Global Benchmarking Program:

Reducing Pedestrian Fatalities and Serious Injuries on Urban Signalized Arterials

U.S. Department of Transportation
Federal Highway Administration

Office of International Programs
FHWA-PL-22-020

September 2022

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TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. FHWA-PL-22-020	2. Government Accession No. N/A	3. Recipient's Catalog No. N/A
4. Title and Subtitle Global Benchmarking Program: Reducing Pedestrian Fatalities and Serious Injuries on Urban Signalized Arterials		5. Report Date September 2022
		6. Performing Organization Code DOT-VNTSC (VOLPE)
7. Author(s) Jonah Chiarenza, ORCID: 0000-0002-0799-5560 Annisha Borah		8. Performing Organization Report No.
9. Performing Organization Name and Address U.S. DOT Volpe National Transportation Systems Center 55 Broadway, Kendall Square Cambridge, MA 02142		10. Work Unit No. V0323
		11. Contract or Grant No. Intra-Agency Agreement 693JJ318N300015, HW05A1
12. Sponsoring Agency Name and Address U.S Department of Transportation Federal Highway Administration 1200 New Jersey Ave, SE Washington, DC 20590		13. Type of Report and Period Final Report June 2020 – September 2022
		14. Sponsoring Agency Code
15. Supplementary Notes Study Team Leads: FHWA Office of Safety Technology – Mike Griffith, Director FHWA Office of Human Environment – Shari Schaftlein, Director		

16. Abstract

This study illustrates the approach international peers take to reducing pedestrian fatalities and serious injuries on urban, signalized arterial roadways, where the majority of U.S. pedestrian fatalities occur. The study seeks to identify innovations in engineering, policy, and planning that may be successfully applied in the United States. The study findings show that New Zealand is likely the best peer country from which the U.S. can learn, based on a combination of pedestrian safety performance and context similarity. The next best matches are Australia, the United Kingdom, and Canada, followed by the Netherlands, Sweden, Denmark, Finland, and Norway. While there are valuable takeaways from work being done in cities in Brazil and Colombia, the other countries are more suitable candidates across a broader range of criteria. The body of this report provides information about the various achievements of all the countries included in this study in advancing pedestrian and other road user safety. Many innovative practices from these countries should be considered by the U.S. in addition to more detailed learning from a study tour to one or more specific countries.

17. Key Words Pedestrian, safety, arterials, innovation, policy, planning, safe system approach, vulnerable road user, data, technology, design, engineering, international	18. Distribution Statement This document is available to the public.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 70	22. Price N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

FHWA Global Benchmarking Program

Reducing Pedestrian Fatalities and Serious Injuries on Urban Signalized Arterials

Desk Review | July 2022

Executive Summary

Over 50 percent more pedestrians were killed on U.S. roadways in 2021 than in 2010.[1] As of 2019, 64 percent of all pedestrian traffic fatalities occurred on arterial roads. To reduce pedestrian fatalities in the U.S., it is essential to address the challenges facing pedestrian safety on arterials.

Between 2010 and 2019, the latest date for which data are available, nine peer countries in a report by the International Transport Forum (ITF) experienced relatively stable or dropping figures.[2] The goal of this desk review is to identify the most suitable international peer countries to help the U.S. learn strategies to reverse the upward trend in pedestrian fatalities.

Overview

This study is being undertaken by the U.S. DOT Federal Highway Administration (FHWA) as part of the Global Benchmarking Program. FHWA and the U.S. DOT Volpe Center (Volpe) will study the approach international peers take to reducing pedestrian fatalities and serious injuries on urban, signalized arterial roadways, where the majority of U.S. pedestrian fatalities occur. The study seeks to identify innovations in line with the following elements that may be successfully applied in the United States:

- **Innovations, especially in engineering, that improve pedestrian safety** as well as other strategies (evaluation, education, equity, enforcement)
- **Policies that effectively prioritize, standardize, and fund engineering practices** that facilitate integration of new and emerging pedestrian safety strategies
- **Performance-based planning and programming practices** that integrate pedestrian safety into roadway design in coordination with land use

Process

This study includes a desk review (documented by this report) and an international study tour to more closely learn from experts in a subset of the countries included in the desk review. The Study Team is composed of staff from FHWA, Volpe, Virginia and California State DOTs (VDOT and Caltrans), the city of Austin, Texas, and the University of North Carolina at Chapel Hill. The Study Team will select the tour country destination(s), attend the tour, and collaborate to produce a final report documenting findings and making recommendations to U.S. DOT.

Peer Country Evaluation

This desk review documents information about peer countries collected from literature reviews and interviews with over 40 subject matter experts and representatives from eleven countries. Information is presented under six focus area to aid in comparative evaluation of best practices and lessons learned between countries:

1. **Design** – engineering practices, signal design, geometric design
2. **Policy** – documented priorities, data-driven targets, funding protocols and prioritization
3. **Planning** – practices to align project prioritization with need and policy
4. **Technology** – innovations that make solutions feasible, cheaper, and better
5. **Data** – information to measure baselines and targets, and to assess performance
6. **Context** – land use patterns and transportation network attributes

Desk Review Findings

Volpe evaluated the information collected from the literature review and interviews to identify the country(s) that could achieve the best combination of:

- Contextual similarity to the U.S.
- Demonstrated success in improving pedestrian safety

All eleven countries included in this desk review exhibit notable, varied examples of innovation in pedestrian safety. In general, these countries (in the case of South America, selected cities within them) acknowledge the need to reduce vehicle speed as part of a systematic or "Safe System" approach to reducing the risk of pedestrian death or serious injury. European countries frequently integrate pedestrian safety improvements with infrastructure that improves safety and access for people riding bikes. Some countries' multi-national design standards—such as in Australasia—make it easier for engineers to experiment, evaluate, and implement newer infrastructure concepts with less effort. Many countries have national roadway safety policies, and many include time-based, measurable goals to advance pedestrian safety.

Conclusion

Table 1 shows peer country evaluation across the most heavily weighted criteria (see Table 2 for a complete representation of all criteria and focus areas). While these objective rankings mask some nuances, they help to demonstrate that **New Zealand is likely the best peer country from which the U.S. can learn, based on a combination of pedestrian safety performance and context similarity.** The next best matches are Australia, the United Kingdom, and Canada, followed by the Netherlands and the rest of the European countries. While there are valuable takeaways from work being done in cities in Brazil and Colombia, the other countries are more suitable candidates across a broader range of criteria. The body of this report provides considerably more information about the various achievements of all the countries included in this study in advancing pedestrian and other road user safety. Many innovative practices from these countries should be considered by the U.S. in addition to more detailed learning from a study tour to one or more specific countries.

Table 1: Country Comparison Matrix (High Weight Criteria Only)

Key:
- ● Criteria met, above average
- ⊙ Criteria met, average
- ○ Criteria met, below average
- ⊗ Criteria not met

Focus Area	New Zealand	Australia	UK	Canada	Netherlands	Sweden	Denmark	Finland	Norway	Brazil	Colombia
Design											
Increased modal separation	●	⊙	●	⊙	⊙	○	⊙	⊙	⊙	⊙	○
Comprehensive design manuals	●	●	⊙	●	⊙	○	⊙	⊙	⊙	○	⊗
Policy											
Alignment of Federal and State funding and implementation	●	○	●	⊙	⊙	○	○	⊙	○	○	○
Federal road design standards (e.g. Safe System)	●	⊗	●	⊙	⊙	●	⊙	⊙	⊙	⊙	⊗
Planning											
Integrated transportation and land use planning	●	●	○	⊙	⊙	⊙	⊙	⊙	⊙	⊙	○
Published planning framework for speed management	●	⊙	●	⊙	○	●	⊙	⊙	⊙	○	⊗
Standardized safety performance assessment models	○	⊙	○	○	⊙	●	⊙	⊙	⊙	⊗	⊙
Data[3]											
Relatively constant or declining pedestrian fatalities 2010-2017	⊙	●	○	○	●	●	●	●	●	⊗	⊗
Context											
Similar land use patterns to the U.S.	⊙	⊙	○	●	○	⊗	⊗	⊗	⊗	○	○
Similar multilane arterials / transportation network to U.S.	●	●	⊙	●	⊙	○	○	○	○	⊙	⊙

(Source: Author)

Contents

Introduction

This study is being undertaken by the Federal Highway Administration (FHWA), an agency within the United States Department of Transportation (U.S. DOT). It is being conducted under FHWA's Global Benchmarking Program, which serves as a tool for accessing, evaluating, and implementing proven international innovations that can help improve highway transportation in the United States. The purpose of this study is to examine noteworthy approaches and innovations used by other countries to achieve reductions in pedestrian serious injury and fatalities on arterial roadways. This study will identify proven practices, policies, and innovations that could be successfully applied in the United States to make existing and planned urban, signalized arterials safer for pedestrians. The following guiding principles will help the study team identify, document, and recommend adoption strategies for best practices from partner countries:

1. **Identify policies that effectively prioritize, standardize, and fund engineering practices** that facilitate integration of new and emerging pedestrian safety strategies on urban signalized arterials.
    a. **Identify innovations that improve pedestrian safety** on existing, signalized, urban arterials and "new" arterials (this may include both entirely new roads and roads being converted into arterials to carry higher volumes of travelers).
    b. **Focus on engineering innovations** but consider how the other 'Es of transportation safety' (evaluation, education, equity, enforcement) reinforce and/or supplement engineering approaches.
2. **Identify data-driven planning practices that effectively integrate pedestrian safety** considerations into urban signalized arterial projects through a Safe System approach, and in conjunction with performance-based planning and programming that is coordinated with land use planning.
    a. **Data systems that are comprehensive** with strong linkages among key elements with information about contributing factors of pedestrian crashes to facilitate studying their underlying issues; and data to evaluate project and program effectiveness
    b. Approaches used to inform future decision-making about **land use planning to best accommodate safe movement of pedestrians**

Peer Country Evaluation

This desk review documents information about peer countries collected from literature reviews and interviews with over 40 subject matter experts and representatives from each country. Information is presented under six focus areas to aid in comparative evaluation of best practices and lessons learned between countries. The focus areas are broadly defined as follows:

1. **Design** – engineering practices, signal design, geometric design
2. **Policy** – documented priorities, data-driven targets, funding protocols and prioritization

3. **Planning** – practices to align project prioritization with need and policy
4. **Technology** – innovations that make solutions feasible, cheaper, and better
5. **Data** – information to measure baselines and targets, and to assess performance
6. **Context** – land use patterns and transportation network attributes

Table 2 illustrates the relative level of pedestrian safety efforts within each country across specific criteria for each of the six focus areas. The information presented in this table is based on a synthesis of literature review findings and interviews with subject matter experts, including municipal employees, researchers, and consultants with direct knowledge of each country. This report reflects data available in 2019. Most of the statistics are pulled from the International Transport Forum's Road Safety Annual Report 2019 to allow for a high degree of consistency and comparability across countries. More recent data for some countries can be found on the International Transport Forum website.[4] 2020 and 2021 traffic fatality data for the United States can be found on the National Highway Traffic Safety Administration website and shows that pedestrian fatalities have continued to rise.[5]

Table 2: Country Comparison Matrix

Key:
● Criteria met, above average
⭘ Criteria met, average
○ Criteria met, below average
⊗ Criteria not met

*Higher Weight Criteria

Focus Area	New Zealand	Australia	United Kingdom	Canada	Netherlands	Sweden	Denmark	Finland	Norway	Brazil	Colombia
Design											
*Increased modal separation	●	⭘	●	⭘	⭘	○	⭘	⭘	⭘	⭘	○
*Comprehensive design manuals	●	●	⭘	●	⭘	○	⭘	⭘	⭘	○	⊗
Innovations in design	●	○	●	⭘	⭘	○	⭘	●	⭘	●	⭘
Prioritization of safety over flow/VRU prioritization	⭘	⭘	⭘	⭘	⭘	○	⭘	⭘	⭘	⭘	○
Policy											
*Alignment of Federal and State funding and implementation	●	○	●	⭘	⭘	○	○	⭘	○	○	○
*Federal road design standards incl. Safe System approach	●	⊗	●	⭘	⭘	●	⭘	⭘	⭘	⭘	⊗
Federal legislation that supports Vision Zero	⭘	⭘	●	⭘	⭘	●	⭘	○	⭘	○	○
Strong leadership support and buy-in	⭘	○	●	⭘	⭘	●	⭘	○	⭘	⭘	●
Federal vehicle safety regulations	⭘	○	○	○	⭘	●	⭘	⭘	⭘	⊗	⊗
Planning											
*Integrated transportation and land use planning	●	●	○	⭘	⭘	⭘	⭘	⭘	⭘	⭘	○
*Published planning framework for speed management	●	⭘	●	⭘	○	●	⭘	⭘	⭘	○	⊗

*Standardized safety performance assessment models	○	⊙	○	○	⊙	●	⊙	⊙	⊙	⊗	⊙
Technology											
On-board vehicle technology to protect non-occupants	⊗	⊗	○	⊗	⊙	●	○	⊙	⊙	⊗	⊗
Infrastructure technology	○	⊙	○	⊙	○	○	○	○	○	⊗	⊗
Data[6]											
*Relatively constant or declining pedestrian fatality 2010-2017	⊙	●	○	○	●	●	●	●	●	⊗	⊗
Increasing VMT 2010-2017	⊙	●	●	●	●	○	⊙	⊗	⊙	⊗	⊙
Average speed ≤ 50 km/hr on urban arterials	⊙	●	●	⊙	●	●	⊙	●	⊙	⊗	⊗
Pedestrian deaths as a percent of all traffic fatalities 2017	●	●	○	⊙	●	⊙	●	●	●	○	○
Context											
*Similar land use patterns to the U.S.	⊙	⊙	○	●	○	⊗	⊗	⊗	⊗	○	○
*Similar multilane arterials / transportation network to U.S.	●	●	⊙	●	⊙	○	○	○	○	⊙	⊙

(Source: Author)

45 percent more pedestrians were killed in the U.S. in 2019 than in 2010. The UK saw a 17 percent increase between 2010 and 2019. Over the same interval, all other peer countries included in a report by the International Transport Forum (ITF) experienced relatively stable or dropping figures.[7] Figure 1 illustrates the comparative number of pedestrian fatalities across the U.S. and study peer countries. The total numbers of fatalities vary in scale largely based on each country's population. However, the trend shown over the past two decades clearly illustrates the stark difference in performance between the U.S. and study peers. The U.S. fatality count climbed dramatically between 2010 and 2019, while data for peer countries largely exhibit the opposite trajectory, with fatality counts dropping and leveling off.

