CPBS Center for Pedestrian and Bicyclist Safety

A Tier-1 University Transportation Center

Analysis of Geographic, Temporal, and Socioeconomic Shifts in Pedestrian & Bicyclist Traffic Injuries

July 2025

A Report From the Center for Pedestrian and Bicyclist Safety

Robert J. Schneider
University of Wisconsin-Milwaukee

Xiaohan Gu
Penn State University

Henry Barbee
University of Wisconsin-Milwaukee

Kyle Nelson
University of Wisconsin-Milwaukee

Nicholas N. Ferenchak
University of New Mexico

Xiao Qin
University of Wisconsin-Milwaukee

About the Center for Pedestrian and Bicyclist Safety (CPBS)

The Center for Pedestrian and Bicyclist Safety (CPBS) is a consortium of universities committed to eliminating pedestrian and bicyclist fatalities and injuries through cutting-edge research, workforce development, technology transfer, and education. Consortium members include: The University of New Mexico; San Diego State University; The University of California Berkeley; The University of Tennessee Knoxville; and The University of Wisconsin Milwaukee. More information can be found at: https://pedbikesafety.org

Disclaimer

Acknowledgments

This study was funded, partially or entirely, by a grant from the Center for Pedestrian and Bicyclist Safety (CPBS), supported by the U.S. Department of Transportation (USDOT) through the University Transportation Centers program. The authors would like to thank CPBS and the USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project. We would also like to thank the City of Milwaukee Department of Public Works and the Spring 2025 University of Wisconsin-Milwaukee Pedestrian and Bicycle Transportation class for helping to pilot test and suggest edits to the draft national PLTS survey. We are especially grateful to all of the anonymous participants who completed and shared the final national PLTS survey with family, friends, and colleagues.

TECHNICAL DOCUMENTATION

1. Project No. 24UWM01	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Analysis of Geographic, Temporal, and Socioeconomic Shifts in Pedestrian & Bicyclist Traffic Injuries		**5. Report Date** June 2025 **6. Performing Organization Code** N/A
7. Author(s) Robert J. Schneider https://orcid.org/0000-0002-6225-3615 Xiaohan Gu https://orcid.org/0009-0005-8688-1201 Henry Barbee https://orcid.org/0009-0005-2759-7120 Kyle Nelson https://orcid.org/0009-0009-3934-1914 Nicholas N. Ferenchak https://orcid.org/0000-0002-3766-9205 Xiao Qin https://orcid.org/0000-0003-0073-3485		**8. Performing Organization Report No.** N/A
9. Performing Organization Name and Address Center for Pedestrian and Bicyclist Safety Centennial Engineering Center 3020 The University of New Mexico Albuquerque, NM 87131		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** 69A3552348336
12. Sponsoring Agency Name and Address United States of America Department of Transportation Office of Research, Development, and Technology (RD&T)		**13. Type of Report and Period Covered** Final Report (June 2025) **14. Sponsoring Agency Code** USDOT OST-R
15. Supplementary Notes Report available at the CPBS website [https://pedbikesafety.org] and DOI https://doi.org/10.21949/dhs7-db66		

16. Abstract

We used quantitative and qualitative methods to explore shifts in fatal and severe (FSI) pedestrian injuries and FSI bicyclist injuries since 2008. We gathered police-reported crash data for more than 20,000 census tracts across eight states during 2008-2012 and 2017-2021. We developed negative binomial and Poisson-Gamma conditional autoregressive models to analyze neighborhood-level factors associated with changes in FSI pedestrian and FSI bicyclist injuries. FSI pedestrian crashes were positively associated with certain neighborhood characteristics in both periods: larger proportions of Black, Hispanic, or low-income populations; higher unemployment rates; higher proportions of retail jobs; having transit nearby; and containing at least one high-traffic arterial roadway. FSI bicyclist crashes were positively associated with higher shares of Black residents; lower incomes; higher unemployment rates; higher proportions of retail jobs; higher population and employment densities; close proximity to transit stops; and at least one high-volume arterial roadway. Certain neighborhood crash disparities became more prominent over time. We also interviewed 13 practitioners to provide insights about local changes in pedestrian and bicyclist safety outcomes during the 2010s. These interviews suggested that increases in pedestrian and bicyclist fatalities may be related to shifts of pedestrian and bicyclist activity to higher-risk parts of urban regions, reduced traffic enforcement potentially leading to higher vehicle speeds and more reckless driving, and automobile-oriented roadways. Recognizing study limitations, information in this report will help practitioners understand policies and other actions that may have the greatest potential to prevent pedestrian and bicyclist injuries in the future.

17. Key Words	**18. Distribution Statement**
Pedestrians; Pedestrian Safety; Cyclists; Bicyclist Safety; Crash Analysis; Neighborhoods; Cities	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	72	

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

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

Analysis of Geographic, Temporal, and Socioeconomic Shifts in Pedestrian & Bicyclist Traffic Injuries

A Center for Pedestrian and Bicyclist Safety Research Report

June 2025

Robert J. Schneider
Department of Urban Planning
University of Wisconsin-Milwaukee

Xiaohan Gu
Department of Civil and Environmental Engineering
Penn State University

Henry Barbee
Department of Urban Planning
University of Wisconsin-Milwaukee

Kyle Nelson
Department of Urban Planning
University of Wisconsin-Milwaukee

Nicholas N. Ferenchak
Department of Civil, Construction and Environmental Engineering
University of New Mexico

Xiao Qin
Department of Civil and Environmental Engineering
University of Wisconsin-Milwaukee

TABLE OF CONTENTS

Acronyms, Abbreviations, and Symbols v
Abstract vi
Executive Summary vii
Introduction 1
Literature Review 2
Research on Pedestrian Injury Shifts 2
Research on Bicyclist Injury Shifts 3
Research Gaps 3
Data and Methodology 4
Pedestrian and Bicyclist Crashes by Census Tract 4
Geographic Scope 4
Temporal Scope 5
Crash Data 7
Analysis Variables 8
Statistical Modeling Approach 9
Practitioner Interviews 10
Interview Content 11
Interview Participants 11
Qualitative Analysis 13
Results 14
FSI Pedestrian Injury Trends 14
FSI Bicyclist Injury Trends 16
Census Tract Characteristics Associated with FSI Pedestrian Crashes 18
Overall Statistical Significance and Spatial Dependence 18

Neighborhood Characteristics Associated with Pedestrian Crashes in both Study Periods 21
Neighborhood Characteristics Associated with Shifts in Pedestrian Crashes 21
Census Tract Characteristics Associated with FSI Bicyclist Crashes 22
Practitioner Insights about Pedestrian and Bicyclist Safety Changes 26
Pedestrian and bicyclist exposure 26
Enforcement and driver behavior 28
Pedestrian risk at night 29
Engineering and roadway design 29
Coordination with State DOTs 31
Policy and Planning 31
Community Advocacy and Leadership 32
Funding and Resources 33
Public Resistance 35
Other Interview Findings 35
Discussion 36
Considerations and Future Research 39
Conclusions and Recommendations 41
References 42
Appendix A. Model Analysis Variables 46
Appendix B. Practitioner Interview Consent Form 51
Appendix C. Practitioner Interview Protocol 56

List of Figures

Figure 1. FSI Pedestrian Crashes by State: Total Number and Percent Geocoded and Included in Analysis, 2008-2012 and 2017-2021 5
Figure 2. Average Annual FSI Pedestrian Crashes Across Eight States: Five-Year Windows 6
Figure 3. Average Annual FSI Bicyclist Crashes Across Eight States: Five-Year Windows 7
Figure 4. State-Level Changes in Fatal Pedestrian Crashes, 2008-2021 14
Figure 5. Change in Pedestrian Crashes in Nine States by Injury Severity Level, 2008-2021 15
Figure 6. State-Level Changes in Fatal Bicyclist Crashes, 2008-2021 16
Figure 7. Change in Bicyclist Crashes in Nine States by Injury Severity Level, 2008-2021 17
Figure 8. Example Spatial Distribution: Los Angeles area FSI Pedestrian Crashes by Tract, 2008-2012 vs. 2017-2021 20
Figure 9. Example Spatial Distribution: Los Angeles area FSI Bicyclist Crashes by Tract, 2008-2012 vs. 2017-2021 25

List of Tables

Table 1. State-Level Changes in Fatal Pedestrian Crashes, 2008-2021 15
Table 2. Change in Pedestrian Crashes in Nine States by Injury Severity Level, 2008-2021 16
Table 3. State-Level Changes in Fatal Bicyclist Crashes, 2008-2021 17
Table 4. Change in Bicyclist Crashes in Nine States by Injury Severity Level, 2008-2021 18
Table 5. Models of Fatal & Severe Injury Pedestrian Crashes per Census Tract, 2008-12 vs. 2017-21 19
Table 6. Models of Fatal and Severe Injury Bicyclist Crashes per Census Tract, 2008-2012 vs. 2017-2021 24

Acronyms, Abbreviations, and Symbols

AADT	Annualized Average Daily Traffic
FSI	Fatal or Severe Injury

Abstract

We used quantitative and qualitative methods to explore shifts in fatal and severe (FSI) pedestrian injuries and FSI bicyclist injuries from 2008 to 2021. We gathered police-reported crash data for more than 20,000 census tracts across eight states during 2008-2012 and 2017-2021. We developed negative binomial and Poisson-Gamma conditional autoregressive models to analyze neighborhood-level factors associated with changes in FSI pedestrian and FSI bicyclist injuries. FSI pedestrian crashes were positively associated with certain neighborhood characteristics in both periods: larger proportions of Black, Hispanic, or low-income populations; higher unemployment rates; higher proportions of retail jobs; having transit nearby; and containing at least one high-traffic arterial roadway. FSI bicyclist crashes were positively associated with higher shares of Black residents; lower incomes; higher unemployment rates; higher proportions of retail jobs; higher population and employment densities; close proximity to transit stops; and at least one high-volume arterial roadway. Certain neighborhood crash disparities became more prominent over time. We also interviewed 13 practitioners to provide insights about local changes in pedestrian and bicyclist safety outcomes during the 2010s. These interviews suggested that increases in pedestrian and bicyclist fatalities may be related to shifts of pedestrian and bicyclist activity to higher-risk parts of urban regions, reduced traffic enforcement potentially leading to higher vehicle speeds and more reckless driving, and automobile-oriented roadways. Recognizing study limitations, information in this report will help practitioners understand policies and other actions that may have the greatest potential to prevent pedestrian and bicyclist injuries in the future.

Executive Summary

Between 2010 and 2023, annual US pedestrian fatalities increased from 4,302 to 7,314 (+70%) and annual US bicyclist fatalities increased from 623 to 1,166 (+87%) (NHTSA 2025a). These tragic pedestrian and bicyclist fatality trends make the US an international outlier for pedestrian and bicyclist fatalities (International Transport Forum 2022; Buehler and Pucher 2023). Understanding the reasons for these poor pedestrian and bicyclist safety outcomes is critical for communities in the US as they seek to improve transportation options, physical activity, public health, and spaces for family and social interaction.

We applied both quantitative and qualitative methods to improve understanding of shifts in fatal and severe (FSI) pedestrian injuries and FSI bicyclist injuries from 2008 to 2021.

Our preliminary descriptive analysis of police-reported pedestrian and bicyclist crashes across nine states showed that crashes with pedestrian and bicyclist fatalities increased more steeply than crashes with severe injuries between 2008 and 2021. Moderate and minor injuries actually decreased over this period. This suggests that increases in pedestrian and bicyclist fatalities are unlikely to be due to increases in overall levels of pedestrian or bicyclist exposure. Rather, fatality increases were likely to be related to changes to roadways, vehicles, or behaviors in the US transportation and land use system.

To analyze factors associated with changes in FSI pedestrian and FSI bicyclist injuries at the neighborhood level, we used negative binomial and Poisson-Gamma conditional autoregressive models. Specifically, we analyzed the number of reported crashes in more than 20,000 census tracts across eight states. We found that FSI pedestrian crashes were positively associated with certain neighborhood characteristics in both periods: larger proportions of Black, Hispanic, or low-income populations; higher unemployment rates; higher proportions of retail jobs; having transit nearby; and containing at least one high-traffic arterial roadway. Between 2008-2012 and 2017-2021, FSI pedestrian crashes became even more prominent in neighborhoods with higher proportions of Black or Hispanic residents, interstates or other freeways or expressways, higher proportions of retail jobs, and transit nearby. FSI bicyclist crashes were positively associated with neighborhoods that have higher shares of Black residents, lower median household incomes, higher shares of unemployed workers, higher proportions of retail jobs, higher population and employment densities, close proximity to transit stops, and at least one high-volume arterial roadway. FSI bicyclist crashes became more prominent during the 2010s in neighborhoods with higher shares of Black and Hispanic residents, higher population density, and a non-interstate freeway or expressway.

We also interviewed local practitioners who work on pedestrian and bicyclist safety issues to identify successful strategies as well as barriers to safety experienced in communities with some of the highest and lowest pedestrian and bicyclist fatality rates. Our practitioner interviews suggested that increases in pedestrian and bicyclist fatalities during the 2010s may be related to shifts of pedestrian and bicyclist activity to higher-risk parts of urban regions, reduced traffic enforcement potentially leading to higher vehicle speeds and more reckless driving, a large proportion of roadways still designed to facilitate high-speed automobile movement over multimodal safety, and a lack of political will and resources to prioritize pedestrian and bicyclist safety needs in certain communities.

These results should be viewed in the context of study limitations, such as not being able to control for potential roadway user behavior changes due to the COVID-19 pandemic. interviews only capturing thoughts from 13 practitioners, crash model data only covering eight states, and only having traffic data from a single year. We recommend further longitudinal research on pedestrian and bicyclist safety outcomes. In particular, it is important to track changes over time to gain an even better understanding of how pedestrian and bicyclist crash rates relate to changes in vehicle design, roadway user behaviors (e.g., driver speeding), and employment shifts.

Still, the information in this report will help practitioners understand policies and other actions that may have the greatest potential to prevent the most serious pedestrian and bicyclist crashes in the future. Overall, the results suggest promising policies and strategies to improve pedestrian and bicyclist safety within communities. We recommend that communities build strong advocacy coalitions, encourage elected officials to make traffic safety a priority, adopt ambitious policies and plans to reduce traffic fatalities, experiment with new roadway designs, implement roadway redesign projects quickly, establish speed safety camera and red light safety camera programs, communicate results of safety initiatives with the public, and increase staff positions and funding for pedestrian and bicycle safety projects and programs.

Introduction

This research project is a part of the overarching Center for Pedestrian and Bicyclist Safety University Transportation Center (CPBS UTC) effort to better understand and combat the overall increase in US pedestrian and bicyclist fatalities over the last 15 years. Between 2010 and 2023, annual US pedestrian fatalities increased from 4,302 to 7,314 (+70%) and annual US bicyclist fatalities increased from 623 to 1,166 (+87%) (NHTSA 2025a). These tragic pedestrian and bicyclist fatality trends make the US an international outlier for pedestrian and bicyclist fatality (International Transport Forum 2022; Buehler and Pucher 2023). Understanding reasons for these poor pedestrian and bicyclist safety outcomes is critical for communities in the US as they seek to improve transportation options, physical activity, public health, and spaces for family and social interaction.

Through a Year 1 CPBS UTC project, our research team conducted a census-tract-level analysis of fatal and severe injury (FSI) pedestrian crashes (Schneider et al. 2024). While that Year 1 project provided new insights, it did not examine bicyclist crashes or develop a broad understanding of potential reasons behind local changes in local pedestrian or bicyclist safety outcomes. Understanding differences in pedestrian and bicyclist crash outcomes between different neighborhoods and different cities over time is essential to preventing future pedestrian and bicyclist fatalities and injuries.

Our study uses data from multiple states to investigate the following questions:

- How much did fatal, severe, and non-severe pedestrian and bicyclist injuries change from 2008 to 2021?
- What exposure, demographic, employment sector, land use, and roadway design characteristics were associated with shifts in FSI pedestrian and FSI bicyclist crashes at the neighborhood level between 2008-2012 and 2017-2021?
- What cities had the highest and lowest pedestrian and bicyclist fatality rates per population in 2008-2012 and 2018-2022, and which cities experienced the greatest increases and decreases in fatality rates?
- What exposure, socioeconomic, land use, transportation system, policy, institutional, and behavioral factors do practitioners think influenced changes in pedestrian and bicyclist fatality rates in their local communities during the 2010s?

The results of our analysis show where and suggest possible reasons why pedestrian and bicyclist fatalities and injuries have increased and decreased the most. This report provides practitioners with support for engineering, education, enforcement, and other safety strategies that can help prevent future pedestrian and bicyclist injuries.

Literature Review

We reviewed prior research on trends in pedestrian and bicyclist injuries over time to provide background for this study. Our review focused on longitudinal analyses of crash data.

Research on Pedestrian Injury Shifts

Our Year 1 CPBS Report provides an overview of previous longitudinal studies on pedestrian injury shifts (Schneider et al. 2024). Overall, this literature shows that:

- Pedestrian fatalities involving children and drunk drivers have decreased while pedestrian fatalities involving large vehicles, and occurring at night, on roadways with speed limits of 35 mph and higher, or on roadways with four or more lanes have increased over the last 40 years (Schneider 2020).
- Most of the growth in pedestrian fatalities during the 2010s occurred during darkness (Hu & Cicchino 2018; Retting 2020; Ferenchak & Abadi 2021; Tefft, Arnold, & Horrey 2021; Ferenchak, Gutierrez, & Singleton 2022).
- Since 2010, pedestrian fatalities have increased the most for people aged 18 to 64 (Tefft, Arnold, & Horrey 2021).
- Pedestrian crashes have increasingly occurred in neighborhoods with high poverty rates, high proportions of non-Hispanic white residents, and low education levels since 2010 (Sanchez Rodriguez & Ferenchak 2023).
- Since 2010, pedestrian fatalities have increased on urban arterials (Hu & Cicchino 2018; Sandt et al. 2020; Ferenchak & Abadi 2021; Tefft, Arnold, & Horrey 2021), and at non-intersection locations (Ferenchak & Abadi 2021; Tefft, Arnold, & Horrey 2021).
- Vehicle size has shown mixed results, with sedans and smaller cars contributing the most to the overall increase in pedestrian fatalities in the 2010s (Tefft, Arnold, & Horrey 2021), even though the number of pedestrian fatalities involving larger vehicles (e.g., sport utility vehicles (SUVs)) continued to rise (Hu & Cicchino 2018; Retting 2020; Ferenchak & Abadi 2021).
- During the 2010s, pedestrian fatalities increased more in urban and suburban areas than rural areas (Hu & Cicchino 2018; Ferenchak & Abadi 2021; Tefft, Arnold, & Horrey 2021), but they have also shifted away from the core of urbanized areas (Ferenchak and Abadi 2021; Sanchez Rodriguez and Ferenchak 2023).
- Road user behaviors related to increases in ridehailing (e.g., Uber, Lyft) (Barrios, Hochberg, & Yi 2020), growth in mobile device ownership and use (particularly among drivers) (Deka & Brown 2016; Retting 2020), driver speeding (Petraglia & Macek 2023), and driver and pedestrian drug use (Thomas et al. 2022) have also been suggested as contributing to increased pedestrian fatalities during the 2010s, but better data is needed to draw clearer conclusions.

