FOUNDATION FOR TRAFFIC SAFETY

Collaborative Sciences Center for ROAD SAFETY

VULNERABLE ROAD USERS

TECHNICAL REPORT

Pedestrian Fatalities on Urban Arterial Roads at Night: An In-Depth Crash Analysis and Three Case Studies

JAN 2025

607 14th Street, NW, Suite 701
Washington, DC 20005
202-638-5944
AAAFoundation.org

Title

Pedestrian Fatalities on Urban Arterial Roads at Night: An In-Depth Crash Analysis and Three Case Studies

(January 2025)

Authors

Lindsay S. Arnold[1], Stephen Heiny[2], Rebecca Steinbach[1], Katherine J. Harmon[2], Seth LaJeunesse[2], Sarah O'Brien[2], Chris Cherry[3], Saurav Parajuli[3], Alessandro Figueroa[2], Jennifer G. Farris[2], Xi Zhang[1], Yuni Tang[2], Jill Cooper[4], Aqshems Nichols[4], Shubha Bamney[1], Brian C. Tefft[1], & Laura Sandt[2]

[1] *AAA Foundation for Traffic Safety*

[2] *University of North Carolina Highway Safety Research Center*

[3] *University of Tennessee–Knoxville*

[4] *University of California–Berkeley*

Foreword

Vulnerable road users are one of the AAA Foundation for Traffic Safety's research focus areas and addressing the safety of all road users is crucial for safe mobility.

The sharp increase in the number of pedestrian fatalities in the United States since reaching a historic low in 2009 has necessitated new research to examine the reasons for the unprecedented increase. Our previous investigation using data through 2018 showed that practically the entire increase has occurred in darkness and mostly on urban arterial roads. This technical report documents a subsequent study to understand the factors driving the increasing trend and strategies to combat it by conducting an in-depth and multilayered investigation of a representative pedestrian fatality and a series of case studies. The results should be helpful to researchers, planners, and jurisdictions working to improve pedestrian safety.

This report is a cooperative agreement between the AAA Foundation for Traffic Safety and the Collaborative Sciences Center for Road Safety, a National University Transportation Center funded by the U.S. Department of Transportation and led by the University of North Carolina.

C. Y. David Yang, Ph.D.

President and Executive Director

AAA Foundation for Traffic Safety

Laura Sandt, Ph.D.

Co-Director, Research Strategy and Implementation

University of North Carolina Highway Safety Research Center

About the Sponsors

AAA Foundation for Traffic Safety
607 14th Street, NW, Suite 701
Washington, D.C. 20005
202-638-5944
www.aaafoundation.org

Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and educational organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

Collaborative Sciences Center for Road Safety
730 Martin Luther King Jr. Blvd., Suite 300
Chapel Hill, NC 27599
www.roadsafety.unc.edu

The Collaborative Sciences Center for Road Safety (CSCRS) was a National University Transportation Center supporting the FAST Act research priority of promoting safety. The team's work involved applying public health principles and systems science to equip current and future transportation professionals and stakeholders with more effective tools to solve complex safety challenges. This multidisciplinary work advanced Safe Systems concepts — such as accounting for human vulnerabilities and human behavior to proactively limit the chance of fatal injury—through research, education, workforce development, and technology transfer.

Table of Contents

Executive Summary

The number of pedestrians killed on U.S. roads and streets has increased by more than 80% since reaching its modern-era record low in 2009. While the contributions of factors such as vehicle size and driver behavior have been the subject of extensive research, two additional factors also stand out: time of day and location. Virtually the entire increase in pedestrian fatalities since 2009 has taken place in darkness, and the vast majority of it has been on urban arterial roads. The purpose of this study was to investigate factors contributing to pedestrian fatalities in darkness on urban arterial roads, to increase awareness of the issue among transportation professionals as well as the public, and to build support for effective countermeasures to reverse the increasing trend.

The research team performed an in-depth investigation of a representative pedestrian fatality in Chapel Hill, NC, using a formal process designed to identify not only the most proximal contributing factors (e.g., road user behavior) but also broader social, environmental, and policy factors that set the stage for such a crash to take place. The investigation included in-person examination of the crash scene and video of the crash, review of the police crash report and related media reports, and consideration of relevant local, state, and federal policies, programs, and plans. Then, the research team performed case studies in three specific cities with varying levels and trends in pedestrian fatalities—Charlotte, NC; Memphis, TN; and Albuquerque, NM—in attempt to elucidate factors associated with pedestrian fatalities in those cities as well as efforts to address them. Analysis of local crash data, policy scans, and interviews with city officials were used to examine the characteristics of locations and neighborhoods where pedestrian injuries and deaths occurred, as well as the policy landscape related to pedestrian safety in each city. The report discusses the findings of the crash investigation and case studies in the context of the current body of evidence regarding pedestrian safety and measures to improve it.

The results of this study highlight the many complex and interconnected factors influencing pedestrian fatalities on urban arterials at night.

The on-scene investigation in Chapel Hill provided many insights likely to be applicable beyond the one specific crash examined. For example, the victim was crossing the road at a 3-legged intersection that lacked a marked crosswalk. The on-scene investigation revealed substantial pedestrian crossing volume at the crash location, which was not unexpected given the surrounding land use. Additionally, pedestrians at this location are required to walk several hundred feet along a poorly lit road without a continuous sidewalk to reach the nearest marked crosswalk. The research also revealed policy-level factors influencing safety at the Chapel Hill crash location that are applicable to many locations. For example, arterial roads in many cities are owned and controlled by the state; local officials are often unable to make changes to or implement countermeasures on these roads. Even on city-controlled roads, pedestrian safety efforts tend to be focused in and around the city centers, whereas a substantial proportion of pedestrian injuries and fatalities occur well outside city centers.

The case studies identified several common factors associated with pedestrian injuries and fatalities in the three cities examined. Most notably, a large majority of pedestrian fatalities occurred on arterial roads and many occurred in darkness, which aligns with national trends. A far greater proportion of pedestrian fatalities than non-fatal injury crashes occurred on arterial roads in darkness. In all three cities, crashes occurred disproportionately in socially and economically disadvantaged neighborhoods. In recent years, the concentration of crashes in more disadvantaged neighborhoods has increased. Pedestrian crash and fatality rates also tended to be higher in neighborhoods with older housing and greater diversity of land use. In all three cities, more than half of all pedestrian fatalities were more than 4 miles from the city center and have, in recent years, moved further from the city center in two of them. The policy scan in Charlotte, Memphis, and Albuquerque identified some crucial challenges to improving pedestrian safety. These included the high cost of fixing the arterial networks, tensions between roads designed for vehicle throughput and pedestrian safety, the local challenges of implementing interventions on state-controlled roads, and public resistance to change.

Introduction

After decreasing for three decades and reaching a historic low in 2009, pedestrian fatalities in the United States have risen dramatically, increasing by 83% to 7,522 in 2022, the highest number since 1981 (NHTSA, n.d.). This increase is disproportionate to overall traffic fatalities, which increased by 25% over the same period. Pedestrian fatalities accounted for about 11% of all motor vehicle deaths from 2000 through 2009—also a historic low—but increased to 18% of all crash fatalities in 2022.

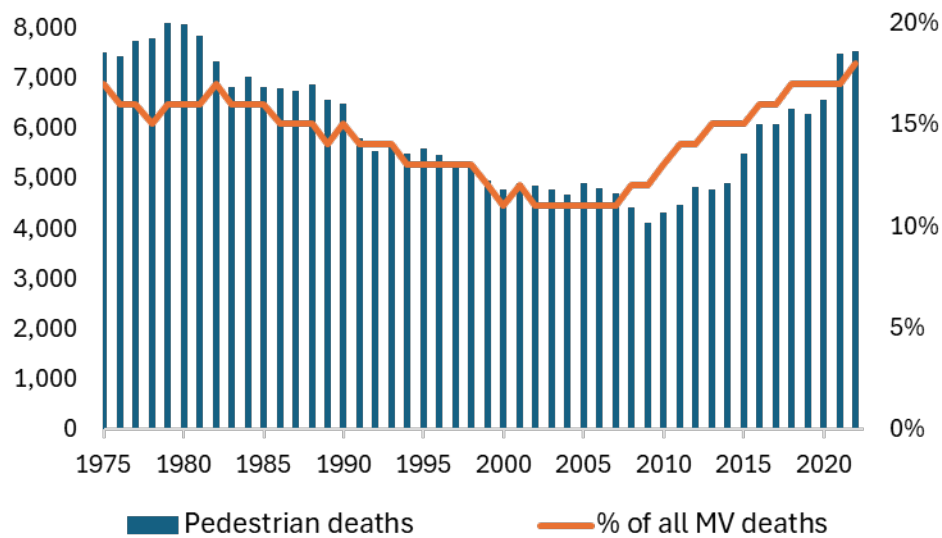


Figure 1. U.S. Pedestrian Fatalities, 1975–2022

This worsening crisis stands in contrast to other developed countries. In 1982, the pedestrian fatality rate per capita in the U.S. was comparable to or lower than that of most other middle- and high-income countries (OECD, 2024). By 2022, most of these other countries had reduced their rates by 70% to more than 90%, while the rate in the U.S. only declined by 30%, leaving the U.S. with a pedestrian fatality rate greater than nearly all of the comparison countries, 2 to 5 times the rates of many of the countries, and up to 10 times greater than the safest countries (Norway and Sweden) (OECD, 2024).

A variety of factors have been implicated in attempts to explain this trend. Examples include: increased distraction due to electronic device use among drivers and pedestrians (Bogel-Burroughs, 2019); the increasing size and popularity of sport utility vehicles and other light trucks, which are more likely than cars to injure or kill a pedestrian in the event of a crash (Tyndall, 2021); increases in driving and pedestrian exposure (National Academies of Sciences, Engineering, and Medicine, 2020); and increased alcohol-impairment among drivers and pedestrians (Chong et al., 2018). However, these factors leave much of the increase unexplained (Tefft et al., 2021).

Previous research examining data through 2018 indicated that a high percentage of pedestrian fatalities, and almost the entire increase since 2009, occurred on urban arterial roads and under dark or low-light conditions (Tefft et al., 2021). Examination of more recent data from the National Highway Traffic Safety Administration (NHTSA) indicate that these trends have persisted through at least 2022 (Figure 2).

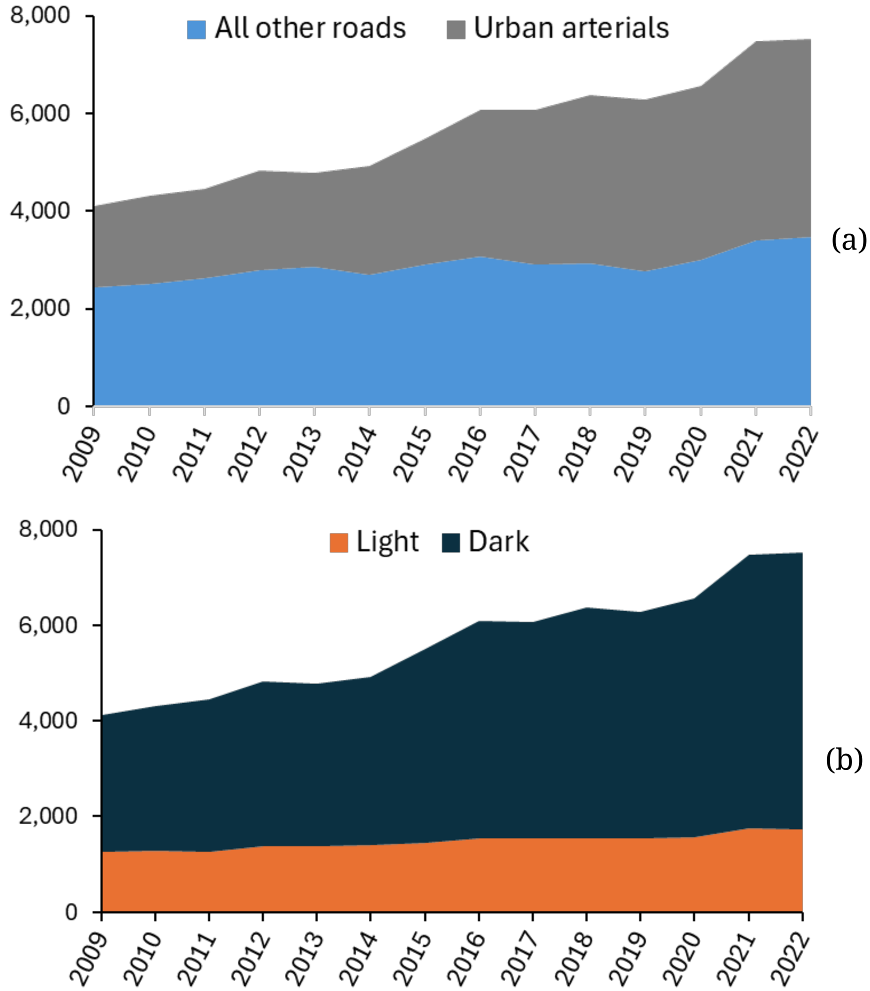


Figure 2. U.S. Pedestrian Fatalities (a) on Non-Freeway Urban Arterials and (b) in Light vs. Dark, 2009–2022. Data: Fatality Analysis Reporting System (NHTSA); analysis by AAA Foundation for Traffic Safety.

The large proportion and increasing trend in pedestrian fatalities on urban arterial roads and at night dictate that understanding and addressing factors contributing to the high and increasing risk under these conditions are key to reversing the escalating trend in pedestrian fatalities. While the high risk of pedestrian fatalities on arterial roads has been researched and well-documented (e.g., Parajuli et al., 2024;

Schneider et al., 2021), the factors contributing to the uniquely increasing trend of pedestrian deaths on urban arterials and in darkness, in particular, have not been adequately elucidated or quantified.

Given the lack of definitive research on the factors underlying the increasing risk of pedestrian fatalities on urban arterial roads in darkness, and the need for more efficient prioritization and provision of traffic safety interventions, the objectives of this collaborative project were to (a) conduct a systems analysis to identify risk factors to explore in depth, and (b) conduct a series of case studies in several cities to elucidate factors associated with varying levels and trends in pedestrian fatalities and local efforts to address them. The first objective was addressed by applying the AcciMap approach, which helped frame the focus and variables for the subsequent case study series by examining, in depth, a representative pedestrian crash fatality, which considered social and environmental factors in addition to proximal factors contributing to the crash. For the second objective, the case studies involved review of plans and policies, interviews with city officials, and analysis of crash data in the cities of Charlotte, NC; Memphis, TN; and Albuquerque, NM. Findings are discussed in the context of the existing body of evidence regarding pedestrian safety.

Systems Analysis Using AcciMapping

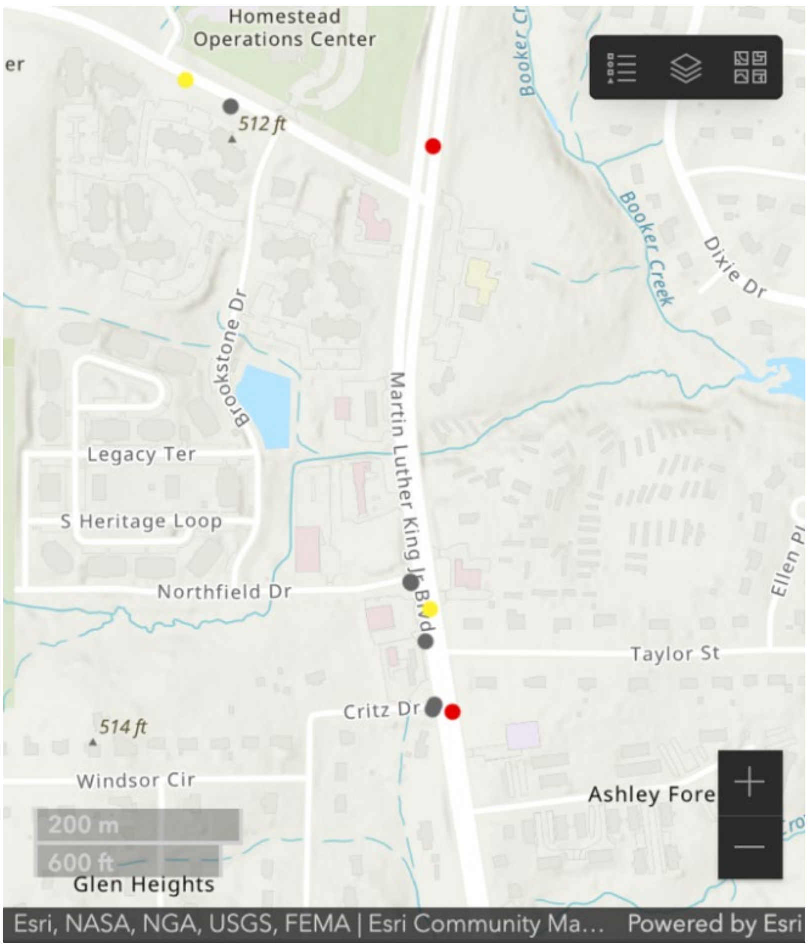
To better understand trends in pedestrian safety on urban arterials at night, the research team first applied systems-based approaches. These tools aid in understanding what impacts fatal pedestrian crashes from different levels of transportation, regulatory, and social systems, acknowledging that the issue stretches beyond the most proximate factors such as the behaviors of the road users involved in the crash. The goal of this first step was to generate topics to explore further in the case studies presented in the next section of this report. The project team collaborated on an AcciMap exercise, completed through a series of workshops. This section outlines the general details of the AcciMap approach and provides an overview of the crash examined by the research team, the work of the team in analyzing that crash through the AcciMap approach, and key findings.