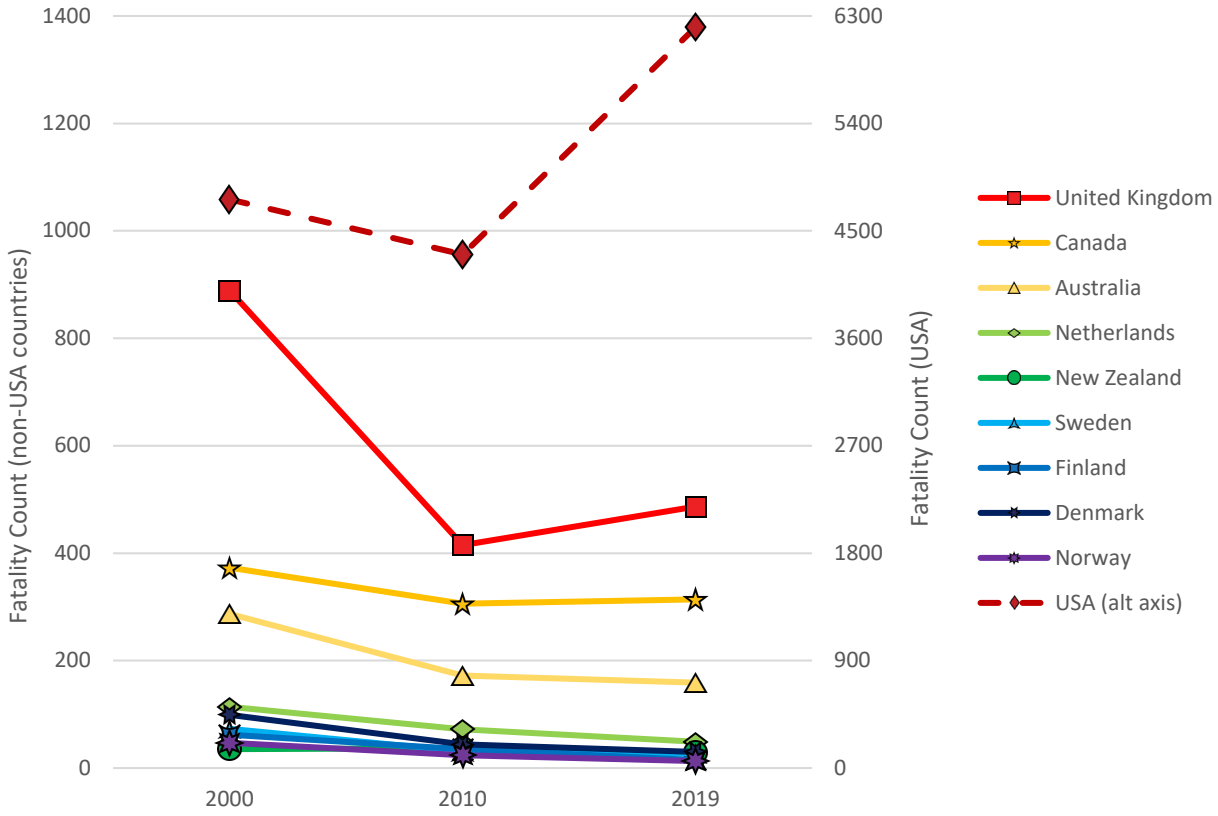

Figure 1: Pedestrian fatality trends 2000 – 2019[8] (Source: Author)

Figure 2 shows the same data, but as a percentage of each country's 2000 fatality count. This shows how the number of fatalities has changed—relative to 2000—as of 2010 and 2019. All countries except the U.S. demonstrate an overall downward trend between 2000 and 2019.

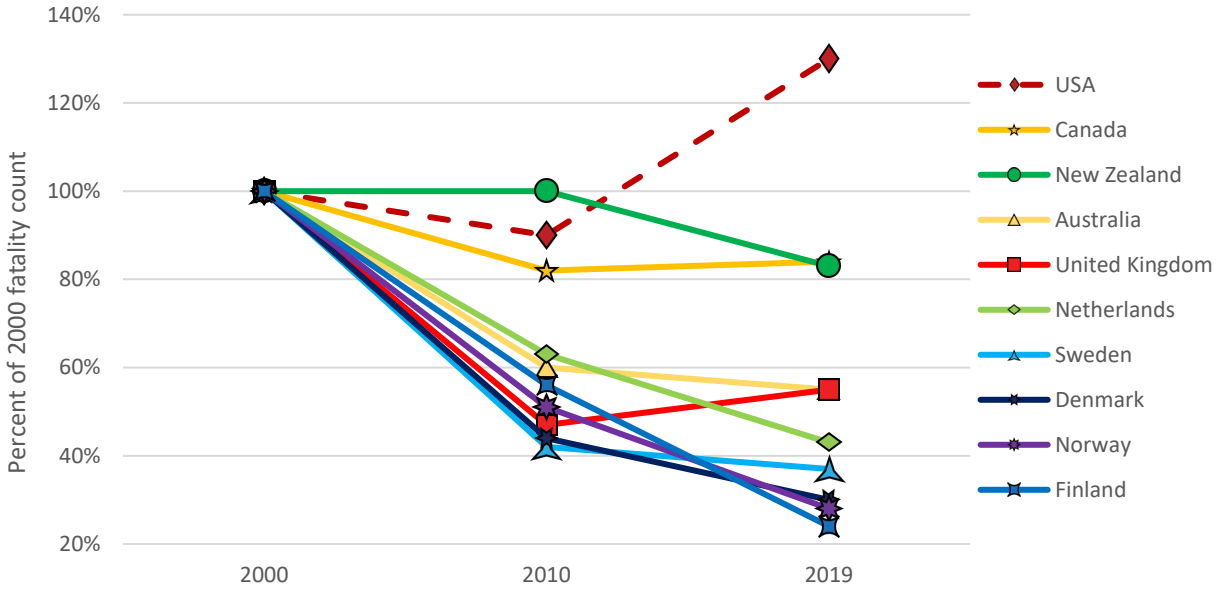

Figure 2: Percent of 2000 fatality count represented by totals over subsequent years (Source: Author)

Domestic Context

Understanding the U.S. context of pedestrian safety on urban, signalized arterials—and on our roadways in general—is critical to identifying best practices from abroad that are most applicable for adapting to U.S. roadways.

Data

According to ITF and U.S. DOT data, the percent change in pedestrian fatalities between 2010 and 2019 was higher for the U.S. than in any other country among those with validated data: the U.S. experienced 45 percent more pedestrian fatalities in 2019 than in 2010. A 2022 analysis by the National Highway Traffic Safety Administration estimates that U.S. drivers struck and killed 7,342 pedestrians in 2021, up 13 percent from the year before.[9] In January 2022, the U.S. DOT published the National Roadway Safety Strategy which outlines the Department's approach to significantly reducing serious injuries and deaths on U.S. highways, roads, and streets.[10]

The U.S. DOT does not have sufficient data to fully comprehend the pre-crash events or other critical characteristics that lead to road user injury or death. The National Highway Traffic Safety Administration's Fatality Analysis and Reporting System (FARS) is the only national census of traffic crash data. Because only fatalities are tabulated at a national scale, this primary research database omits all non-fatal injury collisions, which comprise an estimated 70 times more injuries.[11] While fatalities clearly document very severe crashes, the difference between a serious injury and a fatality can be the result of minor differences in the circumstances of the crash or the condition of the victim. The lack of nationwide data on non-fatal but serious and moderate injury crashes significantly reduces the amount of information available for nationwide roadway safety analysis. Non-fatal but serious injury crashes can be especially significant for pedestrians, bicyclists, and other vulnerable road users who are not protected by a vehicle body. The U.S. also does not have comprehensive national data about infrastructure, which further strains the ability of U.S. DOT or other researchers to understand the connection between roadway design and injury risk. ITF recognizes these challenges are present among most other peer countries and provides summary data using fatalities to benchmark countries' safety performance.

Speed Limits

U.S. State and local governments hold authority over speed limit setting on most public roads.[12] While the 85th percentile speed is not the only factor that State practitioners evaluate when determining speed limits, it is still a common component of speed setting practice.[13] Speed limit setting policies may be restrictive for local governments seeking to reduce speeds based on local conditions. Many infrastructure improvements that increase pedestrian safety, like raised crossings and curb extensions, cannot be included on streets where driver speeds are too high.[14] In addition to reducing the severity of crashes that do happen, reducing speed limits opens the door to many other engineering and design interventions that can further improve pedestrian safety.

Engineering practice can also be an impediment to improving pedestrian safety. It is possible for engineers to build a road for a *target* speed, but to use a *design* speed greater than the target speed to account for speeding drivers. This practice exists apart from—and exacerbates excessive and unsafe speed limits caused by—adherence to the 85th percentile recommendation in the Manual on Uniform Traffic Control Devices (MUTCD) if due consideration is not given to other factors.[15] Note that a proposed change to the next edition of the MUTCD would modify this recommendation to only be applicable to freeways, expressways, and rural highways; however, such facilities are often the urban arterials which are the focus of this report—those with posted speed limits and design speeds that result in traffic speeds that are more likely to cause fatal injuries.[16]

Traffic Control Device Standards and Street Design Standards

The MUTCD and design standards are sometimes conflated, but they are unique and serve different roles. The MUTCD prioritizes national uniformity in traffic control devices. State and local design standards guide the design choices engineers and planners make, which then incorporate traffic control devices—signals, signs, pavement markings—per the MUTCD or a state-adopted version thereof. Practitioners interviewed for this report note that the MUTCD and some design standards can allow engineers to favor traffic operations that minimize vehicle delay, which may result in roadways that optimize vehicle flow over pedestrian safety.[17] Pedestrian and bicycle infrastructure design is evolving as domestic and foreign cities experiment with different approaches to accommodate vulnerable road users. Engineers who are not allowed or encouraged by their agencies or private practices to pursue traffic control device experimentation that deviate from the MUTCD, or design configurations that deviate from established State or local design standards, may not know or feel comfortable implementing such designs without State or Federal guidance. Practitioners noted that engineers may cite MUTCD warrants to defend a reactive approach to road safety. For example, pedestrians or bicyclists may mostly avoid crossing at a given location along a road—because they perceive crossing at that location to be unsafe—despite their desire to make the crossing aligned with a trailhead, a bus stop, or a pedestrian-generating land use. This may result in few or no crashes and low pedestrian volume that fail to meet some of the MUTCD warrant criterion for installing a traffic control signal.

Engineers are allowed to deviate from design standards, using their "engineering judgment" and documenting their rationale based on an engineering study. However, practitioners interviewed for this report note that fear of litigation, time constraints, and professional conventions encourage many engineers to abide by existing standards rather than pursue deviations that may proactively improve pedestrian or bicycle access and safety.[18]

The MUTCD does allow engineers to take a proactive approach to safety as part of an engineering study, by estimating pedestrian, bicycle, and vehicle volumes and anticipating unmet pedestrian demand based on land use. However, practitioners interviewed for this

report note that, as with deviation from design standards, many engineers may not take advantage of this allowance.

FHWA allows experimental treatments under certain circumstances and requires agencies conducting experiments to collect and report data to help inform evaluation of those treatments for potential interim approval and incorporation into future MUTCD updates. However, some practitioners believe that "sufficient" data for new traffic control configurations can be difficult and time-consuming to obtain.[19] Because experimental design interventions in support of vulnerable road user safety are typically limited and/or unique, there is an ongoing dearth of consistent, wide-scale piloting and evaluation of innovation. The subsequent lack of high-quality data documenting those unique traffic control designs' successes and shortcomings delays or prevents innovative measures from being evaluated and potentially incorporated into the MUTCD.

Some States and cities have updated their design manuals to incorporate new pedestrian, bicycle, and transit facility design guidance.[20] The National Association of City Transportation Officials (NACTO) produces a set of national design guides—tailored to an urban context with a focus on pedestrian, bicycle, and transit use—based on the collective input of member cities.[21] U.S. DOT recognized NACTO's Urban Street and Urban Bikeway Design Guides in a 2016 memorandum, and Congress, in the Bipartisan Infrastructure Law, has authorized the use of such recognized design guides by cities and communities on local, federally-funded projects, even without State permission.[22,23] In March 2022, FHWA published "Moving to a Complete Streets Design Model: A Report to Congress on Opportunities and Challenges" to outline the agency's commitment to advancing the widespread implementation of a Complete Streets design model—an approach that prioritizes the safety of all road users.[24]

Federal Funding Mechanisms

Most Federal funding provided to State DOTs is explicitly or implicitly directed to improving asset condition and vehicle and freight flow. These objectives are not aligned with, and may run counter to, improving pedestrian access and safety.[25] The Bipartisan Infrastructure Law (BIL) apportions over $40 billion to the National Highway Performance Program and State Transportation Block Grant Program, while the Highway Safety Improvement Program (HSIP) apportionment totals under $3 billion, and can be used to improve motor vehicle occupant safety in addition to pedestrian access and safety.[26]

BIL does include a new provision under HSIP that requires every State to conduct a Vulnerable Road User (VRU) Safety Assessment; for States where 15 percent or more of the total annual crash fatalities are VRUs, there is a requirement to obligate at least 15 percent of the State's HSIP funding to projects that address VRU safety.[27] Based on 2020 crash data from FARS data, all 50 States and the District of Columbia exceed 20 percent.[28]

Federal discretionary grant funding can be challenging for local communities to access—both because of competition with other grant applicants, and because of the complexity of the

application process and the requirements. Wealthier cities that have bonding capability can raise local, more flexible transportation funding dollars and avoid using Federal money to build their more innovative projects.[29] Indeed, cities like Seattle, San Francisco, and New York are among those with some of the most notable recent innovations in street design. This raises an equity concern, because under-resourced cities, towns, villages, counties, and many rural areas and Tribal Nations, are indirectly penalized by being forced to rely on Federal money that makes implementing innovative projects more difficult.

BIL established the new Safe Streets and Roads for All (SS4A) discretionary program with $5 billion in appropriated funds over the next 5 years. In fiscal year 2022 (FY22), up to $1 billion is available. The SS4A program funds regional, local, and Tribal initiatives through grants to prevent roadway deaths and serious injuries. SS4A is specifically designed to serve cities, towns, counties, and other applicants who do not typically receive direct Federal-Aid. State DOTs are not eligible for SS4A funds, which reduces competition for other applicants.[30]

Land Use and Transportation Context

"Land use" describes the types of development (e.g., residential, commercial, recreational, etc.) and the way it is spread over an area. Land use planning is the process by which the density, the use type, and the location of development in a jurisdiction is guided by local and regional policy. Land use planning has a direct impact on the character and performance of the surrounding transportation network. Lower-density development with more segregation of land use tends to be more auto-oriented. This results in more parking, wider and often faster roadways, and more overall dependence on vehicles for access and mobility. By contrast, denser mixed-use development tends to afford more opportunity for walking, bicycling, and transit use and is less dependent on vehicle use.

In many cities, and certainly in suburban and rural environments, U.S. land use planning has led to low density, auto-dependent environments. This tends to also be true in peer countries like Canada, Australia, and New Zealand. By contrast, peer countries in Europe have higher density environments and multimodal transportation systems. By their nature, these differences have an impact on pedestrian safety, with more auto-oriented environments contributing to higher risk of pedestrian fatalities and serious injury. In looking to international examples for best practices in pedestrian safety, it is important to consider how adaptable various designs, policies, and technologies may be based on their land use and resulting transportation context. Peer countries with a similar land use and transportation context are more likely to provide solutions that can be successfully applied in the U.S.

Vehicle Safety Regulations

As of 2019, the U.S. does not have any vehicle safety standards for non-occupants, and pedestrian safety tests are not included in the New Car Assessment Program.[31, 32] However, the Insurance Institute for Highway Safety (IIHS) has begun testing the performance of vehicles with pedestrian detection-enabled automatic emergency braking.[33] In addition, there is no

regulation of aftermarket vehicle modifications, such as bull bars, which were outlawed in the United Kingdom in 2010.[34] In February 2019, the Insurance Institute for Highway Safety launched its pedestrian ratings of automatic emergency braking systems.[35] They conducted testing on 11 small SUVs and 16 midsize cars. Of those tested, 10 vehicles received superior ratings. The research shows that a growing number of manufacturers are including pedestrian crash prevention systems as standard equipment in vehicles, across luxury and non-luxury brands.

Equity and Enforcement

Black and Hispanic men are four times more likely to be killed while walking than the general U.S. population.[36] Indigenous men are five times more likely to be killed while walking.[37] Most traffic deaths and serious injuries occur in low-income communities and communities of color. It is important to acknowledge and address the role that the transportation system has played in contributing to these inequitable outcomes.

