of research will expand on and update these initial efforts to develop tools and methods that evaluate safety impacts to vulnerable road users. For example, FHWA may collect and assess data on vulnerable road user interactions with ADS, develop improved methods to project vulnerable road user demand, assemble comprehensive Complete Streets measures, and provide practitioners analytical tools for identifying and prioritizing vulnerable road user safety interventions. Measuring the benefits of implementation for HSIP related projects is another area of research to be developed under this objective. The FHWA will partner with NHTSA to study additional tools and methods, such as measuring pedestrian exposure using electronic devices and completing an in-depth crash investigation study for vulnerable road users. Projects related to these emerging and future research areas that are ongoing or planned include:

- ***Third Generation Simulation (TGSim) Data: A Closer Look at the Impacts of Automated Driving Systems on Human Behavior***: The FHWA will collect data on the 23rd Street NW Arterial on the George Washington University Campus using Closed-Circuit Television (CCTV) cameras on tall campus buildings. This project uses object detection to monitor and track pedestrian metrics, such as position and velocity, across five city blocks. This project will contribute to future research on the interactions between vulnerable road users and automated vehicles as compared to interactions between vulnerable road users and conventional vehicles.
- ***Methods to Estimate and Forecast Pedestrian and Bicyclist Demands to Support Safety Investments and Guidance on Crossing Locations***: This activity involves developing and testing planning-level demand estimation methods suitable for individual projects and integrating pedestrian and bicyclist demand estimation into regional models to demonstrate potential applications for active transportation project evaluation. Related to

this work is an ongoing effort to develop crash exposure estimation methods for nonmotorized trips for systemic safety applications. This activity involves conducting case studies and implementation assistance demonstrating how to obtain count data, demand estimates, conflict data, or a combination of these and other data to estimate pedestrian and bicyclist crash exposure for individual projects and larger systems or networks.

- ***Complete Streets Performance Measures Identification Project***: This project aims to develop an agency-wide strategy to coordinate the identification, collection, and use of pedestrian, bicycle, and transit volume, infrastructure, crash data, and many other performance metrics. This initiative seeks to improve the understanding of multimodal safety and connectivity needs as well as equity and climate impacts and will create an inventory of existing and needed research projects and activities in this area.
- ***My Street Pedestrian Crash Tool***: My Street is a web-based, sketch-level planning tool to address pedestrian crashes using a systemic approach. The application is proposed to use a person-based perspective of risks, based on various contexts, and the potential benefits of safety countermeasures. My Street will provide transportation professionals with visuals to communicate the impact of safety improvement options to decision-makers and the public. My Street is proposed to use local crash and roadway data, to automate systemic analysis, and to create maps showing priority locations for safety improvements.
- ***Improving Road Safety for All Users on Federal-Aid Projects***: This project will use information gathered through the "Improving Road Safety for All Users on Federal-Aid Projects" Request for Information (RFI), released in January 2023, and other efforts to develop an informational report and outreach and communications materials and resources on how to consider and integrate safety into all Federal-Aid programs and projects.
- ***Expanding the Compilation and Evaluation of Motorized and Nonmotorized Crash Data in Identifying Safety Needs***: An NCHRP project is investigating motorized and nonmotorized crash data to identify safety needs. As of 2023, there are 46 States that have nonmotorized, pedestrian, and/or bicycle emphasis areas in their Strategic Highway Safety Plans under the HSIP.

Safety Objective 4: Increase vulnerable road user safety through emerging technologies

Future generations of vehicles may increasingly incorporate emerging technologies that may prevent certain crashes from occurring and mitigate the severity of harm caused to vulnerable road users when a crash does occur. Emerging vehicle technologies may include vulnerable road user protection systems and driver assistance technologies such as pedestrian automatic emergency braking, adaptive driving beam (ADB) headlighting systems, and lane keeping assistance to benefit vulnerable road users (such as those using bike lanes). Additionally, emerging micromobility technologies may have impacts on vulnerable road user safety, especially with respect to user conflicts (e.g., micromobility devices vary considerably in size, weight, and speed, and they share space with other vulnerable road users on the roadway).

Connected vehicle technologies are equipment, applications, or systems that use V2X communications to address safety, system efficiency, mobility, equity, and sustainability on our roadways. Connected vehicle technology allows for communication between conventional vehicles, automated vehicles, infrastructure, and vulnerable road users which can serve to protect vulnerable road users by increasing their detection and driver awareness of their presence. Connected vehicle technology can also aid vulnerable road users by alerting them to and increasing their awareness of traffic scenarios and hazards. Through prior research, FHWA has proven that connected vehicle technology, specifically the application of interoperable V2X communications capabilities using the 5.905 – 5.925 GHz spectrum frequency band, is effective in protecting vulnerable road users and drivers. The FHWA and the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) will be providing technical assistant to state and local agencies to support V2X based vulnerable road user system deployments. There is still opportunity to conduct additional research to reduce the cost of implementing connected vehicle technology and advance the use and deployment of the technologies, such as through the DOT Intersection Safety Challenge under Safer Roads actions for the NRSS.

Vehicles equipped with ADS technology offer several potential benefits to the transportation system beyond that which can be achieved with conventional vehicles. However, additional research is needed to address the following potential concerns related to how these vehicles and/or systems will interact with vulnerable road users.

- There are limits to these vehicles' vulnerable road user detection abilities that may put vulnerable road users at risk;
- The locations where ADS-equipped rideshare and delivery vehicles pick up and drop off passengers and goods have the potential to be new points of ADS-vulnerable road user conflict;
- Vulnerable road users may be unaware of the type of vehicle they are interacting with (ADS-equipped, CDA-capable, or conventional); and
- Vulnerable road users may overestimate the detecting capabilities of ADS-equipped vehicles and make risky street crossing decisions.

Emerging technologies and their relationship to vulnerable road user safety is a research area determined by the Administrator pursuant to Section 11122(b)(4) of BIL. Research activities under Networks Objective 1: Enhance vulnerable road user data collection and Equity Objective 1: Understand and reduce disparities in safety, comfort, and mobility across demographic groups are supported by this safety objective. An improved understanding of how emerging technologies impact vulnerable road users differently across demographic groups may also highlight the extent to which such technologies exacerbate or mitigate disproportionate harms. Data that would support this and related objectives include demographic data, facility condition data, and data on the natural and built environments.

This objective is also related to two other BIL requirements:

- Section 11504 of BIL directs the DOT to study the existing and future impacts of self-driving vehicles on transportation infrastructure, mobility, the environment, and safety.

- Section 24219 of BIL directs NHTSA, FHWA, and the ITS JPO to expand vehicle-to-pedestrian research efforts focused on incorporating bicyclists and other vulnerable road users into the safe deployment of connected vehicle systems, including an analysis of the extent to which applications supporting vulnerable road users can be accommodated within existing spectrum allocations for connected vehicle systems.

The FHWA has completed work in alignment with this objective, including the following key project examples:

- ***Tampa Hillsborough Expressway Authority (THEA) Connected Vehicle Pilot***: The objective of the pilot was to use connected vehicle technology to improve safety and mobility of road users in downtown Tampa. A V2X application called Pedestrian Collision Warning (PCW) that detected pedestrians crossing a mid-block crossing and warned approaching equipped vehicles if they were on a crash trajectory with the pedestrian was deployed. Pedestrians were tracked and their trajectory was converted to a personal safety message that was transmitted to the oncoming vehicles via a roadside unit installed at the mid-block. Over the course of the pilot, 21 potential pedestrian crashes were prevented.
- ***Pedestrian Technology Test Bed Phase II Report***: With this work, FHWA presented the development and implementation of a multi-functional Pedestrian Technology Test Bed at the FHWA Turner-Fairbank Highway Research Center (TFHRC), along with a standardized, holistic, and flexible assessment plan strategy. These tools were applied to the assessment of commercially available Vehicle-to-Person (V2P) technologies to identify their strengths and weaknesses and reveal their potential effectiveness for improving pedestrian safety. The test environment supports continued research, testing, and demonstration of connected pedestrian and bicyclist system concepts, standards, applications, and innovative products aimed to maximize road user safety.
- ***Smartphone-Based Mid-Block Pedestrian Crossing In-Vehicle Warning Phase II Report***: The FHWA and ITS JPO developed a V2P smartphone application that allows pedestrians to signal their intent to cross midblock, which triggers an in-vehicle warning to nearby drivers. Previous testing at a closed track with participant drivers indicated that the in-vehicle warning, communicated via a dashboard-mounted smartphone, encouraged drivers to yield at marked midblock crossings. Field tests conducted at three live crossing locations indicated that participants used the application as intended without significant changes in crossing behavior relative to a non-connected smartphone-based alternative.
- ***Integrating Vulnerable Road User Impact Assessments with Vehicle Communication Technologies***: Build on a Small Business Innovative Research project conducted on hardware and software for connected bicycles, FHWA funded a second phase effort called Multimodal Alerting Interface with Networked Shortrange Transmissions (MAIN-ST) to develop the technology to bring bicycles onto V2X networks via a Basic Safety Message for Bicycles (BSM-B).

Emerging and future research will explore the potential role of infrastructure in mitigating concerns around emerging technology and their interactions with vulnerable road users and may investigate the role of augmented reality technology to improve vulnerable road user safety.

The FHWA will ensure that safety and mobility impacts and opportunities for vulnerable road users are incorporated into research and policies on vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), V2P, and V2X communication technologies. The FHWA plans to prioritize ADS-vulnerable road user interaction research needs and implement priority projects related to the following topics: vulnerable road user detection limitations and the potential for infrastructure to support vulnerable road user detection; determining and evaluating new conflict points between vulnerable road users and ads equipped vehicles; vulnerable road user gap acceptance for automated vehicles; and issues related to vulnerable road users interacting within mixed fleets.

The FHWA, in partnership with NHTSA, will support some of these emerging research areas by conducting a literature review on the interactions between automated vehicles and pedestrians and bicyclists, studying the development of an illuminated virtual crosswalk, and studying child safety using optical and V2X digital alerting technology.