Overview of the AcciMap Approach

The AcciMap approach is a systems-based tool used to analyze interconnected events, conditions, and decisions that result in an "accident," such as a motor vehicle collision. Causal factors are arranged in different levels representing various parts of the sociotechnical system from which the incident emerged. For example, these levels could range from high-level factors like social norms, culture, and policy to more immediate precursors to the event such as the roadway environment, surrounding land use, equipment, or actor activities. Each factor is linked to elements that it affects to demonstrate how the factors influence one another. The purpose of the AcciMap is to identify the factors that resulted in a specific incident and then develop interventions and risk management strategies to prevent future incidents of a similar nature (Branford et al., 2009).

An AcciMap is created according to the following steps: identify the outcome, collect data, create an AcciMap template, identify the causal factors and assign factors to the appropriate organizational levels, insert causal links, check the causal logic, finalize the AcciMap, and develop research hypotheses based on the completed AcciMap. These methods are adapted from Branford et. al.'s "Guidelines for AcciMap Analysis" (2009).

- **Step 1. Identify the Outcome**: The first step in the development of an AcciMap is identifying and defining the outcome of interest. As noted earlier, the recent rise in the incidence of pedestrian fatalities has been largely driven by fatalities occurring at non-intersection locations on urban arterials, primarily during nighttime hours (Tefft et al., 2021). Therefore, the research team selected an archetypal case to analyze using the AcciMap methodology. The team selected the case of a fatal pedestrian crash that occurred on December 29, 2022, at an unmarked, midblock crossing on Martin Luther King Jr., Blvd. (MLK Jr Blvd), an urban arterial bisecting a residential area in Chapel Hill, NC. This fatality, described in more detail in the following section, represented the most recent of a string of pedestrian injuries and fatalities occurring on this corridor since 2018 (Figure 3) (Town of Chapel Hill, n.d.). While this case has unique aspects, it also shares many of the characteristics of recent pedestrian fatalities. For example, the fatality occurred at a non-intersection location on an urban arterial during nighttime hours, involved a male pedestrian suspected of alcohol impairment, and involved a sport utility vehicle (SUV) (Tefft et al., 2021).



Map Key	
Color	**Crash Severity**
Red	Fatal
Yellow	Serious Injury
Grey	Minor injury, Possible injury, No injury, Unknown

Figure 3. Chapel Hill Vision Zero Dashboard, 2018–2022

- **Step 2. Collect Data:** An important component of all AcciMap analyses is the collection of data to describe the actors involved, circumstances of the event, and potential contributing factors to the incident. To assess these factors, the research team reviewed the crash report and death certificate for the pedestrian fatality as well as relevant media reports and obituary notices; Google Maps and Earth photos of the location; a video of the crash; and pertinent local, state, and federal policies, programs, and plans. In addition, members of the team interviewed the investigating law enforcement officer and performed an assessment of the crash site on the evening of February 22, 2023. These activities are described in more detail in the following sections.

- **Step 3. Create an AcciMap Template.** All AcciMaps contain three or more levels of organization to which causal factors are assigned. For the AcciMap analysis of the fatal pedestrian collision, the following levels were selected:
    - Outcome
    - Equipment, environment, and actor activities
    - Local operations, agencies, regulations, and laws
    - State agencies, regulations, and laws
    - Federal agencies, regulations, and laws
    - Societal norms and culture

  Figure 4 displays the blank AcciMap template, created in Miro (2023).

Figure 4. AcciMap Template

- **Step 4. Identify the Causal Factors and Assign Factors to the Appropriate Organizational Levels.** Once an AcciMap template has been developed, potential causal factors are identified, typically as part of a group brainstorming activity. Since any given event can have a significant number of causes, causes are limited to those that are potentially modifiable (e.g., poor roadway illumination) through future interventions. Causes that are not modifiable but are necessary for understanding the causal pathways and chain of events are likewise retained (e.g., nighttime). In addition, all causes and contributing factors must have reasonable supporting evidence based on data collected in Step 2. These bounds keep the AcciMap from becoming overly speculative and complex.

  Following a review of the data collected in Step 2, the research team hypothesized potential causal factors using Miro (2023) over the course of a 90-minute virtual meeting. The team began with the most proximal factors to the event (e.g., lighting, road design) and then moved to more distal contributing factors (e.g., federal speed limit setting guidelines). After identifying the preliminary causal factors, the team organized the causal factors into the appropriate organizational levels.

- **Step 5. Insert Causal Links.** Once causal factors have been identified, links can be made between the causes and their effects. For a link to be made, one of the following criteria must be met:

  1. If factor A had not occurred, then B (likely) would not have occurred
  2. B is a direct result of A, with no intermediate factors

  For instance, one causal factor in this crash is a lack of safe pedestrian crossing infrastructure near the BP Gas Station and convenience store on MLK Jr Blvd. This casual factor meets criteria 1: Without a lack of safe crossing infrastructure, the pedestrian probably would not have crossed at an unmarked crossing and the crash would not have occurred.

  While links can be made between causes and effects within organizational levels and to lower organizational levels, causal pathways cannot move away from the outcome. Following the identification of causal factors, team members assigned links between hypothesized causes.

- **Step 7. Check the Causal Logic.** Once the first draft of an AcciMap is complete, with all hypothesized causal factors listed and links inserted, the AcciMap is revised, ensuring that the following items are addressed:

  - Does the sequence of events leading to the outcome (fatal pedestrian collision) make sense? If not, additional causal or contributing factors may need to be added.
  - Is there an overlap between causal factors? If so, causal factors may need to be condensed into a more general causal factor or removed from the AcciMap.

    - Are the causal factors (reasonably) supported by the evidence? If not, causal factors may need to be removed.
    - Are all casual factors connected to the outcome through a causal chain? If not, additional causal links should be added, or the causal factors removed.
    - Do all causal pathways point downwards? If not, causal factors may need to be moved to different organizational levels.

  After the team added causal links in Step 6, the research team reviewed and edited the draft AcciMap, checking causal logic and making revisions, as needed.

- **Step 8. Finalize the AcciMap.** Once all major revisions are completed, the AcciMap is finalized, with edits made to enhance understanding and improve visual appeal.
- **Step 9. Develop Research Hypotheses.** Based on the AcciMap analysis of the fatal pedestrian crash, as well as related activities (e.g., Systems Map analysis), a series of research hypotheses will be generated covering the following three topic areas:
  1. Causes of and contributing factors to urban arterial crashes involving pedestrians
  2. Potential interventions and documented effectiveness
  3. Data and research gaps

Crash Narrative

The fatal pedestrian crash that served as the basis of AcciMap occurred on December 29, 2022, in Chapel Hill, NC. Figure 5 provides an outline of the events leading up to the collision and death based on the information gathered.

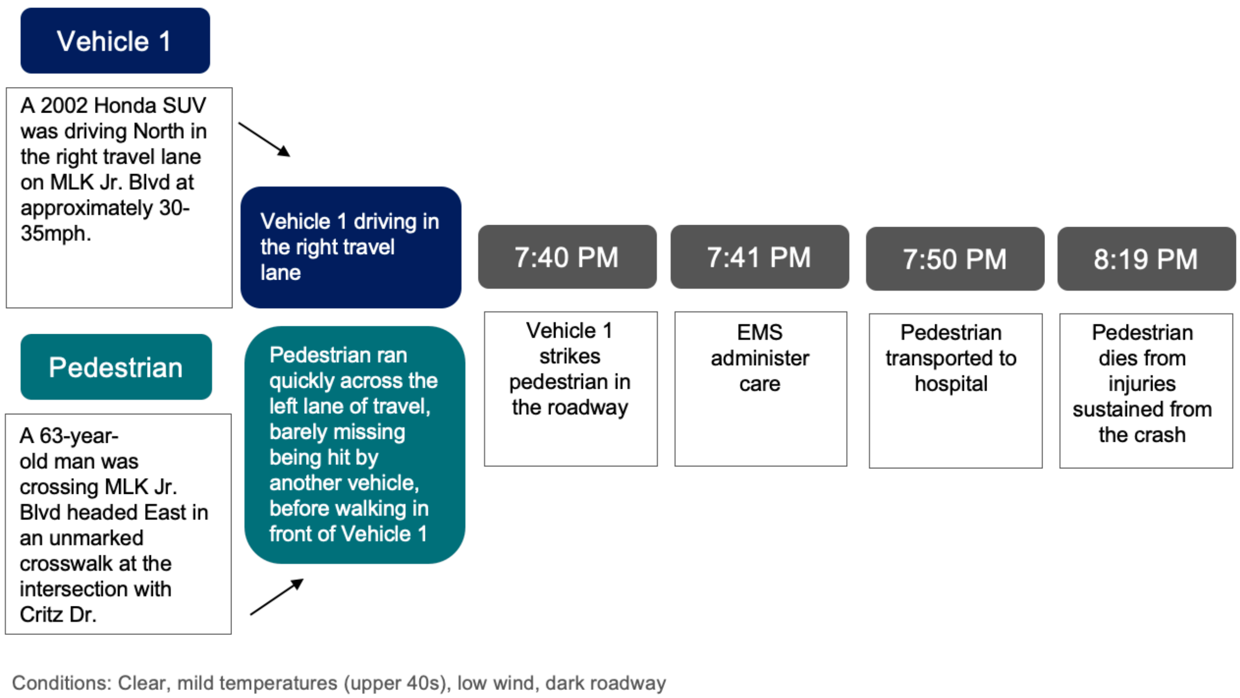


Figure 5. Pedestrian Fatality Crash Sequence, December 29, 2022

Crash Location and Environmental Conditions

The collision occurred at 7:40pm near 1201 MLK Jr. Blvd. The weather was clear, temperatures were mild (in the upper 40°Fs), and there was little wind. Ambient lighting was dark as the crash occurred approximately 57 minutes after last light for this location and date (source: sunrisesunset.io). According to the investigating law enforcement officer, weather did not factor into the crash. The area around the crash site is primarily residential, and there is a nearby BP gas station and food mart that is heavily utilized by the surrounding community. The BP gas station contains a security camera that recorded aspects of the collision; however, the quality of the video was not high and it did not capture all circumstances resulting in the collision. Figures 6 and 7 contain photos and Google Maps streetview images of the crash site for reference.

Figure 6. Crash Site Photos: (a) Driver View (North), (b) Victim Crossing Location (North), Source: maps.google.com; (c) Pedestrian Crossing Location at Critz Dr., Pedestrian View (East), (d) Pedestrian Crossing Location Across from Critz Dr. (West), Source: Site Visit

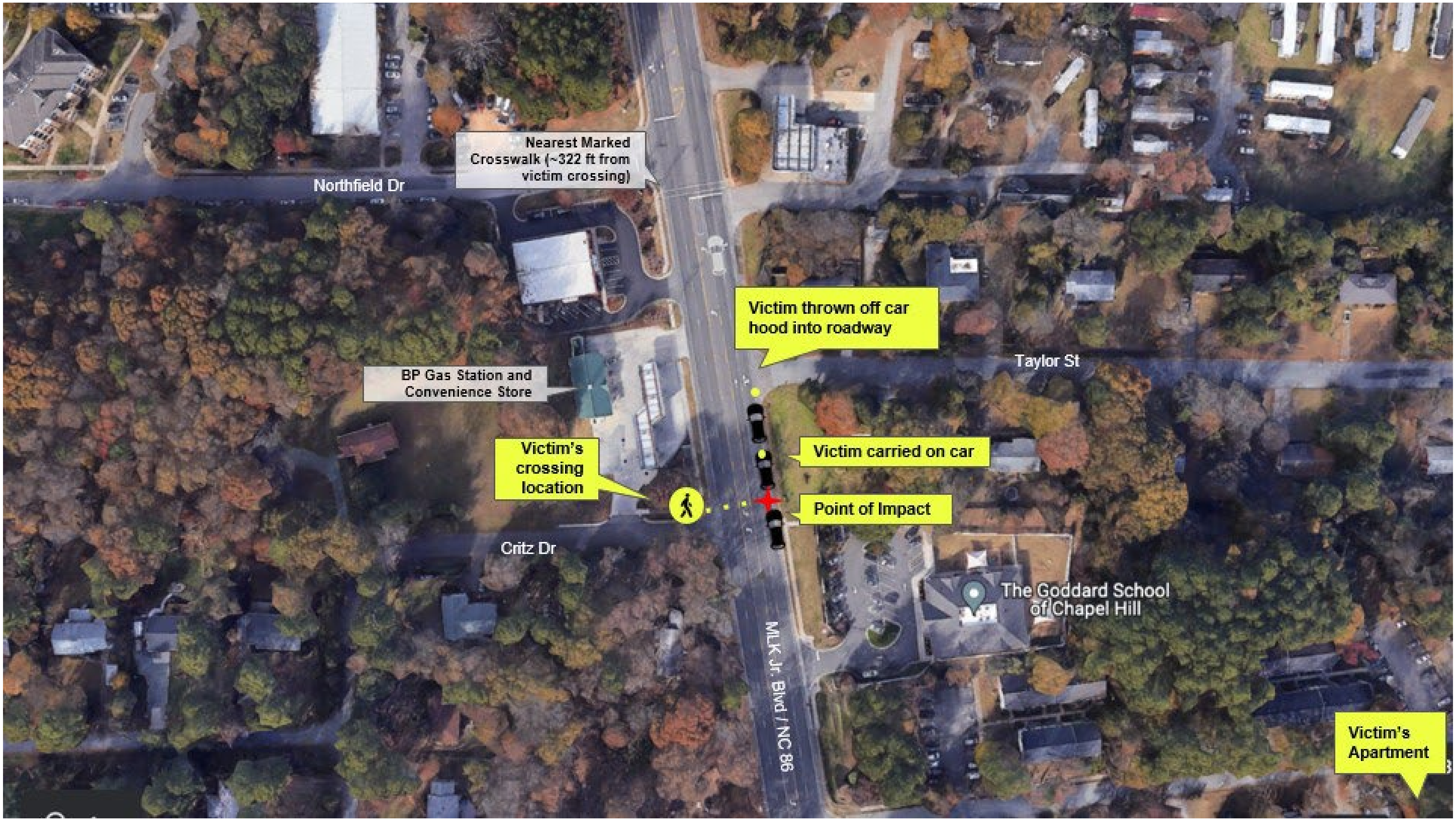


Figure 7. Aerial of Surrounding Neighborhood and Crash Sequence Overlay (Source: maps.google.com)

Road Conditions

The road where the crash occurred is a five-lane urban arterial road owned and operated by the North Carolina Department of Transportation (NCDOT). The road's posted speed limit is 35mph and has four travel lanes and a center two-way turning lane. At the crash location, the roadway is primarily straight and flat, although there is a slight rise for vehicles traveling northbound. On the east side of the road where the crash occurred, there is a mixture of non-continuous paved sidewalks and informal footpaths. The west side of the road has a mixture of non-continous paved sidewalk and an overgrown unpaved shoulder, as well as an unprotected bike lane. While there are some streetlights on this stretch of road, the place where the crash occurred is not well illuminated.