Many cities recognize *enforcement* as one of the four primary "Es" of safety (along with engineering, education, and emergency medical services), which can help to engender safer driving and other roadway user behavior. In 2021, the House Subcommittee on Highways and Transit held a hearing, "Examining Equity in Transportation Safety Enforcement."[38] A summary of the subject matter prepared by legislative staff for this hearing notes that "law enforcement pull over minority drivers at a higher rate than white drivers."[39] Speed safety cameras—which FHWA recently posted as a new proven safety countermeasure[40]—may provide a more unbiased form of enforcement if implemented equitably. However, local opposition has hindered widespread adoption and some practitioners believe this limits scalability.[41]

Australasia

Context

Australia and New Zealand exhibit land use patterns and transportation networks that are similar to that of the U.S. Large single-family residential neighborhoods connect to arterial roads for access to commercial, civic, and recreational uses, which are distributed in a similar fashion to those uses in the U.S. Pedestrian infrastructure consists largely of sidewalks and crosswalks, and bicycling infrastructure is limited or absent on most major roads. While development in New Zealand is limited by topography and protected natural areas, new developments and redevelopment projects occur in both countries and lead to roadway expansion projects, including the creation of "new" arterials from existing 2-lane roads.

Australia

Australia has a federated system of government with six States and two self-governing territories, covering a total area of 2,969,907 square miles. The form of government is a parliamentary constitutional monarchy. In 2020, the population was 25.7 million.[42] The road network comprises 544,267 miles. There are 20.1 million registered motor vehicles.[43]

Design

Austroads[44] provides comprehensive design guidance for application throughout Australia, most notably the fourteen-part *Guide to Road Design* that includes guidelines on geometric design, intersections, and pedestrian and cycle paths.[45] Austroads publications are not government-mandated; however, many State and territory governments adopt Austroads guides into law, making amendments or adding supplemental documents to make the guidance more context-sensitive.[46] Australian States and territories have independent design guides, manuals, and technical publications.

Modal separation is increasingly evident in project design and guidelines. Measures that are highly effective in separating vehicles from vulnerable road users are considered in alignment with the Safe System approach,[47] which was adopted by the Australian Transport Council in 2004.[48] In addition, there is clear prioritization of safety over flow, including on mixed-use arterials. Design guidance states that Safe System interventions could cause significant impacts on traffic operations, which is often the intention of such projects.[49]

Austroads conducted the following case study to evaluate infrastructure improvements that would achieve Safe System outcomes on mixed-use urban arterials.[50] The portion of roadway under review is a 60 km/h undivided two-lane road in Melbourne called Glen Huntley Road. The surrounding environment includes a commercial shopping area, public parks, residential properties, and public transit stops. From 2012 to 2017, 11 pedestrians experienced serious injuries, which are defined as requiring admission to a hospital, and 20 pedestrians experienced minor injuries on this portion of Glen Huntly Road (see Figure 3). A team of researchers, with input from residents, government representatives, and other transportation professionals, identified the following issues on this section of roadway: lack of pedestrian crossing opportunities, lack of cyclist facilities, and outdated streetscape with limited landscaping, among other challenges. The research team developed the proposed design solution, shown in Figure 4, to illustrate how to retrofit this arterial to achieve stronger safety outcomes for pedestrians.

Figure 3. Current conditions of a section of Glen Huntly Road (Source: Google Maps)

The researchers used Austroads' Safe System Assessment Framework (SSAF) to assess the Safe System alignment of the section under current conditions and under the proposed design conditions. The SSAF assesses the impact of infrastructure design and speed management on

potential fatalities and serious injuries. This method of evaluating a roadway is based on exposure and the likelihood of crashes, instead of waiting for actual crashes to occur. This provides a way to defend design interventions in locations that might not have crash histories, but where crashes are inevitable. The safety assessment of the concept design shows a 54% decrease in risk for pedestrians. The research team proposed the following interventions, as shown in Figure 4:

- Raised "speed table" pedestrian crossings (unsignalized)
- Addition of signalized midblock pedestrian crossing
- Textured surface treatments for pedestrian crossings
- Narrowing lanes with addition of pedestrian refuge medians
- Curb extensions with landscaping
- Buildouts at transit stops
- Reduced speed limit and additional signs

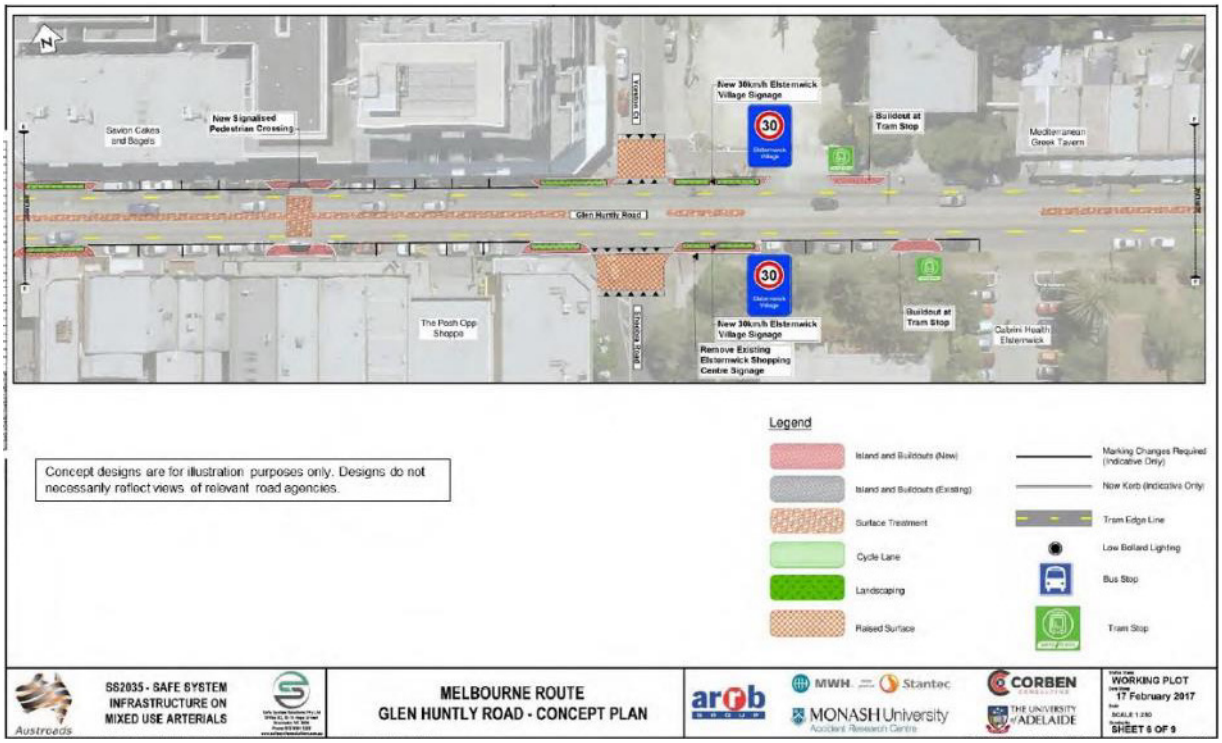

Figure 4. Proposed concept design for a section of Glen Huntly Road (Source: Austroads)

Policy

Various levels of government share the responsibility for road safety.[51] The Federal government regulates vehicle safety standards and allocates investment in infrastructure resources across the national, state, and local road networks. State governments are responsible for funding, planning, designing, and operating the road network. States are also responsible for speed limits, enforcement, driver licensing, and vehicle registration. Local governments have funding,

planning, and operating responsibilities within their jurisdictions. In accordance with this framework, Federal interventions for road safety do not directly involve roadway design.

Austroads develops national guidance on road design, and States and territories then produce their own supplementary material.[52] The National Transport Commission has published a set of model laws called the *Australian Road Rules*, which form the basis of road rules for each State and territory, including the application of the rules and their related offences. These rules have no legal effect, but all States have adopted the rules into their own legislation, at times with some diversion due to the influence of members within the State parliament.[53,54] The *Australian Road Rules* are reviewed every two years. Although Vision Zero concepts are not prevalent in this document,[55] each State has their own Vision Zero plan or strategy.[56] In addition, the *National Road Safety Strategy 2011-2020* represents a commitment by the Federal and State governments to a set of national goals, objectives, and actions that support Vision Zero and the Safe System approach.[57]

Federal legislation does not directly mention Vision Zero, but there is leadership support and buy-in for Safe System concepts. Australia became one of the first countries to formally adopt the Safe System approach when the *National Road Safety Strategy 2001-2010* went into effect.[58] The Australian Government established the Office of Road Safety in 2019 to provide national leadership and coordinate a unified effort to improve road safety outcomes.[59]

The Office of Road Safety funds a number of road safety programs, including the Road Safety Innovation Fund, the Road Safety Awareness and Enablers Fund, and the Road Safety Program.[60] The Road Safety Innovation Fund supports innovative research and development of new and improved technologies and products that enhance road safety under the Safe System approach, including improving pedestrian safety and road design.[61] The Road Safety Awareness and Enablers Fund contributes to reducing road trauma in Australia by conducting road safety awareness, education, and collaboration efforts nationally. Projects target a wide range of road users and road safety issues, such as rural and regional road safety, the impacts of speeding, driveway safety and sharing the road safely with all road users.[62]

The Road Safety Program supports the roll out of road safety treatments on rural and regional roads and greater protection for vulnerable road users, like cyclists and pedestrians, in urban areas.[63] State highways and arterial roads are being upgraded through the application of road safety treatments including shoulder sealing and the installation of rumble strips, to support the safe return of vehicles from the shoulder into the travel lane; physical barriers to prevent run off road crashes; and median treatments to prevent head-on vehicle collisions. Vulnerable road users, including pedestrians and cyclists in urban areas, will see greater protections through road safety upgrades including traffic calming, separated bike lanes, and the installation of raised pedestrian crossings. As a condition of funding, States and territories are required to provide road safety data and report road safety metrics.

Federal vehicle safety regulations are anchored by the Australian Design Rules, which are the national standards for vehicle safety. These rules ensure a minimum level of safety, environmental, and anti-theft protection.[64] The Australian Government, State governments, and automobile associations fund the Australasian New Car Assessment Program (ANCAP), an independent vehicle safety performance assessment program providing credible independent information for consumers. ANCAP safety ratings are closely aligned with Euro NCAP tests and protocols.[65] Vulnerable road user (VRU) protection is one of the four key areas that the ANCAP safety rating system evaluates. ANCAP assesses VRU protection through the design of the front of the vehicle and a vehicle's ability to actively avoid or mitigate impacts with pedestrians or cyclists.[66] Refer to the Technology section for more information concerning vehicle and infrastructure technology.

Planning

The Transport and Infrastructure Council has published a National Road Safety Strategy for every decade, starting in 1992.[67] The *National Road Safety Strategy 2011-2020* integrates the Safe System approach and directly supports Vision Zero, although not by name. The safety strategy, accompanied by three-year action plans, integrates transportation and land use planning and outlines the steps needed to improve road quality, strengthen regulations to promote safer vehicles, and create a culture of safety throughout the country. The safety strategy for 2021-2030 seeks to strengthen the connection between high mobility locations in relation to the road network under a Movement and Place Approach.[68]

Austroads has published guidance for speed management, providing a range of recommendations for effective speeding interventions, case studies that identify best practices, and a web tool that allows practitioners to assess road safety risks due to the speed limit setting process.[69] Some States and territories have their own speed management guidance as well.[70]

The *Australian Transport Assessment and Planning* (ATAP) *Guidelines* provide a comprehensive framework for planning, assessing, and developing Australia's transportation network.[71] The Transport and Infrastructure Council publishes and updates this set of documents. All Australian jurisdictions have endorsed the *ATAP Guidelines*. A sampling of the guiding principles for this document include stakeholder engagement, integration of transportation and land use planning, and a holistic, multi-modal perspective.[72] This framework provides tools and techniques for modelling and analysis, mode specific guidance, and examples to demonstrate the application of the framework.

Technology

Recent initiatives concerning vehicle technology include mandates for Electronic Stability Control and Brake Assist Systems for passenger vehicles.[73] The *National Road Safety Action Plan 2018-2020* calls for increased deployment of Automatic Emergency Braking in heavy and light vehicles, in addition to increased market uptake of vehicles with on-board safety

technologies.[74] The most recent action plan reflects a greater focus on improving safety for heavy and light vehicles than on safety measures to protect vulnerable road users.[75]

The Australian Government is actively working to improve and expand infrastructure technologies. The *National Land Transport Technology Action Plan 2020-2023* determined that connected and autonomous vehicles (CAV) and intelligent transportation systems (ITS) are key areas of research and development.[76] The *2020-2023 Action Plan* identified understanding how CAVs will influence future infrastructure and land use planning as a national priority. The Minister for Infrastructure, Transport, and Regional Development established the Office of Future Transport Technology in 2018 to position Australia for the deployment of transportation technologies through nationally consistent policies and regulations.[77]

Australia has an established automated speed enforcement program.[78] Deployment of mobile and fixed cameras, in addition to the emerging point-to-point camera systems, has become more widespread over the last decade. South Australia saw up to a 21% reduction in injury crashes at intersections where a fixed camera was installed.[79]

Data

From 2010 to 2017, there was a 2.9% decrease in pedestrian deaths.[80] Over the same period, vehicle kilometers travelled increased by 13.7%.[81] The default speed on urban roads is 50 km/h, with increased usage of lower speed limits in areas with high pedestrian activity.[82] In 2017, pedestrian deaths as a percent of all traffic fatalities was 14%, accounting for a total of 167 pedestrian fatalities.[83] Across the world, especially in high population countries, reliable data on serious injuries from crashes is difficult to obtain. This is the case in Australia due to the varying methods by which jurisdictions define and report injuries. In addition, Australia's extensive process of data validation causes a lag in current data reporting.[84] However, the *National Road Safety Action Plan 2018-2020* has established a national definition for "serious injury."[85] A pilot project to link serious injury data across jurisdictions is currently underway. This project seeks to match police crash data and hospital data across all jurisdictions to create a nationally verified data source for measuring serious injuries.

New Zealand

New Zealand consists of two primary landmasses and 600 smaller islands, covering a total area of 103,483 square miles. The form of government is a parliamentary constitutional monarchy. The population is approximately 5 million. The road network comprises 59,203 miles. There are 4 million registered motor vehicles.

Design

Official guidance published by the New Zealand Transport Agency (NZTA) and Austroads informs roadway design in New Zealand. A sampling of NZTA and Austroads guides includes the following: *Safe System Infrastructure on Mixed-Use Arterials,*[86] *Integrating Safe System with Movement and Place for VRUs,*[87] *Pedestrian Planning and Design Guide,*[88] and *Urban Design Guidelines*.[89] New Zealand and Austroads publish *guidelines*, rather than standards or

requirements. Guidelines give engineers the flexibility to implement designs—including new and emerging concepts—based on their own engineering judgement.[90] The one exception to this is the *Traffic Control Devices Manual*, which regulates the use of traffic control devices in roadways.[91]

New Zealand adopted the Safe System Approach in 2010.[92] Safe System principles encourage a reduction in the potential for conflicts between road users.[93] The New Zealand Ministry of Transport established a vision for infrastructure design that embodies Road to Zero principles, grounded in the Safe System approach.[94] This is demonstrated by a trend toward increasing modal separation throughout the country. There is also a growing movement among leadership and transportation professionals towards achieving "safe and appropriate speeds," which involve designing infrastructure that reduces speed. To reduce deaths and serious injuries, designs and speed limits must reflect the intended function, expected safety, and desired character of the roadway.[95] The reduction of a traffic speed through design interventions and other means is calculated as a benefit in cost-benefit analyses.[96]

Figure 5: Norton Road typical cross section (Source: Google Maps)

In addition to designs for speed reduction, specific design improvements for pedestrian safety include road diets and increased modal separation. Many arterials in New Zealand are two lane roads, typically with sidewalks, and sometimes with bike lanes. Arterials often feature a painted or raised/planted center median. Medians provide additional roadway space for design interventions that improve pedestrian safety. For example, see the image of Norton Road in Figure 5.