Some traffic safety studies have analyzed the overall number and types of jobs as explanatory variables (Merlin et al. 2020). Pedestrian fatalities were associated with retail job density (Mansfield et al. 2018) and pedestrian crashes were associated with the number of service jobs (Cai et al. 2016), but we are unaware of longitudinal pedestrian safety studies that have examined the association between pedestrian crash shifts over time and employment by sector.

Methodologically, most longitudinal pedestrian safety studies have analyzed fatalities from NHTSA's Fatality Analysis Reporting System (NHTSA 2025b). There are no national databases that contain comprehensive sets of non-injury crashes. However, Ferenchak, Gutierrez, & Singleton (2022) gathered data from several different states to explore changes in fatalities as well as serious, minor, and possible pedestrian injuries over time.

Research on Bicyclist Injury Shifts

Similarly, most bicyclist safety studies were macro-level studies and have focused on fatal bicyclist crashes due to crash data availability. Some recent studies have highlighted potential geographic shifts in US cyclist fatalities, emphasizing disparities beyond urban cores. Rodriguez and Ferenchak (2024) found that fatalities increasingly occur in suburban, lower-income, and minority neighborhoods across the US. Chaves Lasso et al. (2024) conducted a spatial analysis of pedestrian and bicyclist crashes on arterial roads in Albuquerque, New Mexico, revealing that high-speed, high-access roads with more driveways per mile are more likely to experience bicyclist crashes. Siddiqui et al. (2012) examined the spatial correlation of pedestrian and bicyclist crashes, showing distinctive spatial patterns. Cai et al. (2016) observed that population and employment densities, length of sidewalks, as well as the percentages of walking and biking commuters were positively related to bicyclist crash frequencies in Florida. When compared to other European countries, Buehler & Pucher (2021) found that bicyclist fatalities in the US were much higher from 1990 to 2018, partially due to a lack of bicycling infrastructure, higher urban speed limits, more vehicle miles traveled, as well as more large-sized vehicles. These studies reveal that effective cyclist safety efforts require targeted, fine-grained examinations to understand how both geographic and socioeconomic characteristics would impact bicyclist fatalities.

Research Gaps

Our review revealed that there are few longitudinal studies that examine other pedestrian and bicyclist injury severity levels besides fatalities. Further, very few qualitative studies have been conducted to try to understand the underlying reasons behind changes in pedestrian and bicyclist injuries over time. Our study helps fill gaps in the literature by examining both fatal and severe injury pedestrian and bicyclist crashes and analyzing how these crashes have shifted within census tracts with certain types of characteristics, including land uses and jobs by employment sector. We are also among the first researchers to gather expert opinions about local pedestrian and bicyclist injury shifts from practitioners working to improve safety for these modes in their local communities.

Data and Methodology

This section describes the three main methods we used to analyze FSI pedestrian and FSI bicyclist crash trends over time. First, we gathered police-reported pedestrian and bicyclist crashes from nine states to describe trends in pedestrian and bicyclist injury severity between 2008 and 2021. The nine states were geographically diverse: California, Colorado, Massachusetts, Minnesota, New York, Oregon, Pennsylvania, Washington, and Wisconsin. After we scanned all 50 states, these were the nine that provided pedestrian and bicyclist crash data with injury severity categories for all years within the two analysis periods. Second, we used data from eight states[1] to quantitatively compare FSI crashes in more than 20,000 census tracts during the 2008-2012 baseline period versus the 2017-2021 later period. Third, we conducted semi-structured interviews with practitioners to discuss FSI pedestrian and bicyclist crash trends in their local communities. We qualitatively summarized these interviews to identify common themes related to exposure, socioeconomic, land use, transportation system, policy, institutional, and behavioral factors that practitioners believed might have a relationship with pedestrian and bicyclist crash trends during the 2010s.

Pedestrian and Bicyclist Crashes by Census Tract

This section describes the data collected and analyzed for our quantitative analyses of FSI pedestrian and FSI bicyclist crashes at the census tract level. We analyzed police-reported crash data from eight states to explore shifts in FSI pedestrian and FSI bicyclist crashes between two five-year periods: 2008-2012 and 2017-2021.

Geographic Scope

Our census tract analysis covered the states of California, Colorado, Massachusetts, New York, Oregon, Pennsylvania, Washington, and Wisconsin.[2] Pedestrian crash geocoding rates were high in most states except for Oregon and Wisconsin in the earlier time period (Figure 1). Geocoding rates were similar across our study states for bicyclist crashes. These eight states contained 21,833 census tracts (based on 2010 boundaries) with sufficient data for analysis.

[1] We excluded Minnesota from our census tract analysis because we did not have accurate latitude and longitude data for that state's crashes at the beginning of our analysis process.
[2] We compared 2010-2014 vs. 2017-2021 for Washington because there were fewer than five geocoded FSI pedestrian crashes in the Washington dataset from 2008-2009.

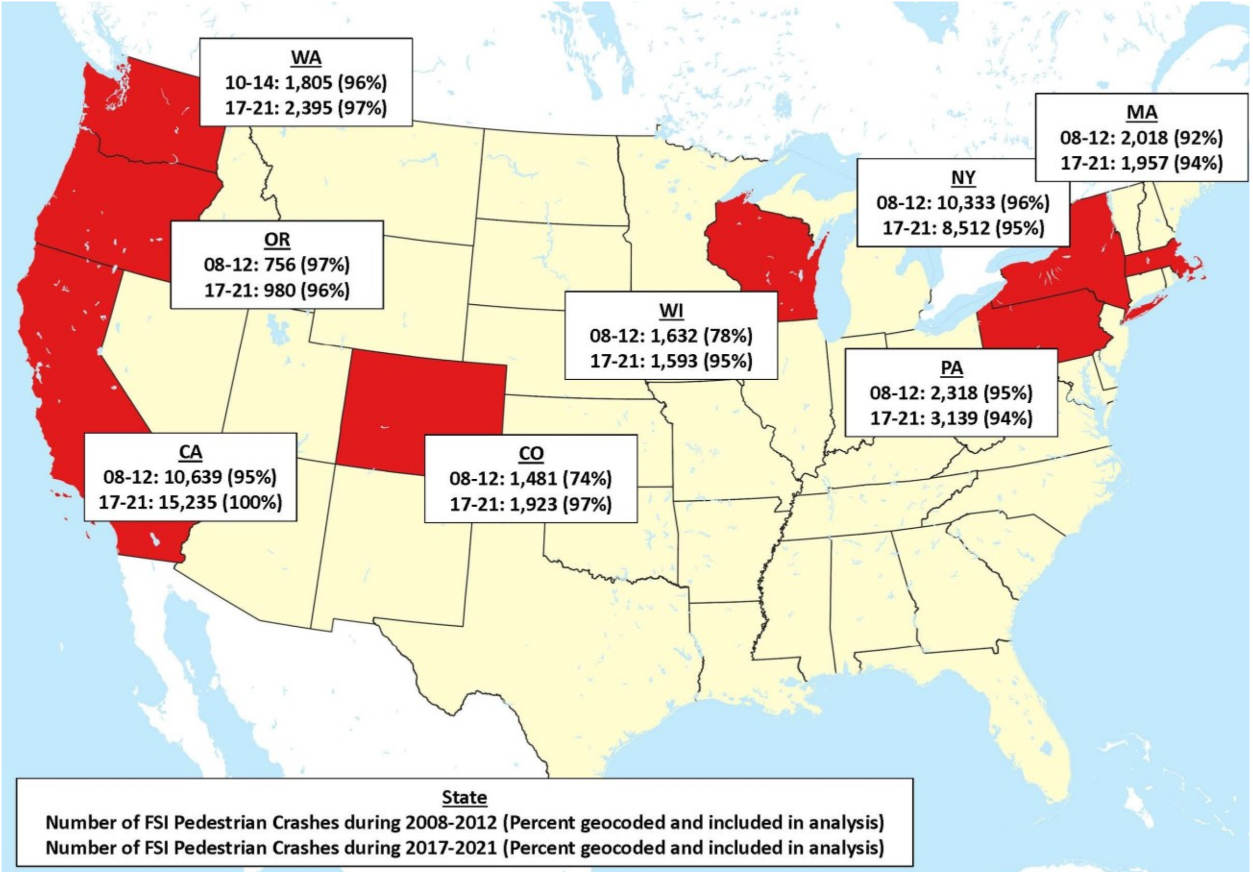

Figure 1. FSI Pedestrian Crashes by State: Total Number and Percent Geocoded and Included in Analysis, 2008-2012 and 2017-2021

Temporal Scope

To provide further justification for our temporal comparison, we analyzed the numbers of reported FSI pedestrian and FSI bicyclist crashes across our eight study states. Considering five-year windows the 2008-2012 and 2017-2021 time periods are at the extreme ends of the data available for our study and have the largest absolute differences in FSI pedestrian crashes across all eight states (Figure 2) and in FSI bicyclist crashes across all eight states (Figure 3). This is a key reason why we compared these two time periods in our census tract models.

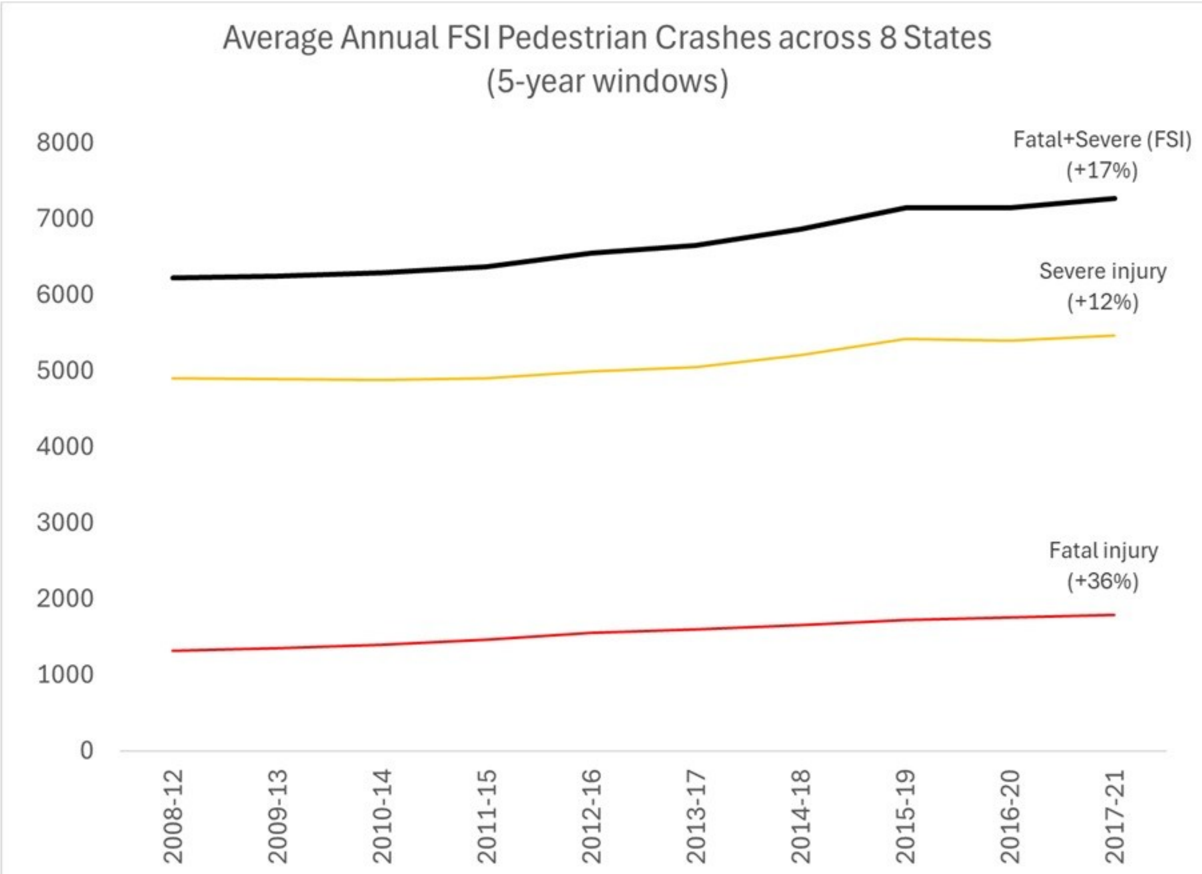

Figure 2. Average Annual FSI Pedestrian Crashes Across Eight States: Five-Year Windows

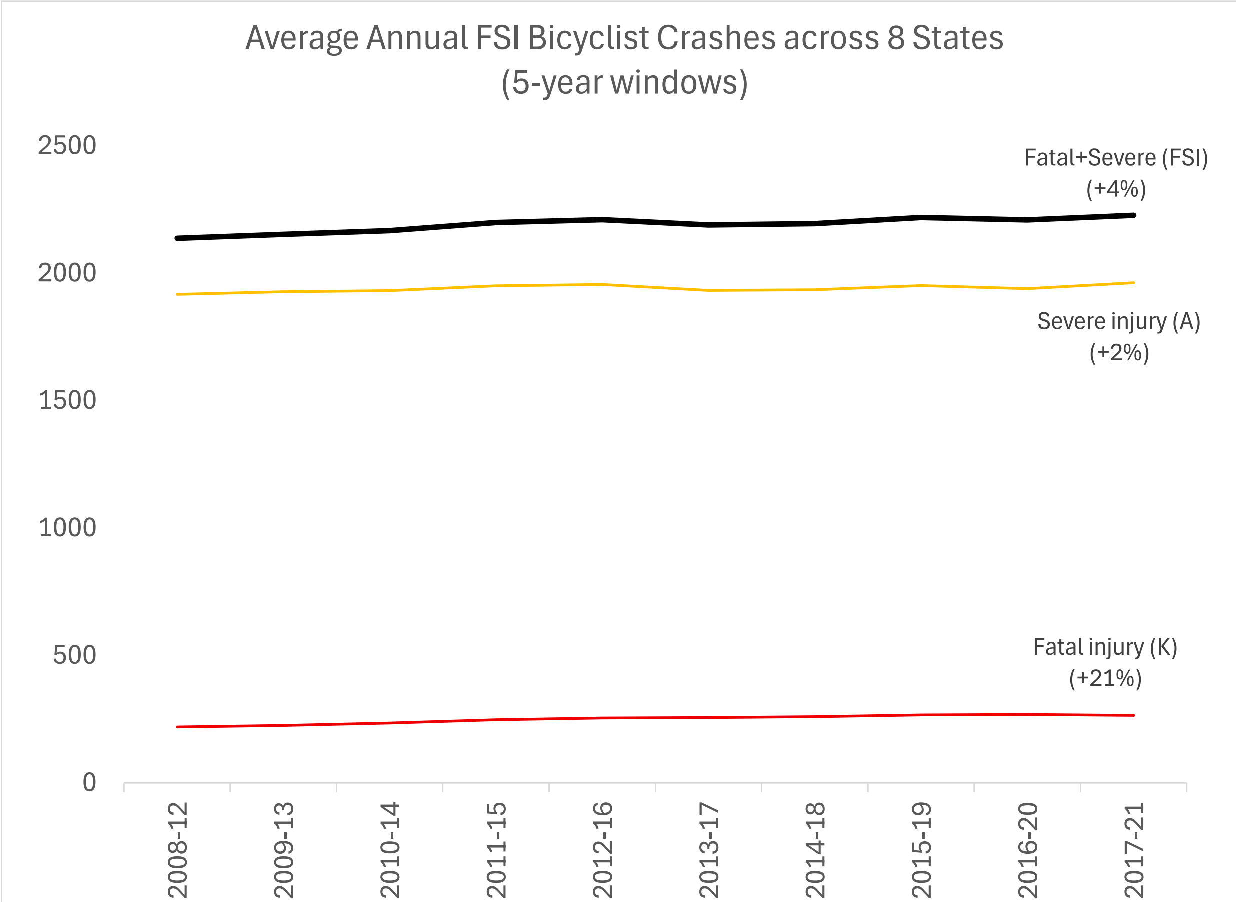

Figure 3. Average Annual FSI Bicyclist Crashes Across Eight States: Five-Year Windows

Crash Data

We analyzed the total number of FSI pedestrian and FSI bicyclist crashes in each census tract for each period. Following state crash reporting systems, we defined a pedestrian crash as a collision between a moving motor vehicle and a pedestrian and similar for a bicyclist crash. We analyzed all pedestrian crashes and all bicyclist crashes from the eight study states in which the most severe injury recorded from the crash was either fatal or severe.

There were 30,982 reported FSI pedestrian crashes across the eight states during 2008-2012 and 35,734 during 2017-2021 (Figure 1). However, because our analysis requires information about the census tract where each crash occurred, we only analyzed crashes with longitude and latitude data. Therefore, we analyzed 28,837 geocodable FSI pedestrian crashes in the first five-year period and 34,763 in the second five-year period. Note that Colorado and Wisconsin had relatively low geocoding rates for their FSI pedestrian crashes during 2008-2012, so we controlled for this data shortcoming by using state-specific dummy variables in our analysis.

There were 10,642 reported FSI bicyclist crashes across the eight states during 2008-2012 and 11,074 during 2017-2021. However, because our analysis requires information about the census tract where each crash occurred, we only analyzed crashes with longitude and latitude data. Therefore, we analyzed 9,942 geocodable FSI pedestrian crashes in the first five-year period and 10,887 in the second five-year period. Note that Colorado had relatively low geocoding rates for FSI bicyclist crashes during 2008-2012.

In most states, injury severity was assessed by law enforcement officers at the scene of the crash. For fatal crashes, a fatal injury could be assigned up to 30 days after the crash had occurred. While some states used slightly different injury scales (and new editions of the Model Minimum Uniform Crash Criteria came out in 2012 and 2017), all states in this analysis used injury scales with "fatal" and "severe" categories (often referred to as "K" and "A" injuries on the KABCO injury severity scale). Example definitions of "severe" included "Injury (Severe)" (California), "Suspected Serious Injury" (Oregon), and "Incapacitating" (Wisconsin).

Major roadways often form census tract boundaries, so we assigned all fatal and severe injury pedestrian crashes in a given census tract and within 50m of its boundary. Therefore, crashes on boundary roadways were counted multiple times, one time in each adjacent tract.

Analysis Variables

To explore our research questions, we analyzed explanatory variables that were associated with the count of FSI pedestrian and FSI bicyclist crashes in each tract that occurred during the 2008-2012 baseline period versus the count that occurred during the 2017-2021 later period (Appendix A). Our explanatory variables came from four sources: the American Community Survey (ACS), the US Census Bureau Longitudinal Employment Household Dynamics (LEHD) Origin-Destination Employment Statistics Workplace Area Characteristics (LODES WAC) dataset, the US Environmental Protection Agency Smart Location Database (SLD), and the Federal Highway Administration Highway Performance Monitoring System (HPMS). Based on these data, we created explanatory variables representing exposure, socioeconomic characteristics, jobs by sector, development density, roadway types, and each individual state.