Crash Sequence

The driver of a 2002 Honda SUV was traveling north on MLK Jr Blvd at aproximately 30–35mph. The 63-year-old male pedestrian was crossing MLK Jr Blvd, headed east, at an unmarked crosswalk at an intersection located at Critz Drive. According to witnesses and confirmed by the video surveillance, the pedestrian ran quickly across the road. He crossed the southbound and center turn lanes and then the left lane of northbound travel, barely missing being hit by another vehicle traveling north before entering the right travel lane and being struck by the Honda SUV. The pedestrian was suspected of being under the influence of alcohol and/or drugs at the time of the collision, although toxicology results were pending at the time of AcciMap development. The striking driver stated that she did not see the pedestrian due to the presence of the vehicle in the left lane of travel. Therefore, she was unable to reduce speed or perform avoidance maneuvers before striking the pedestrian. The investigating law enforcement officer corroraborated her statement, as did review of the video footage. The pedestrian was struck by the front left corner of the vehicle before hitting the front windshield. The pedestrian was carried on top of the car hood for aproximately 120 ft until the vehicle came to a stop. Upon stopping, the pedestrian rolled off the hood and struck the roadway.

An Orange County Emergency Medical Services (EMS) ambulance and crew was at the gas station when the pedestrian was struck. One or more EMS personnel witnessed the crash and administered care immediately. The patient was alive but unresponsive after the crash, and was transported to UNC Medical Center, a Level I Trauma Center approximately 3.4 miles from the crash scene. The patient went into cardiac arrest at the hospital and efforts at resuscitation were unsuccessful. The patient succumbed to his injuries sustained during the crash at 8:19 pm, aproximately 40 minutes after the crash. The patient's primary cause of death was noted as "multiple blunt force trauma"; no comorbidities or contributing factors were noted on the patient's death certificate.

Additional Context

Other serious and fatal crashes have occurred at this area of MLK Jr Blvd. The Town of Chapel Hill's Vision Zero Dashboard shows that there have been at least seven other pedestrian or bicycle crashes within 400 ft of this crash location between 2018 and 2022 (Town of Chapel Hill, n.d.). Within the Town of Chapel Hill's Pedestrian Safety Action Plan, the Town identifies various safety improvements that they would like to see on MLK Jr (Road to Zero Task Force, 2019). Examples of these desired roadway improvements include conducting a road diet, improving pedestrian lighting, narrowing travel lanes, and installing multiuse paths along both sides of the corridor. However, NCDOT owns the road and is ultimately responsible for making any changes to the roadway. For additional information, see the Policy and Practices Scan.

Road Design Assessment

The investigation involved analyzing the road geometry, longitudinal section profile, cross-section, streetlights positions, and recreating the crash events based on the video footage recorded by a camera at the BP gas station to analyze the crash dynamics.

Geometric Design at the Point of Crash

From the observations using Google Earth, the road at the point of interest is very straight, with a slight vertical curve, and an average grade of 0.8% within 800 ft of where the pedestrian was struck. The road is 69.5 ft wide with a 7 ft wide unprotected bike lane on the left and a 3.5 ft shoulder on the right. Figure 8 shows the cross-section and dimensions of lanes at the point where the pedestrian got hit. Two streetlights are positioned on either side of the road but at unequal distances from the edge of the pavement. The pedestrian covered approximately 63 ft, entering the fifth lane before getting hit.

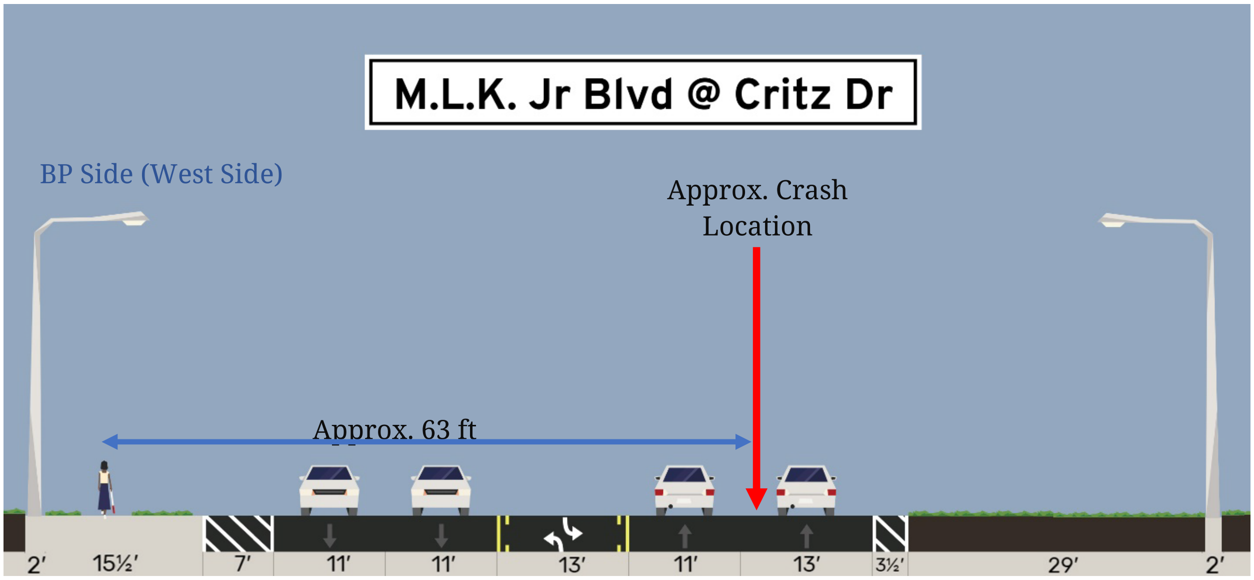


Figure 8. Cross-section of Roadway at Fatal Pedestrian Collision Location: Chapel Hill, NC

Crash Reconstruction

Information about the pedestrian and vehicle speeds was extracted from the video footage recorded by the BP gas station camera. The number of steps the running pedestrian took within a certain interval could be easily discerned from the video. The pedestrian running speed was estimated to be 8 ft/sec, assuming the average stride length to be 2.75 ft. Using a similar approach but counting the number of vehicle lengths covered by the vehicles from the video, it was determined that most vehicles visible in the video were traveling below the speed limit of 35 mph. That said, the striking vehicle was not visible in the video before it hit the pedestrian, and its pre-impact or impact speeds could not be determined from the video. The video footage communicates the vehicle flow just before and during the crash. With the vehicle and pedestrian speeds, the positions of the vehicles and the pedestrian at various time stamps of the video footage could be predicted.

The crash reconstruction reveals that the road users had to navigate the complex transportation system with the rolling gap acceptance and dynamically changing sight triangles. The pedestrian had to find a comfortable gap to complete the crossing in an environment with moving vehicles. Although he was able to find a comfortable gap for the first half of the road, the pedestrian barely avoided crashing with the first northbound (NB) vehicle before getting struck by another vehicle closely following the first NB vehicle on the other lane, suggesting a relatively poor gap acceptance decision by the pedestrian. Since the first NB vehicle, the striking NB vehicle, and the pedestrian were simultaneously moving; the formation of varying sight triangles between the striking vehicle and the pedestrian can also be seen as they move closer.

Figure 9 shows the formation of sight triangles at different instances of the video if both vehicles were moving at a constant speed. The line of sight of the sight triangles could be obstructed by the first NB vehicle moving with a uniform speed, by the vertical curve, due to the poor lighting conditions, or some combination of all of these. The analysis suggested that the striking vehicle, whose speed could not be determined from the video, could be speeding up to 45 mph if the first NB vehicle was the sole cause of visual obstruction. The visual obstruction could also be due to the vertical curve, although not as prominent. The elevation difference between the pedestrian and the vehicle was 2 ft when the striking vehicle, an SUV, was almost 300 ft far from the pedestrian. The pedestrian can be identified and well-illuminated from the camera's position, as seen in the video, but that could not be the same from the driver's perspective.

Figure 9. Formation of Sight Triangles at Fatal Pedestrian Collision Location: Chapel Hill, NC. Timestamps indicate time in seconds from the pedestrian entering the roadway. (Source: maps.google.com)

The crash between the pedestrian and the vehicle could be primarily associated with the line-of-sight obstruction between the pedestrian and the driver inside the striking vehicle, mostly due to the first NB vehicle but also other factors such as poor lighting during the nighttime and the presence of the vertical curve. Another potential factor could be speeding and distraction, as the road is straight with a substantially wide peripheral vision for the driver. The wide multiple-lane road with a center turning lane also becomes a complicated environment to cross as a pedestrian, and with a decent flow of vehicles, it is even difficult to find a safe gap to make the crossing.

Crash Site Visit

To complement the crash report and road design analysis, members of the team visited the crash site on February 22, 2023. On the same day, prior to the site visit, the team heard presentations from team members on the crash report analysis and remote road design analysis. These presentations helped frame the goals of the site visit and the target circumstances to observe including lighting, pedestrian activity, traffic levels, vehicle speeds, and sidewalk and crossing presence.

The team performed the site visit between 7:00 PM and 8:00 PM to observe conditions at roughly the same time of day as the December 29th crash and also in similar low-light conditions. Team members met at a location near the gas station near the crash site and walked along the sidewalk on the west side of MLK Jr Blvd. From this side of the roadway, team members observed the crossing path taken in the crash noting lighting features, visibility, traffic presence and speed, road width, options and opportunities for pedestrian crossings, and sidewalk conditions. The team also crossed the roadway at the traffic light at Northfield Drive to observe conditions on the east side of the road and gauge the conditions and time needed to make a trip using the marked, signalized crosswalk rather than the unmarked crossing.

The site visit confirmed most of the concerns raised by both the crash report and road design analyses related to the conditions of the environment. The main observations from the site visit are listed below:

- The crash site has high pedestrian demand. Throughout the roughly 45-minute site visit, the team witnessed a high number of crossings at or near the crash location using the same origin and destination as the crash victim. Pedestrians used the two-way left turn lane as a stopping point in the middle of crossing to negotiate two directions of traffic in turn. Though an area with high pedestrian demand, there is no marked crosswalk or other roadway elements to facilitate a safe crossing or alert drivers to the presence of pedestrians.
- Roadway design, driveways, and intersecting roads combine to create a complex environment for crossing. Pedestrians must cross four lanes of traffic along with a center two-way left turn lane, which is already a wide crossing. In addition, driveways for the gas station and Critz Drive have vehicles turning right and left on MLK Jr Blvd. These left-turning vehicles may be turning left directly into the travel lanes or be using the center lane to then merge into the travel lanes. Coming from north and south, vehicles enter the center lane early for left turns into driveways or intersecting roads. Altogether, these elements create a complex environment for pedestrians to negotiate when attempting to cross.
- Pedestrians leaving the gas station could walk north to Northfield Drive, which has a signalized, marked crossing and then continue south on the east side of the roadway to return to Ashley Forest Road. Pedestrian facilities along this route, however, are incomplete. There is a sidewalk up to Northfield Drive on the west side of MLK Jr Blvd. On the east side, there is no sidewalk from the signalized crossing south to a spot directly across from Critz Drive. Pedestrian demand is clear as there is a bus stop on the east side of the roadway and the grass side of the road is worn from foot traffic. Not only does this path add significant distance to the trip, but it also does not provide adequate infrastructure.

- Traffic speed is a concern at this location. During the site visit time, speeds of 40 to 45 mph traveling southbound and 35 to 40 mph traveling northbound were observed using a radar gun. While speeding was not noted as a crash factor for this specific crash, speeds like these across four lanes of traffic can make gap judgement and negotiating a crossing difficult. In speaking with one group who lived in the same apartment complex as the crash victim, they noted that they were aware of how dangerous the roadway and crossing is and were aware of the fatal crash in December. They remarked about the speed of vehicles at this location and the difficulty of judging speed, saying, "They're going faster than they look."
- Traffic volume is not mentioned in the details of the December 29th crash, and, because it occurred near the holiday, may not have been a factor. However, in the site visit the high volume of traffic continually flowing through this area was noted. Along with the speeds noted above, this creates a situation with few gaps in traffic to make the crossing. Combined with the long crossing distance, judging the appropriate gap in traffic to cross safely becomes even more difficult.
- The potential impact of roadway lighting was also noted. One traffic light was out during the site visit; however, based on the video reviewed, it was ascertained that this light was most likely on at the time of the crash. There is lighting on either side of the roadway. However, light from oncoming vehicles and the gas station may impact drivers' visibility at night, and there may also be shadows caused by foliage that impact visibility.

Policy and Practices Scan

To add the more upstream level of factors related to the crash, policies that potentially created the environment in which the crash occurred were examined. The policies range from local-level decision making to wider, statewide policies governing roadway funding and design.

State-level policies

In the policy scan, multiple policies at the state level that may have impacted the crash circumstances were identified. The first policy is the method through which projects are funded by the state of North Carolina. The state's mobility formula (https://www.ncdot.gov/initiatives-policies/Transportation/stip/Pages/strategic-mobility-formula.aspx) establishes three funding categories: statewide mobility, regional impact, and division needs. Of these, local projects that would improve the pedestrian environment at the crash site would fall under division needs. This category allows some local input in addition to the other criteria evaluated to determine funding priorities. However, projects not funded at the statewide or regional level also cascade down into these categories. As a result, larger statewide or regional projects compete against smaller projects that may have local support but score lower according to the prioritization criteria.

Other state policies concern the infrastructure in place at this location. The state requires municipalities to establish agreements in order to maintain sidewalks along state-owned roads. This would require Chapel Hill to take responsibility for maintenance of any sidewalk along MLK Jr Blvd and may contribute to the lack of a complete sidewalk network. The lack of sidewalks, lack of crosswalk, and missing curb ramps were noted in the site visit with concerns for meeting ADA requirements. According to state policy, in order to have ADA elements installed, there must first be appropriate pedestrian facilities. The sidewalk on the east side of the roadway stops just before the sidewalk on the west side begins. That gap may have been enough to not qualify for improvements because the facilities do not align across the roadway.

A state policy that may relate specifically to this crash concerns sales of alcohol at convenience marts or gas stations. In North Carolina, convenience stores may sell beer and wine between 7 AM and 2 AM. Though the connection cannot be confirmed in this instance, alcohol availability at this location may have either inspired the trip taken by the pedestrian or led to the potential for impairment.

Regional policies

Policies at the regional level relate to how projects are prioritized and funded by the state. The Durham-Carrboro-Chapel Hill Metropolitan Planning Organization connects local needs in Chapel Hill to the state-level prioritization plan. Safety is a component of the scoring process, with the score based on the number of crashes by vehicle mile traveled. This measure also considers crash history rather than injury risk. While a site with some risk, the crash site, or the roadway in general, may not warrant a high enough safety score to be a priority for funding infrastructure changes.

County policies

The county has little control over transportation planning decisions. However, the county policy of designating a rural buffer may have some effect on this crash. The rural buffer is an area of land around Chapel Hill and Carrboro that must maintain a specified lower density. Development patterns may then result is more development outside the rural buffer with more traffic coming into and out of Chapel Hill on primary arterials like MLK Jr Blvd. While the specific destination of the driver involved in the crash was not known, development patterns have an impact on traffic flow and thus roadway design that may promote higher speeds to accommodate higher volumes of traffic.

Local policies

Local policies related to sidewalk requirements may have some relation to the lack of continuous sidewalk on either side of the road. Chapel Hill's land-use ordinance requires a sidewalk to be constructed in front of any new commercial development. The areas along the route between the residential area and the gas station may lack sidewalks because of the type of development or the absence of development there, explaining the sidewalks gaps for some areas along MLK Jr Blvd.

Another local policy with some potential impact on the crash site is the Traffic Impact Analysis Guidelines policy, which guides town staff through evaluation of a new development's effect on the transportation network. The guidelines rely on the ITE Trip Generation Manual (ITE, 2021), which aims to keep level of service to a minimum of D (out of A – F). This promotes more traffic flow on arterial roadways like MLK Jr Blvd.