Pedestrians can cross legally anywhere along these arterial roadways,[97] and medians give them a place of refuge between travel lanes. Where there is greater demand for pedestrian crossings, additional infrastructure—raised islands, lighting, signs—can provide additional protections, increase the conspicuity of the crossing location, and encourage motorists to be more alert. See Figure 6.

Figure 6: Norton Road with protected median refuge including a raised island, signs, overhead lighting, curb cuts, and tactile dome warning strips (Source: Google Maps)

While medians and median crossing improvements like these are helpful, motorists are not required by law to yield to pedestrians at these unmarked locations. Marked crosswalks are the only locations where drivers are required by law to yield to pedestrians.[98] There are "courtesy crossings" that sometimes include refuge islands to encourage or aid crossings at certain locations, but there is no priority for pedestrians at these points. Roadway design features at these crossings encourage drivers to slow down, and courtesy crossings are often raised above the level of the road and include a textured surface to differentiate it from the primary roadway surface.[99,100] On some arterials, other typical crossing safety features include raised "speed table" pedestrian crossings, refuge islands, anti-skid surfacing,[101] and a special "kea" crossing for use in school zones (Figure 7).[102]

Figure 7. Kea crossing (Source: The New Zealand Automobile Association Inc.)

Figure 8 illustrates a midblock crossing on an urban arterial before pedestrian safety improvements. The following treatments, shown in Figure 9, were applied to improve safety outcomes:

- Raised "speed-table" pedestrian crossing
- Anti-skid surface treatment and color tinting on approach to crosswalk
- Widened, lengthened median refuge

- Parallel, separate pedestrian and bicycle crossings
- Higher visibility poles
- Signage for raised table and recommended lower speed

Figure 8. Pre-project midblock crossing (Source: Google Maps)

Figure 9. Post-project midblock crossing (Source: Google Maps)

The typical pedestrian safety response on a multilane arterial is a signalized crossing.[103] These often feature an "all red" phase during which all vehicle traffic is stopped and pedestrians are allowed to cross. As New Zealand prohibits vehicles from making turns at red lights, this provides an opportunity for pedestrians to cross without any potential conflicting vehicle turning movements. A variant of this signal phasing, called "double phasing," provides an all red phase between each the phases for each direction of traffic. Double phasing decreases the wait time for a pedestrian crossing phase and is intended to increase pedestrian compliance with signals. The additional delay between vehicle phases causes traffic to platoon at intersections.

In combination with the prohibition against turning on red, this increases the size of gaps between vehicles and makes crossing at mid-block locations easier.[104]

Policy

New Zealand publishes a national road safety strategy every 10 years.[105] In March 2010, the New Zealand government released *Safer Journeys*, which was the road safety strategy for 2010-2020.[106] This was the first formal introduction of the Safe System approach in New Zealand. In December 2019, the government launched *Road to Zero*, which is the road safety strategy for 2020-2030.[107] This document firmly established the country's commitment to Vision Zero. In addition, current design guidelines incorporate and support the Safe System approach.

There is strong leadership support for pedestrian safety implementations and Vision Zero among the Ministry of Transport and the New Zealand Transport Agency. The available funding and streamlined funding mechanisms for improving safety conditions for pedestrians are clear evidence of this support. Similar to the U.S., transportation funding is tied to Federal legislation.[108]

A few specific programs have led to many pedestrian safety improvements. The Low Cost, Low Risk program provides for the construction and implementation of transportation improvements.[109] If a project falls within a pre-approved activity class and costs less than NZ$1 million, there is a streamlined application process for obtaining funding. This program has allowed for many quick-build pedestrian safety improvements including traffic calming measures, walking and cycling facilities, and raised platforms at roundabouts. Another strong funding mechanism is the Innovating Streets for People Pilot Fund, which has a goal of helping councils create more people-centered spaces.[110] This program allows towns and cities to quickly mobilize and use tactical urbanism[111] to test and pilot projects to demonstrate value to communities. The pilot fund provides 90% funding assistance to successful applicants, as well as implementation support for the project. This program has funded 70 projects throughout the country, including the piloting of new pedestrian and cycling facilities and intersection safety improvements.[112]

There are no pedestrian or vehicle requirements to warrant crosswalks or signals. Instead of having a warrant system or general minimums, New Zealand takes a more safety-driven approach.[113] Local councils determine where pedestrian crossings are needed, and then these locations undergo safety assessments and public consultations.[114]

The Ministry of Transportation is proposing a law called the Accessible Streets Regulatory Package, which is designed to improve safety and efficiency for active modes of transportation through establishing a national framework for the use of footpaths and proposing a rule change stating that turning drivers must yield to pedestrians.[115]

Currently, there are no Federal vehicle safety regulations that specifically target pedestrian safety. As stated in the *Road to Zero Action Plan 2020-2022*, the government is planning to start

research about increasing safety standards for vehicles entering the fleet.[116] Refer to the Technology section for more details regarding vehicle safety measures.

The *Setting of Speed Limits Rule 2003* created a default speed limit of 50 km/h on urban roads.[117] Updated guidance on setting speed limits was published in 2016 through the *Speed Management Guide*, which better supports a Safe System approach and a consistent network-wide approach to speed management. This guide allows local Road Controlling Authorities (RCAs) to optimize the road network to reduce fatalities and serious injuries.

Planning

In 2016, the NZTA published their *Speed Management Guide*.[118] This document outlines a national framework to help RCAs make informed, accurate, and consistent speed management decisions in communities throughout New Zealand. This document categorizes roads by risk levels and accounts for land use context. While this is the main guidance on speed management, other documents also discuss methodologies for selecting safe and appropriate speeds.

A “Movement and Place Framework” is a concept that applies a land use lens to transportation projects in New Zealand. The UK's *Manual for Streets*, published in 2007, is one of the earliest uses of this framework.[119] It proposes a new approach to defining street hierarchies based on a “Place and Movement Matrix.” Austroads first defined this framework for use in the Australasian context in their 2016 document *The Austroads Guide to Traffic Management Part 4: Network Management*.[120] Since then, there has been increased use of this framework among New Zealand jurisdictions to guide the development of a more context sensitive transportation system. Transportation planners drove these efforts, as they realized that the multiple values of *Place* needed to be given more weight than in the past.[121] Practitioners can use the Movement and Place Framework to deliver an integrated transportation and land use planning approach, as illustrated in Figure 10.

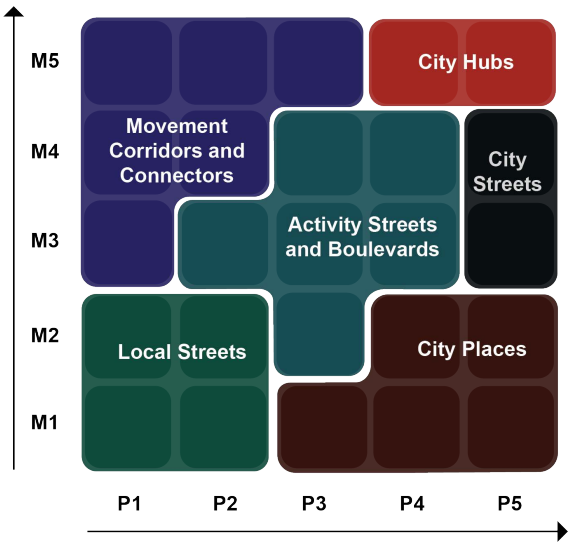

Figure 10: Movement and Place Framework. M1 to M5 indicates a low volume of travel to a high volume of travel. P1 to P5 indicates low density to high density. The six main families highlighted within the framework are used for the prioritization of modes and setting of speeds. (Source: Austroads)

The NZTA is currently restructuring the road classification system, and the new system is called the One Network Framework (ONF).[122] The ONF incorporates the Movement and Place approach to better consider modal priorities, land use, economic activity, community vitality, and future growth. In addition, New Zealand's ten Urban Design Principles include integrated transport and land use planning as a mechanism for using resources more efficiently and preventing urban sprawl.[123]

Numerous design guides include assessment methods, but there is no strong consensus around a standardized assessment model. A group of researchers from Stantec New Zealand and Auckland Transport conducted a study building on Austroads' safe system risk assessment framework.[124] This research develops and illustrates the use of the Crash Risk Assessment Framework (CRAF) and the Multi-User Assessment Framework (MUAF). The CRAF method focuses on medium to higher severity issues and speed management, while the MUAF method identifies lower cost improvements and maintenance activities. Better Conversations on Road Risk is a program that supports RCAs in better understanding community views and expectations, in addition to helping them listen and engage more positively about road safety.[125] The NZTA has published public engagement guidelines, and many of the design guides provide guidance on this topic as well.

Technology

Improving the safety performance of the vehicle fleet is a key strategic objective for New Zealand.[126] The government is leading a comprehensive policy investigation to determine what specific safety technologies they should mandate through standards. Preliminary research has shown that automatic emergency braking (AEB)[127] and rear vision cameras show a lot of promise. Based on available information, New Zealand does not currently have vehicle standards that specifically address pedestrian safety.[128] However, there are strong efforts

underway to increase vehicle technologies like lane-keep assistance, collision warning systems, and AEB within the fleet.[129] Research shows that AEB and other pedestrian detection systems have a positive effect on road safety for vulnerable road users.[130]

New Zealand's national police service has a comprehensive safe speed camera enforcement program, incorporating the use of static speed cameras, mobile speed cameras, and red light cameras.[131] New Zealand is conducting research to ensure the country is prepared for the market penetration of connected and autonomous vehicles (CAV). Completed research on CAV includes public readiness, social impact, and policy implication assessments.[132] The Ministry of Transport AV Work Program continues to investigate potential impacts and build capacity around these new technologies.[133]

Data

New Zealand showed a decrease in pedestrian fatalities for the majority of the last decade, reaching as low as 25 pedestrian deaths in 2016, which accounted for 7.6% of all traffic fatalities.[134] However, in 2017 and 2018 the number of deaths increased to 39 in both years and accounted for over 10% of all traffic fatalities.[135] During the same time, vehicle kilometers travelled (VKT) increased by 17%.[136] Pedestrian volumes are not monitored with great detail, making robust exposure data difficult to obtain.[137]

New Zealand publishes national crash data in an interactive dashboard, which includes not only fatality information, but injury as well. Information is broken down by many different characteristics, including location.[138]

Europe

Context

The design, policy, and planning approach taken by European countries is characterized by arterial roadways that incorporate protections for a broad group of vulnerable road users. Denmark, Sweden, Norway, Finland, the U.K., and especially the Netherlands often plan and design arterial roads in urban areas with separated—frequently raised—cycling infrastructure that creates a buffer between sidewalks and vehicle lanes. Intersection treatments vary, but in general, pedestrians typically share crossing movements with cyclists and vehicles, so they are afforded the same additional buffer (cyclists traveling through the intersection) from vehicles making turning movements. An additional benefit of a larger proportion of vulnerable road users is greater driver awareness of these travelers. These countries also integrate awareness and safety of vulnerable road users into driver training and educational campaigns.

Most of the European countries in this study have also taken a strong policy stance in support of Vision Zero. In addition to national goals and other policies, many European countries maintain Federal design standards that advance a Safe System approach, which prescribes proactive design treatments to combat the risk of traffic deaths and serious injury.

Pedestrian fatalities have fallen between 2010 and 2018 in all the European countries studied except the U.K.; however, Vehicle Miles Traveled (VMT) have concurrently increased in all but Finland and the U.K. All the European countries maintain an average speed of 50 km/h or less on urban arterials.[139] Traffic law enforcement is notoriously stringent in Europe. Norway in particular levies large fines and uses automated speed enforcement to discourage drivers from speeding. European countries are also known to enforce pedestrian and bicycle traffic laws more rigorously than the U.S., and there is a strong culture of obeying pedestrian traffic laws in many European cities.

Providing pedestrian- and cyclist-serving infrastructure that increases those road users' comfort, safety, and convenience also helps to encourage safer vulnerable road user behavior. European cities typically exhibit shorter block lengths, increasing the frequency of designated pedestrian crossing locations and reducing the impulse for pedestrians to cross at mid-block locations. In addition to shorter block lengths, European street geometry is often irregular, following routes that date back hundreds of years or more. In combination, these factors result in more frequent signals and fewer long straightaways, which may help to drivers maintain lower vehicle speeds and more frequently decelerate during a given journey. More frequent signals can also be more effectively timed together to encourage a lower but more constant speed of travel.[140]

Of the European cities explored for this desk review, the majority exhibit high-density urban cores, surrounded by relatively rural land uses. In contrast, most U.S. cities are planned with high-to-moderate density cores, and medium-to-low density suburban and exurban land uses. The scale of roadways varies as well, with only a small subset of European arterial roads comprising more than two lanes of vehicle traffic. U.S. urban arterials typically comprise between four and six lanes, if not more. For two- and three-lane roads and where bicycling and pedestrian infrastructure are being integrated into a roadway, there may well be European examples of design, as well as planning and policy approaches to the standardization and implementation of those designs, that can be adapted to the U.S. context. However, there may be better examples in other countries with more similar land use and transportation contexts.

Denmark

Denmark consists of the Jutland peninsula and more than 400 islands, resulting in a total of 16,631 square miles.[141] The form of government is a parliamentary constitutional monarchy.[142] The population is 5.6 million.[143] The road network comprises 46,328 miles.[144] There are 3.2 million registered motor vehicles.[145]

Design

Danish guidelines for the planning, design, construction, and maintenance of roads are extensive and cover a broad range of topics.[146] These guidelines, developed by standing committees with members from the road sector and published by the Danish Road Directorate, are known as the *Road Rules*.[147] Nearly 800 publicly-available documents are categorized into

the following topics: construction and planning, operation, public procurement, and legislation. The Directorate has translated some of the publications to English,[148] but the vast majority are in Danish. Design guidelines exist for urban streets, urban intersections, and pedestrian areas. Designing for pedestrians is an integrated part of road design, as outlined by the Road Rules.[149]

If the speed limit is 60 km/h or above, modal separation is deemed necessary.[150] If the speed limit is 30 km/h or lower, design guidelines allow for the integration of modes. If the speed limit falls in between 30 and 60 km/h, roadway technicians and engineers should assess accident patterns, traffic volumes, and number of junctions to determine the appropriate level of modal separation. Urban streets, which have a speed limit of 50 km/h or lower, are required to have sidewalks. Widespread speed reduction measures and street narrowing initiatives, in addition to the primary objective of reducing deaths and injuries on Danish roadways, are evidence of the culture of prioritizing safety over traffic flow rates.[151]

Denmark's extensive bike infrastructure improves safety for all modes by reducing conflicts and providing a buffer between pedestrians and cars.[152] Truncated bike lanes are commonly used safety interventions in which a bike lane, often protected, transitions into a shared turning lane.[153] Roadway designers consider this intervention a strong safety approach because cars must focus on merging with bikes before reaching the intersection. This slows drivers down and makes them alert before their focus shifts to turning or other intersection movements.[154] Figure 11 below illustrates a raised bike lane transitioning to a turning lane with a significant buffer region before the intersection.