Our exposure explanatory variables did not include any direct measures of pedestrian or bicyclist activity levels. However, we included total population, total jobs, walk commute mode share (for pedestrian models), public transit commute mode share (for pedestrian models), and bicycle commute mode share (for bicyclist models) as proxies for exposure to help represent the association between pedestrian or bicyclist activity and numbers of FSI pedestrian or FSI bicyclist crashes in each tract. Including these exposure proxies also helps control for the broader effects of the Great Recession and the COVID-19 pandemic on pedestrian, transit, and bicyclist activity levels in the two study periods.

Our final set of explanatory variables were dummy variables representing tracts from each of the eight states. These variables controlled for state-level variation in crash geocoding rates, crash reporting procedures, and injury severity definitions, as well as other state-level differences not captured by other variables.

Statistical Modeling Approach

We used standard negative binomial regression and a Poisson-Gamma conditional autoregressive (CAR) model to identify relationships between our set of explanatory variables and the count of FSI pedestrian and the count of FSI bicyclist crashes. We developed baseline and later-period models using both types of regression.

First, we used SPSS Version 29.0.1.0 (IBM Corp. 2023) to estimate standard negative binomial models of the count of FSI pedestrian crashes and count of FSI bicyclist crashes in each tract. Negative binomial models are appropriate for the over-dispersed distribution of these counts.

Second, we used Crimestat Version 4.02 (Levine 2015) to estimate Poisson-Gamma CAR models. These models accounted for potential spatial correlation among nearby census tracts (e.g., the roadway and socioeconomic characteristics of one census tract might be affected by its neighboring census tracts due to their physical proximity and spillover effects). Crimestat uses a Bayesian hierarchical method to estimate the parameters of the Poisson-Gamma CAR model (Levine 2015).

The Poisson-Gamma CAR model has a spatial autocorrelation term, and it is defined as:

$$y_i \mid \lambda_i \sim Poisson(\lambda_i)$$

with the mean of Poisson-Gamma CAR as:

$$\lambda_i = exp(\boldsymbol{x}_i^T \boldsymbol{\beta} \quad + \epsilon_i + \phi_i)$$

Where, for each census tract *i*:
y_i is the number of FSI pedestrian crashes in tract *i* during a given study period,
λ_i is the mean of the Poisson distribution,
$\boldsymbol{x}_i^T$ is a transposed vector of explanatory variables $\boldsymbol{x}_i$,
$\boldsymbol{\beta}$ is the vector of regression coefficients,
ϵ_i is the random error term, and ϵ_i follows a gamma distribution with a mean of 1 and variance of $1/\psi$. Note that ψ is a positive dispersion parameter that is greater than 0.,
ϕ_i is the spatial random effect that accounts for spatial dependency. Note that this spatial random effect includes a matrix of spatial weights calculated with a negative exponential distance decay function:

$$w_{ij} = e^{-\alpha d_{ij}}$$

Where:

d_{ij} is the distance between the centroid points of census tract i and other tract j and -α is the decay coefficient indicating the degree of spatial weight applied as the distance between centroid points increases.

To estimate our Poisson-Gamma CAR models, we applied decay parameters of 0.5 km, 1 km, 1.5 km, and 2 km for each time period. We used the default values in Crimestat for the priors for the distribution as they are non-informative in our models and used the default number of iterations (25,000) and burn-in (5,000), with 22 samples of 1,000 records drawn. We chose MCMC simulation for estimation because it does a better job with complex functions than other maximum-likelihood estimation approaches (Levine 2015). The Gelman-Rubin (G-R) convergence diagnostics provided for each variable were below 1.2 in each of our models, indicating good convergence (Levine 2015).

We used z-tests to identify significant differences in the corresponding coefficients from the 2008-2012 versus 2017-2021 models. This highlighted specific explanatory variables that experienced shifts in their relationships with FSI pedestrian and FSI bicyclist crashes.

Using the standard negative binomial model structure, we also conducted a Chow Test to determine whether or not there was a significant shift in variable coefficient values across all census tracts in our dataset between the baseline and later period (Bobbit 2023). The Chow Test involved pooling the baseline and after-period datasets and testing the null hypothesis that the coefficient values in the baseline and later period are equal for all variables versus the alternative hypothesis that at least one of the pairs of coefficients is different.

Our models included explanatory variables that had statistically-significant ($p < 0.05$) relationships with the count of FSI pedestrian and FSI bicyclist crashes per tract. During the modeling process, we dropped variables that did not consistently show statistical significance in either the baseline or later period models (with the exception of state dummy variables, which were important to include as controls). To avoid multicollinearity in our models, we calculated variance inflation factors (VIFs) and also ran multiple iterations of the models with different combinations of variables to determine if certain variables had a notable influence on the parameter estimates of other variables. The proportion of households with zero vehicles and roadway density were excluded due to high correlation with other variables.

Practitioner Interviews

Our final method of gathering insights about shifts in FSI pedestrian and FSI bicyclist crashes was to interview practitioners about specific changes in their local communities during the 2010s. We used video conferencing software to conduct online interviews with 13 practitioners between March and June 2025. The interviews lasted between 45 and 60 minutes.

Interview Content

We were interested in practitioner insights about how local policies and practices as well as broader economic and demographic changes were potentially associated with changes in pedestrian and bicyclist safety during the 2010s. Therefore, we developed a semi-structured interview protocol to ask about the following topics:

- Trends in pedestrian & bicyclist commuting and FSI pedestrian & FSI bicyclist crash rates
- Specific shifts in crashes noticed by the experts
- Socioeconomic changes; land use/development changes
- Community-level policies to improve safety
- Engineering, education, enforcement strategies
- Local advocacy; local elected leadership
- Agency institutional changes (e.g., staffing, budget, grants)
- Communication with the public about pedestrian and bicyclist safety strategies
- Public reactions to policies and projects
- Any other topics that interviewees thought were relevant

The interview protocol was approved by the University of Wisconsin-Milwaukee Institutional Review Board in January 2025, and we conducted interviews between March and June 2025. The interview consent form is included as Appendix B, and the interview instrument is included as Appendix C.

Interview Participants

To find participants with expert knowledge about our research topic, we targeted practitioners at local and regional agencies who had worked on pedestrian and bicyclist safety issues in their community during the 2010s. Ideally, interviewees would have worked at the agency for at least five years during that decade. Most of our interviewees met this criterion, but the few that did not had worked elsewhere in the metropolitan area during the majority of 2010s and had paid close attention to transportation issues, so we were confident that all our participants had sufficient experience to share valuable insights about pedestrian and bicyclist safety in their local communities.

We looked for two sets of potential interviewees. Our first group of interview participants was from across the US. To identify communities that would be good to learn from, we calculated pedestrian fatality rates and bicyclist fatality rates per 100,000 residents during 2008-2012 and 2018-2022 for the 100 most populous cities. Then we reached out through our professional networks to identify practitioners who worked in cities that had among the highest or lowest pedestrian fatality rates. Bicyclist fatality rates were more variable, so we did not use these for selecting interviewee communities. Importantly, we also examined how pedestrian fatality rates had changed in each of these cities between 2008-2012 and 2018-2022 and made extra efforts to reach out to communities that had experienced the greatest increases and decreases between these time periods. Second, we used our network of contacts in Wisconsin to identify practitioners working on pedestrian and bicyclist safety at local and regional agencies in the state.

Between March and June 2025, we interviewed practitioners in seven US cities and at six Wisconsin agencies.

Qualitative Analysis

We recorded the interviews and used the automated transcription option within the video conferencing application to document interviewee responses to our questions. Where necessary, we reviewed the recording to ensure that we reported quotes accurately. To conduct our qualitative analysis, the two research team members who conducted the interviews jointly developed a list of 16 general topics mentioned by participants. These topics were:

- Pedestrian and bicyclist exposure
- Land use (development patterns, risk on urban fringe)
- Coordination with state DOT
- Safety-oriented policies
- Community leadership
- Agency resources available
- Enforcement (enforcement strategies, lack of enforcement, etc.)
- Public perception of danger
- Public resistance to safety strategies
- Population Change
- Larger vehicles
- Traffic congestion
- Driver behavior (speeding, reckless driving, distracted driving)
- Education (driver's education, Safe Routes to Schools, public information campaigns)
- Engineering (infrastructure, roadway design)
- Darkness

We developed this list of topics after completing all 13 interviews. Then, one research team member reviewed the interview transcripts and coded each interviewee statement into one or more of the topics. After reviewing specific comments within each topic, we further separated and combined certain topics to highlight key themes that we heard across multiple interviews. In our results section, we report examples of quotes from participants that best illustrate each of the key themes.

Results

This section provides descriptive summaries of FSI pedestrian and FSI bicyclist injury trends from 2008 through 2021. It also presents factors associated with FSI pedestrian and FSI bicyclist injury shifts from our quantitative model analyses and our qualitative interview analysis.

FSI Pedestrian Injury Trends

We analyzed crash-level data to explore changes in pedestrian and bicyclist injury severity levels from 2008 to 2021 across nine states.[3] Overall, crashes that produced pedestrian fatalities ("K" on the KABCO injury scale) in these nine states increased by an average of 51% during this period. However, there was a wide range of changes between states, with Washington (+131%) and Minnesota (+116%) experiencing the greatest increases and New York (-7%) and Wisconsin (-17%) experiencing decreases (Figure 4 and Table 1). However, these trends exhibit fairly high levels of year-to-year variation, especially in less-populous states. For example, fatal pedestrian crashes in Wisconsin increased from 49 in 2021 (last year on graph) to 73 in 2022.

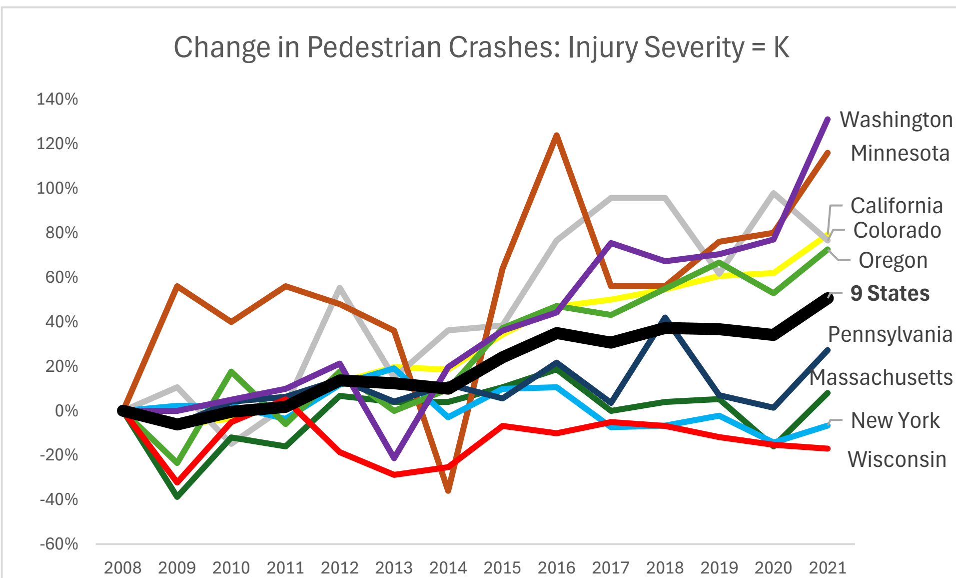

Figure 4. State-Level Changes in Fatal Pedestrian Crashes, 2008-2021

[3] Crash-level data have a single record for each crash, regardless of the number of people involved in it. Each record indicates whether or not a pedestrian or bicyclist was one of the parties involved in the crash, but it does not say how many total pedestrians or bicyclists were involved. For consistency across the full nine-state database, each record only indicates the most severe injury sustained in the crash. This is almost always the pedestrian or bicyclist, but there are exceptions. For example, if there is a crash in which two pedestrians were struck by a vehicle and one sustained an "A"-level injury and the other sustained a "B"-level injury, the crash record would only show the most severe injury ("A" level).

Table 1. State-Level Changes in Fatal Pedestrian Crashes, 2008-2021

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
California	602	563	581	618	679	720	713	809	884	903	931	967	975	1079
Colorado	47	52	40	48	73	54	64	65	83	92	92	76	93	83
Massachusetts	75	46	66	63	80	78	78	83	89	75	78	79	63	81
Minnesota	25	39	35	39	37	34	16	41	56	39	39	44	45	54
New York	273	279	279	263	305	325	265	300	302	253	255	267	234	255
Oregon	51	39	60	48	60	51	56	70	75	73	79	85	78	88
Pennsylvania	143	134	149	152	163	149	160	151	174	148	203	153	145	182
Washington	61	61	64	67	74	48	73	83	88	107	102	104	108	141
Wisconsin	59	40	56	62	48	42	44	55	53	56	55	52	50	49
Grand Total	**1336**	**1253**	**1330**	**1360**	**1519**	**1501**	**1469**	**1657**	**1804**	**1746**	**1834**	**1827**	**1791**	**2012**

We also analyzed trends in pedestrian crashes across the injury severity spectrum. Specifically, we combined data from all nine states to compare year-to-year changes in crashes producing fatal injuries (“K”), severe injuries (“A”), moderate injuries (“B”), and minor or possible injuries (“C”). Between 2008 and 2021, crashes that produced more serious pedestrian injuries generally increased more than crashes that produced less serious pedestrian injuries (Figure 5 and Table 2). In addition, the COVID pandemic in 2020 appeared to produce a greater reduction in less severe pedestrian crashes. Trends in lower injury severity crashes may track more closely with overall pedestrian activity levels, or exposure.

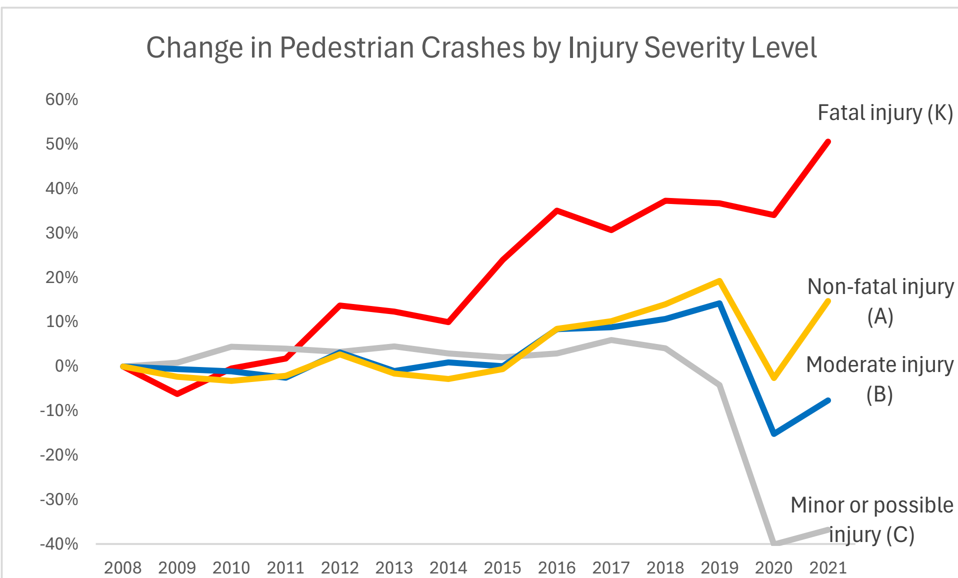

Figure 5. Change in Pedestrian Crashes in Nine States by Injury Severity Level, 2008-2021

Table 2. Change in Pedestrian Crashes in Nine States by Injury Severity Level, 2008-2021

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fatal injury (K)	1336	1253	1330	1360	1519	1501	1469	1657	1804	1746	1834	1827	1791	2012
Non-fatal injury (A)	5050	4933	4886	4945	5187	4968	4907	5020	5477	5564	5758	6022	4917	5794
Moderate injury (B)	11669	11601	11537	11369	12035	11548	11774	11674	12651	12702	12918	13327	9894	10780
Minor or possible injury (C)	18778	18934	19607	19533	19394	19627	19325	19169	19329	19899	19541	17988	11248	11870
Grand Total	**36833**	**36721**	**37360**	**37207**	**38135**	**37644**	**37475**	**37520**	**39261**	**39911**	**40051**	**39164**	**27850**	**30456**

FSI Bicyclist Injury Trends

Overall, crashes that produced bicyclist fatalities in our nine states increased by an average of 14% during this period. The greatest increase was in Pennsylvania (+200%) and the largest decrease was in Minnesota (-38%) (Figure 6 and Table 3). Bicyclist fatality trends by state show even higher levels of year-to-year variation than pedestrian fatality trends, likely due to lower levels of bicyclist activity and fewer total fatal bicyclist crashes.

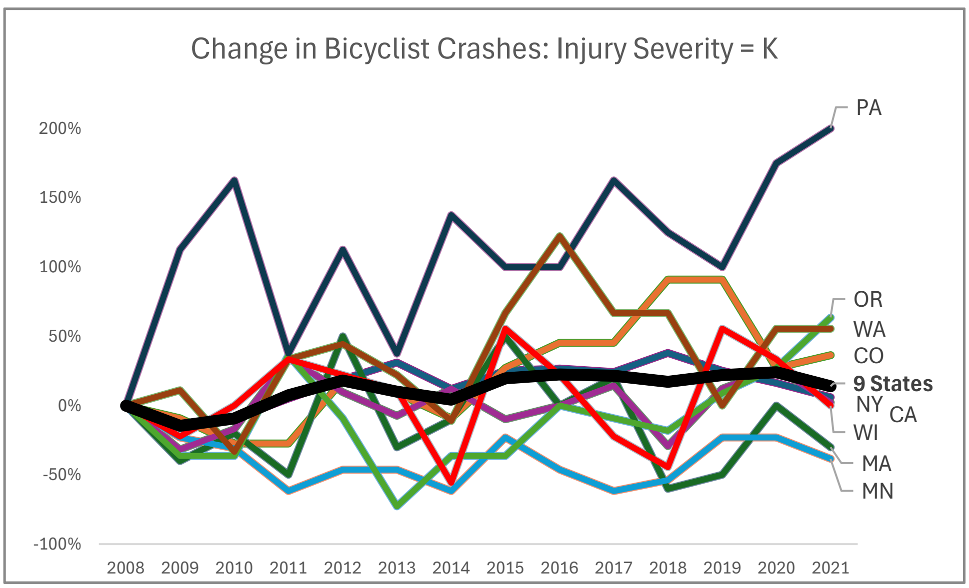

Figure 6. State-Level Changes in Fatal Bicyclist Crashes, 2008-2021

Table 3. State-Level Changes in Fatal Bicyclist Crashes, 2008-2021

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
California	116	100	105	122	138	152	130	145	147	144	160	145	135	123
Colorado	11	10	8	8	13	12	10	14	16	16	21	21	14	15
Massachusetts	10	6	8	5	15	7	9	15	10	12	4	5	10	7
Minnesota	13	10	9	5	7	7	5	10	7	5	6	10	10	8
New York	41	28	34	55	45	38	46	37	41	47	29	46	52	42
Oregon	11	7	7	15	10	3	7	7	11	10	9	12	14	18
Pennsylvania	8	17	21	11	17	11	19	16	16	21	18	16	22	24
Washington	9	10	6	12	13	11	8	15	20	15	15	9	14	14
Wisconsin	9	7	9	12	11	10	4	14	11	7	5	14	12	9
Grand Total	**228**	**195**	**207**	**245**	**269**	**251**	**238**	**273**	**279**	**277**	**267**	**278**	**283**	**260**

Analyzing bicyclist crashes by injury severity level showed similar trends as pedestrian crashes across the nine states. Between 2008 and 2021, crashes that produced more serious bicyclist injuries generally increased more than crashes that produced less serious pedestrian injuries (Figure 7 and Table 4). The lower-severity injuries may be more closely related to overall bicyclist activity levels, or exposure.