Summary of AcciMap Analysis

As mentioned previously, the AcciMap for the fatal pedestrian crash on December 29, 2022, was informed by a review of the crash report, narrative, and diagram; review of the death certificate; an interview with the investigating law enforcement officer; review of the video footage and virtual assessment of roadway design; a scan of relevant local, state, and federal policies and practices; and a road safety assessment performed at the site of the crash. The AcciMap approach identified a variety of factors that contributed to the pedestrian fatality on MLK Jr Blvd, as shown in Figure 10. These included:

- **Societal norms, culture:** Societal norms and cultural factors that contributed to the crash are a (societal) acceptance of traffic injuries and fatalities, pedestrian risk-taking behaviors, and substance abuse. The auto-centric culture of the United States, as well as the prevalence of economic inequalities were also noted.
- **Federal agencies, regulations, laws, and systems:** Examples of factors identified at this level of analysis were insufficient funding for pedestrian projects, inadequate vehicle regulations oriented towards pedestrian safety, and the prioritization of motor vehicle throughput over safety.
- **State agencies, regulations, laws, and systems:** At this level of analysis, the lack of policies, funds, and action to support pedestrian infrastructure were determined to be key crash contributors. In addition, state prioritization of motor vehicle throughput over safety, state control over the local roadway, and state alcohol sales policies were other contributing factors.
- **Local operations, agencies, regulations, laws, and systems:** At the local level, the AcciMap analysis identified limited control over the roadway, poor sidewalk

maintenance, and the prioritization of auto infrastructure over pedestrian infrastructure as key contributing factors.

- **Equipment, environment, and actor activities:** Many factors were identified within this AcciMap category. Poor visibility and lack of pedestrian infrastructure were central elements of this crash. In addition, certain actor activities and behaviors (potential pedestrian impairment, decision to cross an unmarked, poorly lit crossing) contributed to the event. Other factors (pedestrian age, vehicle size) may have contributed to the severity of the injuries sustained and ultimately, death.
- **Outcome:** As noted previously, the outcome of the event was a fatal pedestrian collision.

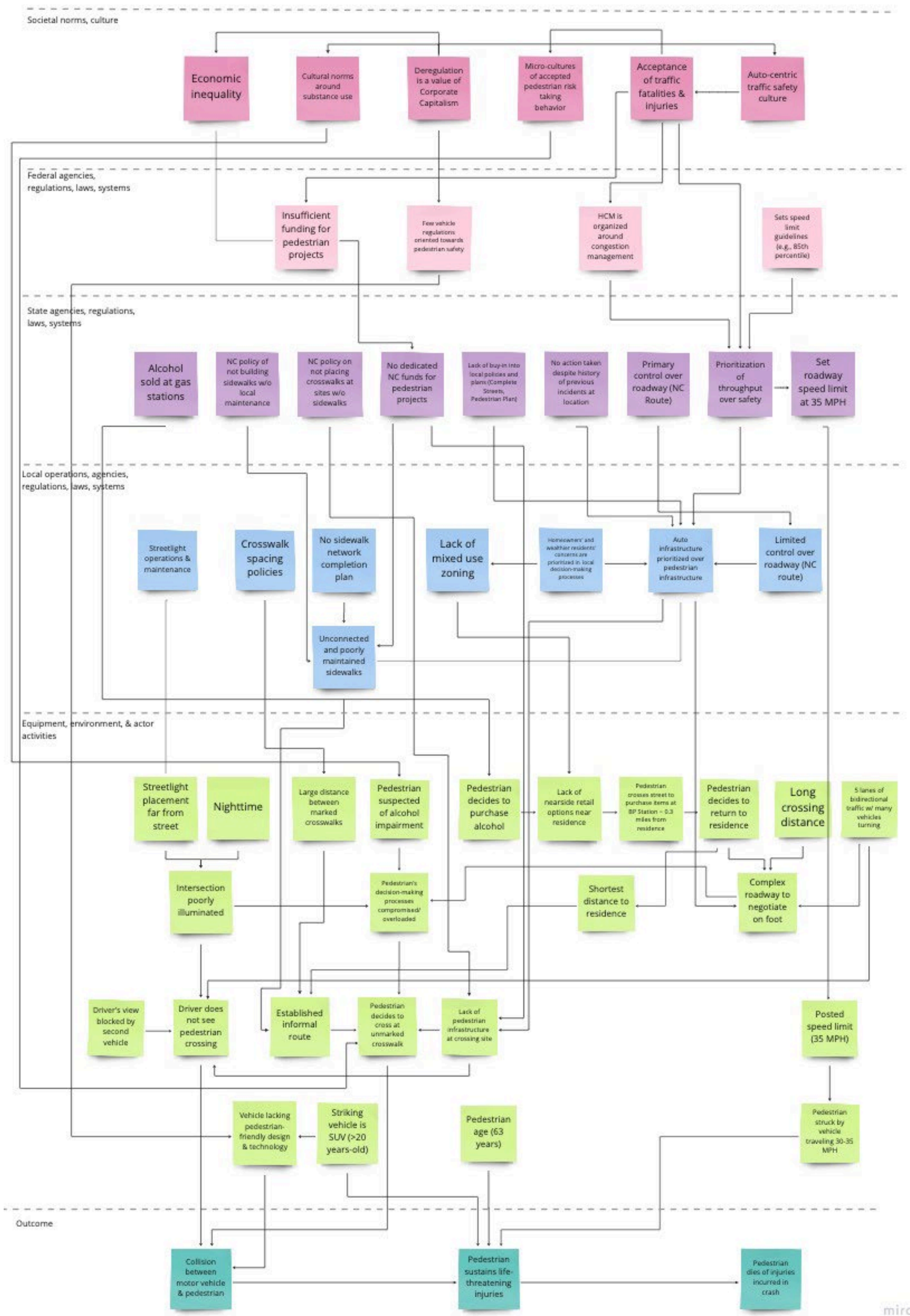


Figure 10. AcciMap of a Fatal Pedestrian Collision: Chapel Hill, NC, December 29, 2022. Detail viewable at Miro.com

Case Studies

Objectives

To better understand the circumstances driving the increase in pedestrian fatalities on urban arterials at night since approximately 2009, safety outcomes and efforts at the city level were explored for locations in states with differing trends in pedestrian fatalities over the period, as well as different policy environments. To the extent possible, changes over time in factors that directly or indirectly affect the likelihood of a pedestrian crash and/or fatality were also considered. To do so, case studies on three cities were conducted, each of which included a scan of relevant city or state documentation, interviews with city officials, and data analysis for the following purposes:

- Describe longitudinal trends in pedestrian crashes that occur on arterial roads at night (i.e., in darkness)
- Describe association of neighborhood characteristics with pedestrian crashes
- Examine clustering of pedestrian crashes
- Explore differences in neighborhood characteristics of pedestrian crashes that occur inside and outside clusters
- Examine the policy landscape related to pedestrian safety

Method

Selection of Case Study Cities

The selection of cities was based on a combination of the following:

- Sufficiently large numbers of pedestrian fatalities to differentiate reliably between random variability and meaningful trends
- Population-based pedestrian fatality rates on urban arterials during darkness over time
- State- and local-level policies determining roadway ownership and design (state vs local control) and speed limit setting
- Comparable populations in terms of income, age, and race/ethnicity distributions

An initial list of candidate cities was identified, and the final cities selected based on review of the selection criteria and consultation with those with knowledge of the locations to gauge their appropriateness for selection. The cities of Albuquerque, NM; Memphis, TN; and Charlotte, NC, were selected. Characteristics, statistics, and features for each of the cities are provided in sections below.

Data

Injury Data. Data were obtained for Charlotte (pedestrian: 2007–2022, all killed and seriously injured crashes: 2013–2022) from the NCDOT's publicly available Bicyclist and Pedestrian Crash Map and Fatal and Serious Injury Crash Map (available at https://ncdot.maps.arcgis.com/). Memphis data (2014–2023) was supplied by the Tennessee Department of Transportation (TDOT), and Albuquerque data (2013–2022) by the New Mexico Department of Transportation. To examine trends in pedestrian crashes on arterials at night, each crash was classified by whether it occurred on an arterial, and whether it occurred during darkness.

Arterial classification. Using the geographic coordinates supplied in the crash data, collisions were linked to the Federal Highway Administration's Highway Performance Monitoring System road network in QGIS. Collisions were coded as having occurred on an arterial road if their geographic coordinates were within 150 feet of a non-limited-access principal arterial or minor arterial road as defined by its functional class. All results reported here except total numbers of pedestrian-involved crashes, injuries, and deaths in each city exclude crashes that occurred on Interstates or freeways, unless the collision occurred within 150 feet of an arterial road, because crashes that occur on limited-access highways were considered outside the scope of the study.

Darkness classification. Darkness status was calculated using the time of crash reported on crash datasets and data retrieved from the SunriseSunset.io Application Programming Interface (source: sunrisesunset.io/api/) on timings of the first light and last light for each day in each case study city. Crashes that occurred before first light or after last light were classified as occurring in darkness (regardless of artificial lighting). Note that this is a stricter definition of darkness and excludes times between dusk and last light (and between first light and dawn) when there is very little visible light and a police officer may code the conditions as "dark."

Neighborhood Characteristics Data. A variety of demographic and socioeconomic variables were examined to characterize the places in which pedestrian injuries and fatalities occurred. Analysis was performed at the level of the census tract.

Assigning crashes to census tracts is challenging, as crashes occurring on arterial roads are the focus of the current study, and arterial roads often delineate boundaries of census tracts. To accommodate small errors in coordinates of crash locations and to allow for the possibility that crashes in one census tract may be influenced by the characteristics of neighboring census tracts, a 0.25-mile buffer was drawn around the location of each crash. These buffers were then spatially joined to census tracts in the QGIS software. Each crash was then apportioned to the census tracts that overlapped with the buffer according to the fraction of the area of the buffer that overlapped each respective tract.

Most neighborhood characteristics data used in the current study (described below) are derived from surveys by the U.S. Census Bureau that are only available publicly at the census-tract level in data files that aggregate data over 5-year periods. Thus, for the purpose of associating crashes with neighborhood characteristics data, crashes in each city were aggregated into two 5-year periods. In Albuquerque and Charlotte, where crash data were from years 2013–2022, the two 5-year periods examined were 2013–2017 and 2018–2022. In Memphis, where crash data were from 2014–2023, data were grouped as 2014–2018 and 2019–2023.

Because the U.S. Census Bureau adjusts the boundaries of census tracts after each decennial census, data for the later period in each city were available for census tracts drawn after the 2020 Census, whereas data for the earlier period were available only for an earlier vintage of census tracts based on the 2010 Census. In crash-level analyses, the corresponding neighborhood characteristics data were used directly as provided by the Census Bureau. However, neighborhood-level analyses required constant geography in order to be interpretable. Thus, neighborhood-level analyses were performed using 2020 Census tract definitions in both periods. Characteristics of 2020 Census tracts in the earlier period were approximated using area-weighted combinations of data for the 2010 Census tracts that comprised them.

American Community Survey. Demographic, socioeconomic, and housing data were sourced from the American Community Survey (ACS) (https://www.census.gov/data/developers/data-sets/acs-5year.html). Two sets of five-year estimates, spanning 2013–2017 and 2018–2022, were gathered for census tracts in Albuquerque and Charlotte; estimates from 2014–2018 and 2018–2022 were used in Memphis as Memphis crash data available for the study were from years 2014–2023 and ACS data for 2023 had not yet been released at the time when this analysis was being conducted. Variables obtained or derived from the ACS and used in the case studies included the following:

- Resident population
- Residential population density (residents per square mile of land)
- Commuter-adjusted daytime population (total residents + number of workers who live elsewhere but work in the census tract – number of workers who live in the census tract but work elsewhere)
- Average population (average of resident population and commuter-adjusted daytime population)
- Percent of households owning zero vehicles
- Percent of households residing in multifamily buildings with ≥50 units
- Median age of occupied housing units

Employment. The Longitudinal Employer-Household Dynamics (LEHD) Origin-Destination Employment Statistics (LODES) dataset (source: https://lehd.ces.census.gov/data/) provides detailed local-level data on U.S. employment in relation to the characteristics of the workers. The LODES Workplace Area Characteristics (WAC) data file was used to characterize people whose workplaces were located in the census tracts where crashes occurred. Data were originally reported at the census-block geographic level and aggregated into census tracts by the research team. LODES data from 2022 were not yet available at the time of the study, thus adapting the approach described by Mansfield et al. (2018), 2022 data were estimated by duplicating observations from 2021. The LODES data were then aggregated into the two periods for each census tract: 2013–2017 and 2018–2022.

Employment data at the census-tract level were compiled by aggregating the data into five categories using the North American Industry Classification System (NAICS) sector codes: office (NAICS sectors 51–55 and 92), retail (sectors 44–45), industrial, transportation, and warehousing (sectors 11, 21–23, 31–33, 42, and 48–49), general services (sectors 56, 61–62, and 81), and entertainment, accommodation, and food services (sectors 71–72) (Mansfield et al., 2018). Census tract-level variables obtained or derived from LODES data included the following:

- Each NAICS sector's percentage of total jobs (jobs in sector divided by total jobs)
- Number of jobs per capita (number of jobs divided by number of residents)
- Percentage of workers by educational attainment
- Activity Diversity Index (a measure of the relative diversity of residential and various commercial land uses in each of the five above-mentioned sectors within a census tract, see Mansfield et al. [2018]).

Social Vulnerability Index. The Social Vulnerability Index (SVI, https://www.atsdr.cdc.gov/place-health/php/svi/) is a multidimensional measure of various aspects of the vulnerability or disadvantage experienced by residents of a community. It was originally designed to assess the resilience of communities when confronted with external stresses on human health, such as natural or human-caused disasters or disease outbreaks. It comprises four indices measuring different aspects of vulnerability: Socioeconomic Status, Household Composition & Disability, Minority Status & Language, and Housing Type & Transportation, which are derived by the CDC using data from the American Community Survey. It also includes an overall vulnerability score combining all four indices. The current study used the four above-mentioned indices and the overall vulnerability score for census tracts in the three case study cities. SVI data from years 2016 (data from 2012–2016) and 2022 (data from 2018–2022) were obtained at census-tract level from CDC/ATSDR. (As with the ACS data, SVI data from years 2014–2018 and 2018–2022 were used for Memphis.)

Distance from City Center. In many cities, pedestrian activity is heavily concentrated in and around the "city center" or "central business district" (CBD). However, there is no standard definition of the location of the city center or CBD. Holian (2019) noted that the location of a city's city hall is a better proxy for the city center than other measures in common use. The distance of each crash from the city center was approximated by computing the point-to-point distance between the coordinates of each crash and the coordinates of the city hall.

Statistical Analysis

Descriptive Statistics and Trends. The proportion of pedestrian injuries and fatalities that occurred on arterial roads in darkness was examined over time. Trends in crashes involving pedestrians were compared to trends in crashes that did not involve pedestrians to gain insight into whether trends in crashes involving pedestrians were similar to or different from general trends in traffic safety overall.

Neighborhood Characteristics. Demographic and socioeconomic characteristics of the locations where crashes occurred were examined by matching each crash to its corresponding census tract and then appending census tract–level data from the ACS, LODES, and SVI data described previously.

The associations of neighborhood characteristics with rates of pedestrian-involved crashes were examined using negative binomial regression models. The outcome variable was the number of pedestrian-involved crashes in each census tract in each period. The average of the resident population and the commuter-adjusted daytime population was used as an exposure variable, as in Mansfield et al. (2018), with its coefficient constrained to 1 so that the coefficients of other variables, when exponentiated, estimated the ratio change in population-based crash rates or fatality rates associated with a 1-unit change in the explanatory variable. All explanatory variables except jobs per capita and residential density were expressed as percentiles or percentages, thus the exponentiated coefficients of these variables represented the ratio change in crash or fatality rate associated with a 1 percentile point or 1 percentage point increase in the variable. Separate models were estimated for all injury crashes (including fatal crashes) and for fatal crashes only, both for crashes at all hours and for crashes occurring on arterials in darkness only.

To examine changes over time in the characteristics of the places where pedestrian crashes occurred, descriptive statistics of the census tracts where crashes occurred in 2013–2017 and 2018–2022 were tabulated and plotted, along with the citywide population-weighted median values of the same variables for comparison.

Cluster Analysis. Cluster analysis was performed to examine the extent to which pedestrian fatalities occurred at locations with high concentrations of crashes involving pedestrians overall. Clustering is an approach that helps uncover the spatial and temporal patterns in the data. Mapping crashes inside and outside clusters furthers understanding of the spatial correlation between crashes and identifies areas with high concentrations of crashes.