Ongoing and planned projects related to this area of research include:

- ***Investigate Key Automated Vehicle Human Factors Safety Issues Related to Infrastructure***: The first study in this project focuses on driver behavior when operating a vehicle with different levels of automation and connectivity while interacting with a bicyclist on a roadway with a dedicated bicycle lane and shared use lane.
- ***Ensuring CDA and Vulnerable Road Users Safety Through Infrastructure***: Phase 1 of this project completed a literature review and gap analysis to determine critical research areas related to how CDA and vulnerable road users will interact. Phase 2 will investigate CDA and bicyclist interactions in a roundabout scenario with a shared lane and a dedicated bike lane.

Equity Goal: Promote equity throughout the transportation planning, design, funding, implementation, and evaluation process

Equity is a research area determined by the Administrator pursuant to Section 11122(b)(4) of BIL. The Department is committed to pursuing a comprehensive approach to advancing equity for all and is taking actions to expand access and opportunity to all communities while focusing on underserved, overburdened, and disadvantaged communities. A central goal of transportation equity is to facilitate social and economic opportunities by providing equitable levels of safe access to affordable and reliable transportation options based on the needs of the populations being served, particularly those that are traditionally underserved. Within the realm of transportation planning for vulnerable road users, equity focuses on ensuring all communities have access to safe, convenient, and comfortable active transportation infrastructure that is well-connected to the broader transportation network, including public transportation. This equity goal supports the Department's mode shift priority and aim of increasing transit ridership, established in the DOT Strategic Plan.

Focusing on equity also supports the purpose of Executive Order 13985, *Advancing Racial Equity and Support for Underserved Communities through the Federal Government*, to address systemic barriers to opportunities and benefits for underserved groups. "Underserved populations" include minority and low-income populations but may also include many other demographic categories that face challenges engaging with the transportation process and receiving equitable benefits.[13] This Vulnerable Road User Research Plan also considers the needs of people with disabilities; older and younger individuals; rural populations; Tribal communities; women; and lesbian, gay, bisexual, transgender, and queer (LGBTQ+) people. Other vulnerable road users of interest who encounter disproportionate harm in the transportation system include those for whom the street is primarily a workplace, such as delivery workers completing trips by bicycle.

Americans with Disabilities Act. The Americans with Disabilities Act (ADA) of 1990 and Section 504 of the Rehabilitation Act of 1973 prohibit discrimination against people with disabilities and ensure equal opportunity and access for persons with disabilities. The ADA requires that public entities and recipients of Federal financial assistance ensure the accessibility of pedestrian facilities in the public right-of-way, such as curb ramps, sidewalks, crosswalks, pedestrian signals, and transit stops in accordance with applicable regulations.

This goal is also in alignment with the DOT Transportation Equity Data and Assessment Tools Research Roadmap. The Equity Research Roadmap identifies opportunities for equity-related research topics across DOT. The roadmap contains two Action Areas that specifically relate to vulnerable road user research: Address Gaps in Data Collection and Measure Equity Outcomes. Relevant research opportunities include the use of passive travel data for equity analysis; filling data gaps on bicycle and pedestrian facilities, travel patterns, and crashes; and developing measures of comfort for people traveling or working in transportation.

This goal will provide evidence for identifying the equity considerations in reducing pedestrian and cyclist crashes and ways FHWA can address disparities in pedestrian crashes through infrastructure solutions, as identified in the DOT Learning Agenda.

The DOT recently conducted a survey of transportation agencies (State DOTs and MPOs) focused on equity in planning and public involvement, and the results of that survey may identify further research and capacity-building needs specific to the consideration of equity in planning and public involvement of projects for people walking, biking, or rolling.

The Equity goal includes research activities that advance equity considerations in transportation planning, programming, and performance measurement. Objectives supporting this goal include:

- Understand and reduce disparities in safety, comfort, and mobility across demographic groups; and
- Integrate equity into the active transportation planning practice.

[13] See FHWA's Environmental Justice Reference Guide for additional information.

Equity Objective 1: Understand and reduce disparities in safety, comfort, and mobility across demographic groups

In alignment with the DOT Strategic Plan direction to reduce racial and gender disparities in transportation-related health and safety outcomes, FHWA seeks to reduce disparities across various demographic groups including Black, Indigenous, and people of color (BIPOC); women; people with disabilities; lower-income people; younger and older individuals; people in rural communities; and LGBTQ+ people. These disparities are often clustered by geography and can be mapped. This means that integrating equity into transportation safety projects is essential when deciding where to apply engineering countermeasures and what measures to implement. Transportation professionals will make more rapid progress toward the goal of zero roadway deaths and serious injuries by addressing the disparate traffic safety outcomes of underserved communities.

The AASHTO CAT research review reveals the following regarding disparities:

- Low-income and BIPOC populations face a disproportionate lack of access to high quality and safe bicycling and pedestrian facilities.
- Poor active transportation conditions disproportionately burden people with disabilities.
- Underserved populations, including those who are BIPOC and/or with lower incomes or who use wheelchairs, are more likely to be involved in pedestrian and bicycling crashes and have more severe injuries.
- Personal safety concerns (including fear of violence and harassment) disproportionately negatively affect women, LGBTQ+ people, and BIPOC, which can lead to reduced participation in walking, biking, and rolling.

Through this objective, FHWA aims to conduct more research to improve data and methods enabling our understanding of how traditionally underserved groups walking, bicycling, and rolling face disproportionate safety, comfort, and mobility impacts. Types of data collected and analyzed under this objective may be related to facilities, perception, demographics, and the built environment. Equity analysis methods can be used to inform work to reduce vulnerable road user fatalities and serious injuries; improve access to multimodal networks; and increase rates of walking, biking, and rolling among underserved groups. It will also inform work under Equity Objective 2: Integrate equity into the active transportation planning practice, Trips Objective 2: Encourage more vulnerable road user trips, and Safety Objective 3: Develop tools and methods to assess safety impacts to vulnerable road users. It may also support other data collection-related objectives as well.

The FHWA has completed limited work in support of this objective, including the following example project, ***The Why and How of Measuring Access to Opportunity: A Guide to Performance Management***. This guide provides State DOTs and MPOs with an overview of the performance management state of practice with a focus on connectivity, multimodal, and livability outcomes.

Emerging and future research in this area may explore impacts to vulnerable road users of historic and present-day investment and disinvestment in active transportation infrastructure, the relationship between bicycle and pedestrian facilities and gentrification, and the roadway safety

needs of people experiencing homelessness or housing insecurity. The impacts, benefits (or potential harms), and outcomes of pedestrian and bicycle investments, particularly for disadvantaged communities, may be understood by assessing access to essential services, opportunities for income and wealth generation, reduction of personal transportation costs, job growth, housing affordability and displacement, and health outcomes. Building on this understanding, FHWA may explore countermeasures and interventions to redress these disparities and prioritize implementation of these countermeasures at project sites that are responsive to the disproportionate fatality and injury impacts, lack of accessible pedestrian facilities for people with disabilities, and poor connectivity that low-income communities and BIPOC experience. The FHWA may also conduct research on accessibility for innovative and quick-build pedestrian and bicycle designs and the equitable application of speed safety cameras. In support of this future research direction, the following are critical ongoing and planned projects:

- ***Pedestrian Safety for Tribal Communities***: This research project includes a systemic safety study that seeks to examine risk factors for pedestrians in rural Tribal settings and to explore transportation planning practices and practical safety strategies for decreasing pedestrian fatalities and injuries in rural Tribal areas.
- ***Tribal Development of Trails and Other Dedicated Pedestrian and Bicycle Infrastructure***: This white paper features trails projects highlighting noteworthy practices that Tribes and their partners use to support the planning and development of trails in Tribal communities. The research provides information and resources for Tribes and Tribal trails champions interested in planning and building dedicated pedestrian and bicycle infrastructure.
- ***Exploring Potential Contributors to Racial and Socioeconomic Disparities in Pedestrian and Bicyclist Morbidity and Mortality***: This project will assess structural causes and potential strategies to address why underrepresented populations are overrepresented as victims in serious injury and fatal pedestrian and bicyclist crashes.
- ***Ensuring Accessibility Around New and Quick-Build Pedestrian and Bicycle Designs:*** This project is reviewing accessibility concerns for innovative new and quick-build pedestrian and bicycle designs and is conducting an experiment with people who are blind in modifying wayfinding cues around quick-build intersection bulbouts. This project will identify critical research needs, and future projects may conduct experiments and recommend new designs to enhance accessibility for all users.

Equity Objective 2: Integrate equity into the active transportation planning practice

An equitable transportation system recognizes the critical role of affordable and reliable transportation in providing access to social and economic opportunities and the travel behavior associated with various demographic groups. Providing more travel choices to all, including bicycle and pedestrian options and active transportation connections to transit, can help the nation to increase access to economic opportunity by meeting the transportation needs of underserved communities. Considering equity throughout the transportation planning process is necessary to develop solutions to the disparities discussed under the previous objective. With this objective, FHWA aims to understand relevant travel behavior and identify best practices,

disseminate information to practitioners, and develop methodologies to enable integration of equity into planning for vulnerable road user safety, comfort, and mobility.

This objective will build on the data-informed understanding developed through the previous equity objective. It may also influence Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity and Networks Objective 3: Integrate vulnerable road user networks into planning, project selection, and workforce development.

The FHWA is partnering with the Federal Transit Administration (FTA) through the Capacity Building Program regarding connections between active and public transportation and equity. The FHWA has completed other work in support of this objective, including the following example project, the ***Shared Micromobility and Equity Primer***. This resource describes actions that local jurisdictions can take to ensure shared micromobility systems enhance equity and includes several successful case studies.