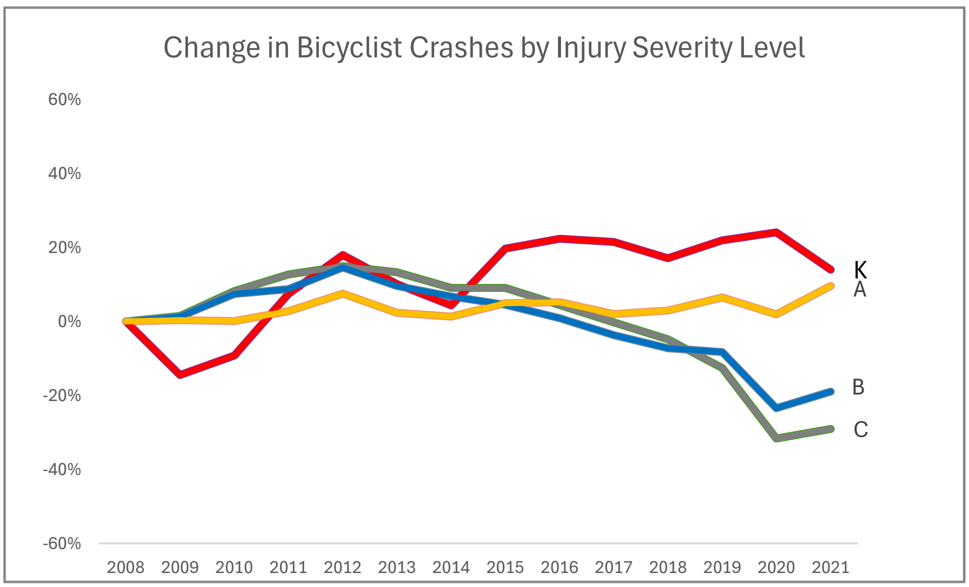

Figure 7. Change in Bicyclist Crashes in Nine States by Injury Severity Level, 2008-2021

Table 4. Change in Bicyclist Crashes in Nine States by Injury Severity Level, 2008-2021

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fatal injury (K)	228	195	207	245	269	251	238	273	279	277	267	278	283	260
Minor or possible injury (C)	10107	10255	10943	11389	11619	11452	11026	11024	10557	10083	9625	8840	6911	7167
Moderate injury (B)	10155	10287	10913	11040	11639	11127	10844	10612	10244	9785	9423	9313	7774	8235
Non-fatal injury (A)	1925	1933	1927	1978	2070	1971	1951	2020	2026	1964	1982	2051	1963	2110
Grand Total	**22415**	**22670**	**23990**	**24652**	**25597**	**24801**	**24059**	**23929**	**23106**	**22109**	**21297**	**20482**	**16931**	**17772**

Census Tract Characteristics Associated with FSI Pedestrian Crashes

Our statistical models of FSI pedestrian crashes across eight states (not including Minnesota) highlighted significant relationships between census tract characteristics during the 2008-2012 baseline period and during the 2017-2021 later period. It also showed how these relationships shifted between 2008-2012 and 2017-2021.

We present three models from the baseline period and three models from the later period (Table 5). Model B1 is the standard negative binomial model for the baseline period, and Model L1 is the standard negative binomial model for the later period. Models B2 and L2 are the Poisson-Gamma CAR models with decay parameter of 0.5 km, and Models B3 and L3 are the Poisson-Gamma CAR models with decay parameter of 2 km (we do not present the 1 km or 1.5 km decay parameter models because they are similar to Models B2 and L2 and B3 and L3).

Overall Statistical Significance and Spatial Dependence

Table 5 shows that most of the coefficients in all six models were statistically significant, indicating good model fit. Each of our Poisson-Gamma-CAR models also had statistically-significant, negative phi values indicating negative spatial dependence. This means that tracts with more crashes tended to have neighboring tracts with fewer crashes. This result is consistent with visual inspection of maps that show the count of FSI pedestrian crashes by tract (Figure 8). Further, the phi values are more negative in the later period, suggesting that this spatial pattern became more prominent during the 2010s. This result also confirms that it is important to analyze pedestrian crashes at a fine-grained geography such as census tracts since there are concentrations of FSI pedestrian crashes within relatively small areas across our eight study states.

Table 5. Models of Fatal & Severe Injury Pedestrian Crashes per Census Tract, 2008-12 vs. 2017-21

	Association between Tract Characteristics & Number of FSI Pedestrian Crashes in a 5-Yr. Period[1]														
	Baseline Period (2008-2012)						Later Period (2017-2021)						Significant Shifts[2]		
	Model B1		Model B2		Model B3		Model L1		Model L2		Model L3		L1 vs B1	L2 vs B2	L3 vs B3
	Exp(β)	Sig.[3]	Exp(β)	Sig.[3]	Exp(β)	Sig.[3]	Exp(β)	Sig.[3]	Exp(β)	Sig.[3]	Exp(β)	Sig.[3]			
Constant	0.638	**	0.683	**	0.807	**	0.656	**	0.664	**	0.717	**			
Exposure Variables															
Total Population (000s)	1.114	**	1.110	**	1.114	**	1.055	**	1.064	**	1.062	**	- -	- -	- -
Total Jobs (000s)	1.027	**	1.025	**	1.021	**	1.035	**	1.035	**	1.028	**	++	++	+
% Transit	3.691	**	3.209	**	3.086	**	1.895	**	2.043	**	1.784	**	- -	- -	- -
% Walk	5.050	**	5.101	**	4.154	**	6.117	**	5.068	**	6.538	**			+
Socioeconomic Variables[4]															
% Black	1.278	**	1.352	**	1.107	*	2.415	**	2.353	**	2.168	**	++	++	++
% Hispanic	1.368	**	1.331	**	1.185	**	2.186	**	2.124	**	1.856	**	++	++	++
Median Income (0000s)	0.929	**	0.926	**	0.923	**	0.977	**	0.973	**	0.974	**	++	++	++
% Unemployed	3.022	**	2.636	**	2.446	**	4.612	**	4.079	**	3.549	**			
Job Variables[5]															
% Retail	1.816	**	1.677	**	1.876	**	2.564	**	2.026	**	2.094	**	++	+	
Land Use Variables															
Population Density (000s)	0.389	**	0.323	**	0.306	**	0.875	**	0.542		0.802				+
Employment Density (000s)	2.299	**	4.023	**	5.716	**	0.822	**	2.299	**	1.204		- -		- -
Transit Nearby	1.320	**	1.309	**	1.277	**	1.380	**	1.376	**	1.437	**		+	++
Roadway Characteristics[6]															
Interstate	1.054	**	1.011		1.031		1.142	**	1.130	**	1.144	**	++	++	++
Other Fwy/Expressway	1.032		0.987		1.004		1.103		1.089	**	1.067	**	++	++	+
Arterial with AADT >20K	1.658	**	1.702	**	1.549	**	1.661	**	1.680	**	1.661	**			+
Overall model															
Quasi Likelihood under Independence Model Criterion (QIC)	15530						16253								
Corrected Quasi Likelihood under Independence Model Criterion (QICC)	15549						16269								
Spatial autocorrelation (Phi)			-2.748	**	-9.685	**			-2.917	**	-10.40	**			

1) All models are based on observations from 21,833 census tracts. Exp(β) presents the exponentiated form of the coefficient estimate. Values less than one indicate a negative relationship and values more than one indicate a positive relationship between the variable and the number of FSI pedestrian crashes. Sig. indicates the statistical significance of the coefficient estimate: ** is $p < 0.01$; * is $p < 0.05$.

2) The Significant Shifts columns show the results of Z-tests of differences between each coefficient value in the baseline period and the corresponding coefficient value in the later period: "++" indicates that the later period coefficient is significantly larger with $p < 0.01$; "+" indicates that the later period coefficient is significantly larger with $p < 0.05$; "- -" indicates that the later period coefficient is significantly smaller with $p < 0.01$; and "-" indicates that the later period coefficient is significantly smaller with $p < 0.05$.

3) We used adjusted standard errors to assess the statistical significance of the coefficient estimates in each Poisson-Gamma-CAR model (2B, 3B, 2L, and 3L) and to identify significant differences in coefficients between the baseline and later period.

4) Other variables tested but not included were Non-Hispanic white, Non-Hispanic Asian, and Non-Hispanic Native American.

5) Other job variables tested but not included in the models were industrial, service, and entertainment.

6) Arterial with AADT >20K indicates that there is at least one roadway in the census tract (other than interstates, freeways, or expressways) with more than 20,000 AADT. The interstate, other freeway/expressway, and AADT variables have the same values in the baseline and later periods, but their relationships with FSI pedestrian crashes in each period are different.

7) State dummy variables are omitted from this table for simplicity of presentation.

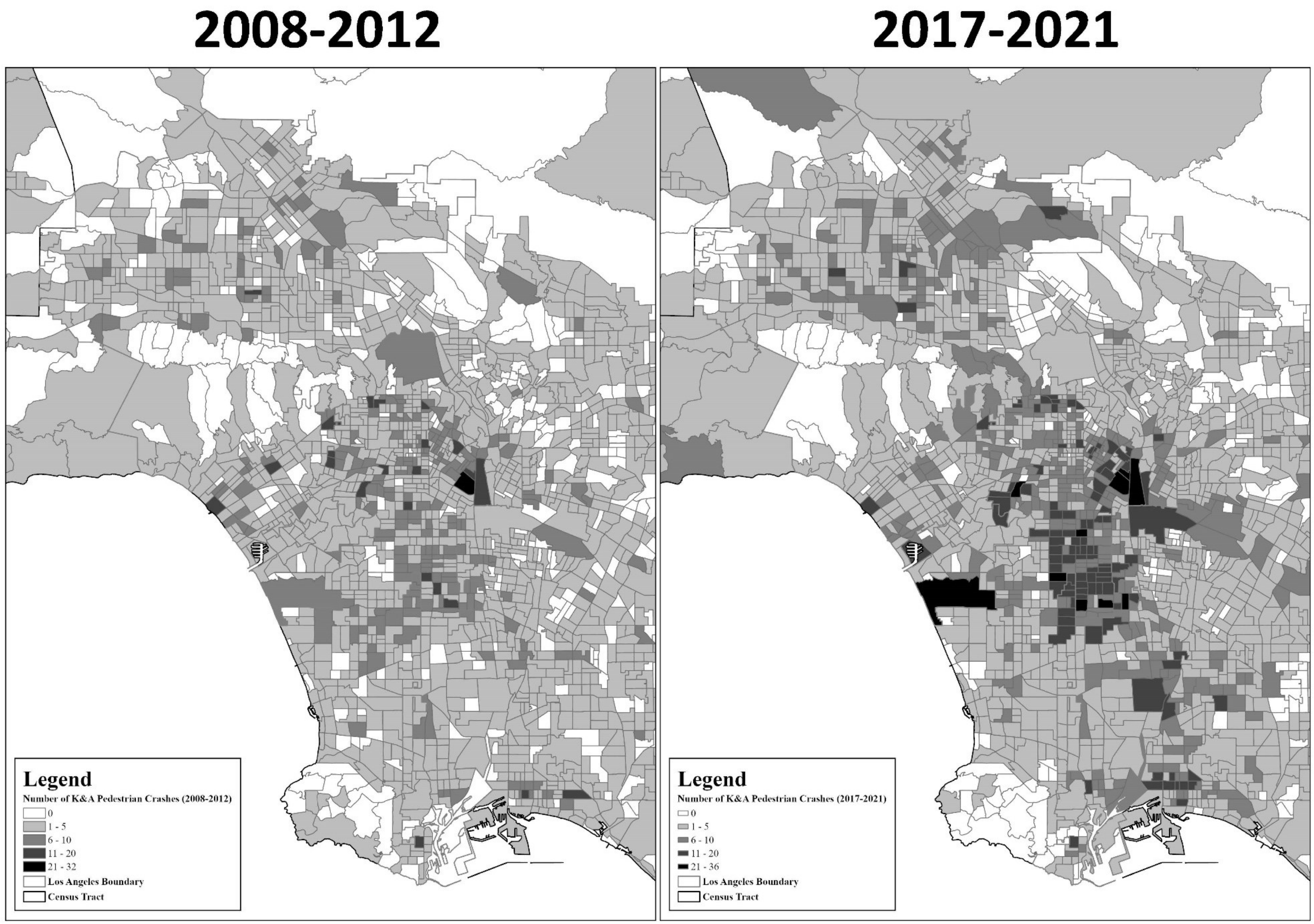

Figure 8. Example Spatial Distribution: Los Angeles area FSI Pedestrian Crashes by Tract, 2008-2012 vs. 2017-2021

Neighborhood Characteristics Associated with Pedestrian Crashes in both Study Periods

Our negative binomial models provided a useful background for understanding the number of FSI pedestrian crashes per tract during 2008-2012 (Table 5, "Baseline" model columns) and during 2017-2021 (Table 5, "Later" model columns). In both study periods, FSI pedestrian crashes were positively associated with exposure proxy variables. For example, all else equal, tracts with one thousand more people during the baseline period were expected to have 11% more FSI pedestrian crashes (the baseline exponentiated coefficient for Total Population (000s) in Models B1, B2, and B3 is 1.11). This association weakened to approximately 6% more FSI pedestrian crashes per thousand additional people in the later period, but it was still positive. The proportion of walk commuters was positively associated with FSI pedestrian crashes. The coefficient of 5.1 in Model B1, indicates that a tract with a one percent higher share of walk commuters is expected to have 5.1% more FSI pedestrian crashes (a proportion of 1, or 100%, walk commuters would have 510% more pedestrian crashes than a proportion of 0, or 0%). The proportion of transit commuters and total tract employment were also positively associated with the number of FSI pedestrian crashes. These exposure proxy variables likely represent overall levels of pedestrian activity.

After controlling for these forms of exposure, the proportion of people in the tract who were Black or Hispanic and the proportion of labor force participants who were unemployed were positively associated with FSI pedestrian crashes in both periods. Median household income was negatively associated with these crashes. FSI pedestrian crashes were also positively associated with the proportion of jobs located in each tract that were in the retail sector. The prominence of retail jobs in our model is similar to previous studies that have analyzed pedestrian fatalities per census tract in the US (Mansfield et al. 2018).

Tracts located close to transit stops generally had more FSI pedestrian crashes in both periods. Lower population densities and higher employment densities were associated with more FSI pedestrian crashes in the baseline period, but these relationships were not as consistent in the later period. Tracts with at least one high-volume arterial roadway (AADT >20,000) were positively associated with FSI pedestrian crashes in both periods.

Neighborhood Characteristics Associated with Shifts in Pedestrian Crashes

Overall, we found evidence that there were different relationships between the full set of explanatory variables and FSI pedestrian crashes in the baseline versus later periods. First, the Chow Test value (65.5) generated by comparing the baseline-period Model B1 with the later-period Model L1 exceeded the critical F-value of 1.51. Second, we found differences in specific variable coefficients between the two time periods (see Significant Shifts columns in Table 5).

While all four exposure variables had significant positive relationships with FSI pedestrian crashes in both periods, they shifted in different ways during the 2010s. The percentage of walk commuters remained a strong predictor of the number of FSI pedestrian crashes in each tract in 2017-2021, so this relationship was statistically similar to the baseline period. Having more population in a tract and having a higher percentage of workers commuting by transit both had a significantly weaker association with the expected number of FSI crashes in 2017-2021 than they did during the baseline period. Both of these shifts could be related to the COVID pandemic: while more people in a neighborhood and a greater proportion of work commuters using transit would typically be related to more pedestrian activity, pedestrian activity levels during COVID (March 2020 into the beginning of 2021) may have been suppressed in neighborhoods with these characteristics, leading to fewer FSI pedestrian crashes during 2017-2021. However, we found the opposite relationship—a statistically stronger association with FSI pedestrian crashes in 2017-2021—for total jobs in a tract. This could possibly relate to activity levels dropping in job centers during COVID and beyond, leaving the remaining pedestrians in these areas exposed to more free-flowing, higher-speed traffic than they experienced in other years. Regardless of the underlying reasons for shifts in exposure variable relationships with FSI pedestrian crashes, these variables were important controls in our models.

After accounting for exposure, we found significant shifts for several other variables. Tracts with higher proportions of Black and higher proportions of Hispanic residents were already associated with higher numbers of FSI crashes during the baseline period, but the magnitude of this association increased significantly between the baseline period and later period. While lower median household incomes were positively associated with FSI pedestrian crashes at baseline, this positive relationship became slightly less pronounced during 2017-2021. The positive association between the proportion of unemployed workers in each tract and FSI pedestrian crashes during the baseline period also grew between the baseline and later period, but this shift was not statistically significant.

Tracts with a high proportion of retail jobs and tracts in close proximity to transit were associated with high numbers of FSI pedestrian crashes during the baseline period, and these positive relationships strengthened in 2017-2021. Both variables exhibited statistically-significant shifts for two of the three model comparisons. Higher employment density was associated with higher numbers of FSI pedestrian crashes during the baseline period, but the magnitude of the relationship between these characteristics became significantly weaker in all three model comparisons during the 2017-2021 period. This suggests that FSI pedestrian crashes trended toward neighborhoods with lower employment density between the baseline and later period.

Finally, neighborhoods with interstates and other types of freeways or expressways experienced significantly more FSI pedestrian crashes in the later period than the baseline period. This shift may indicate increasing pedestrian risk within freeway corridors and on nearby surface streets connecting to freeways.

Census Tract Characteristics Associated with FSI Bicyclist Crashes

During the baseline period (2008-2012), FSI bicyclist crashes tended to occur in census tracts with characteristics related to higher bicyclist exposure (Table 6). Across all eight states, the likelihood of FSI bicyclist crashes was positively related to greater population, more jobs, and especially the percentage of bicyclist commuters. After controlling for bicyclist exposure, FSI bicyclist crashes were positively associated with neighborhoods that have higher shares of Black residents, lower median household incomes, higher shares of unemployed workers, higher proportions of retail jobs, higher population and employment densities, close proximity to transit stops, and at least one arterial roadway with volume higher than 20,000 AADT.