A density-based algorithm, ST-DBSCAN (Birant & Kut, 2007), was used for clustering in QGIS to identify clusters of pedestrian crashes according to spatial and temporal dimensions. The spatial–temporal clustering process requires three different input factors: maximum distance between points in a cluster, maximum time duration between points in a cluster, and minimum cluster size. For this analysis, the following ranges of factors were explored: maximum distances between 250m (820.2 feet) and 1000m (3280.8 feet), maximum time durations between 1 year and 3 years, and minimum cluster sizes between 5 and 20 crashes. The distribution of crashes inside and outside clusters for every possible combination of input factors was then examined. The findings presented are based on a maximum distance of 500 meters (about 1640.42 ft) between crashes, maximum time duration of 2 years and a minimum cluster size of 10 crashes. Both fatal and non-fatal injury pedestrian crashes were included in the clustering algorithm.

Differences in neighborhood characteristics of pedestrian crashes that occur inside and outside clusters were assessed using Poisson regression models. Correlations of variables related to neighborhood characteristics were examined to avoid inclusion of collinear variables in the model. The final model included SVI, activity diversity index (ADI), median housing age, unemployment rate, percentage of households in multifamily buildings, and percentage of households without a vehicle. Separate models were developed to examine (a) all injuries and fatalities regardless of time of day, (b) injuries and fatalities in darkness, (c) all fatalities regardless of time of day, and (d) fatalities in darkness only.

Literature Scan

This component focused on finding available resources to understand each city's approach to safety to provide context to safety outcomes since 2010. These sources consisted of general web searches; searches of city, regional, and state websites; and searches of national sites such as Smart Growth America and the Parking Reform Network, focusing on three main areas:

- Policies (both state and local, e.g., Complete Streets policies, policies concerning state and local control, and speed limit setting)
- Known safety procedures that apply to arterials (especially at night) in the city (e.g., warrants for providing infrastructure, right-on-red policies, traffic impact analysis procedures for deciding on crossing infrastructure)
- Plans related to safety for pedestrians (e.g., Vision Zero plans, safety action plans, and comprehensive plans, and any other background materials)

Interviews with City Officials

Interviews were utilized to provide additional information not found in the literature or data to complete the picture of what is happening in each study location. This task involved the following four steps:

1. Identifying interviewees (1–3) who work on roadway safety in each location. Attempts were made to find interviewees with different roles and different departments depending on the city's organization.
2. Developing an interview protocol for semi-structured interviews. The goal for the interview protocol was to learn about safety priorities, any performance indicators used by the city and/or required by the state, barriers to creating safer environments on the roadways in question, and any other practices not found in the literature.
3. Holding phone/zoom interviews with each interviewee, between 30 minutes and an hour in length.
4. Coding, summarizing, and analyzing the notes from the interviews.

Charlotte, NC

Descriptive Statistics and Trends

Charlotte, NC, had an estimated population of 911,311 as of the 2023 ACS, representing an increase of 4% since the 2020 Decennial Census and 25% since 2010, making Charlotte one of the fastest-growing large cities in the United States. Charlotte has 308 square miles of land area, and an average density of 2956 residents per square mile. Charlotte is a diverse city, with approximately 40% of its residents non-Hispanic White, 35% Black, and 15% Hispanic or Latino. An estimated 47% of Charlotte residents aged 25 years and older possess a bachelor's degree or higher level of education. The median household income in Charlotte is approximately $74,000, and approximately 12% of residents live in poverty. Charlotte has approximately 295 miles of non-freeway arterial roads (U.S. Census Bureau, n.d.-b).

There were 3,696 police-reported crashes involving pedestrians in Charlotte during the 10-year period examined, including 3,245 that resulted in non-fatal injuries and 233 fatal crashes. Excluding crashes that occurred on Interstate highways or other limited access highways, 81% of fatal pedestrian crashes occurred on arterials, 62% occurred in darkness, and 52% occurred on arterials in darkness.

Figure 11 shows fatal crashes involving pedestrians in Charlotte steadily increased from 2013 to a peak in 2018, before starting to decline. The number of fatal pedestrian crashes on arterials during darkness followed a similar pattern, an increasing trend through 2020 before starting to decline. Patterns of non-pedestrian fatal crashes and fatal crashes on arterials during darkness were more variable, but also increased between 2013 and 2022. Notably, the percentage of pedestrian fatalities that occurred on urban arterials during darkness was much higher than corresponding percentages of serious but non-fatal pedestrian injury crashes or crashes of any severity not involving pedestrians. Unlike the other case study cities, the data used to analyze longitudinal trends in non-fatal crashes in Charlotte includes *serious* injury crashes only (the other cities include *any* injury crashes), so caution is advised when comparing these trends across cities. In the following analyses of neighborhood characteristics and clustering in Charlotte, data includes pedestrian crashes of all severities (fatal, serious injury, and any injury).

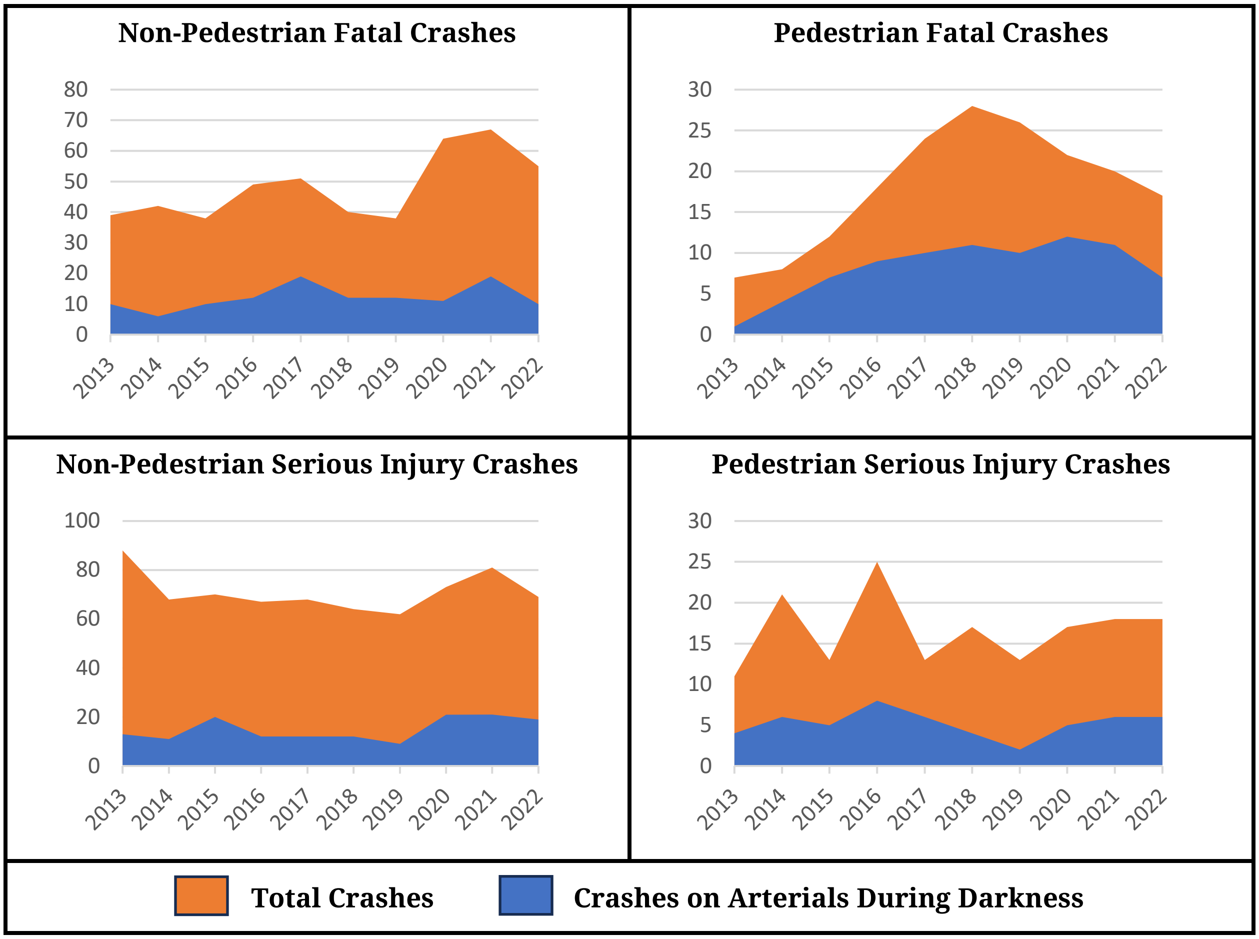


Figure 11. Trends in fatal and serious *injury crashes in Charlotte, NC*

Neighborhood Characteristics. The associations of neighborhood characteristics with rates of pedestrian injury and fatal crashes overall and on arterials in darkness are shown in Table 1. Higher SVI and older median age of housing were associated with higher rates of pedestrian injury and fatal crashes, both overall and specifically on arterials in darkness. Census tracts with a greater proportion of households living in large multifamily buildings with 50+ units had higher rates of pedestrian injury crashes overall and on arterials in darkness, and higher rates of fatal pedestrian crashes overall. Census tracts with a higher proportion of jobs in the food service, entertainment, and accommodations sector had significantly higher rates of pedestrian injury crashes overall and on arterials in darkness, associations with fatal crashes were similar in magnitude but were not statistically significant. Census tracts with higher ADI (greater mix of residences and various types of businesses) had significantly higher rates of pedestrian injury crashes overall and on arterials in darkness; associations with fatal crashes were not statistically significant. Tracts with lower density had higher rates of pedestrian fatalities overall, associations with other outcomes were not statistically significant. While the rate ratios in the table appear small, they represent substantial effects at the population level. For example, while a 1-percentile point increase in SVI was associated with a 1.9% increase in the rate of fatal pedestrian crashes on arterials in darkness, note that the SVI of census tracts in Charlotte varied by 99.5 percentile points (range 0.3–99.8).

Table 1. Rate ratios for population-based rates of pedestrian crashes in relation to neighborhood characteristics, Charlotte, NC, 2013–2022.

		All Injury & Fatal Crashes				**Fatal Crashes Only**			
		All Roads, All Hours		**On Arterials in Darkness Only**		**All Roads, All Hours**		**On Arterials in Darkness Only**	
		IRR	**(95% CI)**	**IRR**	**(95% CI)**	**IRR**	**(95% CI)**	**IRR**	**(95% CI)**
	Social Vulnerability Index	**1.006**	**(1.003–1.009)**	**1.014**	**(1.010–1.019)**	**1.014**	**(1.005–1.023)**	**1.019**	**(1.008–1.030)**
	% Zero-Vehicle HHs	**1.027**	**(1.016–1.037)**	1.011	(0.997–1.024)	**1.022**	**(1.001–1.044)**	1.016	(0.988–1.044)
	Unemployment Rate	1.005	(0.993–1.017)	**0.983**	**(0.970–0.997)**	0.967	(0.926–1.009)	0.958	(0.903–1.015)
	% Multifamily Housing	**1.021**	**(1.015–1.026)**	**1.025**	**(1.019–1.032)**	**1.017**	**(1.005–1.030)**	1.016	(0.999–1.034)
	Median Age of Housing	**1.019**	**(1.014–1.024)**	**1.025**	**(1.018–1.031)**	**1.030**	**(1.018–1.042)**	**1.031**	**(1.016–1.048)**
	Jobs per Capita	1.000	(1.000–1.000)	1.000	(1.000–1.000)	1.000	(1.000–1.000)	1.000	(1.000–1.000)
% Jobs	**Retail**	**1.006**	**(1.000–1.013)**	1.005	(0.997–1.013)	1.011	(0.997–1.026)	1.012	(0.991–1.032)
% Jobs	**Food/Accom/ Entertain**	**1.011**	**(1.004–1.018)**	**1.013**	**(1.002–1.024)**	1.011	(0.990–1.031)	1.020	(0.993–1.049)
% Jobs	**Industrial**	1.001	(0.994–1.007)	0.998	(0.989–1.006)	1.001	(0.984–1.017)	0.998	(0.975–1.021)
% Jobs	**General Services**	1.003	(0.998–1.009)	1.002	(0.995–1.009)	1.005	(0.992–1.019)	1.006	(0.987–1.024)
	% Workers w/ ≤ HS Education	1.019	(0.997–1.041)	**1.032**	**(1.005–1.060)**	1.042	(0.996–1.091)	**1.064**	**(1.006–1.125)**
	Activity Diversity Index	**1.005**	**(1.001–1.009)**	**1.009**	**(1.004–1.015)**	0.998	(0.990–1.006)	0.998	(0.987–1.008)
	Residential Density (100s per sq. mi.)	0.998	(0.996–1.001)	0.999	(0.996–1.003)	**0.987**	**(0.975–0.998)**	0.987	(0.971–1.003)

Note: IRRs (incidence rate ratios) represent % change in fatalities with 1-unit increase in row variable. All row variables except jobs per capita and residential density are expressed in percentile or percentage points. Bolding indicates significance at the 95% level.

Figure 12 shows the distribution of the SVI for the census tracts where pedestrian crashes occurred, as well as the citywide population-weighted median (i.e., the SVI of the census tract where the median resident lives), grouped by the two periods and by crash severity, overall and for crashes on arterials in darkness. The figure shows that the majority of pedestrian injury crashes and virtually all fatal pedestrian crashes occur at locations with higher levels of vulnerability than the citywide median. There was a smaller variation in the SVI for fatal crash locations from 2018 to 2022 than from 2013 to 2017, with fatal pedestrian crashes more concentrated in high-vulnerability census tracts in the later years. Pedestrian injury and fatal crashes on arterials in darkness exhibited a similar temporal pattern—becoming more concentrated in high-vulnerability neighborhoods in the more recent period. Pedestrian injury and fatal crashes on arterials in darkness were also more concentrated in vulnerable neighborhoods overall than were all pedestrian crashes irrespective of time or location.

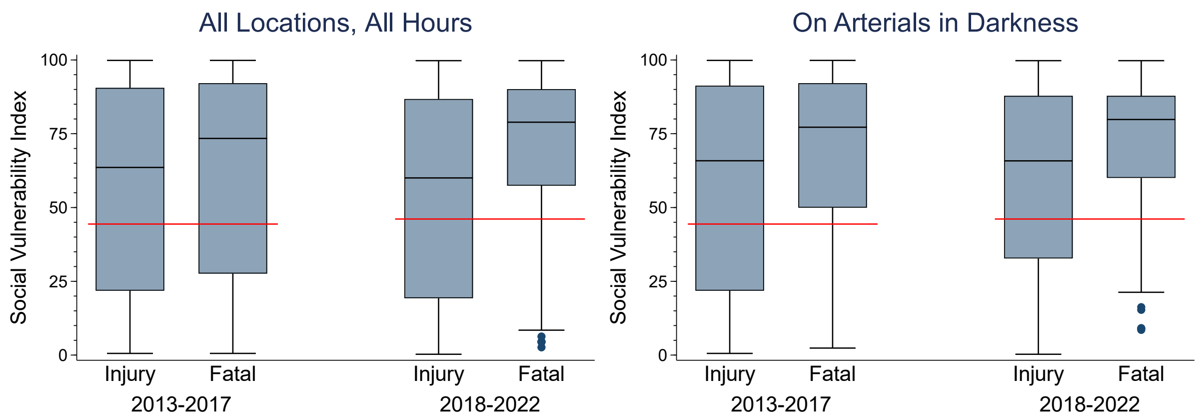


Figure 12. Social Vulnerability Index of locations of pedestrian fatal and injury crashes, Charlotte, NC, 2013-2022. Note: Red lines represent citywide population-weighted median.

Median characteristics of the locations at which pedestrian crashes occurred are shown in Table 2. Pedestrian crashes tended to occur in locations where the percentage of households without vehicles was much greater than the citywide median; however, the difference was smaller in the more recent years (2018–2022) than in the earlier period (2013–2017). Also notably, while the median ADI where pedestrian injury and fatal crashes occurred was much greater than the overall citywide median, the median ADI at fatal crash locations was lower in the more recent period than in the earlier period. The median distance of pedestrian crashes from the city center was greater for fatal crashes than for injury crashes, and was greater in the more recent period than in the earlier period, indicating an increasing proportion of pedestrian injuries and fatalities occurring further from the city center.

Table 2. Median characteristics of locations at which pedestrian injury & fatal crashes occurred, Charlotte, NC, 2013-2022.