Figure 11. Example of a truncated bike lane in Denmark (Source: Danish Road Directorate)

Policy

The Federal Road Directorate's roadway design standards support the Safe System approach. Although these guidelines are not government-mandated, roadway technicians have a deep respect for them and follow the guidance to a high degree.[155] Federal legislation supports Vision Zero principles, but "Vision Zero" is not referred to by name. The adoption of the *Danish Road Safety Commission National Action Plan 2013-2020* affirms the government's commitment to reducing road trauma under the view that crashes are preventable. This document supports the idea that controllable measures like legislation, education, engineering, and safer vehicles can significantly reduce the severity of injuries.[156,157]

In 2001, the Minister of Transport established the Danish Road Traffic Accident Investigation Board (AIB) to compile knowledge about road traffic crashes.[158] The AIB conducts analyses using information from the police, vehicle inspectors, road authorities, and hospitals to understand factors that lead to a crash.

Roadway safety improvements over the past 15 years have mostly benefitted vehicle occupants, so there is currently a greater focus on reducing killed and seriously injured (KSI) rates for vulnerable road users than in the past.[159] Planning and design guidance in the Road Rules, in addition to general awareness among planners and engineers, has made long-term improvements to pedestrian safety possible.[160] Denmark takes a multi-disciplinary approach to road safety as the ministries of transport, justice, interior, and health, and the local municipalities share the responsibility of promoting and achieving a safe transportation

network.[161] The Danish Road Safety Commission sets targets and focus areas, but it does not manage a budget.[162] As a result, the majority of traffic safety work is conducted at the local level. Municipalities are responsible for planning, financing, designing, and maintaining the municipal roads within their jurisdictions.[163] Funding comes from the income tax system at both the State and municipal levels.[164] The Danish State also allocates funding to various municipalities, and the municipalities are then tasked with allocating the funds among their many needs including roads, schools, parks, and other public services. Politics influence how this spending occurs, leading to differences in priorities regarding roadway designs at jurisdictional borders.[165]

Denmark does not have much flexibility in regards to vehicle safety regulations because the European Union dictates the rules for vehicle safety standards.[166] While Denmark does not have the ability to place additional demands on production standards, they can provide tax reductions to encourage certain safety features. Denmark currently taxes vehicles heavily, which is another avenue for promoting pedestrian safety.

Planning

The *Danish Road Safety Commission National Action Plan 2013-2020*, titled "Every accident is one too many – a shared responsibility," addresses speed management in urban areas.[167] Additional guidance on setting speed limits is included as part of the Road Rules. There is evidence of integrated transportation and land use planning. Most planning and assessment guides are published in Danish, so it is difficult to determine whether there are standardized assessment models.

Technology

The Accident Investigation Board has made recommendations concerning vehicle technologies to improve pedestrian safety based on a detailed study of 27 crashes involving pedestrians in urban areas.[168] The AIB recommends the requirement of installing speed limiters for young drivers and convicted speeders and alcohol locks for convicted drunk drivers. The AIB also recommends Electronic Stability Control, AEB systems with built-in pedestrian detection, and pedestrian-friendly fronts with exterior pedestrian airbags. None of these measures are currently mandated, but the EU is working on an updated road safety package that would make additional vehicle safety measures compulsory within the next ten years.[169]

There are very few fixed cameras in Denmark, but efforts are underway to expand this program.[170] Currently, the police have vans equipped with mobile speed monitoring units. There is not much information available in English on other infrastructure technologies implemented in Denmark.

Data

Pedestrian fatality rates decreased by 55% from 2010 to 2017 while vehicle kilometers travelled increased by 20%.[171] There is a standard 50 km/h speed limit in urban areas.[172] There are guidelines for designing and retrofitting roads with lower speed limits; however, the police

control speed limit signage, so they must approve the change.[173] In Denmark, pedestrians account for the second largest share of road deaths, with pedestrian fatalities accounting for 11% of all traffic fatalities.[174] While it is a significant portion, this value represents 20 pedestrian fatalities, which is markedly less than most countries. A common national system for reporting traffic crash data allows for highly accurate fatality data.[175] The police collect fatality data and transfer it to the Road Directorate each week.[176]

Finland

Finland spans a total area of 130,558 square miles and has a population of 5.6 million.[177] The form of government is a parliamentary republic. The road network comprises 48,462 miles.[178] There are 4.6 million registered motor vehicles. The capital city of Helsinki has made great strides in the areas of pedestrian safety and Vision Zero. In 2019, there were zero pedestrian deaths.[179] Helsinki joins Oslo, Norway as the only cities in the world that have achieved this feat.[180]

Design

Holistic speed reduction efforts have been a key factor in Helsinki's success regarding pedestrian safety.[181] Infrastructure and design interventions reinforce the setting of lower speed limits. Raised pedestrian crossings are a commonly used countermeasure as they have proven to increase vehicle yielding and reduce pedestrian risk.[182] Raised intersections greatly improve safety for all modes, but this type of intersection is rarely used due to its high cost. Roundabouts, narrow roadways, and tighter curves (often in the form of square corners) greatly aid speed control.[183] Longer pedestrian refuge islands at bus stops in the middle of streets prevent vehicles from passing buses, improving the efficiency of transit and increasing pedestrian safety around transit hubs. There is a clear prioritization of safety over flow, especially in the city center where vehicle traffic is often rerouted for pedestrian zones.[184] The city's design and planning approach in this area is to increase the number of pedestrian streets, widen sidewalks, and support pedestrian-focused streets for public transport.[185]

A high degree of modal separation is prevalent throughout Helsinki. Figure 12 illustrates a roadway design that clearly separates pedestrians, cyclists, transit, and vehicles using elevation changes, tactical modifications, and various types of buffers.[186] The speed limit on this section of roadway is 30 km/h.

Evaluating the roadway from right to left, the following design elements are used throughout the city to improve safety outcomes:

- Widened sidewalk
- Tree buffer with tactical change
- Bike lane with tactical change; raised above level of roadway
- Buffer of parked cars
- Two narrowed lanes of vehicle traffic
- Raised median with transit shelters, guardrails, and trees

- Two lanes of transit
- Raised median with transit shelters, guardrails, and trees
- Three narrowed lanes of vehicle traffic
- Widened sidewalk with bike parking at the curb, serving as an additional buffer

Figure 12. Modal separation (Source: Google Maps)

At the national level, the Transport Infrastructure Agency is responsible for road design, construction, and maintenance, in addition to road and traffic signs.[187] Cities across Finland are working to lower speed limits in urban areas and increase the construction of pedestrian and bike paths.[188]

Policy

Finland recently updated legislation dealing with traffic flow and safety. The new *Road Traffic Act* went into effect on June 1, 2020.[189] The revised legislation has a core ambition of protecting vulnerable road users.[190] Previously, traffic-related measures were governed by regulations, which are a form of secondary legislation that outline specific details that are subject to regular review.[191] This legislation provides a shift to regulation of these measures by law, which is a form of primary legislation that outlines a more general policy statement or objective and names an executive authority in charge of executing its implementation.[192] Key objectives include promoting walking and cycling, preparing for new technologies and vehicle automation, and deregulation.[193]

The *Road Traffic Act* meets the requirements of European Union legislation, which explicitly supports Vision Zero with a goal of reducing road deaths to almost zero by 2050.[194] Key EU legislation includes road infrastructure safety management and vehicle safety.[195] The vehicle

safety regulations include provisions for non-occupant protection (see the Technology section for more details). The EU provides funding for upgrading road infrastructure and technical assistance for leveraging those funding options. Finland has their own Vision Zero legislation as well. In 2016, the Finnish government approved a resolution that outlined the long-term vision that no one should be killed or seriously injured on the road.[196]

Planning

The Finnish Transport Infrastructure Agency views the integration of transportation and land use planning as an integral part of reaching their agency goals of creating a sustainable community structure and supporting competitive public transit.[197]

In Helsinki, speed management is a primary focus of transportation and traffic planning.[198] In addition to accompanying infrastructure improvements, they have been conducting an aggressive speed limit reduction program. Speed limits on major urban thoroughfares are 40 km/h.[199] With the exception of the busiest main roads, the speed limit rarely surpasses 40 km/h.[200]

Technology

Finland has an extensive speed camera network, where automatic speed cameras cover approximately 3000 km of main roads.[201] In 2019, the police began testing a new batch of high-resolution speed cameras that have upgraded radar technology and better picture quality.[202] The new Road Traffic Act allows the police to monitor driver behavior, not just speeds.[203] The police can now use pictures of drivers holding phones or not wearing seatbelts to enforce road rules. Finland also requires speed limiters on the vehicles of young drivers.[204]

In the realm of connected and autonomous vehicles, the new legislation establishes preconditions for the digitization and automation of traffic.[205] Finland is home to Aurora, an arctic testing ecosystem for intelligent transportation systems and automated vehicles.[206] Aurora is a strong asset because emerging technologies and innovations must be tested and verified in the Arctic environment.[207]

Recently updated EU regulations mandated many vehicle safety features that protect non-occupants.[208] These safety features will become mandatory in 2022, except for the head impact zone enlargement, which will follow soon after. These safety features include:

- Advanced emergency braking
- Head impact zone enlargement for pedestrians and cyclists
- Safety glass in case of crash for pedestrians and cyclists
- VRU detection and warning on front and side of vehicle (trucks and buses only)
- VRU improved direct vision from driver's position (trucks and buses only)
- Rearview back-up camera

Data

From 2010 to 2017, there was a 23% decrease in pedestrian fatality rates.[209] Although there was a slight decrease of 6.7% in vehicle kilometers travelled, the decline in pedestrian deaths is

still significant.[210] There is a general speed limit of 50 km/h in urban areas, but lower speed limits are common, reaching as low as 30 km/h in some urban areas.[211] Pedestrian fatalities accounted for 11% of all road fatalities, which amounted to 27 pedestrian deaths in 2017.[212]

Netherlands

The Netherlands covers a total area of 16,040 square miles and has a population of 17.3 million.[213] The form of government is a parliamentary constitutional monarchy. The road network comprises 86,500 miles.[214] There are 10.4 million registered motor vehicles.

Design

CROW[215] has published hundreds of national guidelines on roadway design, and they continuously work to develop and update new and existing guidance.[216] CROW's *Design Manual for Bicycle Traffic* has received international acclaim, and they are currently working on a design manual for pedestrian facilities.[217] These guidelines are not binding, and the local road authorities ultimately decide on the final road design.[218] CROW considers accessibility, safety, and environment when determining optimal roadway conditions.[219] There is a clear prioritization of safety over flow as the agency supports a reverse hierarchy of priority starting with pedestrians and followed by bikes, transit, and lastly, cars.[220] Designing roads to make conflicts between modes impossible or unlikely is a key part of the Dutch approach to road safety, so there is strong evidence of modal separation.[221] Through their guidelines, CROW works to clearly define acceptable safe roads so that local road authorities can compare the roads within their jurisdictions to the ideal road design and redesign or retrofit the network accordingly.[222]

Engineering and infrastructure measures commonly used to improve pedestrian safety include adjusting traffic lights for the slower walking speeds of the elderly, reducing speeds in pedestrian areas, building median refuge islands and curb extensions, and increasing traffic light-controlled crossings.[223] In locations with high traffic in all modes, local road authorities might build a protected intersection to make traffic movements more predictable and improve safety for all modes. Benefits of this roadway design for pedestrians include shortened crossing distances, lowered driver speeds, and increased driver yielding behavior.[224] Figure 13 illustrates a protected intersection in Amsterdam.[225] The following countermeasures are present to improve safety:

- Corner safety islands
- Parallel, separate pedestrian and bicycle crossings
- Setback pedestrian and bicycle crossings
- Separate signals for each mode
- Forward stop bar for bicycles
- Median refuge islands
- Wide, high-visibility zebra stripes
- High visibility poles
- Colored bike facilities

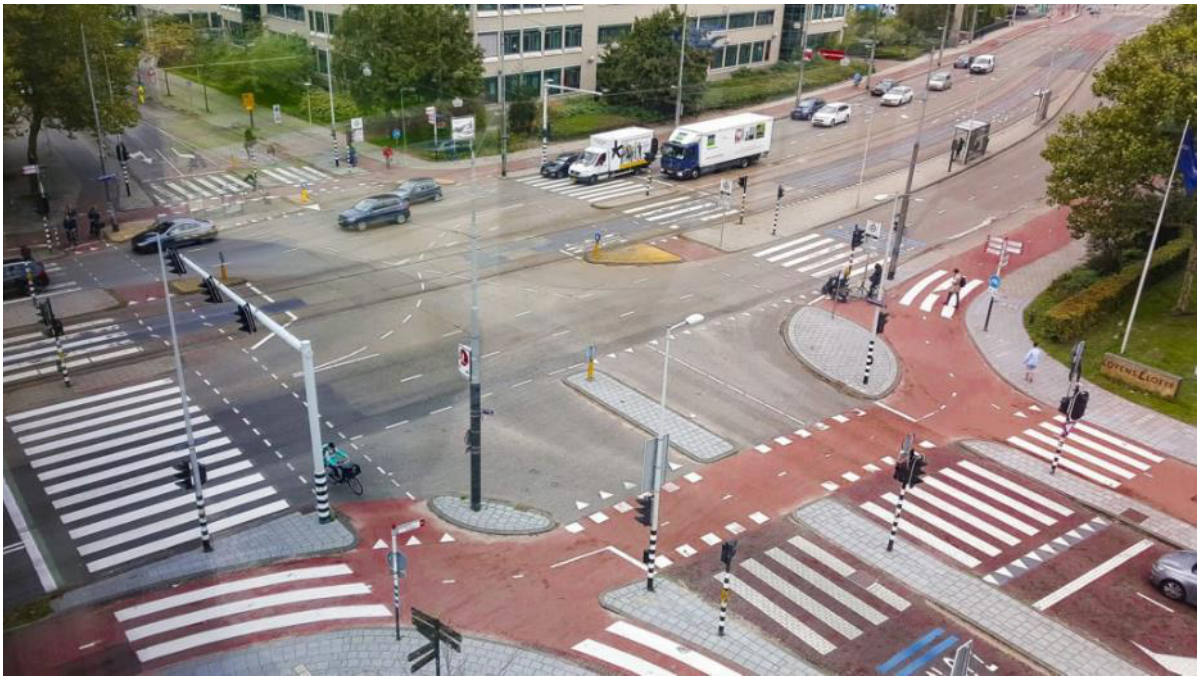

Figure 13: Protected intersection in Amsterdam (Source: Google Maps)

Corner safety islands are raised areas that separate the bike lane from the vehicle travel lane in the intersection and lead to decreased exposure for pedestrians. Corner islands tighten the turning radius, which slows down drivers turning right. This intervention causes bicycle and pedestrian crossings to be set back from the through travel lanes. These setback crossings cause a lateral shift for cyclists, slowing them down as they travel through the intersection. The forward stop bars mark the stopping location for bicycles waiting at red signals. This advanced stop line, in addition to the lateral shift, greatly increases the visibility of cyclists. This allows cyclists to be closer to the intersection, so they get a head start with their crossing, which also improves visibility and decreases crossing distance. The speed limit at this intersection is 30 km/h. This area is a low-emissions zone as indicated by the double blue lines in the bottom right of the image. In these low-emissions areas, which are present in 13 Dutch municipalities, Euro emissions standards determine what vehicles are allowed to drive through the area.[226]

Policy

The Dutch approach to road safety is founded in the concept of Sustainable Safety. While similar to Vision Zero, this concept is unique to the Netherlands. It supports the idea that the traffic environment can and should be designed to systematically reduce the risks present in a traffic system.[227] Sustainable Safety, with the goal of a casualty-free road traffic system, is based on the design principles of psychology, functionality, and biomechanics and the organizational principles of responsibility and learning/innovating.[228] This vision was first developed in the 1990s, and it has had an established national influence on roadway design and

safety since 1998.[229] SWOV, the Dutch institute for road safety research, states that like Vision Zero, Sustainable Safety is an example of the Safe System approach.[230]

In the Netherlands, there is no direct discussion of Vision Zero, but current policies and plans strongly reflect Vision Zero principles. The *Road Safety Strategic Plan 2030* has a "zero casualty ambition."[231] This document outlines nine policy themes to give structure to the Dutch approach to road safety. The first three themes of safe infrastructure, heterogeneity in traffic, and technological developments address the risks associated with the traffic system and the vehicle. The fourth policy theme addresses the risks faced by VRUs.