The model for the later period (2017-2021) showed statistically significant relationships in the same direction as the baseline period across all eight states, and the share of Hispanic residents and the presence of a non-interstate freeway or expressway were also positively associated with FSI bicyclist crashes.

Comparing the coefficients of the baseline period (2008-2012) and later period (2017-2021) models, we found statistically-significant shifts in the association between several tract-level characteristics and FSI bicyclist crashes. Across all eight states, total population, median household income, and close proximity to transit stops had weaker relationships with FSI bicyclist crashes in the later period when compared to the baseline period. After accounting for changes in exposure, FSI bicyclist crashes showed stronger associations in the later period with the share of Black and Hispanic residents, population density, and the presence of non-interstate freeways or expressways.

We also include an example map to show the spatial distribution of FSI bicyclist crashes by tract (Figure 9).

Table 6. Models of Fatal and Severe Injury Bicyclist Crashes per Census Tract, 2008-2012 vs. 2017-2021

	Association between Tract Characteristics and Number of K&A Bicyclist Crashes in a Five-Year Period[1]				
	Baseline Period (2008-2012)		Later Period (2017-2021)		Significant Shifts[2]
	Exp(β)	Sig.	Exp(β)	Sig.	Later vs. Baseline
Constant	0.282	**	0.324	**	
Exposure Variables					
Total Population (000s)	1.083	**	1.025	**	- -
Total Jobs (000s)	1.027	**	1.027	**	
% Bicycle	20152	**	34611	**	
Socioeconomic Variables[3]					
% Black	1.306	**	1.614	**	+
% Hispanic	1.030		1.408	**	++
Median Income (0000s)	0.978	**	0.995	**	++
% Unemployed	1.931	*	3.059	**	
Job Variables[4]					
% Retail	1.387	**	1.403	**	
Land Use Variables					
Population Density (000s)[5]	21.146	**	112.14	**	++
Employment Density (000s)	3.745	**	2.514	**	
Transit Nearby[6]	1.236	**	1.147	**	-
Roadway Characteristics[7]					
Interstate	0.993		1.007		
Other Fwy/Expressway	1.028		1.140	**	++
Maximum AADT >20K	1.425	**	1.369	**	
State (base = California)[7]					
Colorado	0.927		1.227	**	++
Massachusetts	0.865	**	0.689	**	- -
New York	1.388	**	1.144	**	- -
Oregon	0.717	**	0.636	**	
Pennsylvania	0.293	**	0.368	**	++
Washington	0.866	**	0.817	**	
Wisconsin	0.898	*	0.654	**	- -
Overall model					
Log Likelihood	-23562		-24588		
AIC	47169		49220		
BIC	47345		49396		

1) The eight-state models are based on observations from 21,833 census tracts. Exp(β) presents the exponentiated form of the coefficient estimate. Values less than one indicate a negative relationship and values more than one indicate a positive relationship between the variable and the number of K&A bicyclist crashes. Sig. indicates the statistical significance of the coefficient estimate: ** is $p < 0.01$; * is $p < 0.05$.

2) The Significant Shifts columns show the results of Z-tests of differences between each coefficient value in the baseline period and the corresponding coefficient value in the later period: "++" indicates that the later period coefficient is significantly larger with $p < 0.01$; "+" indicates that the later period coefficient is significantly larger with $p < 0.05$; "- -" indicates that the later period coefficient is significantly smaller with $p < 0.01$; and "-" indicates that the later period coefficient is significantly smaller with $p < 0.05$.

3) Other variables tested but not included were Non-Hispanic white, Non-Hispanic Asian, and Non-Hispanic Native American.

4) Job variables are relative to all other job categories (e.g., industrial, service, entertainment).

5) The population density variable was removed from the Wisconsin model due to multicollinearity with other variables.

6) The transit nearby variable indicates that a transit stop is located within 0.75 miles of the center of the census tract.

7) Arterial/Collector maximum AADT variables are relative to the base of maximum AADT <20K. The state dummy, interstate, other freeway/expressway, and AADT variables have the same values in the baseline and later periods, but their relationships with K&A pedestrian crashes in each period are different.

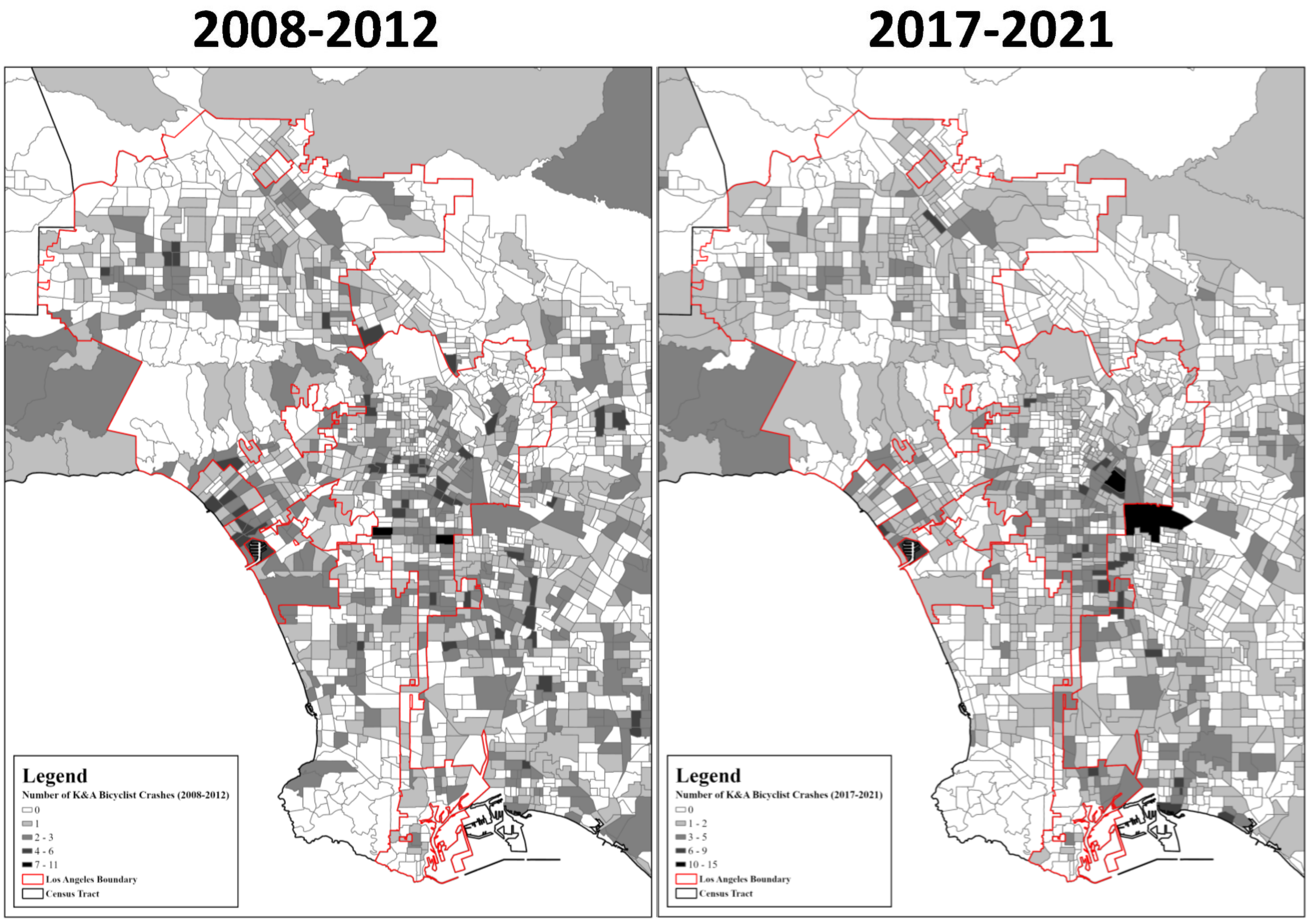

Figure 9. Example Spatial Distribution: Los Angeles area FSI Bicyclist Crashes by Tract, 2008-2012 vs. 2017-2021

Practitioner Insights about Pedestrian and Bicyclist Safety Changes

This section summarizes nine key themes that we identified across our 13 practitioner interviews related to pedestrian and bicyclist safety changes during the 2010s. We illustrate these themes with example quotes from certain interview participants, though they were also mentioned by other interviewees. Where appropriate, these quotes are attributed to interviewees in cities with high pedestrian fatality rates (e.g., among the highest 20 in 2018-2022) or low pedestrian fatality rates (e.g., among the lowest 20 in 2018-2022).

Pedestrian and bicyclist exposure

Pedestrian and bicyclist exposure is related to pedestrian and bicyclist safety because, all else equal, there are more injuries in a community when there is more pedestrian and bicyclist activity. However, walking and bicycling risk tends to be lower when there are more pedestrians and bicyclists (these modes become safer per person and per trip) (Jacobsen 2015).

Based on our interviews, pedestrian and bicyclist activity levels may have increased slightly across whole communities, especially as more sidewalks, on-street bicycle facilities have been provided.

- "…bike numbers have definitely spiked…We've installed a ton more infrastructure, so people can see bike lanes in their neighborhoods where maybe they couldn't before." (low fatality rate city)
- "During this time period is when a lot of our infrastructure improvements came to fruition."
- "A large increase in recreational bike development, trails, etc."

In contrast, the continued and, in some cases increasing, convenience of automobiles and reckless driving behavior has kept pedestrian and bicycle activity levels low.

- "I think the biggest two [factors influencing activity levels] were that there was an increase in the wealthy relying on Uber and Lyft for deliveries, which meant more cars on the road." (low fatality rate city)
- "It continues to be very easy to drive in [City X], and congestion has actually gotten lighter." (high fatality rate city)
- "I think there is a perception of, and a reality of, risk with walking and biking in [City X]. People are scared to do so." (high fatality rate city)

According to our interviewees, new infill development has increased walking and bicycling in specific urban areas, though some of these areas have higher-risk streets. Changes in work patterns have decreased activity levels downtown and a majority of most new developments are on the edge of communities, which has shifted pedestrian and bicycle activity toward these outer areas. Increased walking and bicycling activities in suburban or urban fringe areas is often higher-risk because there are wider, higher-speed roadways; fewer sidewalks and bicycle facilities; and more pedestrian and bicycle infrastructure network gaps.

- "As people need to travel longer, and they need to pass through neighborhoods they aren't familiar with, may perceive as dangerous. They go faster, try to speed through them." (top 20 fatality rate city)
- "Regarding the decline in [pedestrian and bicycle] commuting, there was a change in location of job centers. A move away from downtown, more to suburban areas, and neighboring communities. Those areas have even less infrastructure, so makes commuting harder."
- "During this time we saw migration out of the inner city, many people left the downtown to go to the exurbs." (top 20 fatality rate city)
- "Dispersed development has maybe led to recreational walking and biking."
- "Drastic decrease in city population, while surrounding communities have seen big increase."
- "Housing affordability and stock issues in the city [have led to population decline]."
- "One of the things that's happening is a lot of these new developments are happening in formerly industrial districts, so there's a mismatch of new development, housing, schools in an area that hasn't fully transitioned from industrial. So you have large trucks sort of mixing with areas that maybe didn't have a ton of population before now have a lot of people moving around. And specifically with cycling, we've seen a couple of high-profile fatalities and injuries with trucks turning across bike lanes, and we're trying to design update our designs to address that." (bottom 20 fatality rate city)
- "The newest commercial area is a mile away from my house. There are sidewalks by me, but there is a gap by the freeway, and then the development is on the other side of highway. There are sidewalks over there, but no connector. I see people all the time trying to bike across the highway."
- "Jobs shifting to the suburbs may have influenced bus commuter rates and possibly crashes." (top 20 fatality rate city)
- "Many suburbanites wanted to move out of the inner city and wanted to walk around, but the conditions are so unfriendly for bike and ped there." (top 20 fatality rate city)

Recreational walking and bicycling has increased in some communities.

- "Since 2006, so last 15 years there has been an increase of biking and pedestrian activity, but mostly for recreational use."
- "Trail counters have shown gradual increase, spike during pandemic. Scooters have brought many people out of their cars and houses. A strong desire to just be outside. Could be more interest in nature." (top 20 fatality rate city)

Public transit also declined in the late 2010s and during COVID but has rebounded in the last two to three years. Still, decreases in transit use may have decreased pedestrian activity levels and increased driving.

- "[City X] transit also had more problems with funding, so maybe more people switched to cars, or other ways of getting to work." (top 20 fatality rate city)

Enforcement and driver behavior

Traffic enforcement and ticketing decreased in many communities. Some interviewees suggested that lack of enforcement may have contributed to higher overall traffic speeds, more extreme speeding behavior, and increased levels of reckless driving. Others mentioned increases in reckless driving but did not tie them to enforcement trends.

- "[City X] drivers can drive with impunity. There is not much regulation from police." (high fatality rate city)
- "Overnight high speed crashes is a problem we're trying to address. We are limited on what we are able to do with repeat drivers or drivers without licenses on the road for a variety of reasons. But as we move to this point in Vision Zero 10 years later, that's one of the issues we're trying to figure out how to tackle. It's like the next big issue that we need to really rein in, and that requires city/state cooperation."
- "One of our biggest issues relates to people who have suspended licenses or no licenses or repeat offenders on the road." (low fatality rate city)
- "I was opening a new midblock crosswalk ([City X] drivers never stop for crosswalks), and discussed with officers to sit there and enforce speeding. The most senior ranking officer laughed and said no." (high fatality rate city)
- "The change in police pursuit policy [so that police did not pursue drivers who fled from traffic stops] in mid-2010s and lack of driver education" may have also contributed to increases in pedestrian and bicycle fatality rates. "People could drive with more recklessness without fear of repercussion." (high fatality rate city)
- "Traffic citations dropped by 97% during approximately 2017 to 2021…police cited understaffing; change in protocol for paperwork, more complicated to write citations." This hampered progress on pedestrian and bicyclist safety that City X was making otherwise through roadway design changes. (low fatality rate city)
- "Reckless driving has increased over time." (high fatality rate city)

Several communities mentioned the benefits of having red light safety cameras and speed safety cameras. Not having automated traffic enforcement is also seen as a barrier to better pedestrian and bicyclist safety outcomes, even in communities that have made significant investments in pedestrian and bicycle infrastructure and other roadway safety improvements.

- “Every time we have to go back to the State Legislature, we put together a report that shows the benefits of speed cameras and why we want it renewed and expanded.” (low fatality rate city)
- “Automated enforcement was a big part of advocacy. Cameras were illegal up until 2023, when speed cameras were finally allowed.” (low fatality rate city)
- “We definitely have a issue with speeding overnight. I think maybe the expansion of speed cameras to overnight hours is going to be helpful.” (low fatality rate city)

One interviewee suggested intelligent speed assist to help reduce speeds:

- “A magic wand I would love is like intelligent speed assist on all vehicles…vehicles who have received a lot of speed camera violations could require that. Like an Inner ignition interlocker. I think that would be amazing. But obviously, there’s a lot of political challenges with that kind of program. If you started with like city fleet vehicles and taxis, that could make a big difference.” (low fatality rate city)

Pedestrian risk at night

Nighttime has a higher injury risk for pedestrians and bicyclists than daytime because they are harder for drivers to see and alcohol use is more common. Several interviewees suggested that there may be more people walking at night in their communities.

- “I do know a lot of crashes happened at nighttime, in the dark. There are a lot of warehouses here, where there is a lot of employment activity at night. A lot of people coming and going from work.” (high fatality rate city)
- “A lot in the rural areas, people walking at night, where the visibility of walkers is not good... Wearing darker colors, or the driver is impaired.”
- “In the city, people are walking to get somewhere. And they might be doing it at 9pm, getting off the 3rd shift.” (high fatality rate city)
- “I think that’s feasible that the 3-6am weekday crash increase happened, that was my perception. The general percentage of fatalities that were outside engineering control increased significantly: people driving drunk, driving stolen cars, etc.” (low fatality rate city)

Engineering and roadway design

Nearly every interviewee mentioned adopting “complete streets” or another similar approach to design for the needs of pedestrians, bicyclists, and transit users in addition to private automobiles in all roadway projects. In general, communities made progress adding more sidewalks and bicycle infrastructure (protected bike lanes were emphasized, in particular) during the 2010s.

- “The engineering changes that came out of those programs had a positive impact on safety. The widespread implementation of tools: bulb-outs, leading pedestrian intervals was adopted as widespread blanket policy for whole city.” (low fatality rate city)
- “We've definitely being able to expand…our general design upgrades specifically around intersection safety…both for bikes and pedestrians: improving visibility, slowing turns for vehicles across bike and pedestrian spaces, doing more protected bike lanes and adding more pedestrian space generally. So, taking more space from vehicles and giving it to pedestrians. Adding more islands, shortening crosswalks.” (low fatality rate city)
- “Adopted complete streets ordinance in the last decade. [City X] was first to adopt that in the state…We have bike parking requirements, [City Y], when they do their site plan reviews, they must connect to existing bike paths and sidewalks. There is still much to be done, especially in rural areas.”
- “There's momentum to have more protected bike lanes now, especially with our [City X] corridor studies. And that's something that we've been involved in heavily to advocate for safe alternative transportation.”
- “A lot of the more urban areas have done road diets, but also smaller communities.”
- “We've massively expanded LPIs across the city. And our LPIs are a minimum of 7 seconds. So it's a pretty significant lead interval. And there, I mean, it's thousands of locations now. Now it's like just a standard tool.” (low fatality rate city)
- “A lot of development among river front. Apartment building recently opened, another 107-unit one going to open soon. We added RRFBs there as well. Redoing streets downtown, reintroducing new streets to mall site, introducing a new, curbless design. It’s not always taken into consideration as early or thoroughly as it should be, but I think we’re making progress.”

However, several interviewees noted that they were only able to make substantial design changes to a small fraction of their roadway networks, and many pedestrian and bicycle facilities were still disconnected. There are still large proportions of roadways that prioritize motor vehicle traffic speed and flow at the expense of safety for all modes, particularly pedestrians and bicyclists.

- “For every improvement we're making, there are 20 more streets that are not getting those improvements.” (high fatality rate city)
- “[City X] has wide/straight roads. Leading up to the pandemic, there was still an increase in crashes, but then skyrocketed during pandemic. It makes sense; 10 years of improvements was never going to undo the damage of 60 years of car-centric design before that.” (high fatality rate city)
- “Theres only so much someone can do with a 7-lane road for bike and ped. It's unlikely that, in the blink of an eye, we can take these like huge highways and convert them into dense urban mixed use areas. So there's a mismatch in terms of what people want and the place that they choose to live.” (high fatality rate city)

Further, there are other system-level changes that occurred during the 2010s that worked against community progress on road design.