Emerging and future research under this objective will further explore how to incorporate equity into the active transportation practice, including during planning, implementation, and the evaluation of projects. Through this objective, FHWA will pursue research projects that support robust community engagement and respond to stated community needs. In support of the future research direction for this objective, the following critical projects are planned or ongoing:

- ***Use of Shared Mobility to Promote Equity***: Identify and promote ways that shared mobility can help to improve equity in communities throughout the U.S. by integrating bicycle, pedestrian, and transit options for people in all types of communities. Pursue additional research and case studies as needed regarding the safety benefits of shared mobility. Examine linkages between walking, bicycling, transit, and shared mobility, for example, through the provision of bike racks on car share vehicles, the emergence of electric bikes, and accessible (i.e., adaptive) bike share options.
- ***Integration of Access and Safety Across Agencies***: Provide education and technical assistance to non-transportation agencies (e.g., public health, housing, labor, natural resource, and parks and recreation) to encourage integration of pedestrian and bicycle access and safety into their projects and programs that promote equity.
- ***State DOT ADA Transition Plan Implementation Handbook***: This handbook will highlight successful practices in removing pedestrian facility barriers for people with disabilities. State DOTs were surveyed to identify best practices completing ADA self-evaluations, collecting and managing data, communicating with the disability community, and designing and constructing facilities in the public right of way. Accessible pedestrian networks are essential to the ability of all road users to fully utilize transportation services and have access to employment, education, and other opportunities.
- ***Local Public Agency ADA Transition Plan Implementation Handbook***: The majority of pedestrian facilities are located under the jurisdiction of counties, cities, and small towns across the country. They have the same requirements for an ADA transition plan as their State DOTs, but many have limited resources to perform self-evaluations and develop ADA transition plans. Many agencies struggle with implementation due to lack

of technology and expertise. This handbook will comprise best practices used by agencies to effectively utilize the resources they have to remove barriers and create accessible pedestrian networks.

Networks Goal: Achieve safe, accessible, comfortable, and connected multimodal networks in communities throughout the U.S.

Networks are interconnected active transportation facilities—which may include sidewalks, on-street bike lanes, and trails—that help people get where they need to go. Enhancing vulnerable road user connections reduces barriers and increases equitable access to jobs and services for all, especially when nonmotorized networks provide access to transit. The presence of well-connected, complete nonmotorized networks can also play a role in reducing traffic congestion on roadways by enabling local travelers to replace short driving trips with nonmotorized and/or transit trips. Networks may promote modes of transportation that are sustainable and more resilient to climate change as well.

Transit Flex. The FHWA seeks to prioritize safety, mobility, and accessibility for all transportation network users, including pedestrians, bicyclists, transit riders, micro-mobility users, freight and delivery services providers, and motorists. A key goal is to provide an equitable and safe transportation network for travelers of all ages and abilities, including those from marginalized communities facing historic disinvestment. The FHWA encourages consideration of strategies that improve infrastructure for non-motorized travel, public transportation access, and increased public transportation service in underserved communities; and plan for the safety of all road users, particularly those on arterials, through infrastructure improvements and advanced speed management. *Transit Flex* allows funds from certain FHWA programs to be "flexed" to the FTA to fund projects for transit agencies and to be used for transit projects. Transit Flex is relevant to Networks Objective 3: Integrate vulnerable road user networks into planning, project selection, and workforce development.

The Networks goal includes research activities that support assessing network quality, connectivity and use, and developing networks with all types of users and ability levels in mind. Objectives supporting this goal include:

- Enhance vulnerable road user facility data collection;
- Improve measurement and analysis of vulnerable road user network connectivity; and
- Integrate vulnerable road user networks into planning and project selection.

Networks Objective 1: Enhance vulnerable road user facility data collection

Alongside the need for safety-related vulnerable road user data (see Safety Objective 3: Develop tools and methods to assess safety impacts to vulnerable road users), transportation professionals rely on accurate, comprehensive facility data in order to fund, plan, design, construct, and evaluate active transportation facilities and networks. However, few agencies possess a comprehensive, regularly updated database on active transportation facility conditions and operations. Among the agencies that do maintain these types of data, there is variation in collection methods and quality control. Therefore, it is difficult to report the degree of nonmotorized network coverage and to track increases in coverage. Better facility data will eliminate information gaps regarding the nonmotorized network and enable assessment of

facility and network quality in support of Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity.

Through this objective, FHWA aims to address inconsistencies and gaps in nonmotorized facility data collection to ensure agencies are using reliable, up-to-date, and comprehensive facility data to guide decision making. The objective directly aligns with the data and methods research area determined by the Administrator pursuant to Section 11122(b)(4) of BIL, as well as Section 11122(b)(2) of BIL, which requires this plan to prioritize research on the *impacts of access to low-traffic stress corridors on safety and rates of bicycling and walking,* and Section 11122(b)(3), which requires this plan to prioritize research on *tools to evaluate the impact of transportation improvements on projected rates and safety of bicycling and walking*. The objective supports collection of nonmotorized facility and infrastructure data which may lead to a better understanding of limitations or gaps in access to low stress traffic corridors and improve safety and planning at a network scale.

The FHWA has completed limited work in support of this objective, including the following example project, the ***WalkOn™ Mobile Application***. This mobile application enables crowdsourcing of sidewalk condition data for use by practitioners to facilitate pedestrian network planning.

Emerging and future research under this objective may include development of a national repository for pedestrian facility data. The Department's Learning Agenda identifies a need to continue the development of the Model Inventory of Roadway Elements (MIRE) to fully include pedestrian and bicycle infrastructure that improves safety and develop analytics tools that can be used by agencies to identify needs and document progress of bicycle and pedestrian infrastructure. Improvements to MIRE will facilitate more comprehensive research on bicycle and pedestrian networks.

The FHWA is actively pursuing or plans to pursue significant work in alignment with this objective, including:

- ***National Bikeway Network System***: This initiative is under development and will enable agencies to share bicycle facility geospatial data in a uniform manner.
- ***Expanding the Availability and Deployment of Data***: This effort involves building on the ongoing coordinated and comprehensive effort among DOT stakeholders to expand the availability and deployment of data about pedestrian and bicycle network infrastructure. Projects include updating the Travel and Monitoring Analysis System (TMAS) to accept bicycle and pedestrian count data, and revisions to the 2016 Traffic Monitoring Guide to update data definitions.
- ***Bicycle Network Expansion Impact on Safety***: This activity involves conducting research in cities with long-established count programs and a history of bicycle network expansion to identify relationships between bicycle network extent and serious injury/fatality rates.

Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity

Building on Networks Objective 1: Enhance vulnerable road user facility data collection, improved tools and methods to analyze data at a network scale are required to inform evidence-based decision making. The objective directly aligns with the data and methods research area as determined by the Administrator pursuant to Section 11122(b)(4) of BIL, as well as the requirement in Section 11122(b)(3) that this plan prioritize research on *tools to evaluate the impact of transportation improvements on projected rates and safety of bicycling and walking*. Effective measurement and analysis of vulnerable road user network connectivity can help transportation practitioners identify high priority network gaps, implement cost-effective solutions that address multiple needs, optimize potential benefits, and measure the long-term impacts of strategic pedestrian and bicycle investments.

Some improvements have been made to pedestrian and bicycle data collection methods and analysis tools, and research on nonmotorized transportation issues has increased. For example, FHWA published the *Measuring Multimodal Network Connectivity Pilot Grant Report* identifying a range of options available for measuring network connectivity and tracking change over time, covering low stress methodologies.

Key examples of significant work the FHWA has completed in alignment with this objective include:

- ***Evaluation of Level of Service Methodologies***: This effort involved the evaluation of level of service methodologies to incorporate multimodal considerations and include new and emerging bicycle facility types. To further this effort, FHWA published the *Guidebook for Measuring Multimodal Network Connectivity*, which includes fact sheets on bicycle and pedestrian level of service connectivity measures. The FHWA's multimodal connectivity pilot program includes implementation of bicycle and pedestrian level of service analysis.
- ***Manual on Pedestrian and Bicycle Connections to Transit***: The FHWA supported FTA in developing and promoting this guidebook, which covers topics including pedestrian and bicycle access improvement opportunities, station area design, bicycle parking and bike share at transit stations, and more.
- ***Targeted Technical Assistance in Richmond, VA***: The FHWA published a study conducting a bicycle and pedestrian network connectivity analysis around future Bus Rapid Transit stations in Richmond, VA.
- ***Bicycle Network Planning & Facility Design Best Practices in the Netherlands and U.S.***: This effort involved the exploration and application of information generated through international best practices research, building upon a cooperative agreement with the Netherlands. The FHWA also conducted three ThinkBike workshops with support from the Dutch embassy.
- ***Case Studies in Delivering Safe, Comfortable, and Connected Pedestrian and Bicycle Networks Volume II***: This report highlights pedestrian and bicycle network principles and showcases examples from communities across the country.

While the state of the practice is moving forward, there is still a need to mainstream and institutionalize these efforts, especially in terms of network connectivity. To this end, FHWA prioritizes projects and research that improve the measurement and analysis of network connectivity, both through building upon existing methods and evaluation tools, as well as promoting innovation and the development of new analytical tools and methods. The Neighborhood Access and Equity discretionary grant program included in the Inflation Reduction Act includes eligibilities for planning and constructing active transportation networks and spines (23 U.S.C. 177(a)(1)(D)), which furthers the need for supporting agencies in conducting multimodal network connectivity planning and analysis. The Active Transportation Infrastructure Investment Program, authorized by Section 11529 of BIL but not yet appropriated funding, also focuses on planning and constructing active transportation networks and spines.