There is strong leadership support for road safety initiatives. The Ministry of Infrastructure and Water Management has commissioned a study to identify areas that pose the highest accident risk.[232] In addition, the Federal government will be providing support to municipalities and provinces to assist with mapping out and addressing road safety risks. The creation of a road safety data taskforce is underway to provide data and information to road maintenance authorities.[233] In the past, parliamentary support of these efforts have been lacking. In 2017, 32 organizations throughout the Netherlands worked together to publish a manifesto calling on the Dutch Parliament to make road safety a national priority, and this document was received positively by the legislative body.[234]

Leadership continually states that safety is the number one priority; however, there are gaps that exist in engineering applications, funding, and multiagency cooperation that directly challenge the goal of zero roadway fatalities.[235] While there is currently great importance placed on pedestrian safety engineering, it is not treated with the same rigor as auto-oriented design.[236] The Federal government primarily funds State highways, but there are some funds available for various road safety initiatives.[237] Regional and local governments have authority over their own roads and infrastructure, so they bear the primary burden of funding road safety improvements on urban arterials.[238]

The European Union's recently updated vehicle safety regulations establish mandates for many safety features that protect non-occupants.[239] In addition to these regulations, the Netherlands is actively working to increase the share of smart vehicles on the road with safe driver support systems.[240] Currently, there are no legal requirements that ITS or ADAS must comply with,[241] but there is a goal to have a national policy and legislation aimed at the safe integration of new vehicle technologies by 2030.[242]

Planning

The development of the road network is based on the concept of mono-functionality.[243] The ideal road has only one function for all modes, which depends on land use and flow. According to this design principle of functionality, the road network is broken down into three categories: through roads, access roads, and distributor roads. Through roads are focused on flow, and as a result, cars have the highest priority. These types of roads are not permitted within urban areas. Access roads offer direct access to residential areas, and they have a 30 km/h speed limit

in urban areas. Distributor roads connect through roads with access roads, and they have speed limits of 50 km/h in urban areas. This functional classification is important because it informs the integration of transportation and land use planning.

There is no specifically defined speed management guidance in the Netherlands as speed limits are determined based on the function and location of roads.[244] Whenever different modes are mixed, speed limits are decreased.[245] It is likely that CROW has additional guidance on speed management within their published design guides.

Sustainable Safety 3rd Edition calls for a proactive and risk-based approach for roadway assessment.[246] This approach uses crash statistics and road safety performance indicators, or surrogate safety measures, to justify preventative actions. Surrogate safety measures utilize observable non-crash traffic events instead of waiting for actual crashes to occur.[247] The city of Rotterdam has developed a model that uses this approach to predict high-risk locations.[248] The model is based on a self-learning algorithm that searches for patterns and crash prediction factors in a large data set including objective data on infrastructure, traffic, and public space. This model helps the city select streets and intersections to prioritize when making roadway improvements.[249]

Technology

The Euro NCAP has played a major role in increasing the safety of the vehicle fleet, especially concerning non-occupant safety.[250] Euro NCAP tests how well vehicles protect vulnerable road users, and they give additional points to vehicles that have automatic emergency braking systems.[251] In addition, regulations for vehicle safety laid out by the European Union are increasingly protective of vulnerable road users.[252] They recently mandated Intelligent Speed Assistance (ISA) in all newly manufactured light vehicles starting in 2022.[253] ISA uses sign recognition and GPS data to automatically limit vehicle speeds. The Dutch speed camera enforcement program has effectively reduced offenses and the number of crashes.[254]

Data

From 2010 to 2017, pedestrian fatality rates decreased by 20%;[255] however, the reduction of road fatalities has slowed in recent years.[256] The decrease in pedestrian fatalities has occurred despite an increase in vehicle kilometers travelled.[257] Urban distributor roads have speed limits of 50 km/h,[258] with requirements for a high degree of modal separation if a mix of modes is present. Pedestrian fatalities accounted for almost 10% of all road fatalities, which amounted to 58 pedestrian deaths in 2017.[259]

Norway

Norway covers a total area of 125,000 square miles and has a population of 5.4 million.[260] The form of government is a parliamentary constitutional monarchy. The road network comprises 58,293 miles.[261] There are four million registered motor vehicles. The capital city of Oslo has clearly prioritized the safety of pedestrians, as there were zero fatalities for vulnerable road

users in 2019.[262] Norway proved to be the safest country for all road users in 2019, with only two deaths per 100,000 people.[263]

Design

In Norway, Federal and local road safety agencies have strongly established that safe infrastructure requires separate and connected pedestrian and cyclist paths.[264] Due to the challenging terrain of mountains, glaciers, and fjords, much of the country's infrastructure is complex and inefficient.[265] For example, pedestrian bridges and tunnels are common interventions for improving modal separation.[266] This is not a typical intervention internationally because of the high cost of heavy infrastructure and earthwork projects, but in Norway, the geography allows for few other options.

The Institute for Transport Economics (TOI)[267] publishes the *Handbook of Road Safety Measures*. This document, which is over 900 pages long, is a reference manual of road safety measures.[268] The main purpose of the document is to describe the effects of road safety measures on road safety as objectively as possible. TOI publishes this handbook to outline all current research, not to be design or policy guidance.[269] This handbook helps roadway engineers make strong arguments to justify the necessity of road safety improvements.[270]

In addition to the extensive research available to inform roadway decisions, the National Public Roads Administration (NPRA) publishes a national manual for roadway design and construction.[271] This manual consists of hundreds of documents providing standards and guidance on all aspects of the transportation network. The manual is broken down into two levels, which do not translate to English well. The primary level consists of norms and guidelines, which are both authorized by law.[272] Norms apply to all public roads, while guidelines apply only to national roads. Information and guidance found in this level take precedence over any other information. The secondary level consists of guides, which are supplemental documents to the norms and guidelines that provide detailed descriptions of how agencies and engineers can use the requirements.[273]

Vision Zero is the basis for all road safety work in Norway.[274] As a result, there is a clear prioritization of safety over flow. At a national level, the Norwegian Council on Road Safety is working to increase restrictions on cars in cities.[275] In addition, there is political consensus regarding a zero growth target for the share of cars in cities.[276] The city of Oslo is transitioning to a system in which engineers can implement road safety measures without traffic studies even if the measures might cause congestion or slow down traffic.[277]

A design intervention used consistently throughout urban areas in Norway is to decrease the number of vehicle travel lanes. Figure 14, located in Oslo, illustrates this intervention.[278] The majority of streets that used to have three or four lanes have been transitioned to roads with only one lane of traffic in each direction with the addition of some of the following measures:

- Wide sidewalks
- Separated, colored bike facilities

- Bus lane
- Floating bus stop
- Raised, curb-separated bike lane (not as common)

Figure 14. Updated roadway design in Oslo (Source: Google Maps)

This type of roadway design limits vehicle traffic and decreases the complexity of crossing the street. The wide sidewalks allot double the amount of space to pedestrians than to cars, illustrating the country's commitment to pedestrian prioritization. The colored bike facilities increase the visibility of cyclists and provide a visual alert to drivers. The floating bus stop adds another layer of modal separation, effectively providing a physical buffer to separate cyclists from faster-moving vehicle traffic. In addition, this measure reduces conflicts between bus and bike traffic.

Policy

The Norwegian Parliament adopted Vision Zero legislation in 2001.[279] The Ministry of Transport and Communications publishes a *National Transport Plan* every four years to outline high-level policy and investment priorities, in addition to defining road safety targets for achieving Vision Zero.[280] The NPRA, in collaboration with five other Federal agencies, publishes shorter-term national road safety action plans every four years.[281] These action plans provides specific measures for meeting the targets outlined in the *National Transport Plan*.

Road safety policy in Norway is collaborative, with consistent coordination across government agencies and community stakeholders.[282] The government sectors actively involved with road safety efforts include the Directorate of Health, the Directorate of Education and Training, Correctional Services, the Police, and local municipalities, among others.[283]

When the NPRA transferred the authority of traffic-controlling signs and markings from the police to the cities, cities became more empowered to implement innovative roadway

designs.[284] Before they had this authority, cities had to apply to the police or the national road authority to install bike lanes or close streets to vehicle traffic, and this process could delay projects for years. With the authority to place road signs and markings, the city of Oslo increased their rate of bike implementation by ten times.[285]

The extent of leadership support for road safety initiatives varies greatly based on who is in power,[286] but Parliament has shown consistent support of Vision Zero and progressive road safety measures throughout the years. The Ministry of Transport and Communications has significantly increased the funds for transportation in urban areas in the recent years.[287] The zero growth target for cars in urban areas may increase the number of injuries to pedestrians and cyclists as more people walk and cycle, which has necessitated an increase in national spending in urban areas to continue to develop pedestrian, cyclist, and transit infrastructure.[288] While the number of injuries to pedestrians and cyclists may increase, the theory of "Safety in Numbers" indicates that the risk of injury will decrease as the volume of these road user groups increases; in other words, the rate of injury and the likelihood that any one VRU will be injured drops as more people walk and bicycle.[289] Federal vehicle safety regulations are limited to those mandated by the European Union. The EU regulations are increasingly incorporating mandates for non-occupant protection.[290]

Planning

The Norwegian Council for Road Safety runs two programs that exemplify the Norwegian road safety planning approach. The Traffic Safe Municipalities program, established in 2015, is a certification program for local municipalities that are undertaking and implementing strong road safety work within their jurisdictions.[291] The Council defines clear criteria for systematic and coherent transportation planning at the local level, and it requires municipalities to coordinate across different agencies and with local organizations.[292] As more municipalities participate in the program and receive certification, the overall consistency of traffic safety measures throughout the country will improve. The Norwegian Council for Road Safety also leads a program called Heart Zones.[293] This program integrates transportation and land use planning to establish car-free zones around school areas to ensure that students can safely walk or cycle to school.[294] Heart zones are common throughout the country, and they require national coordination between governments and local organizations.[295]

Speed management is an established part of the Norwegian approach to road safety. The *NPRA Manual* includes requirements and guidelines for speed management.[296] There is a high level of compliance with speed limits because there are high fines for speeding.[297] In urban areas, it is general practice to control vehicle speeds primarily through physical measures rather than speed limits and enforcement.[298]

The NPRA conducts an in-depth accident analysis investigation for every fatal crash that occurs in the country.[299] With support from the police, they analyze what factors led to the crash and the degree of severity. The resulting report typically includes recommendations for roadway improvements at the crash site and for national application.[300]

Technology

Increasing market penetration of vehicle safety measures greatly contributed to the decline in the number of fatalities and serious injuries on Norwegian roadways.[301] The Euro NCAP and European Union vehicle safety regulations are contributing to the growth of a vehicle fleet that is increasingly including more measures for vulnerable road user protection.[302] The further development and implementation of connected and autonomous vehicles is a national priority, as stated in the *National Plan of Action for Road Safety 2018-2021*. Additionally, Norway has an extensive automatic speed control program.[303]

Data

From 2010 to 2017, pedestrian fatality rates decreased by 58%.[304] During the same time, vehicle kilometers travelled increased by 6.4%.[305] 50 km/h is the standard speed limit on urban roads;[306] however, municipalities have the authority to set speed limits as they see fit.[307] The city of Oslo has vowed to set a standard citywide speed limit of 30 km/h in the near future.[308] Pedestrian deaths account for 9% of all traffic fatalities, which totaled 10 pedestrian deaths in 2017.[309]

Sweden

Sweden consists of a primary landmass and thousands of coastal islands, covering a total area of 173,860 square miles.[310] The form of government is a parliamentary constitutional monarchy. The population is 10.2 million. The road network comprises 87,540 miles.[311] There are 6.3 million registered motor vehicles.

Design

Sweden developed the concept of Vision Zero in the mid-1990s, and the Swedish Parliament adopted the policy in 1997.[312] This policy led to a radical shift in the approach to roadway design. Instead of regarding road users as the primary cause of accidents, the general public and transportation professionals came to an understanding that the traffic environment is the main cause of death in the roadway.[313] As such, the main burden for road safety was placed on transportation system designers and engineers.[314] The following ideology has been accepted by government officials and transportation professionals alike.[315] According to Vision Zero, fatalities and serious injuries are caused by system failures rather than by individual road users' lack of capability. Humans will always make mistakes, and the transport system has to compensate for people's shortcomings. While individual road users still have a responsibility for their behavior, the ultimate responsibility for safety goes back to the system designers to introduce further support for the road users.

The biggest design implication that immediately arose from the new policy was 2+1 roads.[316] A 2+1 road has alternating single and double lanes in a given direction with a flexible median barrier to prevent head-on collisions. The separation of opposing directions of traffic through barrier separation has been a primary focus in Swedish roadway design.[317] This countermeasure has been implemented on almost 2,500 miles of roadway with an investment

of approximately $1.4 billion U.S.D.[318] 2+1 roads have reduced the road fatality rate in Sweden by 80%.[319] However, this implementation is best suited for wide, high-speed roads, so 2+1 roads are typically located in rural areas where there is a decreased presence of other modes.

In urban environments where there is a higher concentration of pedestrians and cyclists, common road safety measures include decreasing speed limits, separation of cars and vulnerable road users, building roundabouts, safe intersections with dedicated areas for crossing the road at bus stops, and constructing speed humps.[320] Roundabouts have become the desired intersection type.[321] They are safer for pedestrians than traffic signals because pedestrians only cross one direction of traffic at a time, so crossing distances remain short.[322] The tight circles of roundabouts force drivers to slow down, so vehicle speeds remain slower than the alternative signalized intersections as well.[323] Roundabouts reduce the number of conflict points, decrease the severity of conflicts that might occur, and significantly limit the speeds of vehicles moving through the intersection.[324] Figure 15 depicts a roundabout in Stockholm.[325] The following treatments are present that greatly improve the safety for pedestrians at the intersection: parallel, separate pedestrian and bicycle crossings; 30 km/h speed limit; and median refuges.

Figure 15: Street view of roundabout in Stockholm (Source: Google Maps)

The *National Transport Plan 2018-2029* includes a functional goal of passability, which is the concept of preserving stretches of road for high-speed vehicle traffic.[326] This concept directly challenges the prioritization of safety over flow. Transport Analysis[327] has proposed that "accessibility" replace "passability" in the *Swedish Traffic Ordinance* to foster a safer urban environment for pedestrians and cyclists.[328]

Policy

As the creator of Vision Zero, Sweden has shown significant innovation in the realm of policy, and the extent of leadership buy-in and support is unique. Vision Zero changed the way that road safety was viewed and understood internationally. It changed the view of responsibility in the roadway, attitudes towards the demands on road users for safety, and most importantly, the ultimate objective of road safety work.[329] This was a major departure from all other road safety policies at the time.[330] Many national policies exhibit the high degree of support for Vision Zero from the Government Offices of Sweden and the Swedish Parliament.