- "…larger vehicles, increased homelessness, traffic citations dropped by 97% during approximately 2017 through 2021…"

Speed limits were mentioned by a few interviewees, but they were not mentioned as often as other elements of road design.

- "Since starting Vision Zero, we've had a lot of different tools that we've deployed across the city to try to get our bike and pedestrian fatalities down. One of the biggest tools has been our abilities to lower speed limits around the city." (low fatality rate city)
- "The citywide speed limit changed from 30 to 25 because of [Vision Zero]." (low fatality rate city)

Coordination with State DOTs

A high proportion of community pedestrian crashes occur on state-owned roadways. Interviewees suggested that state DOT practices are changing to prioritize pedestrian and bicyclist safety more, but some interviewees mentioned local jurisdiction priorities for safety sometimes conflict with state DOT mobility goals on state highways within their communities.

- "Many of the pedestrian crashes tended to be clustered in neighborhoods of lower income, neighborhoods of color. Also cluster along state owned highways, so the largest streets in the city in terms of the number of lanes, the width." (high fatality rate city)
- "Working with the state is important, they lead most of our projects. We've seen a higher focus on pedestrian and bike connectivity within those projects as well. Lane reduction rather than expansion, etc."
- "In the region, highway improvement projects have provided better bike accommodations for new road projects [relative to older projects]."

Policy and Planning

Communities that have the best pedestrian and bicyclist safety outcomes have developed strong safety policies and plans. Several agencies have prioritized traffic safety through Vision Zero initiatives and devote resources to reduce pedestrian and bicyclist crash risk.

- "Vision zero generally started 10 years ago. So we're working with our 10 year vision Zero plan from 2015 right now, and have been putting energy and effort into that for the past 10 years." (low fatality rate city)
- "Some cities, I think, are nervous about adopting the [Vision Zero] terminology, but I think at 10 years we're actually trying to figure out how to double down and re-center the message." (low fatality rate city)

- “The city has been making investments in bike and walk infrastructure for more than a decade now, and there is an amazing trail system, more bike lanes. But without an official plan with time-bound goals, advocacy is just purely reactive.” (high fatality rate city)

Interviewees noted the importance of federal leadership on multimodal policy and funding, leading to local projects that have improved pedestrian and bicyclist safety.

- “We [add pedestrian and bicycle facilities as a part of roadway projects] now because [State X] Department of Transportation redid their section on bike and ped accommodations to reflect federal policy.”
- “A lot of new roads are funded by fed dollars, which has requirements for bike ped improvements.”
- In 2019-20, there was “a dedicated funding pot for multimodal [projects and programs] for the first time. Almost $4 mil per year now. We are doing more with other local funds: paving program, restriping and adding concrete improvements. We’ve always been good at receiving CMAQ and TAP funds, as well as STP and general reconstruction. We’ve done a better job at incorporating STP into walking and biking…No matter the grant or program, we’ve tried to do a better job advancing walking and biking goals.” (high fatality rate city)
- “We are updating our long-range transportation plan and have been trying to emphasize the severity of deaths. We look at data, have community input, and then celebrating what is existing. We’ve also worked to show statistics to bring attention to those issues.”

Safe Routes to Schools plans are also common.

- “Probably the most recent positive element has been that we had a safe route to school plan, and that was done by our regional planning commission.”

Community Advocacy and Leadership

Local advocacy is crucial to support agency-led pedestrian and bicycle safety initiatives. All interviewees mentioned interactions with community advocates, and most were beneficial for pedestrian and bicyclist safety.

- “There are many advocacy groups. They had much success, too. The community, businesses, and leaders in the neighborhood made a big difference in what got built. [Neighborhood X] ended up getting bike improvements before [Neighborhood Y], since [Neighborhood X] wanted it and pushed for it, and [Neighborhood Y] didn’t.” (low fatality rate city)
- “We definitely have strong advocates that are help us push for some of the things like the speed limit reductions and speed camera expansion. They’re really good around the pedestrian safety piece. I think the cycling advocates at times can be detrimental to some of our work. They’re good in sort of like pushing us or pushing the council or other

people to try to get us to do more and be better. But I think a lot of their messaging is like '[City X] is a shit show. Don't ever bike here because you'll die unless we do XY and Z.'" (low fatality rate city)

- "We get feedback from bike and pedestrian advocacy groups. They show up to public involvement meetings, and this often make us take another look at a project to see if it is enough or could be more."
- After 2020, "broader traffic safety started to resonate with the community." But not during the 2010s. (high fatality rate city)
- "The biggest challenge I think is awareness in the community elected leaders, not including city staff. It was hard convincing them of the importance of any of this. General attitude is that crashes are terrible but there is nothing we can do about it. Lack of awareness that there are things we can do." (high fatality rate city)
- "[City X] lacks organized advocacy like it does in other communities. Vision Zero has not really been proposed: city staff talked about it, but there was no serious effort to consider it…And most of the attempt to tackle the problem involved enforcement by police for jaywalking." (high fatality rate city)
- "We didn't do much at all for communication. We relied on community partners, community walks/bike rides. Some elected officials were supporters, but it was overall more hands off." (high fatality rate city)

Still, some interviewees mentioned limits to political support.

- "Projects were controversial, but funding grew, employment grew, so that indicates that the political environment was supportive of us. The flipside is that the counterbalancing forces [(e.g., unhoused people experiencing crashes, larger vehicles, people driving quickly for delivery jobs, huge drop in traffic enforcement)] were very frustrating, to us and to elected officials who ran on improving safety, and weren't seeing the results. The fact that [our City X] was still doing better than most other cities in the US was acknowledged, but it is not a winning message when the numbers could have been so much higher, and that was promised." (low fatality rate city)

Funding and Resources

The interviews revealed differences in resources available for traffic safety between communities with the highest and lowest pedestrian fatality rates.

- "We've been really funded well to get a lot of these improvements moving and on the ground with a lot of support from politicians, both at the city and state level. Not without having to push, but we're really making some progress there." (low fatality rate city)
- "We have a lot of resources, funding and educational staff that are going out and talking about vision zero, handing out flyers directly to drivers or other street users talking to them directly. We have a lot of programming and events that we do around the city where

vision zero teams are out talking to people on the street. So I think people understand what it is and that it exists." (low fatality rate city)

- "We actually had a high mark of staff right before COVID, I think 2018, 2019. A lot of that came from new staff brought on for vision zero, for our Greenway bicycle initiative, and for our street plan initiative…As people left, we weren't really able to refill those positions, so we're back below our high mark, even though we're doing more and being asked to do more. So far we've been able to figure it out. But we did get a lot of resources dedicated to all of these efforts at the beginning." (low fatality rate city)
- "[City X] had a passage of a large bond measure…a lot of it went to bike and ped improvements and livable streets [including staff positions]…Two full time positions were created just to create Vision Zero policy and monitoring. With the rise in Uber and Lyft, a TNC tax was passed…which gave dedicated funding to bike and ped as well…A third funding source…took a portion of increased tax revenue from increased population and dedicated it towards transportation." (low fatality rate city)
- [City X] had a history of annexing low-density suburban areas for many decades in the late 20th Century. "The areas…that were annexed, they were already terrible places to walk and bicycle, and we incorporated them, adding more burden to the city's resources. No consideration whether this was sustainable or not. Big parts of the city look the same because of this. Funding has decreased for safety because of these annexation. More attention geared towards building highways to go in and out of inner city. Poorer neighborhoods cannot lobby as much for improvements/ new facilities as more affluent neighborhoods, so they continue to deteriorate." (high fatality rate city)
- "I think a big reason advocacy lacks in [City X] is because [City X] has many problems, and many other problems are judged as more important. 1/3 of residents are impoverished, school system is struggling, long history of racial injustice, crime. These other issues take precedent over bike and pedestrian issues, not seen as important. Also car-centric for so long, that it is part of the culture." (high fatality rate city)
- "The biggest challenge is having enough funding and supporting the type of projects that the local community would desire. Our dept has focused on smaller projects like resurfacing, rather than expensive restructuring. This limits our bike and ped improvements we can do."
- "Over time, the narrative changed that we were a more bike-friendly city…For pedestrian[s], we did not build up the infrastructure as heavily as bikes. Easier to stripe a street than build or maintain a sidewalk." (high fatality rate city)

Interviewees in jurisdictions with some of the best safety outcomes emphasized consistent institutional support and resources over time. On the other hand, communities with high fatality rates have not experienced long-standing institutional support.

- "We didn't have a ped/ bike program until 2015. Ped plan took longer to craft a strategy for. Politically, and just getting our heads around, it was hard." (high fatality rate city)

- “First half of 2010s were golden age of bike and ped policy for many cities, [our City X] missed that trend. We missed the entire decade really.” (high fatality rate city)
- After 2018 there was “good change in leadership within department.” Prior to this, “staff within department was set in their ways, bike and ped was not priority. There has been a change in the last few years…More top down approach, making safety overall a priority.” (high fatality rate city)

Public Resistance

The most common reasons for public resistance to pedestrian and bicycle safety initiatives are traffic congestion and impacts on automobile parking. In some communities, residents on the fringe of urban areas are more resistant to pedestrian and bicycle infrastructure investments.

- “Again, the engineering projects did work. The small ones no one complained about. If we were removing travel lanes, adding bike lanes etc., [it] was extremely controversial. This can result in change of project scope, or mostly long delays. The quick build program allowed us to only take months to implement something, but then the outreach would take so long, which hampered progress too.” (low fatality rate city)

Other Interview Findings

In general, there were not notable differences between the insights from practitioners in Wisconsin communities versus cities in other parts of the US. Still, Wisconsin practitioners were more likely to mention the aging population having an impact on the times and locations of pedestrian and bicyclist activity. There was no consensus about how an aging population ultimately impacted pedestrian and bicyclist safety.

Discussion

Our study provides new details about trends in pedestrian and bicyclist injuries from 2008 to 2021. It also identified several important factors that are associated with the increase in FSI pedestrian and bicyclist crashes over this time period.

By analyzing non-fatal injury crashes in nine states we were able to see that the steep increase in pedestrian fatalities and the moderate increase in bicyclist fatalities since 2009 were not mirrored by crashes with lower injury severity levels. Crashes with severe injuries ("A" level) have increased less steeply than crashes with fatalities, and crashes that are not severe ("B" and "C" level) generally decreased over this time period. This suggests that the factors associated with the increase in fatalities are more likely to be related to changes in characteristics of the system (e.g., behaviors, roadway context) than pedestrian or bicyclist exposure.

We identified specific neighborhood characteristics that were associated with FSI pedestrian and FSI bicyclist crashes in 2008-2012 and 2017-2021 and found evidence of neighborhood-level shifts in both pedestrian and bicyclist crashes between these two periods. These results underscore the value of analyzing pedestrian and bicyclist crash data at a fine-grained geographic scale, such as the census tract level, and also highlight several overarching pedestrian safety issues. The following sections first discuss the implications of the FSI pedestrian crash model results and then discuss the implications of the FSI bicyclist crash model results.

First, major automobile thoroughfares had a significant association with FSI pedestrian crashes in both study periods, and interstate and other freeways and expressways had an even stronger relationship with these crashes in 2017-2021. Automobile-dominated transportation systems tend to have higher pedestrian crash rates. To reduce pedestrian risk, communities should pursue mode shift strategies to reduce automobile traffic volumes (e.g., compact, mixed-use development; robust local and regional public transit networks; roadway pricing). Arterial roadways with more than 20,000 AADT often have combinations of high speeds and multiple through and turning lanes. Traffic speeds on these high-volume streets should also be kept as low as possible to reduce pedestrian injury risk.

Second, certain land use contexts were associated with FSI pedestrian crashes. State, regional, and local agencies should make proactive pedestrian safety improvements in neighborhoods with lower population densities, that are served by transit, and that have concentrations of retail jobs. In particular, our results underscore pedestrian safety needs in commercial roadway corridors outside of city centers surrounded by lower-density neighborhoods (these corridors often have strip malls and big-box retail). Retail districts might experience more pedestrian crashes than other areas because they have particularly high levels of pedestrian activity, riskier driver and pedestrian behaviors, or some combination of both of these characteristics (Schneider et al. 2010; Mansfield et al. 2018). Retail workers may also face high-risk pedestrian conditions as they walk to and from bus stops to access jobs in these corridors. Retail corridor development should be pursued in coordination with roadway designs that facilitate slower vehicle speeds and provide narrower and more protected pedestrian crossings.

Third, FSI pedestrian crashes were not spread evenly across population groups. There were significantly more FSI pedestrian crashes in neighborhoods with high levels of unemployment and low incomes. There were also racial disparities in FSI pedestrian crashes, as neighborhoods with higher proportions of Black residents or Hispanic residents had more FSI pedestrian crashes. These racial disparities worsened between 2008-2012 and 2017-2021. One possible reason for these racial disparities could be that communities of color have been historically segregated into areas that tend to have higher-risk pedestrian conditions (Sanders & Schneider 2022). While we controlled for freeway presence and high-volume arterial roadways, it is possible that predominantly Black or Hispanic neighborhoods tended to have more built environment characteristics associated with pedestrian risk, such as incomplete or poorly-maintained sidewalk networks, lower-quality lighting at night, or more high-speed and multi-lane roadways. Further, communities of color may have been displaced in some metropolitan regions between our two study periods from central city neighborhoods with relatively low pedestrian risk toward peripheral, higher-risk areas. However, behavioral reasons for these disparities also need more investigation. For example, it is possible that speeding, red-light running, and other forms of reckless driving could have increased in certain communities, leading to increased FSI pedestrian crashes. Further research into the reasons behind racial disparities in FSI pedestrian crashes is crucial since these disparities grew significantly between our two study periods. Meanwhile, transportation agencies should engage with residents to proactively implement pedestrian safety initiatives in Black and Hispanic communities where FSI pedestrian crashes are trending upward.

Similar to our findings on FSI pedestrian crashes, we found that neighborhoods with arterial roadways with more than 20,000 AADT had a strong relationship with FSI bicyclist crashes in both study periods. Those with freeways and expressways had an even stronger relationship with FSI bicyclist crashes in 2017-2021. To improve bicyclist safety, in addition to promoting mode shift strategies, communities should also invest in building better and more connected bicycle networks and infrastructure to reduce bicyclist crash risk and injury severity.

Additionally, several land use variables were positively associated with FSI bicyclist crashes. In other words, transportation agencies at different levels should prioritize bicyclist safety in neighborhoods with higher population and employment densities, that are served by transit, and that have concentrations of retail jobs. Specifically, our results emphasize improving bicyclist safety measures in denser areas with high levels of bicyclist exposure. Such areas tend to have increased bicyclist crash risk due to elevated cyclist and automobile intersections and conflicts due to complex road designs and higher traffic volumes (Chen et al., 2018; Siddiqui et al., 2012). These findings point to the importance of targeted infrastructure interventions—such as protected bike lanes and traffic calming devices to reduce these elevated risks in dense areas.

Moreover, certain population groups experienced disproportionately higher rates of FSI bicyclist crashes. There were significantly more FSI bicyclist crashes in neighborhoods with high levels of unemployment and low incomes, and the relationship between the percentage of unemployed workers and FSI bicyclist crashes worsened in 2017-2021. Neighborhoods with higher proportions of Black residents or Hispanic residents had more FSI bicyclist crashes, and these racial disparities worsened between 2008-2012 and 2017-2021. Similar to the factors that may have contributed to higher pedestrian crash risks, it is also possible that, historically, Black and Hispanic neighborhoods often had less access to active transportation infrastructure, including a lack of dedicated bicycle facilities, poorly-maintained road surfaces, and insufficient lighting. Transportation agencies should prioritize investments in underserved neighborhoods where bicyclist crash risks are disproportionately high.

Our qualitative analysis of 13 local practitioner interviews suggested that increases in pedestrian and bicyclist fatalities during the 2010s may be related to:

- Shifts in pedestrian and bicyclist activity away from downtown areas and toward higher-risk roadways on the periphery of urban areas.
- Higher vehicle speeds and more reckless driving, potentially associated with reduced levels of traffic enforcement.
- A high remaining proportion of automobile-oriented roadways in many communities, even where progress is being made to redesign some roadways for slower speeds and better pedestrian and bicycle facilities. The high-speed, multi-lane roadways that have been developed over many decades continue to cultivate social expectations for high-speed vehicle mobility, which is associated with higher traffic injury risk, especially for pedestrians and bicyclists.
- Communities lacking resources and having other social and economic problems that prevent them from prioritizing traffic safety, particularly for pedestrians and bicyclists.

There are likely to be other reasons for increases in pedestrian and bicyclist fatalities throughout the US since 2010, including larger vehicles and more driver distractions, but these were major themes mentioned across multiple practitioner interviews.

In addition to devoting more resources for traffic safety in general, our interviews suggested that cities with lower pedestrian and bicyclist fatality rates had strong community advocacy and political support for traffic safety, adopted ambitious policies and plans to reduce traffic fatalities, established programs to quickly experiment with new roadway designs, implemented large numbers of roadway redesign projects, experimented with and expanded automated enforcement programs, communicated positive safety results with the public, and increased staff positions and funding to implement pedestrian and bicycle safety projects and programs.

Other countries have improved pedestrian and bicyclist safety over the last 40 years, including between 2008-2012 and 2017-2021, so the US should also look internationally for policy strategies to address these trends. In addition to the engineering strategies mentioned above (e.g., close sidewalk gaps, reduce motor vehicle lanes, slow motor vehicle speeds, add bicycle infrastructure), agencies should also pursue the following strategies to prevent FSI pedestrian and bicyclist crashes: increase development density and mix to reduce trip distances, reduce automobile parking supply and increase parking prices, and install speed safety cameras and red-light safety cameras (Buehler & Pucher 2021; Buehler & Pucher 2023).

Considerations and Future Research

Our study provides important insights about neighborhood-level and city characteristics associated with FSI pedestrian and FSI bicyclist crashes and how these characteristics changed between 2008-2012 and 2017-2021, but additional work is needed. Our qualitative analysis was limited to 13 interviews. While each of these interviews lasted longer than 45 minutes and provided in-depth insights from local pedestrian and bicycle safety experts, practitioners from other communities may have had different experiences with safety strategies. Further, since the interviewees were all professionals from the same general field, they may share certain knowledge and opinions from their educational backgrounds, training experiences, professional network discussions.

In our quantitative models, the last part of our 2017-2021 analysis period included the peak of the COVID pandemic, which had a major impact on traffic volumes (FHWA 2025) and traffic safety outcomes, especially for people of lower socioeconomic status (Tefft & Steinbach 2024). We believe that it is important to include data from 2020 in our analysis because FSI pedestrian and FSI bicyclist crashes continued to happen. Further, there is no evidence that trends in FSI pedestrian and FSI bicyclist crashes returned to either 2008-2012 or pre-pandemic conditions as COVID receded. In fact, annual US pedestrian fatalities did not exceed 7,000 until *after* 2020 and have remained above 7,000 through 2023 (NHTSA 2025b). We used the latest data available for this study to help describe what may be emerging as a new reality.