A future direction for this objective involves continued engagement, future research opportunities, and resource development to support the planning of multimodal networks. Next steps may include hosting peer exchanges or webinars to share noteworthy examples and lessons learned; supporting further research to identify new and validate existing data sources, including the refinement of existing data tools; conducting additional pilots to explore connectivity analysis methods and measures that were only marginally addressed through completed pilot projects such as network density, route directness, and network quality; supporting multimodal network analysis pilots specifically addressing specialized analysis scenarios, such as walk- and bike-sheds around schools or connectivity in environmental justice areas; and establishing a technical-transfer activity to help mainstream the practice of multimodal network connectivity. Key examples of projects currently underway or planned aligned with this objective are:

- ***Complete Streets Modeling Best Practices and Gaps Analysis***: This effort is assessing current capabilities related to the modeling and analysis of Complete Streets. A best practices document will be developed describing how current analysis, modeling, and simulation tools can be applied to Complete Streets. A separate document will be developed to identify where current tools need to be improved in order to better model Complete Streets.
- ***Geospatial Economic Multimodal Transportation System Modeling (GEMS) Complete Street Study***: This study will leverage the GEMS model to analyze the impact of Complete Street policies on transportation network performance, demands for different modes, and different population groups.
- ***Infrastructure Construction Cost and Maintenance Documentation Study***: This effort involves the study of procedures for, and implications of, documenting nonmotorized infrastructure construction and maintenance costs within the context of larger multimodal projects. The deliverable will be a recommended framework for collecting pedestrian and bicycle project costs using a case-study approach. The FHWA's Office of Safety has ongoing research into standard construction cost elements for pedestrian and bicycle facilities.
- ***It's Transportation for All of US (ITS4US)***: The ITS4US Deployment Program is a $40 million multimodal effort to identify ways to provide more efficient, affordable, and accessible transportation options for underserved communities that often face greater

challenges in accessing essential services. The program aims to solve mobility challenges for all travelers with a specific focus on underserved communities. Projects within this program include developing pedestrian data standards, creating software to connect rural and disadvantaged populations to health care, streamlining access to multi-agency transit trips, and furthering the development of accessible autonomous shuttles. This program will enable communities to build local partnerships and develop and deploy integrated and replicable mobility solutions to achieve complete trips for all travelers.

- ***Fostering Innovation in Pedestrian and Bicycle Transportation Pooled Fund****:* This program supports State, MPO, and local pedestrian and bicycle experimentation with, and evaluation of, projects that promote design flexibility, contribute to connected networks, and encourage collaboration.

Networks Objective 3: Integrate vulnerable road user networks into planning, project selection, and workforce development

Active transportation network data, including vulnerable road user volume and infrastructure data, can help guide transportation decision making. While vulnerable road user needs should be considered as part of the planning, prioritization, and selection of transportation projects, barriers to this full integration exist. The objective directly aligns with the planning and policy development research area determined by the Administrator pursuant to Section 11122(b)(4) of BIL. Through this objective, FHWA aims to institutionalize vulnerable road user network considerations in the practice of transportation decision making by informing policy development and advancing established policies like the NRSS, internal and external workforce development, and engagement with research collaborators (e.g., through use of the Transit Flex program).

The FHWA has completed several key projects in alignment with this objective including:

- ***Small Town and Rural Multimodal Networks***: This project provides information, illustrations, and a discussion of how to implement multimodal facilities in a rural context.
- ***Implementing Context Sensitive Design on Multimodal Corridors***: This guide provides an easy-to-use resource that clearly communicates the principles, techniques, and design solutions highlighted in the original Institute of Transportation Engineers (ITE) Designing Walkable Urban Thoroughfares: A Context Sensitive Approach document.
- ***Safety for All Users***: This report provided information to States and MPOs to adopt standards for the design of Federal surface transportation projects for safe and adequate accommodation of all users, focusing on pedestrians and bicyclists.
- ***Bicycle and Pedestrian Transportation University Coursebook***: This coursebook for use in University-level courses has been updated and supports mainstreaming bicycle and pedestrian transportation content.
- ***FHWA Local Public Agency (LPA) Resources***: These informational resources include pedestrian and bicycle content as part of the FHWA Federal-aid Essentials for Local Public Agencies video library, LPA reference material, and the five regional Transportation Workforce Centers. These resources inform local public agencies on how

Federal-aid funds can be used to construct safe, convenient, and accessible walking and bicycling facilities.

- ***Noteworthy Local Policies That Support Safe and Complete Pedestrian and Bicycle Networks***: This resource provides local and state agencies with tools to develop policies that support the development of safe and complete bicycle and pedestrian networks for users of all ages and abilities.

Emerging and future research areas involve further developing and implementing effective outreach strategies and encouraging stakeholders to integrate vulnerable road user network objectives and needs into State and local projects, programs, policies, and other initiatives. For example, FHWA plans to develop informational resources for State, MPO, and local agency staff on conducting pedestrian and bicycle experimentation and evaluation projects, including examples and best practices.

The FHWA is actively pursuing or is planning significant work in alignment with this objective including:

- ***Statewide Pedestrian and Bicycle Planning for Network Connectivity***: This project would update an existing FHWA guide on statewide pedestrian and bicycle planning from 2014 to include recent trends toward incorporating network planning and connectivity analysis into such plans. This guide update would also incorporate contemporary methods of delivering walking and bicycling improvements using a Complete Streets approach and place a greater emphasis on planning for equity in walking and bicycling plans.
- ***Bicycle Facility Information***: The FHWA developed and continues to promote guides to encourage design flexibility and to help agencies determine appropriate types of bicycle facilities, as well as when to integrate transportation and recreational trail infrastructure. An example is the FHWA Bikeway Selection Guide, which is intended to help transportation practitioners streamline the bikeway selection process, accelerate project delivery, foster the development of connected networks, and improve safety for all users.
- ***Sidewalk Selection Guide***: This product will develop contextual information on pedestrian facility dimensions and features and serve as a companion document to the FHWA Bikeway Selection Guide. This work will complement existing new design documents from AASHTO and the U.S. Access Board (Public Rights-of-Way Accessibility Guidelines) to provide a design-focused resource that matches appropriate pedestrian facility design traits to given street and land-use contexts.
- ***National Highway Institute (NHI) Courses***: The FHWA updated the Bicycle Facility Design course to include innovations in bicycle planning and design and converted it to be web-based. A future project will update the NHI Pedestrian Facility Design course to reflect advances in pedestrian transportation planning and design. The FHWA is also creating a course covering Complete Streets topics.
- ***Update Research in Progress (RiP) Database***: This effort involves updating and enhancing pedestrian and bicycle research projects listed in the RiP database. This database and a data-entry system allows users in State DOTs, the DOT, University Transportation Centers (UTC), and other DOT-funded activities to add, modify, and

delete information on their current research projects. Ensuring that the RiP database includes the latest pedestrian and bicycle research[14] will promote awareness and coordination throughout the research process.

- ***Ambassador Program to Integrate and Institutionalize Pedestrian and Bicycle Resources***: The ambassador program trains staff within DOT to spearhead efforts to integrate and institutionalize pedestrian and bicycle resources into ongoing activities such as the Policy Council, Operations Futures Group, Resource Center, Federal-aid Essentials for Local Public Agencies video library, LPA reference material, and via the regional Transportation Workforce Centers, Tribal Technical Assistance Centers, and Federal Lands Highway. This internal workforce development reinforces safety culture within the Department and better positions DOT staff to aid stakeholders in support of NRSS objectives.
- ***Coordination Among Pedestrian and Bicycle Stakeholders***: Enhanced coordination contributes to improved outcomes in the research process and includes coordination on work in progress, needs identification, problem statement development, and project funding. The FHWA has been coordinating with the Transportation Research Board (TRB) Pedestrian and Bicycle Committees and the AASHTO Joint Technical Committee on Nonmotorized Transportation. The FHWA also engages in coordination among pedestrian and bicycle research stakeholders by reviewing and sharing NCHRP comments and through TRB.

Trips Goal: Get more people walking, bicycling, and rolling

Increases in the number of walking, biking, and rolling trips can likely be attributed to several factors including changing attitudes towards nonmotorized transportation, more complete networks connecting origins and destinations and providing access to transit, and improved infrastructure – such as more sidewalks, better bike facilities, Complete Streets, and shared use paths.[15] Proactively and intentionally increasing vulnerable road user trips is an integral part of supporting the Administration's priorities and improving mobility for all people and businesses, access to jobs and essential services for all, resilience for all communities, public health outcomes, and land use decisions.

The Trips goal includes research activities that facilitate increased walking, biking, and rolling trips. Objectives supporting this goal include:

- Improve data collection and measurement of vulnerable road user trips;
- Encourage more vulnerable road user trips; and
- Assess the benefits associated with vulnerable road user trips.

Trips Objective 1: Improve data collection and measurement of vulnerable road user trips

This objective is directly related to Section 11122(b)(3) of BIL, which requires this plan to prioritize research on *tools to evaluate the impact of transportation improvements on projected*

[14] The database contains several relevant projects to pedestrian and bicycle network research, an example of which is "Expanding Mobility Options for All: Optimizing and Extending the Biking Infrastructure to Generate Complete Street Networks in Atlanta."

[15] See the Strategic Agenda for Pedestrian and Bicycle Transportation (pp. 15-17) for more information.

rates of bicycling and walking. Consistent with the finding of the *Complete Streets Report to Congress* that there is a need to "improve data collection and analysis to advance safety for all users," FHWA recognizes that there is a broad need to improve data collection and measurement of vulnerable road user trips to support safety, mobility, equity, and other DOT and FHWA priorities. This objective will also help inform pedestrian and cyclist risk for the benefit of decision making on infrastructure identified in the DOT Learning Agenda.

Data and performance measurement are necessary to guide and evaluate the success of vulnerable road user-focused initiatives. Access to accurate and comprehensive data for active transportation modes helps transportation agencies identify and prioritize projects that will promote safety and access for vulnerable road users, as well as conduct project and program evaluations. Comprehensive vulnerable road user trip data includes information on volume, mode, traveler safety and comfort perceptions, facility, routing, trip generation, demographics, and the natural and built environment. Complete trips data is also relevant to Safety Objective 3: Develop tools and methods to assess safety impacts to vulnerable road users; Networks Objective 1: Enhance vulnerable road user facility data collection; and Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity.