Due to a plateau in road fatalities after 2010, Sweden renewed their commitment to Vision Zero in 2016 in an official document that outlines the aim to intensify road safety efforts through assessing the current state of road safety work, challenges and opportunities, and the necessary future direction for Swedish road safety.[331,332] This document states the need for parallel vehicle safety and road infrastructure initiatives to optimize the safety benefits of each. It also includes a renewed commitment to the improved safety of VRUs, for whom accident trends have not been as positive as for drivers.[333]

In 2018, the government adopted a national plan for infrastructure, the *National Transport Plan 2018-2029*. This document discusses the Urban Environment Agreements, in which the central government will co-finance municipal and regional investments in infrastructure for public transportation and cycling, which inherently increase pedestrian safety.[334] In general, Swedish counties and municipalities hold the primary responsibility for local road safety. With independent powers of taxation, municipalities have a high degree of autonomy and independently fund the vast majority of road safety projects.[335] The plan also includes funding for research and innovation on active mobility.[336]

Planning

The *National Transport Plan* has established the importance of building housing in conjunction with transportation investments. Comprehensive and interdisciplinary research has shown that housing greatly influences mobility, and both are imperative for an accessible and inclusive Sweden.[337] The National Negotiation on Housing and Infrastructure facilitates agreements between the Federal government and municipalities for the co-financing of investments in public transportation and cycling, in addition to the construction of thousands of units of housing.[338] The government signed agreements with a number of municipalities, such as Stockholm, Gothenburg, and Malmö.[339]

The Swedish Transport Administration has stated that achieving safer speeds is the single biggest factor for reaching the target roadway fatality levels.[340] Current national laws set a default speed limit of 50 km/h in urban areas.[341] Municipalities have the power to decrease speed limits below the default values if those changes are justified based on traffic safety, passability, and the environment. Local agencies interested in decreasing the speed limit conduct speed limit reviews, which typically include a plan for introducing the new limits to the road network.[342] Through thorough review and analysis, Traffic Analysis recommends a default

speed limit of 40 km/h in urban areas. However, their 2017 report states that a default speed limit of 30 km/h would have a greater positive effect on traffic safety than a 40 km/h speed limit, but that the slower limit would cause significant travel time losses for vehicles.[343] Given that "passability" is a roadway functionality goal of the *National Transport Plan*, vehicle travel time influences roadway decision-making.

The Swedish Transport Administration, the Swedish National Road and Transport Research Institute, and the Swedish Transport Agency conduct an annual analysis on traffic safety developments to report on successes and challenges, on a number of indicators, of the current road safety work.[344] The report also works to improve the understanding of the interconnected relationships between infrastructure, vehicles, and road users.[345]

Technology

On-board vehicle technology regulations for protecting non-occupants is governed by the European Union's vehicle safety requirements, which are considerably progressive in the area of non-occupant protection.[346] The Strategic Vehicle Research and Innovation Program is a partnership between the Swedish government and the automotive industry for the joint funding of research, innovation, and development focused on the areas of climate, environment, and safety.[347]

Sweden refers to their speed enforcement cameras as "traffic safety cameras."[348] Because the police force is operating with extremely limited personnel, the cameras carry out the majority of speed enforcement efforts in the country.[349] Currently, 4,400 km of the road network are monitored, with plans for the continued expansion of the program.[350] The purpose of this program is not to fine as many people as possible, but rather, to nudge people to comply with the speed limits and to serve as a reminder to slow down.[351] This is also why there are road signs before each camera and no hidden cameras.

The *National Transport Plan* outlines the goal of having fixed and mobile connected sensors that report deficiencies in real time and is integrated into planning and maintenance systems.[352] Demonstration and pilot projects to increase knowledge about digitization are in planning phases.[353]

Data

From 2010 to 2017, pedestrian fatality rates increased by 19%, coupled with a 9% increase in vehicle kilometers travelled.[354] The default speed limit in urban areas is 50 km/h.[355] Municipalities can further lower speed limits, so it is common to see 30 km/h speed limits in urban areas as well. Pedestrian deaths as a percent of all traffic fatalities is 15%, accounting for a total of 37 pedestrian deaths in 2017.[356]

United Kingdom

The United Kingdom (UK) includes England, Wales, Scotland, and Northern Ireland, covering a total area of approximately 94,000 square miles.[357] The form of government is a parliamentary

constitutional monarchy. The population is 65.7 million. The road network comprises 262,850 miles.[358] There are 38.9 million registered motor vehicles. Some government departments serve the entire UK; however, many departments do not apply to all of the UK because some aspects of government are devolved to Scotland, Wales, and Northern Ireland.[359] This means that the central government transfers power to the regional administrations. The governments of Scotland, Wales, and Northern Ireland are responsible for their own departments of transportation.[360] Therefore, the UK Department of Transport only serves England; however, data from all of Great Britain is often presented in aggregate. England, Wales, and Scotland make up Great Britain.

Design

Highways England[361] and local authorities set road safety standards, and the Department for Transport (DfT) provides support for the improvement of these standards.[362] The DfT publishes national guidance and best practice documents on a variety of topics concerning road safety, including guidance on cycle infrastructure design and planning local cycling and walking networks.[363] A primary focus of the DfT's road safety work is to build bicycle lanes that are physically separated from pedestrians and vehicle traffic, with a long-term goal of building thousands more miles of protected bike lanes.[364] Local traffic authorities can apply to the DfT to pedestrianize a highway.[365]

The *Highway Code* outlines mandatory rules for road users in Great Britain, and it covers general rules of the road.[366] The DfT has proposed an amendment to the code to improve road safety for VRUs This amendment would introduce a hierarchy of road users through clearly establishing pedestrian and cyclist priority in the roadway.[367]

Figure 16 illustrates a midblock crossing on an urban arterial in London before and after safety improvements were made.[368] The following treatments, shown in Figure 17, were applied to improve safety outcomes. One lane of traffic in the north-bound direction was removed and the south-bound lanes were narrowed. This allowed for the addition of a two-way cycle track with an additional turning lane that is fully protected by a raised median. There are now parallel, separate crossings for pedestrians and cyclists with signals for each mode. The vehicle stop line is set back significantly from both crossings. Pedestrians have two median refuge islands, which greatly decreases the length of the crossing. There is a lateral shift in the pedestrian crossing that intersects the cycle tracks to add another level of awareness for pedestrians to watch out for cyclists.

Figure 16: Pre-project midblock crossing (Source: Google Maps)

Figure 17: Post-project midblock crossing (Source: Google Maps)

Policy

The DfT determines the road safety strategy for Great Britain.[369] DfT sets road safety targets, leads legislation efforts, and produces infrastructure design guidance. In 2015, they published a road safety statement titled "Working Together to Build a Safer Road System."[370] This document marks the UK's official adoption of the Safe System approach. It sets protecting VRUs through infrastructure and vehicle improvements as a key priority. An updated road safety statement published in 2019, titled "A Lifetime of Road Safety," focuses on shifting the UK's road safety approach to an integrated approach that focuses on both collision prevention and post-collision response.[371]

The design guidance produced by the DfT includes and supports the Safe System approach. There is strong leadership support for road safety initiatives, as evidenced by massive investments in this area. In May 2020, the government allocated £2 billion of dedicated funding to support cycling and walking initiatives.[372] DfT also supports the Cycling and Walking Investment Strategy, which was enacted through the Infrastructure Act of 2015.[373] This program supports the government's goal of making cycling and walking the natural choice for

shorter trips, or as part of longer trips, by 2040. This program includes a projected investment of over £770 million pounds for cycling and walking over the course of five years, supporting nine different projects.[374] The Safer Roads Fund is another investment strategy in which high-risk highways are treated with engineering design interventions, utilizing a £100 million commitment from the DfT.[375] Many other funding mechanisms supporting road safety are currently underway as well.

Planning

Local authorities are responsible for setting speed limits on the local road network.[376] The DfT has published guidance to assist with this process, suggesting that localities conduct a comprehensive study to determine safe speeds.[377] The document calls for the importance of considering the presence of VRUs. DfT asks that traffic authorities consider the introduction of more 20 mph speed limits in urban areas to ensure greater safety for pedestrians and cyclists.[378] Areas with 20 mph speed limits, in conjunction with engineering design measures and speed cameras, become self-enforcing, low-speed areas.[379]

Many of the funding programs have assessment models built into the program. For example, the DfT conducts formal monitoring and evaluation of major funding programs concerning cycling and walking.[380] In addition, the Safer Roads Fund includes a road safety impact assessment.[381] Local authorities were able to use the iRAP Star Rating methodology to develop a business case for investment. iRAP is the International Road Assessment Program, and the tools they provide include risk mapping, star rating systems, safer roads investment plans, and policy and performance tracking.[382] The iRAP process assists engineers with understanding the risks present along a certain route and possible treatments to reduce the risk.[383]

Technology

Although the UK is no longer a part of the European Union, the UK Vehicle Certification Agency has committed to mirroring the vehicle safety standards.[384] The European Parliament has ratified a new package of measures that will apply to all vehicles beginning in 2022.[385] These regulations include Intelligent Speed Assistance, lane-keeping assistance, automatic emergency braking, and safety glass to protect vulnerable road users, among others. The DfT, in partnership with the Center for Connected and Autonomous Vehicles, is working to support the safe testing, sale, and use of connected and autonomous vehicles.[386]

Data

From 2010 to 2017, there was a 17% increase in pedestrian fatality rates throughout the UK.[387] The number of vehicle miles travelled during that time increased as well.[388] The national, UK-wide speed limit is 30 mi/h (50 km/h) in urban areas.[389] Pedestrian deaths as a total of all traffic fatalities in the UK is 26%, accounting for 485 pedestrian deaths in 2017.[390]

Americas

Context

For the purposes of this desk review, Brazil and Columbia are included as representative South American countries with cities—Fortaleza and Sao Paulo, and Bogota, respectively—that have made concerted efforts to tame their large arterial networks to more safely accommodate pedestrians, as well as other VRUs. While these cities' progress does not necessarily reflect national performance, they demonstrate how a Safe System approach can produce notable change, particularly at intersections, to increase safety with low-cost improvements like paint and bollards.

Canada is perhaps most similar to the U.S. context, with urban centers surrounded by suburban communities that feature high volume arterials as key routes within a network of low-density, segregated land use types. Canada has national guidance for roadway design, including a national speed management guide, and recently launched a national Road Safety Strategy to officially adopt the Safe System approach, setting a long-term goal of zero deaths and serious injuries on Canadian roadways.[391] Canada exhibits a slight reduction in pedestrian fatalities between 2010 and 2017, though it also rose closer to the 2000 high in 2016.

Brazil

Brazil covers a total area of 3.29 million square miles, and the population is 211.7 million.[392] The form of government is a Federal presidential republic. The road network comprises 1.2 million miles, and approximately 153,000 miles are paved.[393] There are 2.8 million registered motor vehicles.[394] Through strong leadership priorities and an influx of funding, the cities of Fortaleza and Sao Paulo have made significant strides is improving pedestrian safety in the recent years.

Design

Design standards that support the safety of pedestrians and cyclists exist, but the standards are not comprehensive.[395] Engineering interventions implemented in Fortaleza include narrowed vehicle travel lanes, bike lanes, raised pedestrian crossings, curb extensions, and where necessary, completely redesigned intersections.[396] The Cidade 2000 neighborhood in Fortaleza pedestrianized nearly 13,000 square feet of parking and vehicle travel lanes, establishing pedestrians as the highest modal priority in the area.[397]

The city of Sao Paolo and local partners use tactical urbanism to test design strategies and justify the permanent implementation of design projects.[398] Figure 18 and Figure 19 illustrate an intersection in the Santana neighborhood of Sao Paulo before and after tactical urbanism was used to calm the speeds in the area. The traffic calming interventions shown in Figure 19 includes a roundabout and curb extensions, which in addition to slowing traffic through diversion and reduced turning radii, also created expanded public space furnished with planters, outdoor seating, and umbrellas. Two parking spots were converted into a parklet. Data collected before and after the project showed positive results: there was a 75% increase in safe pedestrian crossings and a 40% increase in driver yielding.[399]

Figure 18: Pre-project intersection configuration (Source: Google Maps)

Figure 19: Post-project intersection configuration (Source: Global Designing Cities Initiative)

Policy

The National Traffic Department under the Ministry of Cities is the lead government agency conducting road safety work in Brazil.[400] They are responsible for the development and implementation of the *National Traffic Policy*, in addition to the implementation of the regulatory standards and guidelines determined by the National Traffic Council.[401] In 2012, Brazil passed legislation that established the *National Policy on Urban Mobility*, which outlined principles, guidelines, and tools to help cities develop urban mobility plans.[402] The legislation, backed by $67 billion in Federal resources, requires cities to undertake urban mobility planning in order to receive Federal development funding.[403] Investments to upgrade high-risk locations are made through the Operation RodoVida program, which targets 100 of the most dangerous stretches of highway with increased enforcement and awareness campaigns.[404]

As the recipient of the first International Vision Zero for Youth Leadership Award, Fortaleza is a leader in prioritizing youth pedestrian and cyclist safety.[405] Fortaleza launched a bike-share service with child-sized bikes and training wheels called Mini Bicicletar.[406] This program supported over 6,000 rides in the first few months of operation. Traffic calming efforts are

focused in areas where high proportions of pedestrians are forced into the roadbed. The City of Sao Paolo adopted a Road Safety Plan in 2019 titled "Vida Segura."[407] This document states the city's commitment to Vision Zero and the Safe System approach.[408] The purpose of this document is to guide road safety policies in the city, and it includes sections on street design, speed management, and post-crash care.

Both Sao Paolo and Fortaleza are increasing efforts to lower speed limits and improve road infrastructure to protect vulnerable road users.[409] The cities receive funding from the Bloomberg Initiative for Global Road Safety and technical guidance from the World Resources Institute (WRI Brasil). Pilot projects include the following: pedestrianizing streets, converting intersection into roundabouts, and increasing the amount and quality of public spaces.[410]

Planning

Audits or safety assessments are required before the building of new road infrastructure can commence; however, inspections of existing roads are not carried out on a large scale.[411] The *National Policy on Urban Mobility* focuses on supporting public transportation, walking, and cycling through a stronger integration of transportation and land use planning and policies.[412]

Sao Paulo has implemented a program called Area Calmas, which is a comprehensive speed management program that aims to improve pedestrian and cyclist safety through traffic calming strategies.[413] As of June 2019, 12 reduced speed areas were planned throughout the city.[414] The Vida Segura Plan in Sao Paulo outlines plans for the reclassification of the local road network.[415] The local transportation agency plans to reduce the speed limit on arterial roads to 50 km/h, and if a high-speed road lacks safe infrastructure for vulnerable road users, it will be reclassified as an arterial.[416]

Technology

The national vehicle safety standards do not provide requirements for pedestrian protection.[417] Latin America is significantly lacking in vehicle safety standards compared to Europe.[418]

Data

From 2006 to 2016, which represents the most recent data available, Brazil showed a significant decrease in the number of pedestrian fatalities. The pedestrian fatality rate decreased from 5.5 per 100,000 population in 2006 to 2.8 per 100,000 in 2016, which represents a 49% decrease.[419] The national speed limit in urban areas is 80 km/h.[420] Pedestrian deaths as a percent of all traffic fatalities is 18%, which accounted for 6,957 deaths in 2015.[421]

Colombia

Colombia covers a total area of nearly 440,000 square miles, and the population is 49 million.[422] The form of government is a presidential republic. The road network comprises 128,300 miles. There are 14.2 million registered motor vehicles.[423] The capital city of Bogotá, in particular, has made great strides in the area of road safety. From 1996 to 2006, Bogotá had a 50% decrease in

road fatalities, and this trend has continued through recent times due to strong mayoral leadership and external funding and technical support from Bloomberg Philanthropies.[424]

Design

National design standards that support the safety of pedestrians and cyclists do not currently exist.[425] The country has adopted a policy to separate and protect VRUs; however, poor infrastructure and road behavior has led to increased risk for all road users, especially pedestrians and cyclists.[426] Bogotá's most recent design guidance, including the *Public Space Manual* (2018) and the *Cycling Manual* (2020), illustrate the city's commitment to adding more public space and increasing the number of bike lanes.[427] As a result, there is strong evidence of modal separation throughout the city.