Our census tract analysis represented eight states. Future studies should incorporate data from more states, especially as more states build robust historical crash databases with accurate latitude and longitude coordinates. Further, our neighborhood-scale unit of analysis (census tracts) led to only having a small number of FSI pedestrian and FSI bicyclist crashes per tract, even using five-year analysis periods. We considered conducting an analysis with a larger number of shorter time periods, but this approach is hampered by a large amount year-to-year variation in crash counts at the tract level. Further, we considered conducting an analysis with larger geographic areas (e.g., public use microdata areas or counties) to increase the number of crashes in each unit of analysis. However, these larger units tend to contain a greater range of populations and land uses, obscuring the more distinct socioeconomic characteristics, land uses, and job types that are delineated by census tracts.

We were only able to acquire 2016 HPMS data that accounted for roadway characteristics at the time of the study, so it is important to incorporate more recent data that could better represent roadway characteristics in each study period to better understand whether there has been significant changes in roadway characteristics between study periods and how they impact FSI pedestrian and FSI bicyclist crash risks. While our study focused on neighborhood-level FSI pedestrian and FSI bicyclist crash risks, it would be beneficial to conduct analyses at the roadway segment level to more precisely identify high-risk locations and understand the specific roadway design features contributing to FSI pedestrian and FSI bicyclist crashes.

While we found eight states with pedestrian and bicyclist crash data that fit the needs of our longitudinal analysis, there are likely to be inconsistencies between how law enforcement officers in different states (and even local jurisdictions within states) define severe pedestrian and bicyclist injuries. We also know that pedestrian and bicyclist crashes, even those that involve severe injuries, are often underreported or misdiagnosed (Stutts & Hunter 1998; Doggett, Ragland, and Felschundneff 2018; Ferenchak & Osofsky 2022).

Future research should explore the influence of several other variables on shifts in FSI pedestrian and FSI bicyclist crashes. Our practitioner interviews and other studies have noted the important association between roadway characteristics and pedestrian and bicyclist fatalities (Mansfield et al. 2018; Schneider 2020), so a longitudinal examination of roadway design changes on shifts in pedestrian and bicyclist crash risk would be insightful. Importantly, we only represented pedestrian and bicyclist exposure indirectly through population, employment, and pedestrian, bicyclist and transit commuting variables. Future studies should incorporate locally-specific pedestrian and bicyclist counts, pedestrian and bicyclist trips, and other more direct measures of pedestrian and bicyclist activity levels.

Further, we did not include driver, pedestrian, and bicyclist behavior and vehicle characteristics, some of which may have changed between 2008-2012 and 2017-2021 and influenced shifts in FSI pedestrian and FSI bicyclist crashes. While these variables are challenging to collect at a fine-grained geographic scale, future neighborhood-level pedestrian and bicyclist safety research should also explore these variables.

Associations between other land use and transportation characteristics and FSI pedestrian and FSI bicyclist crashes deserve additional investigation. The association between neighborhoods served by public transit and FSI pedestrian crashes increased between 2008-2012 and 2017-2021. However, there could be differences between pedestrian safety outcomes along transit routes in dense, urban core areas compared to suburban arterial corridors. There may also be important differences in overall FSI pedestrian, and potentially, bicyclist crash outcomes between urban, suburban, and rural contexts that require different safety strategies.

Conclusions and Recommendations

Our trend analysis of police-reported pedestrian and bicyclist crashes across nine states showed that crashes with pedestrian and bicyclist fatalities increased the most steeply, but moderate and minor injuries actually decreased between 2008 and 2021. Our eight-state census tract models showed that FSI pedestrian crashes were positively associated with certain neighborhood characteristics in both periods: larger proportions of Black, Hispanic, or low-income populations; higher unemployment rates; higher proportions of retail jobs; having transit nearby; and containing at least one high-traffic arterial roadway. Between 2008-2012 and 2017-2021, FSI pedestrian crashes became even more prominent in neighborhoods with higher proportions of Black or Hispanic residents, interstates or other freeways or expressways, higher proportions of retail jobs, and transit nearby. FSI bicyclist crashes were positively associated with neighborhoods that have higher shares of Black residents, lower median household incomes, higher shares of unemployed workers, higher proportions of retail jobs, higher population and employment densities, close proximity to transit stops, and at least one high-volume arterial roadway. FSI bicyclist crashes became more prominent during the 2010s in neighborhoods with higher shares of Black and Hispanic residents, higher population density, and a non-interstate freeways or expressway.

Our 13 practitioner interviews suggested that increases in pedestrian and bicyclist fatalities during the 2010s may be related to shifts of pedestrian and bicyclist activity to higher-risk parts of urban regions, reduced traffic enforcement potentially leading to higher vehicle speeds and more reckless driving, a large proportion of roadways still designed to facilitate high-speed automobile movement over multimodal safety, and a lack of political will and resources to prioritize pedestrian and bicyclist safety needs in certain communities.

These results should be viewed in the context of study limitations, such as the interviews only capturing thoughts from 13 practitioners and study models only covering eight states, having limited traffic data, and not including any direct measures of roadway user behavior. Still, the results provide practical insights for improving pedestrian and bicyclist safety. Transportation agencies should prioritize pedestrian and bicyclist safety in areas such as arterial roadways, retail areas, and lower-income communities. We recommend that communities build strong advocacy coalitions, encourage elected officials to make traffic safety a priority, adopt ambitious policies and plans to reduce traffic fatalities, experiment with new roadway designs, implement roadway redesign projects quickly, establish speed safety camera and red light safety camera programs, communicate results of safety initiatives with the public, and increase staff positions and funding for pedestrian and bicycle safety projects and programs.

References

Barrios, J.M., Hochberg, Y.V., and Yi, H. (2023). The cost of convenience: Ridehailing and traffic fatalities. Journal of Operations Management, 69(5), pp.823-855.

Bobbit, Z. (2023). What is a Chow Test? (Explanation & Example), Statology, Accessed November 15, 2024, https://www.statology.org/chow-test/

Buehler, R. and Pucher, J. (2021). The Growing Gap in Pedestrian and Cyclist Fatality Rates between the United States and the United Kingdom, Germany, Denmark, and the Netherlands, 1990–2018. Transport Reviews, 41(1), pp.48-72.

Buehler, R. and Pucher, J. (2023). Overview of Walking rates, Walking safety, and Government Policies to Encourage more and Safer Walking in Europe and North America. Sustainability, 15(7), p.5719.

Cai, Q., Lee, J., Eluru, N., & Abdel-Aty, M. (2016). Macro-level pedestrian and bicycle crash analysis: Incorporating spatial spillover effects in dual state count models. Accident Analysis & Prevention, 93, 14–22. https://doi.org/10.1016/j.aap.2016.04.018

Chaves Lasso, Y. T., Ferenchak, N., Lin, Y., & Losada-Rojas, L. L. (2024). Statistical and spatial analysis of pedestrian and bicyclist crashes on arterials roads, https://doi.org/10.2139/ssrn.5009070

Chen, P., Sun, F., Wang, Z., Gao, X., Jiao, J., & Tao, Z. (2018). Built environment effects on bike crash frequency and risk in Beijing. Journal of Safety Research, 64, 135–143, https://doi.org/10.1016/j.jsr.2017.12.008

Deka, D. and Brown, C. (2016). What Do Planning Professionals, Police, and Pedestrians in General Think About Distracted Driving and Walking? Transportation Research Record, 2582(1), pp.42-50.

Doggett, S., D.R. Ragland, G. Felschundneff. (2018). Evaluating Research on Data Linkage to Assess Underreporting of Pedestrian and Bicyclist Injury in Police Crash Data, University of California, Berkeley Safe Transportation Research and Education Center, UC Berkeley Research Reports, Available online, January 23, 2024, https://escholarship.org/uc/item/0jq5h6f5

Federal Highway Administration (FHWA). (2025). February 2025 Traffic Volume Trends. Available online, April 24, 2025, https://www.fhwa.dot.gov/policyinformation/travel_monitoring/25febtvt/figure1.cfm

Ferenchak, N.N., and Abadi, M.G. (2021). Nighttime pedestrian fatalities: A comprehensive examination of infrastructure, user, vehicle, and situational factors. Journal of Safety Research, Volume 79, Issue 0, pp 14-25.

Ferenchak, N.N., Gutierrez, R.E., and Singleton, P.A. (2022). Shedding light on the pedestrian safety crisis: An analysis across the injury severity spectrum by lighting condition, Traffic Injury Prevention, 23:7, 434-439, DOI: 10.1080/15389588.2022.2100362

Ferenchak, N. N., and Osofsky, R. B. (2022). Police-reported pedestrian crash matching and injury severity misclassification by body region in New Mexico, USA. Accident Analysis & Prevention, 167, 106573.

Hu, W. and Cicchino, J.B. (2018). An examination of the increases in pedestrian motor-vehicle crash fatalities during 2009–2016. Journal of safety research, 67, pp.37-44.

IBM Corp. (2023). IBM SPSS Statistics for Windows, Version 29.0.1.0 Armonk, NY: IBM Corp.

International Transport Forum. (2022). Road Safety Annual Report 2022, OECD Publishing, Paris, Accessed December 10, 2023, https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2022.pdf

Jacobsen, P.L. (2015). Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury prevention, 21(4), pp.271-275.

Jang, K., S.H. Park, S. Kang, K.H. Song, S. Kang, and S. Chung. (2013). "Evaluation of Pedestrian Safety: Pedestrian Crash Hot Spots and Risk Factors for Injury Severity," Transportation Research Record: Journal of the Transportation Research Board, Volume 2393, 104-116.

Levine, N. (2015). CrimeStat: A Spatial Statistics Program for the Analysis of Crime Incident Locations (v 4.02). Ned Levine & Associates, Houston, Texas, and the National Institute of Justice, Washington, D.C. August.

Loukaitou-Sideris, A., R. Liggett, and H. Sung. (2007). "Death on the Crosswalk: A Study of Pedestrian-Automobile Collisions in Los Angeles," Journal of Planning Education and Research, Volume 26, pp. 338-351.

Mansfield, T., D. Peck, D. Morgan, B. McCann, and P. Teicher. (2018). "The Effects of Roadway and Built Environment Characteristics on Pedestrian Fatality Risk: A National Assessment at the Neighborhood Scale," Accident Analysis and Prevention, Volume 121, pp. 166-176.

Merlin, L.A., Cherry, C.R., Mohamadi-Hezaveh, A. and Dumbaugh, E. (2020). Residential accessibility's relationships with crash rates per capita, Journal of Transport and Land Use, 13(1), pp.113-128.

National Highway Traffic Safety Administration (NHTSA). (2025a). Fatality Analysis Reporting System (FARS) Encyclopedia, FARS Data Tables, Accessed June 15, 2025, https://www-fars.nhtsa.dot.gov/Main/index.aspx

National Highway Traffic Safety Administration. (2025b). Fatality Analysis Reporting System Analytical User's Manual, 1975-2023, DOT HS 813 706. Accessed June 15, 2025, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813706

Petraglia, E. and Macek, K. (2023). Pedestrian Traffic Fatalities by State: 2022 Preliminary Data (January - December), Governors Highway Safety Association, Accessed December 10, 2023, https://www.ghsa.org/sites/default/files/2023-06/GHSA%20-%20Pedestrian%20Traffic%20Fatalities%20by%20State%2C%202022%20Preliminary%20Data%20%28January-December%29.pdf

Retting, R. (2020). Pedestrian Traffic Fatalities by State: 2019 Preliminary Data, Spotlight on Highway Safety. Governors Highway Safety Association, Washington, DC. Accessed January 31, 2022: https://www.ghsa.org/resources/Pedestrians20

Rodriguez, O. and Ferenchak, N.N. "Longitudinal spatial trends in U.S. pedestrian and bicyclist fatalities" (2024). https://digitalrepository.unm.edu/ce_etds/327

Sanchez Rodriguez, O. and Ferenchak, N.N. (2023). Longitudinal Spatial Trends in US Pedestrian Fatalities, 1999–2020. Transportation Research Record, DOI: 10.1177/03611981231190637

Sanders, R.L. and Schneider, R.J. (2022). "An Exploration of Pedestrian Fatalities by Race in the United States," Transportation Research Part D: Transport and Environment, Volume 107, https://doi.org/10.1016/j.trd.2022.103298

Sandt, L., Brookshire, K., Heiny, S., Blank, K., Harmon, K. (2020). Toward a Shared Understanding of Pedestrian Safety: An Exploration of Context, Patterns, and Impacts. Pedestrian and Bicycle Information Center, Chapel Hill, NC.

Schneider, R.J. (2020). "United States Pedestrian Fatality Trends, 1977 to 2016," Transportation Research Record: Journal of the Transportation Research Board, Volume 2674, Number 9, pp. 1069-1083. DOI: 10.1177/0361198120933636

Schneider, R.J., Diogenes, M.C., Arnold, L.S., Attaset, V., Griswold, J. and Ragland, D.R. (2010). Association between roadway intersection characteristics and pedestrian crash risk in Alameda County, California. Transportation Research Record, 2198(1), pp.41-51.

Schneider, R.J., Gu, X., Nelson, K. and Ferenchak, N.N. (2024). Geographic and Time-of-Day Shifts in Pedestrian Crashes by Injury Severity Level, Center for Pedestrian and Bicyclist Safety University Transportation Center, Final Report, Available after September 1, 2025, https://www.pedbikesafety.org/projects/23uwm04

Siddiqui, C., Abdel-Aty, M., & Choi, K. (2012). Macroscopic spatial analysis of pedestrian and bicycle crashes. Accident Analysis & Prevention, 45, 382–391. https://doi.org/10.1016/j.aap.2011.08.003

Smart Growth America. (2022). Complete Streets Policy Adoption, Accessed December 10, 2023, https://smartgrowthamerica.org/wp-content/uploads/2016/08/Complete-Streets-Policy-Adoption-2000-2021-1.pdf

Stutts, J.C. and Hunter, W.W. (1998). "Police-Reporting of Pedestrians and Bicyclists Treated in Hospital Emergency Rooms," Transportation Research Record, Journal of the Transportation Research Board, Volume 1635, pp. 88-92.

Tefft, B.C., Arnold, L.S., & Horrey, W.J. (2021). Examining the Increase in Pedestrian Fatalities in the United States, 2009-2018 (Research Brief). Washington, DC: AAA Foundation for Traffic Safety.

Tefft, B.C. and Steinbach, R. (2024). COVID-19 pandemic exacerbated socioeconomic disparities in motor vehicle traffic fatalities. American Journal of Epidemiology, kwae068.

Thomas, F. D., Darrah, J., Graham, L., Berning, A., Blomberg, R., Finstad, K., Griggs, C., Crandall, M., Schulman, C. Kozar, R., Lai, J., Mohr, N., Chenoweth, J., Cunningham, K., Babu, K., Dorfman, J., Van Heukelom, J., Ehsani, J., Fell, J. Whitehill, J. Brown, T., and Moore, C. (2022). Drug prevalence among seriously or fatally injured road users, National Highway Traffic Safety Administration, DOT HS 813 399, Accessed December 10, 2023, https://www.nhtsa.gov/sites/nhtsa.gov/files/2022-12/Alcohol-Drug-Prevalence-Among-Road-Users-Report_112922-tag.pdf

Appendix A. Model Analysis Variables

This appendix provides descriptive statistics for the dependent and explanatory variables used in the FSI pedestrian crash and FSI bicycle crash model analysis.

Pedestrian Model Dependent Variables (n = 21,833 tracts)

Variable	Years[1]	Mean	SD	Min	Max
FSI Crashes: Number of fatal (K) and severe (A) injury pedestrian crashes in and within 50m of census tract boundary	2008-2012	2.17	2.82	0.00	36.00
	2017-2021	2.52	3.09	0.00	55.00

1) We compared 2010-2014 vs. 2017-2021 for Washington.

Bicycle Model Dependent Variables (n = 21,833 tracts)

Variable	Years[1]	Mean	SD	Min	Max
FSI Crashes: Number of fatal (K) and severe (A) injury bicyclist crashes in and within 50m of census tract boundary	2008-2012				
	2017-2021				

1) We compared 2010-2014 vs. 2017-2021 for Washington.