The FHWA has pursued significant work improving vulnerable road user data collection and measurement, including the following completed research projects:

- ***Incorporating Qualitative Data in the Planning Process: Improving Project Delivery and Outcomes***: This report highlighted emerging tools, techniques, and resources for gathering qualitative public and stakeholder input to inform the planning process, improve project outcomes, and contribute to accelerating project delivery. This resource includes examples relevant to pedestrian and bicycle planning.
- ***Guidebook for Developing Pedestrian and Bicycle Performance Measures***: This guidebook was created to help communities develop performance measures that can fully integrate pedestrian and bicycle planning in ongoing performance management activities. It highlights a broad range of ways that walking and bicycling investments, activity, and impacts can be measured and documents how these measures relate to goals identified in a community's planning process. It discusses how the measures can be tracked and what data are required, while also identifying examples of communities that are currently using the respective measures in their planning process.
- ***Example Practices for Performance-Driven Programming Report***: This report highlights how State DOTs and MPOs are implementing performance-driven programming processes and aligning transportation investment decisions with the Federal performance areas for safety, infrastructure condition, and system performance. The guide includes examples of how States and MPOs have applied performance-driven programming to bicycle and pedestrian planning practice.

The FHWA's emerging and future activities under this objective will support bicycle and pedestrian counting initiatives and explore novel data collection methods to collect vulnerable road user data, including video detection, thermal sensors, and passive collection. Uniform national data collection standards (e.g., regarding data formats, geographic scale, and

demographic and infrastructure elements) may enable performance comparisons across States and new analytical methods can incorporate vulnerable road user operations into traditional traffic analyses. New and nontraditional data (e.g., passive datasets) present opportunities as novel sources of information to identify network gaps, prioritize projects, diagnose safety hotspots, assess equity, and measure and forecast route and mode choice changes. However, there are also challenges in leveraging this data to develop insights into vulnerable road user trips. For example, such data may lack transparency around assumptions and methodologies and could be prone to biases, so its use should be coupled with independent data collection and analysis. The FHWA is actively pursuing or plans to pursue projects in alignment with this objective, including:

- ***Guidebook for Statewide Pedestrian and Bicycle Volume Data Programs***: State DOTs and other transportation agencies are interested in establishing reliable and thorough programs to collect, share, and use volume data on where people are walking, bicycling, and rolling. This project would compose a guide for those agencies to establish such programs, and advise on best practices in ensuring data reliability, choosing count locations for full representation, staffing and maintenance concerns, and more.
- ***Enhancing Vulnerable Road User Detection and Volume Data Through Advanced Imaging Techniques Project***: This study aims to improve the collection of vulnerable road user count data to better understand vulnerable road user exposure when involved in a motor vehicle collision. This project specifically tests the ability of thermal infrared sensors and LiDAR sensors to detect vulnerable road users and their count data at intersection and midblock locations by comparing them with high resolution CCTV Digital Video Recorders (DVR) camera feeds.
- ***Pedestrian and Bicycle Counting Initiatives Through Every Day Counts (EDC)***: This effort will include providing technical assistance to agencies for buying counting equipment and establishing effective regional count programs. This will improve data collection to determine rates of bicycling and walking.
- ***TMAS***: This effort will promote TMAS as the national repository of pedestrian and bicycle volume data to track trends, conduct research, and develop the basis for comprehensive performance measurement of nonmotorized modes. This effort will conduct outreach and promotion to encourage agencies to collect and submit pedestrian and bicycle counts to TMAS.

Trips Objective 2: Encourage more vulnerable road user trips

This objective, encourage more vulnerable road user trips, is directly related to the Section 11122(b)(2) of BIL, which requires this plan to prioritize research on the *impacts of traffic speeds, and access to low-traffic stress corridors, on rates of bicycling and walking* requirement. High quality, low-stress active transportation facilities[16] can enhance the personal comfort of vulnerable road users, which in turn can increase participation in active transportation modes. Personal comfort reflects a collection of considerations including a sense of safety from

[16] Logically connected active transportation facilities can also encourage more vulnerable road user trips and are discussed in the Networks goal section of this plan.

motorized traffic, a sense of personal security when using active transportation (e.g., protection against crime or harassment, safe lighting, and sufficient sight distances), and environmental comfort (e.g., protection from excessive heat).

Facility quality is influenced by design and maintenance approaches. Designing to minimum accommodations (e.g., a minimum sidewalk width) may not result in comfortable experiences for vulnerable road users and therefore may limit vulnerable road user trips. Inaccessible pedestrian networks may keep people with disabilities from reaching healthcare, employment and educational opportunities and fully participating in their community. Similarly, the spacing between marked crosswalks may impact vulnerable road user comfort because of how it affects the directness of walking and rolling routes. Maintenance strategies for active transportation infrastructure, including approaches using asset management programs, can sustain facility quality and convenience for improved vulnerable road user comfort and safety.

As the number and types (e.g., form factors, sizes, speeds) of micromobility devices proliferate and provide growing mobility options for more vulnerable road user trips, more research is needed on user safety and street design, the role of micromobility in meeting unmet travel demand for underserved populations, its impact on traveler behavior and mode choice, connections with resilience planning, and parking management implications for vulnerable road users.

Initiatives to encourage more vulnerable road user trips under this objective are directly aligned with research and projects for Safety Objective 1: Increase vulnerable road user safety through roadway design improvements and Networks Objective 2: Improve measurement and analysis of vulnerable road user network connectivity.

An example of significant work the FHWA has completed in alignment with this objective includes the ***Micromobility Research Roadmap***; the purpose of this internal research roadmap was to acquire new insights, better data, and more sophisticated understanding of how States, MPOs, cities, and other jurisdictions can capitalize on the benefits of micromobility while mitigating negative impacts.

The FHWA's emerging and future research under this objective will investigate the impact of low-stress corridors on rates of bicycling and walking, develop mainstreaming methods for local agencies to communicate the safe use of walking and bicycling facilities, provide information on maintaining active transportation infrastructure for enhanced safety, and coordination with NHTSA to collect longitudinal information on bicyclist and pedestrian attitudes and behaviors. In support of this research direction, FHWA is actively pursuing or plans to pursue the following projects:

- ***Guide for Maintaining Active Transportation Infrastructure for Enhanced Safety***: This updated guide will address the needs for pedestrian facility maintenance, common maintenance issues, inspection, accessibility, compliance with repair and replacement requirements and the MUTCD, maintenance measurers, funding, and construction techniques to reduce future maintenance.

- ***Mainstream and Promote Awareness for the Safe use of Walking and Bicycling Facilities***: This project will mainstream methods for local agencies to communicate the safe use of walking and bicycling facilities. This project will ensure vulnerable road users know what to expect before they first encounter new active transportation facilities.
- ***Electric Bicycle Trends, Impacts, and Opportunities Literature Review***: This research project and case study development addresses topics such as ridership trends, safety, physical activity and health, accessibility for people with disabilities, equity, trail infrastructure and environment, energy and emissions, and freight use cases.

Trips Objective 3: Assess the benefits associated with vulnerable road user trips

This objective is directly aligned to the benefits of promoting biking and walking research area determined by the Administrator pursuant to Section 11122(b)(4) of BIL. A significant benefit to explore is the potential to reduce greenhouse gas emissions by increasing use of low- or zero-emission transportation modes such as public transportation, bicycling and walking. The Administration is committed to a whole-of-government approach to reducing economy-wide net greenhouse gas pollution by 2030. The BIL provides considerable resources (e.g., through the Carbon Reduction Program (23 U.S.C. 175)) to help advance this goal in the transportation sector. The BIL also provides resources to improve the resilience of transportation infrastructure (e.g., through the Promoting Resilient Operations for Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Formula Program (23 U.S.C. 176(c)), helping States and communities prepare for hazards such as wildfires, floods, storms, and droughts exacerbated by climate change. The FHWA's goal is to encourage the advancement of projects that address climate change and sustainability in alignment with the President's greenhouse gas reduction, climate resilience, and environmental justice commitments.

Beyond climate and sustainability, there are other benefits associated with increased vulnerable road user trips, such as improved public health outcomes, economic development benefits, and better access to transit. Understanding and measuring these benefits of vulnerable road user trips can enable transportation planners and decision makers to better identify and prioritize transportation investments to improve community and environmental outcomes. This is particularly important given these are nontraditional benefits that may not be included in typical cost-benefit analyses. For example, developing high-quality data can help demonstrate how mode-shift from driving to walking or bicycling trips contributes to climate change mitigation.

The Department has completed limited work in support of this objective, including the following example project, the ***Transportation and Health Tool***. This tool, created in coordination with the CDC, provides data on a set of transportation and public health indicators for each U.S State and metropolitan area that describe how the transportation environment affects safety, active transportation, air quality, and connectivity to destinations. It also provides information and resources to help agencies better understand the link between transportation and health to identify strategies to improve public health through transportation planning and policy.

Future research areas include studying the linkage between walking and bicycling and climate change, greenhouse gas emissions, resiliency, health, stormwater management, emergency evacuation, and economic development. The FHWA aims to continue research to improve

transportation and health connections, and develop consistent, comparable, and compatible datasets across transportation and health related disciplines. The FHWA is actively pursuing or plans to pursue work in alignment with this objective, including:

- ***Intelligent Transportation Systems Climate Solutions for Complete Streets***: This is an exploratory effort to investigate the applicability of ITS and technologies such as digital infrastructure, connected vehicles, automation, and the electrification of the transportation system (e.g., electric vehicles and charging stations) to reduce emissions in a Complete Streets environment. Promising technology applications will be described, and their technology readiness will be assessed. Based on the results, future research activities could be pursued.
- ***Trails as Resilient Infrastructure***: This project explores the role of trails in climate resilience and emergency response under the Recreational Trails Program (23 U.S.C. 206). The study is investigating how trails have supported health and wellbeing during the COVID-19 pandemic, can become critical infrastructure during an emergency when other transportation facilities are inaccessible, can support activities including evacuation and search and rescue, and are often vulnerable to impacts from climate change and extreme weather due to their locations.
- ***Disaster Relief Mobilization Study***: Pursuant to Section 11505 of BIL, this project will study the utility of incorporating the use of bicycles into the disaster preparedness and disaster response plans of local communities. The study will include, among other things required in Section 11505, a vulnerability assessment of the infrastructure in local communities that supports active transportation, including bicycling, walking, and personal mobility devices.
- ***Economic Benefits of Connected Networks***: This project will explore the economic benefits associated with the development and promotion of connected networks (including trails) such as workforce attraction and retention, cost savings from improved public health, and impacts on local businesses.