The city of Bogotá launched their *Bogotá Better for All* development plan in 2015, which established their goal of becoming the first megacity with zero traffic fatalities.[428] The mayor during this time, Enrique Peñalosa, prioritized pedestrian safety as a major concern.[429] Administrative priorities coupled with support from the World Resources Institute and the Bloomberg Initiative for Global Road Safety enabled massive infrastructure and road safety improvements.[430] Pedestrian deaths have declined every year since 2015, with a 20.5% decrease from 2015 to 2019.[431] The greatest decline occurred from 2018 to 2019, with a 17% reduction in pedestrian fatalities.[432] Figure 20 and Figure 21 illustrate typical roadway configurations for major signalized urban arterials before and after pedestrian safety improvements. The following treatments, demonstrated in Figure 21, are commonly applied to improve safety outcomes:

- Wide, continental pedestrian crossing markings
- Parallel, separate pedestrian and bicycle crossings
- Pedestrian signals
- Wide median refuges, often raised or curb protected
- High visibility signal poles
- Bollards to protect pedestrian areas (median refuges and sidewalks at the corners of intersections) from motor vehicles

Figure 20: Typical pre-project crossing configuration (Source: Google Maps)

Figure 21: Typical post-project crossing configuration - painted crosswalks and bike-walks, bollards, and brightly painted signal poles (Source: Google Maps)

Policy

As outlined by the *National Road Safety Plan 2011-2021*, the Government of Colombia has defined road safety as a priority and a State policy.[433] This plan encourages the development and application of comprehensive policies and actions aimed at reducing fatal and non-fatal crashes in the road network.[434] Local authorities have the legislative ability to reduce speeds based on local conditions.[435]

In Bogotá, mayoral leadership in the area of road safety, and often specifically for pedestrian safety, is a key reason for the strong advances made. In 2017, Bogotá adopted a Vision Zero road safety plan to improve coordination and prioritization of road safety work.[436] International agencies have had a significant impact on road safety work in Bogotá since 1996, which marked the beginning to a new, more active approach to road safety.[437] In 1996, the Japanese International Development Agency helped the city develop the *1996 Urban Transport Master Plan*.[438] The World Bank supported the city's primary mass transit system, the bus rapid transit system called TransMilenio.[439] Most recently, Bloomberg Philanthropies has provided technical assistance and financial investments to support road safety management and planning.[440]

Planning

Bogotá's District Development Plan, *Bogotá Better for All*, outlines the goal of building more than 75 new miles of bike paths and more than 38 million square feet of public space, in addition to maintenance on existing paths and areas.[441] In a massive program of work spanning four years, the goal for the increase in public space was achieved in December 2019.[442] The capital city has an established speed management program, which provides for the systematic evaluation of current speed limits based on function, environment, and operational characteristics of the road.[443] Infrastructure interventions are supported by the program, in addition to speed cameras, increased enforcement and signage, and school zones with decreased speed limits of 30 km/h.[444]

An analysis of the policy-making processes of Colombia conducted by the OECD in 2013 resulted in three key recommendations.[445] The first was to improve planning and prioritization for road construction projects. The second was to increase the amount and quality of data and information available to improve monitoring and evaluation. The third was to improve

coordination between the Federal and regional governments regarding the separation of responsibilities and management of resources for road safety work. In 2019, the Colombian Government committed to improving the monitoring and evaluation of road conditions and road safety using iRAP tools.[446] In addition, Bogotá published an auditing guide for urban roads in 2019.[447]

Technology

The national vehicle safety standards do not provide requirements for pedestrian protection.[448] Latin America is significantly lacking in vehicle safety standards compared to Europe.[449]

Data

In Colombia from 2010 to 2017, there was a 10% increase in pedestrian fatalities, paired with a 19% increase in vehicle kilometers travelled.[450] In Bogotá, for which more recent data is available, pedestrian fatalities decreased by 20% from 2015 to 2019.[451] Nationally, the speed limit on urban arterials is 60 km/h; however, considerations are underway to reduce the speed limit to 50 km/h.[452] Bogotá reduced the urban speed limit to 50 km/h in September 2019.[453] Pedestrian deaths as a percent of all traffic fatalities throughout the country is 27%, accounting for 1,790 deaths in 2017.[454]

Canada

Canada consists of ten provinces and three territories, covering a total area of over 3.8 million square miles.[455] The form of government is a Federal parliamentary democracy under a constitutional monarchy. The population is 37.7 million. The road network comprises 648,000 miles.[456] There are 24.6 million motor vehicles.

Design

The Transportation Association of Canada (TAC)[457] develops and publishes comprehensive roadway design guidance.[458] These documents are not legal mandates; the purpose of the guidance is to serve as a reference to aid roadway design practitioners.[459] TAC also publishes the *Manual for Uniform Traffic Control Devices for Canada* (MUTCDC).[460] The sixth edition of the *MUTCDC* is expected to be complete in November 2020, and this edition will most notably feature new traffic control devices and examples of how the devices should be applied.[461] The Manual has no legislative authority, and all roadway design practitioners use it to varying degrees.[462]

Canada adopted the Safe System approach in 2016, and as a result, there is increasing evidence of modal separation and pedestrian prioritization.[463] A government task force focused on VRU safety around heavy vehicles stated in a 2018 report that the transportation network should be designed to limit interactions between VRUs and road traffic.[464] This document outlines intersection design countermeasures that improve VRU safety around all vehicle types. One recommended solution to the conflict between pedestrians and turning vehicles at an intersection is a pedestrian scramble operation.[465] A pedestrian scramble is a type of traffic signal phasing that stops vehicle traffic in all directions, giving pedestrians exclusive access to

cross the intersection laterally and diagonally.[466] Toronto conducted a pilot project to test the efficacy of this countermeasure at an urban intersection, Yonge St and Dundas St W., with high volumes of pedestrians attributable to dense commercial land uses and a hub of transit routes including an underground metro station, as well as on-street tram and bus routes.[467] Figure 22 and Figure 23 illustrate the intersection design that accompanied the updated signal phasing.[468] This project implementation led to time-savings for pedestrians and increased usage of the diagonal crossing.[469] This project caused a 25 second average increased delay for vehicles, which was determined to be an acceptable tradeoff given the safety and operational benefits.[470] These benefits include increased pedestrian visibility, reduced conflict between vehicles and pedestrians, and reduced pedestrian crossing time and exposure.[471]

Figure 22: Street view of pedestrian scramble configuration at Yonge St and Dundas St W. in Toronto (Source: Google Maps)

Figure 23: Aerial view of pedestrian scramble configuration, commercial land uses, and transit connections at Yonge St and Dundas St W. in Toronto (Source: Google Maps)

Policy

The responsibility for road safety work is divided among the different levels of government. The Federal government sets national priorities and establishes vehicle regulations and standards.[472] Provinces and territories administer road safety programs and set policies and

regulations regarding the roadways.[473] Local municipalities are responsible for funding local road infrastructure, and they are required to operate within the provincial guidelines.[474] However, the Federal government operates multiple funding programs to assist with the building and maintenance of road infrastructure, generally through bilateral cost-sharing agreements with provinces or municipalities.[475] While Federal funding is available for provinces and territories that prioritize investment in active transportation infrastructure, a 2018 government report states that there is room for the Federal government to expand their leadership and support in this area.[476]

In 2016, Canada launched the *Road Safety Strategy 2025* (RSS 2025), which marked the official adoption of the Safe System approach and outlined the long-term goal of achieving zero deaths and serious injuries on Canadian roadways.[477] One of the strategic objectives of this plan is to improve the safety of vehicles and road infrastructure. *RSS 2025* includes a flexible approach to Federal funding that allows jurisdictions to implement road safety programs that specifically address local needs.[478] The plan also includes the development of an inventory of best practice countermeasures to support national consistency and serve as a resource to jurisdictions who are developing their own road safety plans.[479]

A growing number of municipalities are formally adopting Vision Zero policies.[480] Toronto's *Vision Zero Plan* includes an equity impact statement that discusses how road safety work should be implemented to build a safe and inclusive city.[481] This includes conducting analyses on KSI collision data and other demographics information to target improvements in locations that will benefit the most vulnerable populations, thereby using a data-driven approach to ensure the equal distribution of infrastructure improvements. In addition, Toronto is working to ensure that police enforcement groups apply Vision Zero policies consistently and without targeting certain groups.[482]

Planning

Land use planning is an important aspect of Canada's approach to pedestrian safety and accessibility.[483] While municipalities or provinces may have their own assessment methods, there does not appear to be a standard and nationally consistent method or model for the assessment of road safety projects. The Canadian Council of Motor Transport Administrators (CCMTA), which publishes the best practice inventory of road safety measures, developed an assessment tool to determine strong countermeasures to be included in the inventory.[484] This assessment evaluates a project based on its general characteristics, cost-benefit analysis, and research-based evidence that supports the initiative.[485]

TAC published their *Speed Management Guide* in 2016.[486] This guidance focuses primarily on infrastructure methods of managing speeds, but it does briefly discuss enforcement and education methods as well. In addition, many provinces and territories have their own guidance on setting speed limits.[487] Local transportation agencies have the authority of modifying speed limits based on local conditions.[488]

Technology

Transport Canada is the Federal agency responsible for transportation policies and programs.[489] They are the primary government agency conducting research and establishing policy concerning connected and autonomous vehicles.[490] They are currently evaluating crash-warning systems, specifically pedestrian detection and warning systems on heavy vehicles and the safety benefits of automatic emergency braking technology for pedestrians.[491] They also fund research, testing, and development of infrastructure technologies.[492] There are no vehicle safety standards that protect non-occupants.[493] Many municipalities use automated speed enforcement to promote safe speeds in their jurisdictions.[494]

Data

From 2010 to 2017, there was a 2.3% decline in the pedestrian fatality rate.[495] Over the same period, vehicle kilometers travelled increased by 14%.[496] The average speed on urban arterials is 50 km/h.[497] Pedestrian deaths as a percent of all traffic fatalities is 16%, which amounted to 299 pedestrian deaths in 2017.[498]

End Notes

The FHWA Global Benchmarking Program study team has identified Australia and New Zealand as peer countries for further research and analysis on the topic of pedestrian safety on urban arterials. A combination of virtual and in person exchanges will be documented in a forthcoming report. The goal of the report, like this desk review, will be to inform the U.S. approach to implementing solutions to improve safety for pedestrians on urban arterial roads. For more information, please see: https://international.fhwa.dot.gov/programs/mrp/gbp.cfm.

Appendix

Table 3: List of Subject Matter Experts Contacted as Part of the Desk Review

Name	Country	Entity	Entity Type
Soames Job	Australia	World Bank	NGO
Blair Matthew Turner	Australia	World Bank	NGO
Julie Taylor	Canada	Parachute Canada	NGO
Carlos Urrego Duran	Colombia	Bloomberg Philanthropies	NGO
Claudia Diaz Acosta	Colombia	Secretaría Distrital de Movilidad	Gov (City)
Julian Gonzalez Flechas	Colombia	Secretaría Distrital de Movilidad	Gov (City)
Jeff Risom	Denmark	Gehl Studio	Private Design Firm
Anne Eriksson	Denmark	Danish Road Directorate	Gov (Federal)
Emile Oosterbrink	Netherlands	CROW	NGO
Hillie Talens	Netherlands	CROW	NGO
Fred Wegman	Netherlands	Delft University of Technology	Academic
Henk Stipdonk	Netherlands	NL Inst. for Transport Policy Analysis	Gov (Federal)
Paul Schepers	Netherlands	SWOV	NGO
Rob Methorst	Netherlands	SWOV	Gov (Federal)
Shane Turner	New Zealand	Abley	Private Engineering Firm
Skye Duncan	New Zealand	NACTO	National Association
Glen Koorey	New Zealand	Via Strada	Private Transportation Firm
Kathryn King	New Zealand	NZ Transport Agency	Gov (Federal)
Sam Bourne	New Zealand	NZ Transport Agency	Gov (Federal)
Sigurd Lotveit	Norway	Norwegian Public Roads Admin	Gov (Federal)
Svein Ringen	Norway	Norwegian Public Roads Admin	Gov (Federal)
Henrik Wildenschild	Norway	Norwegian Public Roads Admin	Gov (Federal)
Kenneth Svensson	Sweden	Swedish Transport Administration	Gov (Federal)
Judy Fleiter	Switzerland	Global Road Safety Partnership	NGO
Phil Erickson	USA	CD+A	Private Planning Firm
Jesse Mintz-Roth	USA	City	Gov (City)
Vu Dao	USA	City	Gov (City)
Anthony Chung	USA	City	Gov (City)
Warren Logan	USA	City of Oakland	City Administration
Saravana Suthanthira	USA	County	County Transportation Commission

Name	Country	Entity	Entity Type
Cathleen Sullivan	USA	County	County Transportation Commission
Carolyn Clevenger	USA	County	County Transportation Commission
Matthew Ridgeway	USA	Fehr & Peers	Private Transportation Firm
Natalie Draisin	USA	Fia Foundation	NGO
Fabrizio Prati	USA	NACTO	National Association
Matthew Roe	USA	NACTO	National Association
Jamie Parks	USA	SFMTA	City DOT
Mike Sallaberry	USA	SFMTA	City DOT
Mike King	USA	Traffic Calmer	Private Transportation Firm
Claudia Adriazola-Steil	USA	World Resources Institute	NGO
David Vega-Barachowitz	USA	XYZ Studio	Private Design Firm

Table 4: FHWA Global Benchmarking Study Team

Name	Title	Office	Study Team Role
Mr. Mike Griffith	Director	FHWA Office of Safety Technology	Co-Lead
Mr. Darren Buck	Pedestrian and Bicycle Planning Lead	FHWA Office of Human Environment	Co-Lead
Ms. Tamara Redmon	Pedestrian Safety Manager	FHWA Office of Safety Technology	Member
Ms. Lee Austin	Traffic Engineer	City of Austin	Member
Dr. Laura Sandt	Director	Collaborative Sciences Center for Road Safety; Pedestrian and Bicycle Information Center, University of Chapel Hill North Carolina Highway Safety Research Center	Member
Ms. Rachel Carpenter	Chief Safety Officer	California Department of Transportation	Member
Mr. Mark Cole	State Highway Safety Engineer	Virginia Department of Transportation	Member
Mr. Jonah Chiarenza	Transportation Planner	U.S. Department of Transportation Volpe Center	Report Lead
Ms. Annisha Borah	Technology Policy Analyst	U.S. Department of Transportation Volpe Center	Researcher

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