Explanatory Variables (n = 21,833 tracts)

Exposure Variables[1]	**Years**	**Mean**	**SD**	**Min**	**Max**
Total Population (000s): Total population of census tract, in thousands	2008-2012	4.349	1.849	0.027	39.143
	2017-2021	6.650	4.651	0.048	64.359
Total Jobs (000s): Total number of jobs in census tract, in thousands	2010[3]	2.050	4.852	0.001	194.564
	2019	2.416	5.788	0.002	203.607
% Transit: Proportion of workers commuting by public transit	2008-2012	0.101	0.171	0.000	1.000
	2017-2021	0.086	0.153	0.000	0.925
% Walk: Proportion of workers commuting by walking	2008-2012	0.041	0.065	0.000	0.736
	2017-2021	0.035	0.058	0.000	0.721
Socioeconomic Variables[1]	**Years**	**Mean**	**SD**	**Min**	**Max**
Population under 18: Number of people < 18 years old	2008-2012	1024.202	593.976	0.000	11306.000
	2017-2021	1449.740	1161.535	0.000	13811.000
% Population under 18: Proportion of population < 18 years old	2008-2012	0.229	0.069	0.000	0.659
	2017-2021	0.213	0.063	0.000	0.665
Population over 64: Number of people > 64 years old	2008-2012	562.805	332.480	0.000	6272.000
	2017-2021	1077.669	867.642	0.000	11295.000
% Population over 64: Proportion of population < 64 years old	2008-2012	0.134	0.067	0.000	0.930
	2017-2021	0.164	0.070	0.000	0.919
Asian: Number of people who are Asian alone (non-Hispanic ethnicity)	2008-2012	352.642	620.629	0.000	11508.000
	2017-2021	611.339	1176.398	0.000	25877.000
% Asian: Proportion of population that is Asian alone (non-Hispanic ethnicity)	2008-2012	0.077	0.119	0.000	0.921
	2017-2021	0.088	0.127	0.000	0.910
Black: Number of people who are Black alone (non-Hispanic)	2008-2012	330.301	672.156	0.000	15530.000
	2017-2021	430.878	787.465	0.000	21178.000
% Black: Proportion of population that is Black alone (non-Hispanic)	2008-2012	0.084	0.170	0.000	1.000
	2017-2021	0.080	0.154	0.000	0.991
	2008-2012	18.018	67.706	0.000	2498.000

Native American: Number of people who are Native American alone (non-Hispanic)	2017-2021	26.056	112.564	0.000	3319.000
% Native American: Proportion of population that is Native American alone (non-Hispanic)	2008-2012	0.005	0.024	0.000	0.875
	2017-2021	0.004	0.019	0.000	0.769
White: Number of people who are White alone (non-Hispanic)	2008-2012	2577.199	1753.748	0.000	23285.000
	2017-2021	3829.999	3637.995	0.000	51102.000
% White: Proportion of population that is White alone (non-Hispanic)	2008-2012	0.601	0.316	0.000	1.000
	2017-2021	0.560	0.303	0.000	1.000
Other Race: Number of people who are other race alone, including Native Hawaiian/Pacific Islander (non-Hispanic)	2008-2012	21.036	58.487	0.000	1300.000
	2017-2021	43.328	89.581	0.000	1563.000
% Other Race: Proportion of population that is other race alone, including Native Hawaiian/Pacific Islander (non-Hispanic)	2008-2012	0.005	0.014	0.000	0.384
	2017-2021	0.007	0.015	0.000	0.335
Hispanic: Number of people who are Hispanic ethnicity	2008-2012	956.045	1282.914	0.000	13784.000
	2017-2021	1476.946	1942.562	0.000	25650.000
% Hispanic: Proportion of population that is Hispanic ethnicity	2008-2012	0.207	0.237	0.000	1.000
	2017-2021	0.227	0.237	0.000	1.000
Median Income (0000s): Median household income, in ten-thousands of dollars	2008-2012	6.239	2.930	0.250	25.000
	2017-2021	13.813	11.568	0.250	151.821
Zero Vehicles: Number of households with 0 vehicles	2008-2012	202.042	354.989	0.000	6254.000
	2017-2021	251.053	398.107	0.000	6736.000
% Zero Vehicles: Proportion of households with 0 vehicles	2008-2012	0.129	0.172	0.000	1.000
	2017-2021	0.120	0.165	0.000	0.971
Labor Force: Number of people in the labor force	2008-2012	2239.781	998.331	1.000	13544.000
	2017-2021	3429.421	2431.965	38.000	36748.000
Unemployed: Number of people in labor force who are unemployed	2008-2012	212.958	136.980	0.000	2132.000
	2017-2021	193.170	161.405	0.000	2923.000
% Unemployed: Proportion of people in labor force who are unemployed	2008-2012	0.098	0.053	0.000	0.657
	2017-2021	0.060	0.038	0.000	0.481
Workers: Number of workers	2008-2012	1987.470	920.158	1.000	22542.000
	2017-2021	3179.108	2302.164	33.000	33263.000
Home: Number of workers working from home	2008-2012	92.807	89.817	0.000	3523.000
	2017-2021	354.758	382.951	0.000	5330.000
% Home: Proportion of workers working from home	2008-2012	0.047	0.039	0.000	1.000
	2017-2021	0.105	0.067	0.000	0.502
Employment Variables[2]	**Years**	**Mean**	**SD**	**Min**	**Max**
Retail: Number of retail jobs (CNS07)	2010[3]	205.390	426.743	0.000	8988.000
	2019	219.447	443.321	0.000	8657.000
% Retail: Proportion of total jobs that are retail jobs (CNS07)	2010[3]	0.119	0.122	0.000	1.000
	2019	0.108	0.109	0.000	1.000

Office: Number of office jobs (CNS09+CNS10+CNS11+CNS12+CNS13+CNS20)	2010[3]	434.075	2067.500	0.000	96427.000
	2019	504.703	2530.722	0.000	113432.000
% Office: Proportion of total jobs that are office jobs (CNS09+CNS10+CNS11+CNS12+CNS13+CNS20)	2010[3]	0.140	0.127	0.000	1.000
	2019	0.134	0.127	0.000	1.000
Industrial: Number of industrial jobs (CNS01+CNS02+CNS03+CNS04+CNS05+CNS06+CNS08)	2010[3]	436.906	1311.829	0.000	51889.000
	2019	514.991	1561.427	0.000	53151.000
% Industrial: Proportion of total jobs that are industrial jobs (CNS01+CNS02+CNS03+CNS04+CNS05+CNS06+CNS08)	2010[3]	0.212	0.206	0.000	1.000
	2019	0.209	0.203	0.000	1.000
Service: Number of service jobs (CNS12+CNS14+CNS15+CNS16+CNS19)	2010[3]	779.505	2148.672	0.000	187175.000
	2019	932.114	2184.975	0.000	69213.000
% Service: Proportion of total jobs that are service jobs (CNS12+CNS14+CNS15+CNS16+CNS19)	2010[3]	0.419	0.218	0.000	1.000
	2019	0.431	0.215	0.000	1.000
Entertainment: Number of entertainment jobs (CNS17+CNS18)	2010[3]	194.013	445.853	0.000	12838.000
	2019	245.172	553.981	0.000	15685.000
% Entertainment: Proportion of total jobs that are entertainment jobs (CNS17+CNS18)	2010[3]	0.110	0.113	0.000	1.000
	2019	0.117	0.112	0.000	0.948
Low-Wage: Number of low-wage workers (<$1250/month) (CE01)	2010[3]	471.610	805.850	0.000	30360.000
	2019	453.988	901.949	0.000	61008.000
% Low-Wage: Proportion of total jobs that are low-wage (<$1250/month) (CE01)	2010[3]	0.307	0.120	0.000	1.000
	2019	0.243	0.094	0.000	0.862
Land Use Variables[4]	**Years**	**Mean**	**SD**	**Min**	**Max**
Population Density (000s): Gross population density (people/acre) on unprotected land (D1b) in thousands	2010	0.018	0.032	0.000	0.623
	2018/2020	0.018	0.032	0.000	0.410
Employment Density (000s): Gross employment density (jobs/acre) on unprotected land (D1c) in thousands	2010	0.006	0.039	0.000	1.389
	2018/2020	0.007	0.044	0.000	1.693
Employment Mix: 5-tier employment entropy (denominator set to observed employment types in the CBG) (D2b_E5Mix)	2010	0.522	0.225	0.000	0.990
	2018/2020	0.655	0.153	0.000	1.000
Intersection Density: Street intersection density (intersections per square mile of total land area) (D3b) in thousands	2010	0.079	0.061	0.000	0.781
	2018/2020	0.098	0.080	0.000	1.422
Transit Nearby: The nearest transit stop is less than ¾ mile (1207 m) away from the census tract centroid (1 = yes; 0 = no)	2010	0.455	0.498	0.000	1.000
	2018/2020	0.534	0.499	0.000	1.000
Roadway Variables[5]	**Years**	**Mean**	**SD**	**Min**	**Max**
Interstate: Census tract contains an interstate highway (1 = yes; 0 = no)	2016	0.216	0.411	0.000	1.000
Other Freeway/Expressway: Census tract contains a non-interstate freeway or expressway (1 = yes; 0 = no)	2016	0.223	0.416	0.000	1.000
Arterial with AADT >20K: There is at least one roadway in the census tract (other than interstates, freeways, or	2016	0.584	0.493	0.000	1.000

expressways) with more than 20,000 AADT. (1 = yes; 0 = no)					
State Dummy Variables	**Years**	**Mean**	**SD**	**Min**	**Max**
California: California census tract (1 = yes; 0 = no)	2010	0.359	0.480	0.000	1.000
Colorado: Colorado census tract (1 = yes; 0 = no)	2010	0.055	0.228	0.000	1.000
Massachusetts: Massachusetts census tract (1 = yes; 0 = no)	2010	0.064	0.245	0.000	1.000
New York: New York census tract (1 = yes; 0 = no)	2010	0.000	0.000	0.000	0.000
Oregon: Oregon census tract (1 = yes; 0 = no)	2010	0.213	0.410	0.000	1.000
Pennsylvania: Pennsylvania census tract (1 = yes; 0 = no)	2010	0.037	0.189	0.000	1.000
Washington: Washington census tract (1 = yes; 0 = no)	2010	0.144	0.351	0.000	1.000
Wisconsin: Wisconsin census tract (1 = yes; 0 = no)	2010	0.065	0.247	0.000	1.000

1) Exposure and socioeconomic variables data source (except for Total Jobs): US Census Bureau American Community Survey 5-year estimates (2008-2012 and 2017-2021 data).

2) Job variables data source: US Census Bureau Longitudinal Employment Household Dynamics LODES WAC v8.0 (2010 and 2019). LODES variable codes are shown in parentheses.

3) The LODES WAC employment data for Massachusetts are from 2011 and 2019.

4) Land use and transportation system variables data sources: US Environmental Protection Agency Smart Location Database (EPA SLD) v2 (2010) and v3 (2018 and 2020) for land use and road and intersection density variables. EPA SLD variable codes are shown in parentheses. We averaged the SLD variable values from census block groups to the census tract level.

5) Functional classification variables and arterial AADT variables data source: Federal Highway Administration Highway Performance Monitoring System (2016). We used the 2016 HPMS dataset because that edition had the most complete AADT data for our eight states, and it was in the middle of our earlier and later analysis periods. To represent traffic volume, we categorized each tract according to its highest-volume roadway AADT in 2016. While we only had reliable roadway classification and traffic data from 2016, we were still able to test if the associations between these roadway variables and FSI pedestrian crashes changed between the baseline and later study period.

Appendix B. Practitioner Interview Consent Form

This appendix includes the consent form that was used for our local practitioner interviews.

Informed Consent for Research Participation
IRB #: 25.155-UWM
IRB Approval Date: 01/24/2025

Study title	Understanding Local Changes in Pedestrian and Bicyclist Safety
Researcher[s]	Robert Schneider, PhD. Professor of Urban Planning. Principal Investigator. Henry Barbee, Nate Hemze, Carl Sveen, and Kyle Thorne. Research Assistants.

We're inviting you to participate in a research study. Participation is completely voluntary. If you agree to participate now, you can always change your mind later. There are no negative consequences, whatever you decide.

What is the purpose of this study?
Nationally, pedestrian and bicyclist traffic fatalities each increased by more than 50% between 2010 and 2020. We want to understand how transportation system policy, budget, project implementation, and other contextual changes (e.g., population growth/decline, development activity, pedestrian and bicyclist activity, automobile traffic patterns) may have impacted pedestrian and bicyclist safety in specific communities.

What will I do?
We will conduct interviews with professionals in several local, regional, and state jurisdictions to find out why pedestrian and bicyclist safety may have changed in their communities between approximately 2010 and 2020. We will ask you about policies, budget allocations, roadway projects, other actions, and contextual changes that have taken place in your community. We will also discuss changes in pedestrian and bicyclist fatality rates. The interview should take approximately 30 to 45 minutes.

Risks

Possible risks	How we're minimizing these risks
Some questions may be personal or upsetting. For example, there may be emotional discomfort talking about pedestrian and bicyclist injuries and deaths.	You can skip any questions you don't want to answer.
Some responses that you provide may be critical of your organization or other local, state, or national organizations that control resources that are	We will anonymize your responses when sharing the results. This means that we will not share your name with any quote that we use. Instead, we will list a general position (e.g., planner, engineer) and organization/community size (e.g., small city agency, state agency) with each quote. Further, we

important for your professional work.	will generalize specific agency or community information from your quotes (e.g., "we had a positive experience working with [state agency name] to increase pedestrian safety projects in [city name]").

There may be risks we don't know about yet. Throughout the interview, we will let you know if any topics may be sensitive or potentially put you at personal or professional risk. You can request that we not use certain interview responses if you are not comfortable with certain information that you share.

What if I am harmed because I was in this study?
If you're harmed from being in this study, let us know. If it's an emergency, get help from 911 or your doctor right away and tell us afterward. We can help you find resources if you need psychological help. You or your insurance will have to pay for all costs of any treatment you need.

Other Study Information

Possible benefits	• Our results will help transportation safety planners, engineers, advocates, and others in the field better understand how transportation system policy, budget, project implementation, and other contextual changes impact pedestrian and bicyclist safety. • When the study is published, you may see how the effectiveness of pedestrian and bicycle safety initiatives in your own community compare with other communities. These results should help professionals dedicate community resources to most effectively reduce pedestrian and bicyclist injuries.
Estimated number of participants	Approximately 30
How long will it take?	30-45 minutes
Costs	None
Compensation	None
Future research	De-identified (all identifying information removed) data may be shared with other researchers. You won't be told specific details about these future research studies.
Recordings	We will record our interview with you (both audio and video). The recording will be used to review key discussion themes and to make sure that we provide accurate quotes from the interview when reporting our results. If you do not want to be recorded, you should not participate in this study.
Funding source	This study is funded by the US Department of Transportation's University Transportation Centers Program through the Center

	for Pedestrian and Bicyclist Safety (CPBS) University Transportation Center (UTC) (Grant number 69A3552348336) and by the Wisconsin Department of Transportation through "Analysis of Geographic, Temporal, and Socioeconomic Shifts in Pedestrian & Bicyclist Traffic Injuries" (Project 0092-24-60).

Data Security

What identifying information will be collected and why?	We will collect your name, title, professional role, and contact information so that we can schedule the interview with you. We will not publish your name, organization, or other contact information when we publish the results of this study, but we will provide a general description of the types of professionals and organizations that participated. When using a quote from your interview, we will list a general position (e.g., planner, engineer) and organization/community size (e.g., small city agency, state agency) with the quote. We will not list your name with that quote. Further, we will generalize specific agency or community information from your quotes (e.g., "we had a positive experience working with [state agency name] to increase pedestrian safety projects in [city name]").
How long will my data be kept?	The audio and video recording will be destroyed after it has been transcribed. The text transcription will be destroyed after it has been de-identified and entered into a de-identified interview response database. The de-identified interview database will be kept indefinitely for future research.
How is data kept secure?	• We'll store all electronic data on a password-protected, encrypted computer. • As with any data collected online, there is always a risk of data being hacked or intercepted. We're using a secure system to collect this data (Zoom recording), but we can't completely eliminate this risk.

Who might see my data and why?

The researchers	To conduct the study and analyze the data.
The IRB (Institutional Review Board) at UWM The Office for Human Research Protections (OHRP) or other federal agencies	To ensure we're following laws and ethical guidelines.

Anyone (public)	We plan to share our findings in publications and presentations. You will not be identified by name. If we quote you, we will use a pseudonym. Our funding agency asks us to make a de-identified version of our dataset (i.e., interview responses) public so other researchers can use it.

Contact information:

For questions about the research, problems, or complaints	Robert Schneider, PhD Professor of Urban Planning	414-977-7740 / rjschnei@uwm.edu
For questions about your rights as a research participant, problems, or complaints	IRB (Institutional Review Board; provides ethics oversight)	414-662-3544 / irbinfo@uwm.edu

Remember, your participation is completely voluntary, and you're free to withdraw from the study at any time. Do you have any questions about the study? Do you agree to participate?

Appendix C. Practitioner Interview Protocol

This appendix describes the process that we followed and questions that we asked during our interviews with local practitioners.

Understanding Changes in Local Pedestrian and Bicyclist Safety
Professional Interview Questions
Center for Pedestrian and Bicyclist Safety University Transportation Center
University of Wisconsin-Milwaukee
Robert J. Schneider, PI
December 2024

Interview Guide and Questions

Welcome the potential participant to the Zoom call and start recording.

Review the Interview Consent Form with the potential participant. Remind them that their participation is completely voluntary, and they are free to withdraw from the study at any time.

0) Do you have any questions about the study? Do you agree to participate?

If the respondent does not answer yes to agree to participate, end the interview. If they agree to participate, continue below.

Over the last two decades, the US Department of Transportation and many state and local governments have established goals to increase overall levels of pedestrian and bicycle activity and to reduce pedestrian and bicyclist traffic fatalities. This interview is designed to gain insights from local and state practitioners about changes to pedestrian and bicyclist fatality outcomes in their communities, particularly during the decade of the 2010s. Thank you for participating and sharing your thoughts with us.

1) Please state your name, title and role that you serve in your organization, including how your role is related to pedestrian and bicycle transportation.

Before we discuss pedestrian and bicyclist fatalities, we want to ask briefly about changes in pedestrian and bicyclist activity levels in your community, which is important context for understanding trends in the numbers of pedestrian or bicyclists who were killed.

2) We have data on changes in pedestrian and bicyclist commuting to work from the American Community Survey. In your jurisdiction, pedestrian commuting increased/decreased by X% and bicycle commuting increased/decreased by Y% between the 2008-2012 and 2018-2022 periods. Do you think that overall pedestrian or bicyclist activity (including walking or bicycling for shopping, social activities, school, etc.) followed a similar trend? If not, why not? Why do you think that your jurisdiction's trends in pedestrian or bicyclist activity levels occurred? Are there any strong seasonal or special event patterns of pedestrian or bicyclist activity in your community *(e.g., school, college, festivals), including among tourists? How have overall population and job levels changed in your community between 2008-2012 and 2018-2022?*

3) Now let's move on to pedestrian and bicyclist safety. Our research team collected data on changes in pedestrian and bicyclist fatality rates (fatalities per population) in your jurisdiction between 2008-2012 and 2018-2022. Tell the participant that in their jurisdiction, pedestrian fatality rates increased/decreased by X% and bicyclist fatality rates increased/decreased by Y% between the 2008-2012 and 2018-2022 periods. Why do you think that these trends occurred?

4) Across the US, we noticed a trend of pedestrian fatalities increasing significantly during the 3-6am time period on weekdays. Do you think that this is happening in your community? If so, why?

The following questions provide information about the broader context for pedestrian and bicyclist safety changes in your community.

5) What community-level policies have been adopted in your jurisdiction since 2010 that are either directly or indirectly intended to improve pedestrian or bicyclist safety? When were these policies adopted? Do you think that they have been implemented successfully? If any barriers have slowed the implementation of these policies, please describe them.

6) What advocacy efforts have been initiated among local community members or community groups to either directly or indirectly improve pedestrian or bicyclist safety? Were there any actions taken that were not specifically intended to improve pedestrian or bicyclist safety, but that you think helped?

7) What socioeconomic changes have occurred in your community (or within specific parts of your community) since 2010 (e.g., job shifts, poverty shifts, educational attainment shifts, age shifts)? Do you think these relate to pedestrian or bicyclist safety outcomes? If so, how?

8) What land use and development changes have occurred in your community since 2010 (e.g., zoning changes, new development, redevelopment, vacancies, demolition, parking lot changes)? How has public transit service and ridership changed in your community since 2010? Do you think these land use or transit service changes relate to pedestrian or bicyclist safety outcomes?

The following questions are about actions that your organization has taken to try to improve pedestrian and bicyclist safety since 2010.

9) What changes have been implemented within your organization (e.g., staffing, budget, grants) to either directly or indirectly improve pedestrian or bicyclist safety?

10) Please provide some examples of engineering/roadway design changes, education programs, or enforcement programs that were intended to improve pedestrian or bicyclist safety in your community.

11) How has your organization communicated the pedestrian or bicyclist safety benefits of policy or project changes with the public? Have elected officials in your community helped communicate the importance of pedestrian or bicyclist safety? How has the public reacted to policy or project changes that have been implemented in your community?

12) What challenges has your organization faced when trying to a) create institutional changes within your own organization; b) make engineering, education, or enforcement changes in your community; or c) communicate the pedestrian or bicyclist safety benefits of certain actions to community members?