Section 4. Conclusion

Over the next five fiscal years, FHWA looks forward to furthering research supporting improved safety, access, and mobility for people walking, biking, or rolling. Given the extensive benefits of increasing vulnerable road user trips, DOT and FHWA will continue to leverage opportunities to simultaneously address safety, equity, and climate change and sustainability priorities through vulnerable road user research activities. While FHWA has a long history of advancing vulnerable road user research, there is much work to be done, as articulated through this plan's ambitious safety, equity, networks, and trips goals.

To implement this plan, FHWA will integrate the activities identified herein into FHWA's broader standard research planning and prioritization process through the AMRP and internal and external roadmaps and plans that guide FHWA's research activities. In implementing this plan, FHWA will leverage a long history of strong partnerships and collaborations with other DOT Operating Administrations; Tribes; local, State, and Federal agencies; academic institutions; and private industry organizations to coordinate efforts and benefit from the unique capabilities of each entity to advance shared goals. To evaluate progress toward achieving this

plan's goals and objectives, FHWA will develop biannual updates on the status of activities identified in and findings of research conducted pursuant to this plan.

Appendix A. Source Material Reviewed

The team reviewed the following source material in developing the Vulnerable Road User Research Plan:

- FHWA Complete Streets Questionnaire Summary[17] (July 2022)
- NHTSA Safety in Numbers: A Literature Review (June 2022)
- DOT Equity Action Plan (April 2022)
- DOT Strategic Plan FY 2022-2026 (March 2022)
- DOT Learning Agenda (March 2022)
- Moving to a Complete Streets Design Model: A Report to Congress on Opportunities and Challenges (March 2022)
- Summary Feedback from Vulnerable Road User Safety Assessment Listening Session[18] (March 2022)
- Safe Streets and Roads for All (SS4A) Stakeholder Engagement Documentation[19] (March 2022)
- DOT National Roadway Safety Strategy (January 2022)
- IIJA RFI Responses (December 2021)
- Summary of Public Comments Received on the DOT's RFI on Transportation Equity Data (November 2021)
- Measuring Multimodal Network Connectivity Pilot Grant Report (October 2021)
- AASHTO CAT Research Roadmap (July 2021)
- U.S. Government Accountability Office (GAO) Pedestrians and Cyclists: Better Information to States and Enhanced Performance Management Could Help DOT Improve Safety (May 2021)
- FHWA Pedestrian and Bicycle Safety Program Plan (January 2021)[20]
- DOT Pedestrian Safety Action Plan (November 2020)
- NTSB Safety Research Report Bicyclist Safety on U.S. Roadways: Crash Risks and Countermeasures (November 2019)
- NTSB Special Investigation on Pedestrian Safety (September 2018)
- DOT Strategic Agenda for Pedestrian and Bicycle Transportation (September 2016)

[17] As part of an internal performance management effort, FHWA identified and reviewed Statewide Bicycle and/or Pedestrian Plans and reported effective practices in plan implementation and monitoring to advance safety and accessibility across the highway network.
[18] The FHWA engaged stakeholders from across the transportation industry to provide input on the development of the vulnerable road user assessment guidance required by BIL in 23 U.S.C. 148(l)(7).
[19] The FHWA engaged stakeholders in developing the notice of funding opportunity for the SS4A discretionary grant program.
[20] The FHWA developed the Pedestrian and Bicycle Safety Program Plan as an internal planning and management document.

Appendix B. Relevant Prior Stakeholder Engagement

The matrix below identifies stakeholder engagement reflected in the listed source materials.

Source	Academia	Practitioners - State	Practitioners - Regional	Practitioners - Local	DOT – FHWA	DOT – Other OAs	Other Federal	Private sector
FHWA Complete Streets Questionnaire Summary		•			•			
NHTSA Safety in Numbers: A Literature Review	•					•		
DOT Equity Action Plan			•		•	•		
DOT Strategic Plan FY 2022-2026		•	•	•	•	•	•	•
DOT Learning Agenda						•		
Moving to a Complete Streets Design Model: A Report to Congress on Opportunities and Challenges		•	•	•	•	•		•
Summary Feedback from Vulnerable Road User Safety Assessment Listening Session		•	•	•	•			•
SS4A Stakeholder Engagement Documentation			•	•				•
DOT National Roadway Safety Strategy					•	•	•	
IIJA RFI Responses	•	•	•	•				•
Summary of Public Comments Received on the DOT's RFI on Transportation Equity Data	•	•	•	•			•	•

Source	Academia	Practitioners - State	Practitioners - Regional	Practitioners - Local	DOT – FHWA	DOT – Other OAs	Other Federal	Private sector
Measuring Multimodal Network Connectivity Pilot Grant Report		•	•					
AASHTO CAT Research Roadmap	•	•	•	•	•	•	•	•
U.S. GAO Pedestrians and Cyclists: Better Information to States and Enhanced Performance Management Could Help DOT Improve Safety	•	•			•	•	•	•
FHWA Pedestrian & Bicycle Safety Program Plan	•	•	•	•	•	•	•	•
DOT Pedestrian Safety Action Plan	•	•	•	•	•	•	•	•
NTSB Safety Research Report Bicyclist on US Roadways: Crash Risks and Countermeasures					•	•	•	
NTSB Special Investigation Report on Pedestrian Safety				•	•	•	•	•
DOT Strategic Agenda for Pedestrian & Bicycle Transportation	•	•	•	•	•	•	•	•
Enhancing the Safety of Vulnerable Road Users at Intersections RFI	•	•	•	•	•	•	•	•

Appendix C. Additional Background on Relevant DOT and FHWA Strategies, Plans, and Reports

This Vulnerable Road User Research Plan is consistent with other relevant plans and priorities as articulated by DOT and FHWA leadership.

DOT Strategic Plan for FY 2022-2026

This Vulnerable Road User Research Plan aligns with the Department's Strategic Plan for FY 2022-2026, which established six strategic goals in the areas of safety, economic strength and global competitiveness, equity, climate and sustainability, transformation, and organizational excellence. The Department's strategic goals inform and are supported by the research activities prioritized in this Vulnerable Road User Research Plan.

DOT NRSS

The NRSS (issued January 27, 2022) commits the DOT and FHWA to respond to the current crisis in traffic fatalities by "taking substantial, comprehensive action to significantly reduce serious and fatal injuries on the Nation's roadways," in pursuit of the goal of achieving zero highway deaths. The FHWA recognizes that zero is the only acceptable number of deaths on our roads and achieving that is our safety goal. The NRSS sets a vision and goal for the safety of the Nation's roadways, adopts the Safe System Approach principles to guide DOT's and FHWA's safety actions, advances support for Complete Streets policies to improve road safety, and identifies actions the Department will take in pursuit of five core objectives corresponding to the Safe System Approach elements: Safer People, Safer Roads, Safer Vehicles, Safer Speeds, and Post-Crash Care. The Safe System Approach has six principles: 1) Death and serious injuries are unacceptable; 2) Humans make mistakes; 3) Humans are vulnerable; 4) Responsibility is shared; 5) Safety is proactive; and 6) Redundancy is crucial.

DOT Learning Agenda

The DOT Learning Agenda, released in accordance with the Foundations for Evidence-Based Policymaking Act of 2018 (Evidence Act) in March of 2022, identified four priority questions for evidence gathering related to pedestrian and cyclist safety:

- How can we gather and analyze additional information on pedestrian and cyclist risk to inform decision making on infrastructure and other safety interventions? (NHTSA/FHWA)
- What road configurations are associated with the highest risk of pedestrian and cyclist crashes? (FHWA)
- What are the equity considerations in reducing pedestrian and cyclist crashes? (NHTSA)
- How can FHWA address disparities in pedestrian crashes through infrastructure solutions? (FHWA)

The Vulnerable Road User Research Plan covers a broader range of topics than the four Learning Agenda questions, and will inform future updates to the Learning Agenda.

FHWA Moving to a Complete Streets Design Model: A Report to Congress on Opportunities and Challenges

The report identified five overarching areas of opportunity for FHWA as it moves ahead in its Complete Streets efforts:

- Improve data collection and analysis to advance safety for all users.
- Support rigorous safety assessment during project development and design to help prioritize safety outcomes across all project types.
- Accelerate adoption of standards and guidance that promote safety and accessibility for all users and support innovation in design.
- Reinforce the primacy of safety for all users in the interpretation of design standards, guidelines, and project review processes.
- Make Complete Streets FHWA's default approach for funding and designing nonaccess-controlled roadways.

DOT Research, Development, and Technology (RD&T) Strategic Plan

This plan presents the Department's transportation research priorities and strategies for FY 2022-2026 and beyond. The purpose of the plan is to outline a national transportation research vision to guide America's research priorities and improve coordination of transportation research. It defines the role of the Department's RD&T programs to lead the transformation of our Nation's transportation system in partnership with stakeholders. The plan identifies vulnerable road user safety as a critical research topic.

FHWA Annual Modal Research Plan (AMRP)

FHWA's AMRP is a two-year plan and outlook of FHWA's RD&T efforts. The FHWA FY 2023 – 2024 AMRP identifies several vulnerable road user-relevant research activities and topics, including enhancing vulnerable road user safety; improving roadway designs that meet the needs of vulnerable road users; integrating vulnerable road user analysis into transportation planning and project development; and reducing congestion, improving operations, and enhancing freight productivity to support safety of all users, the efficient movement of people and goods, and equitable mobility.

FHWA Strategic Agenda for Pedestrian and Bicycle Transportation

The Strategic Agenda for Pedestrian and Bicycle Transportation ("2016 Strategic Agenda")[21] is a framework to guide FHWA's pedestrian and bicycle initiatives and investments over a 5-year time horizon. The agenda is an update to DOT's 1994 National Bicycling and Walking Study.