	Citywide		Injury & Fatal Crash Locations				Fatal Crash Locations			
			All		Arterials in Darkness		All		Arterials in Darkness	
	2013–17	2018–22	2013–17	2018–22	2013–17	2018–22	2013–17	2018–22	2013–17	2018–22
Social Vulnerability Index	44.4	46.1	63.6	61.1	67.8	68.4	73.4	78.9	77.2	79.8
% Zero-Vehicle HHs	4.2	3.7	11.2	7.8	11.2	7.3	12.7	8.0	13.4	8.0
Unemployment Rate	5.1	3.2	5.7	3.6	5.7	3.7	6.8	3.9	8.0	3.9
% HHs in Buildings w/ 50+ Units	1.3	1.6	2.3	4.4	2.1	3.6	1.4	1.5	1.0	1.9
Median Year Housing Built	1989	1994	1983	1987	1981	1984	1976	1979	1976	1978
Jobs per Capita	0.22	0.23	0.50	0.53	0.56	0.47	0.43	0.30	0.40	0.29
% Jobs–Retail	8.7	9.0	6.6	6.6	8.1	9.0	10.3	9.2	12.6	10.9
% Jobs–Food/Accom/Entertain	9.0	9.1	8.9	8.6	8.9	9.0	10.8	7.8	10.8	9.3
% Workers w/ ≤ HS Education	30.4	30.6	32.1	32.0	32.1	32.5	34.0	33.5	34.7	33.8
Activity Diversity Index	38.2	39.6	54.5	53.5	56.1	53.7	55.9	47.5	52.9	45.0
Residential Density (100s per sq. mi.)	28.3	30.8	32.8	34.2	33.0	30.6	28.1	26.1	28.0	28.0
Distance from City Center (mi)			3.9	4.1	3.8	4.4	4.0	4.9	4.5	4.8

Clustering. Figure 13 illustrates the geographic distribution of fatal pedestrian crashes in Charlotte, with those in clusters shown in purple and those that occurred outside of clusters shown in green. Overall, 58 of 178 fatal pedestrian crashes (33%) occurred in clusters of pedestrian-involved fatal and injury crashes, indicating that these were places with a high density of pedestrian crashes, whereas the remaining 67% occurred outside of such clusters. Fatal pedestrian crashes in Charlotte were less likely to occur in clusters compared to injury pedestrian crashes, nearly half of which occurred in clusters (Table 3).

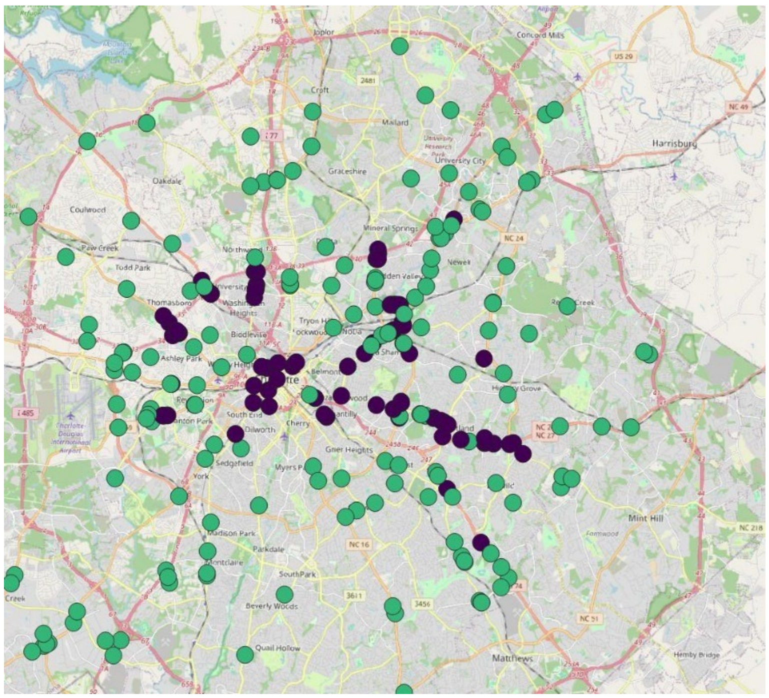


Figure 13. Fatal pedestrian crashes in Charlotte, NC, 2013–2022 (crashes in clusters shown in purple)

Clusters of pedestrian crashes were located in and around the central business district while those not in clusters were more widely and evenly distributed throughout the city. Fatal crashes that occurred in clusters were more likely than those outside of clusters to occur on arterials and in darkness; however, a large majority of fatal pedestrian crashes outside of clusters occurred on arterials and more than half occurred in darkness. When examining non-fatal injury crashes, those that occurred in clusters were much more likely than those outside of clusters to occur on arterials, though the percentage that occurred in darkness was similar irrespective of whether crashes occurred inside or outside of a cluster. Fatal crashes were much more likely than non-fatal injury crashes to occur on arterials and in darkness irrespective of clustering.

Table 3. Pedestrian injury and fatal crashes on arterials and in darkness in relation to clustering, Charlotte, NC, 2013 – 2022.

		N	% on Arterials	% in Darkness	% on Arterials in Darkness
Fatal	**All**	178	81%	62%	52%
	Inside of Clusters	58	90%	69%	59%
	Outside of Clusters	120	78%	59%	48%
Injury	**All**	3,092	61%	30%	19%
	Inside of Clusters	1,406	71%	29%	20%
	Outside of Clusters	1,686	53%	32%	18%

Table 4 shows rate ratios indicating the relative proportions of pedestrian crashes occurring inside versus outside of clusters in relation to selected neighborhood characteristics. Most results were similar in magnitude, and all were consistent directionally, regardless of whether all injuries or only fatalities were examined and regardless of whether analyses included all hours of the day or were limited to those occurring during darkness. Overall, pedestrian crashes were more likely to occur in clusters in areas with lower social vulnerability, lower unemployment, lower activity diversity, older housing, greater proportion of households living in multifamily housing, and greater proportion of zero-vehicle households. Only housing age and zero-vehicle households remained statistically significant in models examining only fatalities, though results for other characteristics were similar in magnitude and direction to those based on all injuries and fatalities.

Table 4. Rate ratios for characteristics of locations of pedestrian crashes in and out of clusters, Charlotte, NC, 2013–2022

	Injuries & Fatalities		Fatalities Only	
	All Times	**Darkness Only**	**All Times**	**Darkness Only**
Social Vulnerability Index	1.00 (1.00–1.00)	**1.00 (0.99–1.00)**	0.99 (0.98–1.00)	**0.99 (0.97–1.00)**
Activity Diversity Index	**1.00 (0.99–1.00)**	**0.99 (0.99–1.00)**	0.99 (0.98–1.00)	0.99 (0.98–1.01)
Median Housing Age	**1.03 (1.03–1.04)**	**1.04 (1.03–1.05)**	**1.03 (1.01–1.05)**	**1.03 (1.00–1.05)**
Unemployment Rate	**0.98 (0.97–0.99)**	0.98 (0.96–1.01)	0.99 (0.95–1.04)	1.00 (0.95–1.06)
% Multifamily Housing	**1.03 (1.02–1.03)**	**1.03 (1.02–1.03)**	1.01 (1.00–1.03)	1.01 (0.99–1.03)
% Zero-Vehicle Households	**1.03 (1.03–1.04)**	**1.03 (1.02–1.05)**	**1.09 (1.06–1.13)**	**1.09 (1.05–1.13)**

Note: 95% confidence intervals for the rate ratios are shown in parentheses. Bolding indicates significance at the 95% level. Median housing age calculated as 2024-median year built.

Findings from Literature Scan and Interview with City Officials

The City of Charlotte, NC, has been persistently working to improve traffic safety since it created its first complete streets policy in the early 2000s. From its Transportation Action Plan (City of Charlotte, 2011) and Urban Street Design Guidelines (City of Charlotte, 2007) that supported the policy early on, the City has more recently added a Vision Zero Action Plan (City of Charlotte, 2019) and a Strategic Mobility Plan (City of Charlotte, 2022a). These documents build in more direct focus on pedestrian safety. One major change that is leading to improved safety efforts is the City's decision to invest in pedestrian, bicycle, and Vision Zero programs through dedicated stand-alone funding. For example, Charlotte passed its 2025 budget in June 2024, which includes $20 million for Vision Zero efforts (City of Charlotte, 2024). Since 2014, Charlotte has made a more concerted effort—developing a High Injury Network (HIN) to prioritize where to invest, introducing tools to engage with the public while collecting valuable data through apps like Envision My Ride to help Charlotte Area Transit consider transit needs, and more routinely installing rectangular rapid flashing beacons and pedestrian hybrid beacons at pedestrian crossings. Now, the HIN data drives much of the project prioritization, and while all fatalities are included in the HIN, pedestrian and bicycle fatalities are given more weight.

In 2019, Charlotte adopted their Vision Zero Action Plan and introduced their HIN. The plan focuses on four key areas, each of which includes a strategy table listing key benchmarks and actions to take to reach them. Some key pedestrian-related benchmarks through 2030 include the following:

- Constructing 10 to 20 miles of sidewalk annually
- Constructing or improving crossings at 25 locations annually (and increasing that number incrementally every 5 years up to 50 sites annually)
- Identifying and implementing traffic calming projects prioritized on the HIN on local streets
- Installing leading pedestrian interval (LPI) or LPI+ treatments
- Constructing raised intersections
- Formalizing a process to prioritize and improve lighting at locations along the HIN (in fact, Charlotte's new lighting policy now mitigates the issue they had of lighting being "engineered out" of a project due to insufficient funding)

Spurred by its Vision Zero work, the City of Charlotte has also made significant strides in reducing posted speed limits on local streets, particularly in Uptown, where the city has taken over ownership from NCDOT of most streets in order to set the speed limits consistently at 25 mph. As the biggest city in North Carolina, Charlotte exhibits more jurisdictional control on their streets than other cities within the state. This has given the City of Charlotte more latitude to make changes directly for pedestrian safety, such as reducing speed limits. Charlotte's DOT also uses different models than NCDOT to set speed limits; they run three different models that consider different minimum thresholds for different street classifications and select the lowest speed that results from the three. They also track speeding citations annually, and the Charlotte-Mecklenburg Police Department works closely with the Charlotte DOT Traffic Safety group. Prior to 2019, these departments coordinated to investigate every fatal pedestrian crash; with the roll-out of the Vision Zero Action Plan, the task force now investigates every serious injury crash, too.

The 2022 Strategic Mobility Plan further supports pedestrian safety priorities. It includes a sidewalk program to construct over 250 miles of new sidewalk to fill in gaps on all arterials and collectors, which was funded through a $50 million bond in 2022. The plan also identified 97 pedestrian crossings for improvement or new construction and 581 signals for upgrades to improve pedestrian safety through additions such as accessible pedestrian signals or LPI phasing. The Strategic Mobility Plan's vision aspires to achieve vision zero along with a "50–50 mode share" by 2040 where half of all commute trips will be made via walking, bicycling, and/or transit. Charlotte also recognizes the relationship between mobility and affordable housing. Within a series of equitable policies laid out in the plan, the first is "Create Accessible and Equitable Mobility" with the action to "protect and increase affordable housing near major transportation investments and mobility corridors." Through a series of connected policies, Charlotte plans to "Strengthen the Pedestrian System" to support a 10-minute neighborhood goal (ensuring all residents' home are within a 10 minute-distance of walkable, car-free areas with important services and amenities) and to "Support the Transit System" through better access to bus stops, including pedestrian crossings and bus stop amenities.

While funding is always challenging, the City Council and larger constituency has demonstrated to be "pro-safety." As an example, one city staffer pointed to the establishment of the Pedestrian Crossing Committee, which was formed to handle the volume of requests the city receives from the public who want better crossing opportunities. Currently, these projects are driven by the requests, and they tend to line up with the HIN; however, they are considering moving toward a more data-driven selection process in the future.

While the Charlotte Streets Manual (City of Charlotte, 2023), Streets Map (City of Charlotte, 2022b), and Urban Street Design Guidelines offer technical support for Complete Streets implementation, the process has evolved from considering Complete Streets on a project-by-project basis to baking the Complete Streets elements into the process for all projects. Charlotte staff feel that most of the "low-hanging fruit" of Complete Streets retrofits have been taken care of, so the ones that remain are those that will take a heavier lift to happen, and they are also more likely to be on state-owned roads. Still, the culture has shifted from thinking of Complete Streets as "should we" to “which ones and how”? Charlotte also continues to evolve its design standards and double-down on what works. They have a new Separated Bike Lane guide, as well as a Safe Routes to School Toolkit in the pipeline. They are also exploring Road Safety Audits, another tool that they have not previously utilized.

Memphis, TN

Descriptive Statistics and Trends

Memphis, TN, had an estimated population of 618,639 as of the 2023 ACS, representing a decline of 2.3% since the 2020 Decennial Census and 4.4% since 2010 (U.S. Census Bureau, n.d.-c). Memphis has 297 square miles of land area, and an average density of 2,083 residents per square mile. Memphis is a majority-Black city, with 64% of residents identifying as Black or African American, 24% as non-Hispanic White, and 8% as Hispanic or Latino. An estimated 28% of Memphis residents aged 25 years and older possess a bachelor’s degree or higher level of education. The median household income in Memphis is approximately $48,000, and approximately 24% of residents live in poverty. Memphis has approximately 530 miles of non-freeway arterial roads.

There were 5,172 police-reported crashes involving pedestrians in Memphis during the 10-year period examined, including 3,993 that resulted in non-fatal injuries and 469 fatal crashes. Excluding crashes that occurred on Interstate highways or other limited access highways, 85% of fatal pedestrian crashes occurred on arterials, 53% occurred in darkness, and 46% occurred on arterials in darkness.

Figure 14 shows an increasing trend in both non-pedestrian and pedestrian fatal crashes in Memphis over the study period. Similarly, both pedestrian and non-pedestrian fatal crashes on arterials during darkness steadily increased from 2015 to 2023. By contrast, trends in non-pedestrian and pedestrian injury crashes on arterials during darkness were relatively stable over the study period. Most strikingly, fatal pedestrian crashes nearly quadrupled from 2014 to 2022 (from 23 to 89), whereas non-fatal injury crashes involving pedestrians increased by only 11% over the same period.