The 2016 Strategic Agenda established a strategic, collaborative approach for making walking and bicycling viable transportation options for people of all ages and abilities in communities throughout the U.S. The agenda articulated goals and supporting actions to promote safe, accessible, comfortable, and connected bicycle and pedestrian networks; ensure the safety of nonmotorized travelers; advance equitable access for everyone to jobs, schools, and essential services; and expand transportation options and choices for all. The 2016 Strategic Agenda is a

[21] The 2016 Strategic Agenda is available publicly.

research and deployment plan identifying 98 actions organized under four goal areas: networks, safety, equity, and trips.

The 2016 Strategic Agenda is oriented around two quantitative goals informing FHWA's pedestrian and bicycle activities:

- Achieve an 80 percent reduction in pedestrian and bicyclist fatalities and serious injuries in 15 years and achieve zero pedestrian and bicyclist fatalities and serious injuries in the next 20 to 30 years.
- Increase the percentage of short trips[22] represented by bicycling and walking to 30 percent by the year 2025. This would be a 50 percent increase over the 2009 value of 20 percent.

The agenda identified 98 actions organized under four goal areas:

- ***Networks***: Achieve safe, accessible, comfortable, and connected multimodal networks in communities throughout the U.S.
- ***Safety***: Improve safety for people walking and bicycling.
- ***Equity***: Promote equity throughout the transportation planning, design, funding, implementation, and evaluation process.
- ***Trips***: Get more people walking and bicycling.

Actions were also characterized by one of four process-oriented types:

- ***Capacity Building***: Providing guidance and educational resources that increase the ability of transportation professionals and advocates to plan, design, fund, build, maintain, and operate bicycle and pedestrian networks.
- ***Policy***: Clearly defining principles, requirements, and desired outcomes for Federal agencies, States, MPOs, localities, transit agencies, and other entities on the use of Federal resources toward advancing bicycle and pedestrian transportation.
- ***Data***: Working with partner agencies to define, collect, assemble, store, maintain, interpret, and use information about bicycle and pedestrian safety and system usage.
- ***Research***: Working with partner agencies to identify and investigate issues that affect bicycle and pedestrian safety and system usage.

A 2021 review of the status of actions identified in the 2016 Strategic Agenda identified that the majority of actions (53) identified in the agenda are in progress, about a third (32) are complete or complete with continuing activities in progress, and 13 actions are not yet started. Example actions from the 2016 Strategic Agenda and 2021 Program Plan highlighting work completed to date, work that is currently underway, and work that is planned for the future are identified in the *Research Priorities* section of this report.

[22] Short trips are defined as trips 5 miles or less for bicyclists and 1 mile or less for pedestrians.

FHWA Pedestrian and Bicycle Safety Program Plan

The Pedestrian and Bicycle Safety Program Plan ("2021 Program Plan")[23] incorporates the Safe System Approach, systemic safety, and equity as overarching themes and has been developed around five primary principles:

- Directly address fatalities and serious injuries through data-driven prioritization;
- Build on the state of research, considering the state of the practice;
- Focus on outreach and implementation;
- Focus on the user; and
- Integrate the Safe System Approach.

The plan organizes proposed activities that FHWA could undertake to improve active transportation safety into five categories:

- ***Research***: Includes basic problem identification, developing methodologies, evaluating technologies.
- ***Guidance Development***: Includes building on research results by developing how-to guides, noteworthy documents, informational guides, or prototype tools for methods, and conducting additional targeted research to complement results.
- ***Awareness and Outreach***: Includes informing practitioners about available guidance, noteworthy practices, and new resources through outreach activities.
- ***Implementation Assistance***: Includes helping agencies put guidance and products into practice through training, case study or pilot implementation assistance, hands-on use of new methods, advanced development of software tools, and standards development.
- ***Mainstreaming***: Includes supporting the widespread use of actions proven to be effective in improving pedestrian and bicyclist safety through activities geared towards integrating safety into agency core practices and standard procedures.

AASHTO Research Roadmap

Topics of particular interest for this Vulnerable Road User Research Plan include accessibility for pedestrians and cyclists with disabilities; connected and autonomous vehicles; bicycle and pedestrian data; economic benefits of walking and bicycling; equity and bicycling, pedestrian travel, and personal safety; micromobility; modeling; and speed management.

[23] The 2021 Program Plan is an internal planning and management document.

Appendix D. Additional Background on Relevant External Research

This appendix compiles recent vulnerable road user research conducted by University Transportation Centers (UTCs) and through the National Cooperative Highway Research Program (NCHRP), as identified in the AASHTO CAT Research Roadmap.

Table D-1. Relevant Current UTC Research

Project Title	Proponent	Brief Description
Exploring Data Fusion Techniques to Derive Bicycle Volumes on a Network	National Institute for Transportation and Communities (UTC)	Research project aimed at fusing traditional and emerging data sources together to derive bicycle volumes for an entire transportation network.
Transportation Equity Needs Assessment Toolkit	Center for Transportation, Equity, Decisions & Dollars (UTC)	A resource for MPOs, transportation agencies, and communities as they work to advance equity in traditionally underserved communities. Provides a framework for a transportation equity needs assessment and an equity-based project identification and prioritization process.
Safe Intersection Crossing for Pedestrians with Disabilities	Mobility21 (UTC)	Addresses remaining obstacles to the general deployment of PedPal, a smartphone app that assists pedestrians with disabilities in safely crossing signalized intersections.
Quantification of Societal Bicycle Impacts (Phase III)	Center for Advanced Multimodal Mobility Solutions and Education (UTC)	Research to identify positive bicycle facility impacts by estimating bicycle facility usage. Usage predictions can form the basis for broad spectrum estimates of bicycle facility impacts upon health, food availability, employment access and ultimately regional sustainability.
Shared Bus/Bike Lane Safety Analysis: Assessing Multimodal Access and Conflicts	Urban Mobility and Equity Center (UTC)	Using video observation and survey data, this study analyzed cyclist safety on shared bus bike lanes as a function of geometric configuration, bus frequency, and level of service.
Estimation of Pedestrian Compliance at Signalized Intersections Considering Demographic and Geographic Factors	Center for Advanced Multimodal Mobility Solutions and Education (UTC)	Study developed estimation models to predict pedestrian compliance at traffic signals as a function of traffic, demographic, geospatial and road design factors.

Project Title	Proponent	Brief Description
Investigating Bicyclist Safety Perceptions and Behaviors at Roundabouts	Mountain-Plains Consortium (UTC)	Characterized and evaluated how bicyclists perceive the safety of roundabouts overall and of specific design and operational characteristics of roundabouts. Research aimed to inform intersection design practices to improve bicycling safety outcomes.
Pedestrian Behavior and Interaction with Autonomous Vehicles	Center for Advanced Multimodal Mobility Solutions and Education (UTC)	Proposed the use of virtual reality as a means to overcome the safety challenges inherent in studying pedestrian-vehicle interactions and focused on identifying any differences in pedestrian behavior when connected and autonomous vehicles are introduced to the traffic stream.
Managing Increased Demand for Curb Space in the City of the Future	PacTrans (UTC)	Research to increase the understanding of existing curb usage and provide new solutions to the individuals and agencies responsible for managing this scarce resource.
Consumer Attitudes and Behavioral Implications in the New Era of Shared Mobility	Center for Teaching Old Models New Tricks (UTC)	Examined attitudes, perceptions, and preferences of user's mobility choices toward dockless bike share and the associated impacts on other modes of transportation as well as the local economy.
Dock-based and Dockless Bikesharing Systems: Analysis of Equitable Access for Disadvantaged Communities	National Center for Sustainable Transportation (UTC)	Evaluated the potential benefits of dockless bike sharing systems to improve accessibility to disadvantaged communities, and to compare them with dock-based systems.
Examining Market Segmentation to Increase Bike-share Use: The Case of the Greater Sacramento Region	National Center for Sustainable Transportation (UTC)	Aimed to deepen understanding of how bike sharing systems could expand opportunities of the most underserved in transportation. Study used data from household and bike-share user surveys in the Sacramento region to perform behavioral modeling and market segmentation.
Mobility for the People: Evaluating Equity Requirements in Shared Mobility Programs	National Institute for Transportation and Communities (UTC)	Documented equity requirements from 239 shared micromobility programs across the U.S. and compiled into an online dashboard, which city officials can use to find what other similar-sized cities are doing.

Project Title	Proponent	Brief Description
Evaluation of Transportation Network Infrastructure, Safety, and Travel Route Characteristics of Bike Share, Electric-Powered Pedal-Assist Bike Share, and Electric Scooter System Operation	Southeastern Transportation Research, Innovation, Development and Education Center (UTC)	Study to establish a better understanding of mobility as a service (MaaS) option to accommodate shared mobility demand.
E-bike sharing and the infrastructure implications and environmental impacts of new technology in transportation systems	Center for Transportation, Equity, Decisions & Dollars (UTC)	Framework towards quantitatively assessing the impact of adopting e-bikes from an environmental and operational perspective.
Driver Behavior in the Presence of E-Scooters within Varying Infrastructure	SAFER-SIM (UTC)	Investigated how transportation infrastructure and e-scooter riding behavior affect driver behavior. In addition, assessed whether driver attitudes can be associated with certain driving behaviors.
E-Scooters and Public Health: Understanding the Implications of E-Scooters on Chronic Disease	National Institute for Transportation and Communities (UTC)	Used the Integrated Transport and Health Impact Model (ITHIM) to perform the first known analysis of E-Scooters on a range of morbidity outcomes. Also investigated the sensitivity of assumptions such as length of walk to reach scooters, parked cars, and other modes.
Impacts of Speed on Dockless Electric Scooter Crashes	Center for Advanced Multimodal Mobility Solutions and Education (UTC)	Based upon safety concerns for riders and pedestrians, the University of Texas implemented an agreement with e-scooter vendors to electronically reduce maximum e-scooter speeds to 8 mph on most of the campus. The study investigates whether the mandatory speed reduction has had any impact on the number of e-scooter involved crashes and their severity.
Micromobility Safety Regulation: Municipal Best Practices Review	SAFE-D (UTC)	Explored what types of regulations municipalities and regions are imposing in an effort to address the safe deployment of e-scooters.

Project Title	Proponent	Brief Description
Understanding micromobility safety behavior and standardizing safety metrics for transportation system integration	Collaborative Sciences Center for Road Safety (UTC)	Explored micromobility safety data and methods to improve injury surveillance.
Barriers and Opportunities for Using Rail-Trails for Safe Travel in Rural, Isolated, and Tribal Communities	Center for Safety Equity in Transportation (UTC)	Explored barriers and opportunities for more effectively using rail-trails for safe travel in rural, isolated, tribal, and indigenous communities. Used crowdsourced data from a fitness app to estimate bicycle volumes on trails.
Assessing the Relative Risks of School Travel in Rural Communities	Center for Safety Equity in Transportation (UTC)	Assesses the rural community roadway environment which introduces several safety challenges for school-aged children, parents, the local community, and commuters, particularly during morning arrival and afternoon dismissal periods when pedestrian and vehicular traffic and pedestrian-vehicle interaction are at its highest.

Table D-2. Relevant Current NCHRP Research

Project Title	Proponent	Brief Description
Measuring Investments and Benefits of Active Transportation Investments When Accomplished as Part of Other Roadway Projects (20-05)	Transportation Research Board	Synthesis program that documents the current state of knowledge and practice on specific topics.
Implementation Support Program (20-44)	Various	Provides funding to facilitate the use of NCHRP research by state DOTs and other transportation agencies.
Legal Studies Program (20-06)	Transportation Research Board	Conducts research on legal issues with highway and transportation projects.
Guidebook on Pedestrian and Bicycle Volume Data Collection (Report 797)	Transportation Research Board	Focused on the broad range of pedestrian and bicycle counters and noted that active transportation count data can be used to monitor facility usage, inform before-and-after assessments to determine facility impacts, monitor travel patterns, inform safety analyses to quantify exposure for interpreting crash data, project prioritization, and multimodal model development.
State DOT Usage of Bicycle and Pedestrian Data: Practices, Sources, Needs, and Gaps (07-31)	Anticipated project	Provides important information on data availability, storage, maintenance, and gaps, and what data agencies need.
Data Visualization Methods for Transportation Agencies (Web-Only Document 226)	Transportation Research Board	Offers another model for a data application tool. Although not specific to active transportation, and focused on the end product of data presentation, the report demonstrates the importance of specialized data skills and effective data presentation.
Safety Performance for Active Transportation Modes using Exposure Models (17-102)	Not yet awarded	Advance the predictive safety performance methodologies for pedestrians, bicyclists, and those using mobility-assistive devices through exposure estimates and prediction models that can be used by state and local DOTs to help evaluate the likely safety performance at a given location. Develop information and resources that can be used to inform multimodal decision-making in different design and land use contexts, and different modal priorities.

Project Title	Proponent	Brief Description
Guidebook for Urban and Suburban Roadway Cross-Sectional Reallocation (15-78)	Kittelson & Associates	Develop a guidebook and decision-making framework for roadway designers, planners, and others for identifying, comparing, evaluating, and justifying context-based cross-sectional reallocations of existing urban and suburban roadway space for multimodal safety, access, and mobility.
Midblock Pedestrian Signal Warning and Operation (03-141)	Texas A&M Transportation Institute	Research focused on when signals are suitable for midblock crossings.
Strategies to Improve Pedestrian Safety at Night (17-97)	Toole Design Group	Research on lighting for shared-use path intersections.
Traffic Signal Design and Operations Strategies for Non-Motorized Users (03-133)	Kittelson & Associates	Developed a guide for traffic signal design and operations strategies that addressed the needs of non-motorized users and increased their respective multimodal connectivity.
Design Options to Reduce Turning Motor Vehicle - Bicycle Conflicts at Controlled Intersections (15-73)	Toole Design Group	Develop information and tools for transportation practitioners to use to reduce turning conflicts between motor vehicles and bicycles at controlled intersections.
Safety Evaluation of On-Street Bicycle Facility Design Features (15-74)	Texas A&M Transportation Institute	Provide practitioners at state DOTs and other transportation agencies with data-driven guidelines for selecting context-appropriate design features for safety improvements to existing separated and non-separated on-street bicycle facilities and for the planning of new facilities.
Warrants for a Pedestrian Traffic Control Signal and for Other Pedestrian Traffic Control Devices (03-143)	Anticipated project	Crossing treatment selection at transit crossings.
Impacts of Active Transportation Network Gaps (08-149)	Alta Planning + Design	Focuses on understanding the causes of gaps in networks, how to complete gaps, and the impacts of completion using a variety of performance measures.
Development of a Manual for Assessing Safety Hardward (MASH) Barrier to Shield Pedestrians, Bicyclists, and Other Vulnerable Users from Motor Vehicle (22-37)	Texas A&M Transportation Institute	Research on barrier selection in select circumstances, including on highway and major arterial locations.

Project Title	Proponent	Brief Description
Motorist behavior and safety impacts on bicyclists from centerline and shoulder rumble strips on high-speed two-lane highways (17-106)	Not yet awarded	Develop a guide on various rumble strip applications, with a focus on their impact on bicyclists' safety.
Valuation of Transportation Equity in Active Transportation and Safety Investments (08-150)	Anticipated project	Develop data-driven tools and guidelines for use by practitioners in safety decision making and in supporting Safe System principles.
Strategies for advancing equity in transportation planning by increasing diversity, equity, and inclusiveness in the transportation planning profession (08-152)	Not yet awarded	Identify meaningful and effective strategies for state DOTs and other transportation agencies to increase and sustain diversity, equity, and inclusion of their transportation planning staff. Strategies will be specific, focused, and designed to foster an inclusive work culture for agencies where DEI in transportation planning is a priority.
Identify emerging approaches for public engagement to meaningfully involve minorities, low-income, and other vulnerable populations (08-161)	Not yet awarded	Develop a manual with practical strategies, processes, methods, and procedures for understanding and establishing meaningful public engagement in transportation decision-making with an emphasis on the engagement of vulnerable communities.
Identify practices and policies to advance social justice and equity into transportation decision-making (08-162)	Thrivance Group, LLC	Identify effective policies, strategies, or actions for DOTs and MPOs that evolve from well-intentioned policy gestures toward intentional approaches and actionable mechanisms, with metrics of accountability, to strategically reduce harms and adverse impacts, and continuously increase equity in future transportation investments, both operational and capital, and for new mobility and innovative technologies.
Practices to Promote Equity in Transportation Funding (Synthesis 53-01)	University of Texas at Arlington	Document state DOT practices to promote equity in programmatic and discretionary funding plans, policies, and processes for both capital and operational projects, potentially through distribution methodologies, formulas, tools, or evaluation criteria.

Project Title	Proponent	Brief Description
Understand how access to employment, health care, education, and other vital needs varies for different population groups in different settings, and methods for effectively assessing mobility and accessibility needs (NCHRP 08-159)	Not yet awarded	Develop a guide that provides specific direction on how to advance equity in accessibility through transportation. Include appropriate analytical and instructional resources for agencies to use to identify gaps in equity of access and determine appropriate transportation solutions to bridge those gaps within their own service jurisdictions.
Crossing Solutions at Roundabouts and Channelized Turn Lanes (Report 834)	Transportation Research Board	Presents guidance on the application of crossing solutions at roundabouts and channelized turn lanes at signalized intersections for pedestrians with vision disabilities.
Guide for Roundabouts (03-130)	Kittelson & Associates	Develop a guide that will serve as the primary source for guidance on all aspects of roundabouts.
Incorporating New Mobility Options into Transportation Demand Modeling (20-102(29))	University of Central Florida	Push non-standard transportation demand modeling forward, including methods that could be useful for pedestrian and bicycling modeling, but will likely leave significant needs for modeling walking and bicycling.
Understand the role of transportation infrastructure investment in gentrification and displacement and identify effective policies and strategies to address these effects (08-160)	Not yet awarded	Develop a guide and supportive resources that provide practical instruction on how to predict, avoid, and mitigate the negative gentrification effects of transportation investment.
Pedestrian and Bicycle Safety Performance Functions for the Highway Safety Manual (17-84)	MRI Global	Developed pedestrian and bicycle SPFs using risk-based or predictive methods, for transportation practitioners at all levels to better inform planning, design, and operations decisions. The research team addressed a broad range of issues related to evaluating pedestrian and bicycle safety such as, but not limited to, analyzing the barriers to collecting pedestrian and bicycle safety performance data and developing performance-based decisions in the United States.

Project Title	Proponent	Brief Description
Estimating Effectiveness of Safety Treatments in the Absence of Crash Data (17-86)	Vanasse Hangen Brustlin	Develop a procedural guide for using alternative measures of safety in the absence of crash data for developing crash modification factors and functions and other quantifiable measures in the absence of crash data. The procedural guide will support informed decision-making during project planning, project development, and other road safety management activities.
How to Measure and Communicate the Value of Access Management (25-47)	University of South Florida	Developed guidance for transportation agencies on identifying and communicating the value of access management at the program, corridor, and project levels. The guidance involves techniques to identify, measure, and assess the benefits and costs of access management using both quantitative and qualitative metrics.
Safety of Vulnerable Road Users in a C/AV Future (20-102(33))	Anticipated project	Explore how vulnerable road users could be protected by C/AV and infrastructure technologies in the absence of user-carried smartphone or wearables (e.g., audio, external vehicle displays).
Dynamic Curbside Management in the Era of CAVs, SAVs, Scooters, Transportation Network Companies (TNCs), and Traditional Vehicles (NCHRP 20-102(26))	Fehr & Peers	Develop a guidebook for state, regional, and local transportation agencies on developing and implementing a dynamic curbside management program.
Micromobility Policies, Permits, and Practices (Synthesis 20-05/Topic 52-13)	University of South Florida (CUTR)	Documents policies, permits, and practices that state DOTs are engaged with in regard to micromobility.