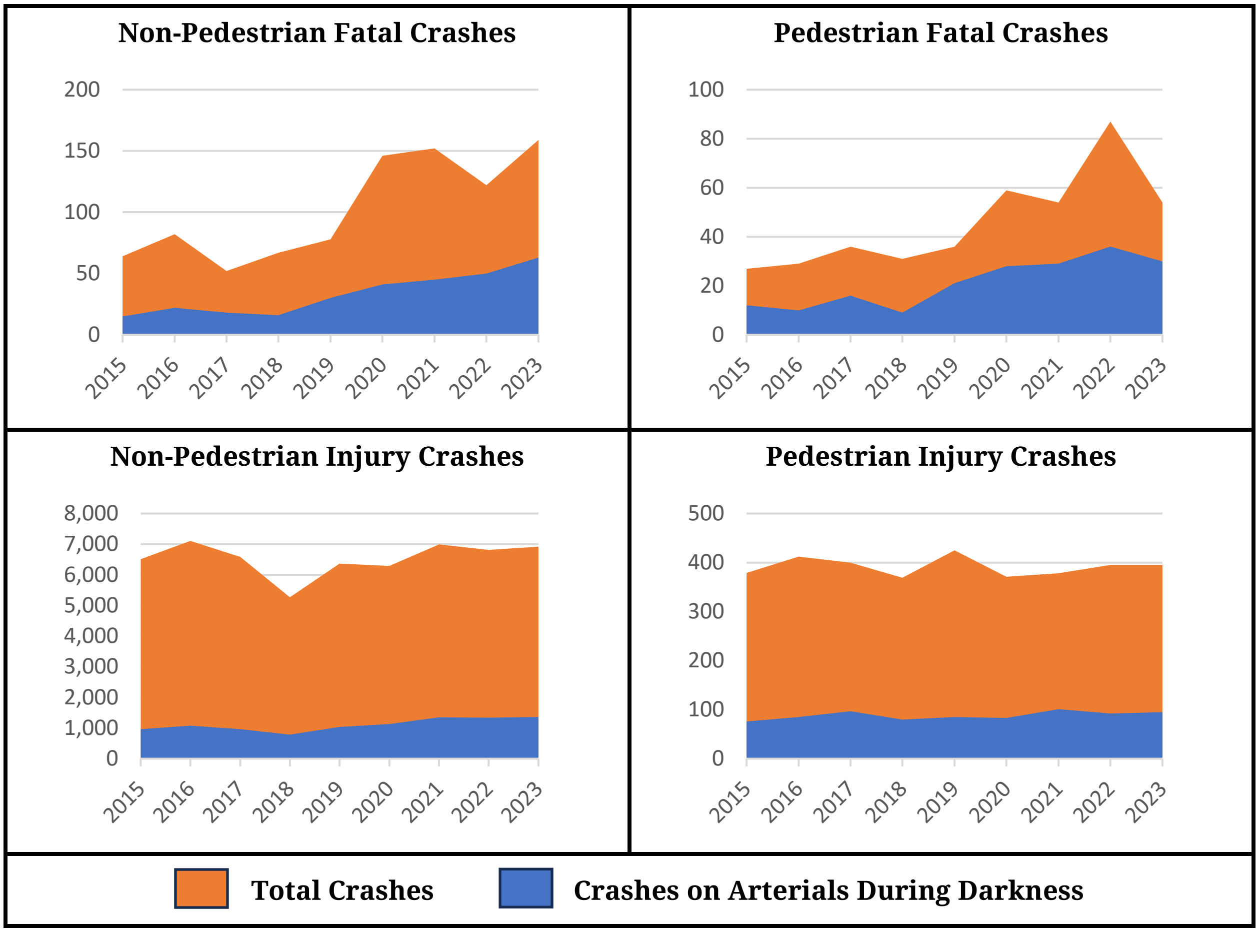


Figure 14. Trends in fatal and non-fatal injury crashes in Memphis, TN

Neighborhood Characteristics The associations of neighborhood characteristics with rates of pedestrian injury and fatal crashes overall and on arterials in darkness are shown in Table 5. Neighborhood characteristics associated with higher rates of all four outcomes include the neighborhood SVI; higher (older) median age of occupied housing units; higher percentage of jobs in the entertainment, food service, and accommodations sectors; higher percentage of workers with high school or lower education levels; and higher ADI (i.e., greater mix of residential and various commercial land uses). In all cases, values of rate ratios for statistically significant variables were equal or larger in magnitude in models examining crashes on arterials in darkness than when examining all crashes together. Note that while the rate ratios in the table appear small, they represent substantial effects at the population level. For example, while a 1-percentile point increase in SVI was associated with a 1.5% increase in the rate of fatal pedestrian crashes, the SVI of census tracts in Memphis varied by 98.5 percentile points (range 0.8–99.3).

Table 5. Rate ratios for population-based rates of pedestrian crashes in relation to neighborhood characteristics, Memphis, TN, 2014–2023.

		All Injury & Fatal Crashes				Fatal Crashes Only		
		All Roads, All Hours		On Arterials in Darkness Only		All Roads, All Hours		On Arterials in Darkness Only	
		IRR	(95% CI)	IRR	(95% CI)	IRR	(95% CI)	IRR	(95% CI)
Social Vulnerability Index		**1.012**	**(1.009–1.016)**	**1.015**	**(1.011–1.019)**	**1.015**	**(1.009–1.021)**	**1.015**	**(1.009–1.022)**
% Zero-Vehicle HHs		**1.013**	**(1.005–1.021)**	1.003	(0.994–1.013)	1.000	(0.986–1.014)	0.994	(0.978–1.009)
Unemployment Rate		1.004	(0.996–1.013)	1.006	(0.995–1.018)	1.010	(0.992–1.027)	1.009	(0.986–1.032)
% Multifamily Housing		1.001	(0.994–1.009)	1.006	(0.996–1.016)	0.998	(0.983–1.013)	0.991	(0.976–1.006)
Median Age of Housing		**1.030**	**(1.025–1.035)**	**1.035**	**(1.029–1.041)**	**1.046**	**(1.036–1.055)**	**1.046**	**(1.036–1.056)**
Jobs per Capita		0.980	(0.935–1.027)	0.955	(0.904–1.008)	0.960	(0.899–1.026)	**0.946**	**(0.903–0.990)**
% Jobs	**Retail**	1.000	(0.993–1.007)	1.000	(0.991–1.009)	0.995	(0.983–1.008)	0.995	(0.983–1.008)
% Jobs	**Food/Accom/ Entertain**	**1.012**	**(1.005–1.020)**	**1.016**	**(1.007–1.026)**	**1.015**	**(1.002–1.027)**	**1.018**	**(1.007–1.029)**
% Jobs	**Industrial**	0.996	(0.990–1.002)	0.998	(0.991–1.006)	0.997	(0.986–1.007)	0.999	(0.987–1.011)
% Jobs	**General Services**	0.998	(0.992–1.003)	1.000	(0.993–1.007)	1.000	(0.990–1.010)	1.003	(0.993–1.013)
% Workers ≤ HS Education		**1.030**	**(1.016–1.045)**	**1.043**	**(1.025–1.062)**	**1.041**	**(1.017–1.066)**	**1.055**	**(1.030–1.081)**
Activity Diversity Index		**1.011**	**(1.007–1.015)**	**1.014**	**(1.010–1.019)**	**1.007**	**(1.002–1.013)**	**1.011**	**(1.005–1.017)**
Residential Density (100s per sq. mi.)		1.002	(0.998–1.007)	1.002	(0.996–1.008)	0.993	(0.984–1.001)	0.994	(0.985–1.003)

Note: IRRs represent % change in fatalities with 1-unit increase in row variable. All row variables except jobs per capita and residential density are expressed in percentile or percentage points. Bolding indicates significance at the 95% level.

Figure 15 shows the distribution of the SVI for the census tracts where pedestrian crashes occurred, as well as the citywide population-weighted median (i.e., the SVI of the census tract where the median resident lives), grouped by the two periods and by crash severity, overall and for crashes on arterials in darkness. Fatal crashes were more concentrated in higher-vulnerability neighborhoods than were injury crashes. Fatal crashes became slightly less concentrated (though still highly concentrated) in higher-vulnerability communities in the more recent period as approximately 80% of all fatal pedestrian crashes in 2014 through 2018 and 72% of fatal pedestrian crashes in 2019 through 2023 occurred in census tracts with SVI higher than the citywide median. Pedestrian injury crashes on arterials in darkness were somewhat more concentrated in higher-vulnerability neighborhoods compared with pedestrian injury crashes overall, especially in the earlier period. Locations of fatal pedestrian crashes on urban arterials in darkness were quite similar to overall fatal pedestrian crash locations with respect to SVI.

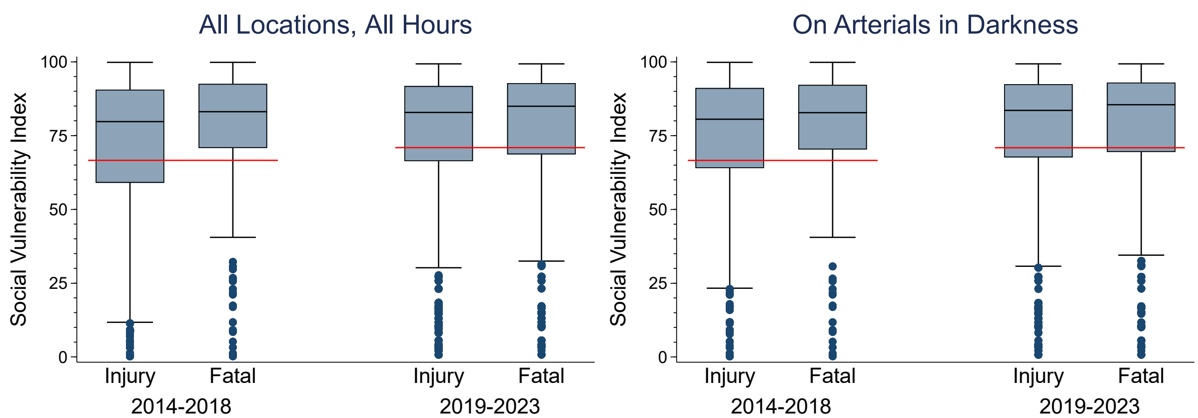


Figure 15. Social Vulnerability Index of locations of pedestrian fatal and injury crashes, Memphis, TN, 2014–2023. Note: Red lines represent citywide population-weighted median.

Median characteristics of the locations at which pedestrian crashes occurred are shown in Table 6. Pedestrian crashes tended to occur in locations where the percentage of households without vehicles was much greater than the citywide median; however, the difference was smaller in the more recent years (2019–2023) than in the earlier period (2014–2018), especially for fatal pedestrian crashes. Also notably, while the median ADI where pedestrian injury and fatal crashes occurred was greater than the overall citywide median, the median ADI at pedestrian crash locations was lower in the more recent period than in the earlier period, especially in the case of fatal crashes. The median distance of pedestrian crashes from the city center was over 6 miles in both periods for all categories of crashes examined, and increased for fatal crashes (but not for injury crashes) in the more recent period relative to the earlier period, indicating an increasing proportion of fatal pedestrian crashes occurring further from the city center.

Table 6. Median characteristics of locations at which pedestrian injury & fatal crashes occurred, Memphis, TN, 2014–2023.

	Citywide		Injury & Fatal Crash Locations				Fatal Crash Locations			
			All		Arterials in Darkness		All		Arterials in Darkness	
	2014–18	2019–23	2014–18	2019–23	2014–18	2019–23	2014–18	2019–23	2014–18	2019–23
Social Vulnerability Index	66.6	70.9	80.6	83.0	80.9	84.4	83.1	85.0	82.8	85.5
% Zero-Vehicle HHs	6.0	6.4	12.3	12.6	12.2	11.9	14.7	10.9	13.8	10.9
Unemployment Rate	6.6	5.2	8.9	7.9	9.0	8.9	9.1	9.8	9.1	9.8
% HHs in Buildings w/ 50+ Units	0.7	0.7	2.0	1.8	2.1	1.5	1.3	1.1	2.1	1.1
Median Year Housing Built	1972	1973	1963	1964	1963	1963	1961	1961	1962	1961
Jobs per Capita	0.18	0.16	0.28	0.26	0.31	0.24	0.26	0.19	0.31	0.19
% Jobs–Retail	11.5	10.9	10.4	9.8	11.3	9.4	12.6	9.4	11.3	9.2
% Jobs–Food/Accom/Entertain	9.4	8.5	8.7	7.8	8.5	7.5	8.0	6.5	8.1	5.9
% Workers w/ ≤ HS Education	33.5	34.9	34.3	35.7	34.6	35.9	34.8	36.5	34.8	36.8
Activity Diversity Index	34.1	31.0	40.6	40.0	42.3	36.9	39.1	34.7	41.5	34.6
Residential Density (100s per sq. mi.)	32.5	30.4	32.3	30.5	32.3	30.5	30.0	27.9	28.2	27.7
Distance from City Center (mi)			6.5	6.6	6.5	6.5	6.2	7.0	6.7	7.0

Clustering. Figure 16 illustrates the geographic distribution of fatal pedestrian crashes in Memphis, with those in clusters shown in purple and those outside of clusters shown in green. Overall, 181 of 432 fatal pedestrian crashes (42%) occurred in clusters of pedestrian-involved crashes, indicating that these were places with a high density of pedestrian crashes, whereas the remaining 58% occurred outside of such clusters. The percentage of pedestrian non-fatal injury crashes that occurred in clusters was slightly higher than the corresponding percentage among fatal crashes at 46% (Table 7).

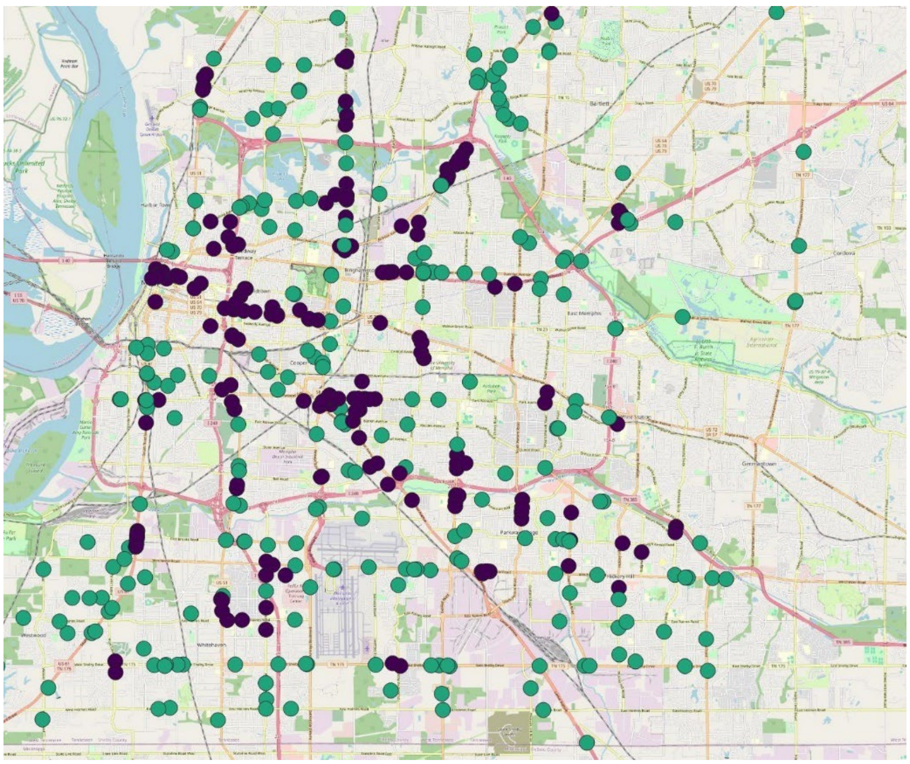


Figure 16. Fatal pedestrian crashes in Memphis, TN, 2014–2023 (crashes in clusters shown in purple)

Fatal crashes in clusters were somewhat concentrated in the city center, though many occurred beyond the city center as well. In contrast, fatal pedestrian crashes that were not in clusters were more widely distributed. However, fatal pedestrian crashes that occurred outside of pedestrian crash clusters had several notable similarities to those that occurred inside of clusters: 84% of fatal pedestrian crashes outside of clusters occurred on arterials, 55% occurred in darkness, and 47% occurred in darkness on arterials, very similar to the corresponding percentages among fatal pedestrian crashes that occurred in pedestrian crash clusters (86% on arterials, 50% in darkness, 45% on arterials in darkness). Among non-fatal injury crashes, those that occurred in clusters were much more likely to occur on arterials and slightly more likely to occur in darkness. Fatal crashes were much more likely than non-fatal crashes to occur on arterials and in darkness irrespective of clustering.

Table 7. Pedestrian injury and fatal crashes on arterials and in darkness in relation to clustering, Memphis, TN, 2014–2023

		N	% on Arterials	% in Darkness	% on Arterials in Darkness
Fatal	**All**	432	85%	53%	46%
	Inside of Clusters	181	86%	50%	45%
	Outside of Clusters	251	84%	55%	47%
Injury	**All**	3,746	69%	31%	23%
	Inside of Clusters	1,713	76%	33%	26%
	Outside of Clusters	2,033	64%	29%	20%

Table 8 shows rate ratios indicating the relative proportions of pedestrian crashes occurring inside versus outside of clusters in relation to selected neighborhood characteristics. Results are shown for models based on all injury crashes including fatal crashes and for fatal crashes only, at all hours of the day and during darkness only. Pedestrian crashes were more likely to be clustered in areas with higher levels of social vulnerability, higher activity diversity, older housing, lower unemployment, higher proportion of households in multifamily housing, and higher proportion of households having no vehicle. All rate ratios were similar in magnitude and consistent in direction in all four models. Some results were not statistically significant in the model of fatal crashes, likely due to the smaller number of crashes included in that model, but rate ratios in models of fatal crashes were similar or identical to those in corresponding models that included injury crashes in addition to fatal crashes.

Table 8. Rate ratios for characteristics of locations of pedestrian crashes in and out of clusters, Memphis, TN, 2013–2022

	Injuries & Fatalities		Fatalities Only	
	All Times	**Darkness Only**	**All Times**	**Darkness Only**
Social Vulnerability Index	**1.02 (1.01–1.02)**	**1.01 (1.01–1.02)**	**1.01 (1.01–1.02)**	**1.02 (1.01–1.03)**
Activity Diversity Index	**1.01 (1.01–1.01)**	**1.01 (1.01–1.02)**	**1.01 (1.00–1.02)**	1.01 (1.00–1.02)
Median Housing Age	**1.03 (1.03–1.03)**	**1.03 (1.03–1.04)**	**1.03 (1.02–1.05)**	**1.04 (1.01–1.06)**
Unemployment Rate	**0.98 (0.97–0.98)**	**0.98 (0.97–0.99)**	0.98 (0.96–1.00)	0.98 (0.95–1.01)
% Multifamily Housing	**1.01 (1.01–1.01)**	**1.01 (1.01–1.01)**	**1.01 (1.00–1.02)**	1.01 (1.00–1.02)
% Zero-Vehicle Households	**1.01 (1.01–1.02)**	**1.01 (1.01–1.02)**	1.01 (0.99–1.03)	1.01 (0.99–1.04)

Note: 95% confidence intervals for the IRRs are shown in parentheses. Bolding indicates significance at the 95% level. Median housing age calculated as 2024-median year built.

Findings from Literature Scan and Interviews with Local Officials

Across Tennessee, there are 96,197 miles of highway. Of these, the TDOT maintains 14,462 miles. The remaining highway miles are controlled either by a county or a municipality. In Memphis, the city maintains the majority of highway miles (Tennessee Department of Transportation, n.d.). In unincorporated areas, Shelby County maintains the roadway. Transportation planning across the region is under the Memphis Urban Area Metropolitan Planning Organization. State law determines how speed limits are set, the parameters for speed limits, and who has responsibility for setting them. Interstates have a maximum speed of 70 mph, while other roads have a maximum of 65 mph. TDOT sets speed limits on highways, while municipalities are authorized to set speed limits on roads within their jurisdiction, excluding controlled access highways. For either the state or a municipality to lower the speed limit, a speed study must be performed. Changes to speed limits rely on the 85^{th} percentile of speed, and reduction may not go below the mean speed. Studies may also use the USLIMITS2 tool to determine speed limits (Tennessee Department of Transportation, 2018).

Within the city's policy landscape, Complete Streets has been a policy consideration since 2013. The mayor signed a resolution for a Complete Streets Policy for Memphis in early 2013 (City of Memphis, 2013). The policy guided responsible city departments to consider all modes when designing, building, and maintaining city streets while requiring agencies to justify why a roadway project did not include all modes where applicable. These include interstate locations, issues related to historical sites, or a lack of demand for certain facilities. The policy also sought to link the city departments with Shelby County and the Metropolitan Planning Organization ensure planned projects align with the Complete Streets Policy. Signing of the Complete Streets Policy led to the development of the Complete Streets Project Delivery Manual later in 2013, with an update to the manual in 2015 (City of Memphis, 2015). This manual outlined guidance for planning and design, as well as the life of a project for implementing Complete Streets. The manual guides stakeholders through considerations on a street's purpose and how street design accommodates different types of users. The manual also establishes a priority of modes for designing streets, where the city ranks pedestrians as a priority, followed in order by bicyclists, transit, automobiles, and freight. This priority guides the development of cross sections that incorporate roadway function, traffic composition, and current and future land use. The project manual pulls from a mix of existing plans developed by the city to produce this guidance.

Planning for Complete Streets and other multimodal considerations was pulled into a more recent effort in Memphis 3.0. Memphis 3.0 is the comprehensive plan covering future growth in land use planning and incorporates transportation planning for the city (City of Memphis, 2019). The plan was developed with significant community input and guides much of the current development in Memphis. With Memphis 3.0, the city published an updated Complete Streets Manual in 2020 (City of Memphis, 2020). The updated manual links much of the content from the original Complete Streets Manual with the land-use elements of the Memphis 3.0 plan. The manual maintains the focus on roadway elements in the cross section with a focus on the area divisions from the Memphis 3.0 plan. In this plan, much of the pedestrian focus is on areas where pedestrians are expected, referenced as anchors in the plan. These include citywide anchors like the downtown, community anchors, central parts of neighborhoods, and communities themselves.

While Memphis has operated with a Complete Streets policy since 2013, adapted and updating its guidance along the way, cultural barriers may be preventing pedestrian safety from becoming a citywide focus. Much of the more recent Complete Streets manual focuses on improving areas that have higher pedestrian demand along with the land use to match it; areas within either the urban core or in the central parts of neighborhoods. However, as pedestrian crashes have increased, the locations have moved beyond these focus areas, occurring more often on arterials that are viewed less as pedestrian corridors and more as thoroughfares. As noted in interviews, one issue is getting the public involved in larger efforts to improve safety in such areas. An impression from the public is there are relatively few pedestrians or cyclists. When the choice is between making space for people walking or biking or for vehicles, there is a perception that residents of the city would rather not lose the lanes reserved for cars. Another issue is how pedestrian fatalities are viewed. Rather than a systemic issue related to the network, pedestrian deaths are often framed as an individual, behavioral problem: related to drugs or alcohol or homelessness. Altogether, a larger picture that pedestrians are out of place may be hindering citywide action on safety.

Interviewees shared that Memphis has also been experiencing population movement that changes where and when people are walking and driving. This is partly an effect of residents moving away from near the downtown to more suburban areas, leading to more people living in less dense areas along higher speed, higher capacity roadways. Some of this movement relates to a greater availability of public housing outside of the core city. In addition, more of the lower wage employment is in the outer areas of the city, mostly in freight and logistics. These industries and locations not only cause reliance on vehicles to get to work, they also mean that traffic is active at most hours of the day.

Memphis 3.0 and Complete Streets set some goals for how the city can look and how to create safer places. However, safety work from much of the city is seen as either something to be handled through enforcement or some pieces of engineering, like signals. The city still lacks capacity to launch a wider effort at addressing safety, so programs like Vision Zero have not taken root. The state is involved in some measure on the roads it maintains. TDOT runs a spot safety program to identify and fund safety projects in specific locations. The state also assists in building out high injury network maps for the city. One potential for the future is with a recently won Safe Streets and

Roads for All (SS4A) grant from the U.S. Department of Transportation. The grant funds a safety action plan for the city, which creates an opportunity to employ a more systemic approach to addressing safety issues for pedestrians in the city.

Albuquerque, NM

Descriptive Statistics and Trends

Albuquerque, NM, had an estimated population of 560,274 as of the 2023 ACS, representing a slight decline of 0.8% since the 2020 Decennial Census but a 2.6% increase since 2010 (U.S. Census Bureau, n.d.-a). Albuquerque has 187 square miles of land area, and an average density of 2,992 residents per square mile. Approximately half of all residents of Albuquerque identify as Hispanic or Latino, 37% as non-Hispanic White, 3% as Black, and 5% as American Indian. An estimated 38% of Albuquerque residents aged 25 years and older possess a bachelor’s degree or higher level of education. The median household income in Albuquerque is approximately $61,500, and approximately 16.5% of residents live in poverty. Albuquerque has approximately 276 miles of non-freeway arterial roads.

There were 2,963 police-reported crashes involving pedestrians in Albuquerque during the 10-year period examined, including 2,431 that resulted in non-fatal injuries and 321 fatal crashes. Excluding crashes that occurred on Interstate highways or other limited access highways, 95% of fatal pedestrian crashes occurred on arterials, 62% occurred in darkness, and 52% occurred on arterials in darkness.

Figure 17 shows trends in fatal and injury crashes involving pedestrians in Albuquerque, as well as fatal and injury crashes not involving pedestrians for comparison. Non-pedestrian fatal crashes in Albuquerque demonstrated two peaks over the study period, one in 2016 and the other from 2020 to 2021, with trends in these crashes on arterials during darkness exhibiting a similar pattern. Trends in fatal pedestrian crashes were more variable over the study period, however a larger proportion of these appear to occur on arterials during darkness compared to both non-pedestrian and pedestrian injury crashes. After reaching a high in 2016, trends in non-pedestrian injury crashes appear to have declined, with a small proportion of these crashes occurring on arterials during darkness.

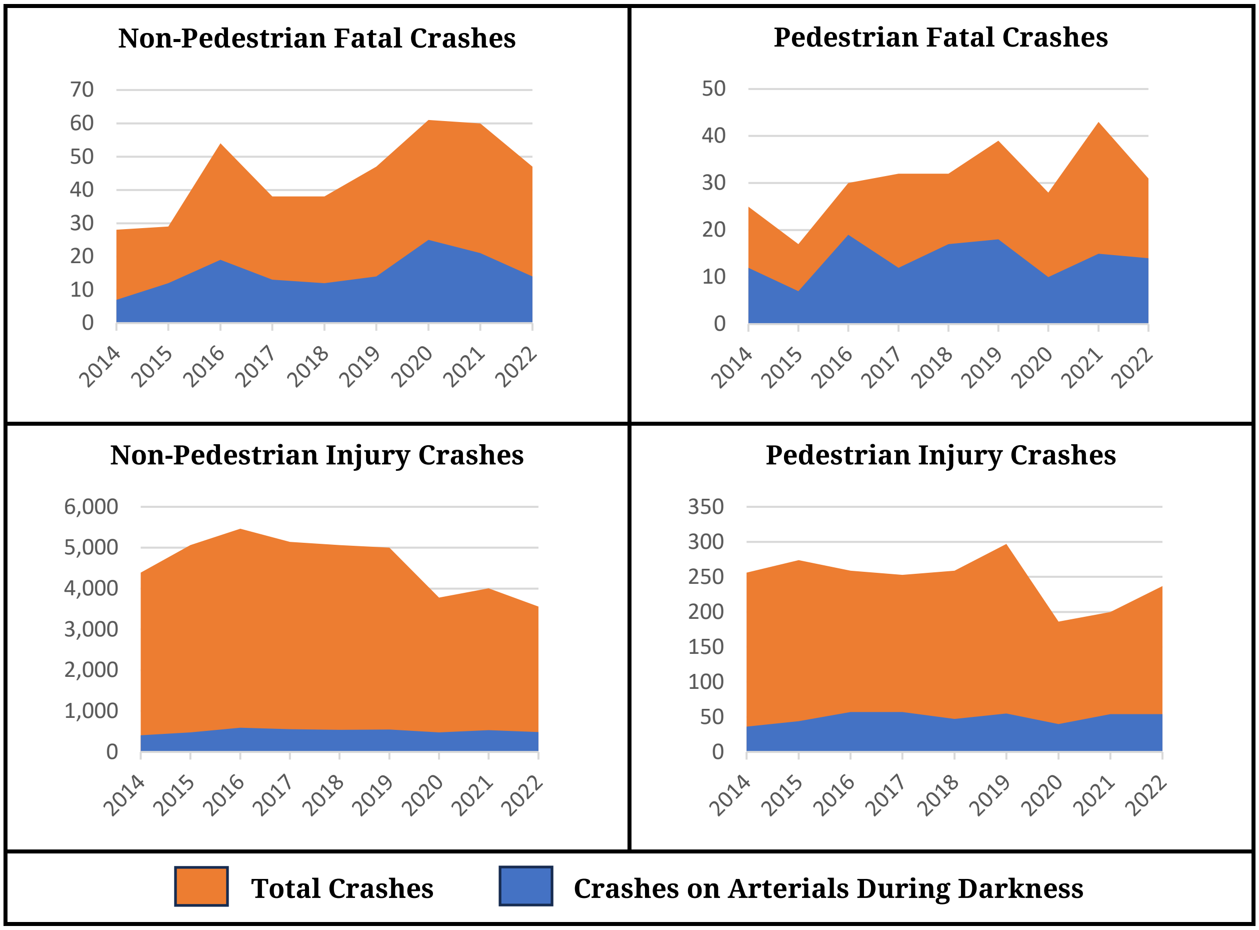


Figure 17. Trends in fatal and non-fatal injury crashes in Albuquerque, NM

Neighborhood Characteristics. The associations of neighborhood characteristics with rates of pedestrian injury and fatal crashes overall and on arterials in darkness are shown in Table 9. Census tracts with a higher SVI had higher rates of all four outcomes examined. Census tracts with higher ADI (greater mix of residences and various types of businesses) also had higher rates of all four outcomes. Census tracts with older housing, higher residential density, and a higher percentage of jobs in the retail sector had higher rates of pedestrian injury crashes overall and on arterials in darkness, though associations with fatal pedestrian crashes were not statistically significant. Census tracts with higher numbers of jobs per capita, and tracts with higher unemployment rates, had lower rates of pedestrian fatal crashes overall and on arterials in darkness. While the rate ratios in the table appear small, they represent substantial effects at the population level. For example, while 1-percentile point increase in SVI was associated with a 2.2% increase in the rate of fatal pedestrian crashes, note that the SVI of census tracts in Albuquerque varied by 96 percentile points (range 3.8–99.8).

Table 9. Rate ratios for population-based rates of pedestrian crashes in relation to neighborhood characteristics, Albuquerque, NM, 2013–2022

		All Injury & Fatal Crashes				Fatal Crashes Only			
		All Roads, All Hours		On Arterials in Darkness Only		All Roads, All Hours		On Arterials in Darkness Only	
		IRR	(95% CI)	IRR	(95% CI)	IRR	(95% CI)	IRR	(95% CI)
	Social Vulnerability Index	**1.010**	**(1.005–1.014)**	**1.015**	**(1.009–1.021)**	**1.022**	**(1.013–1.030)**	**1.022**	**(1.012–1.032)**
	% Zero-Vehicle HHs	1.010	(0.998–1.022)	1.014	(0.996–1.032)	**1.028**	**(1.003–1.053)**	1.020	(0.991–1.049)
	Unemployment Rate	0.993	(0.980–1.007)	0.986	(0.964–1.008)	**0.955**	**(0.921–0.991)**	**0.941**	**(0.900–0.985)**
	% Multifamily Housing	1.004	(0.995–1.014)	1.005	(0.992–1.018)	1.004	(0.987–1.021)	1.006	(0.987–1.026)
	Median Age of Housing	**1.015**	**(1.009–1.022)**	**1.015**	**(1.006–1.024)**	1.007	(0.996–1.019)	1.001	(0.988–1.015)
	Jobs per Capita	1.056	(0.995–1.121)	0.985	(0.910–1.066)	**0.884**	**(0.808–0.967)**	**0.883**	**(0.796–0.979)**
% Jobs	**Retail**	**1.012**	**(1.002–1.021)**	**1.013**	**(1.001–1.026)**	1.012	(0.998–1.026)	1.011	(0.995–1.027)
% Jobs	**Food/Accom/ Entertain**	**1.011**	**(1.002–1.021)**	1.010	(0.997–1.022)	0.998	(0.983–1.014)	0.995	(0.978–1.014)
% Jobs	**Industrial**	1.001	(0.991–1.010)	0.997	(0.985–1.010)	0.992	(0.977–1.008)	0.987	(0.969–1.005)
% Jobs	**General Services**	1.004	(0.996–1.011)	0.998	(0.988–1.008)	0.994	(0.982–1.006)	0.992	(0.978–1.006)
	% Workers w/ ≤ HS Education	1.012	(0.986–1.038)	1.015	(0.979–1.053)	1.016	(0.971–1.065)	1.037	(0.982–1.096)
	Activity Diversity Index	**1.015**	**(1.009–1.021)**	**1.013**	**(1.006–1.021)**	**1.010**	**(1.001–1.018)**	**1.011**	**(1.001–1.022)**
	Residential Density (100s per sq. mi.)	**1.009**	**(1.004–1.014)**	**1.010**	**(1.003–1.016)**	1.001	(0.994–1.009)	1.002	(0.994–1.011)

Note: IRRs represent % change in fatalities with 1-unit increase in row variable. All row variables except jobs per capita and residential density are expressed in percentile or percentage points. Bolding indicates significance at the 95% level.

Figure 18 shows the distribution of the SVI for the census tracts where pedestrian crashes occurred, as well as the citywide population-weighted median (i.e., the SVI of the census tract where the median resident lives), grouped by the two periods and by crash severity, overall and for crashes on arterials in darkness. In the earlier period examined (2013–2017), the locations of pedestrian injury crashes and fatal crashes were distributed similarly with respect to SVI, with approximately 70% of injury crashes and 71% of fatal crashes occurring in neighborhoods with higher levels of vulnerability than the citywide median. In the more recent period (2018–2022), the median SVI at the locations of pedestrian injury and fatal crashes decreased slightly, but the distribution narrowed, and the proportions occurring in neighborhoods more vulnerable than the citywide median increased to 76% of injury crashes and 80% of fatal crashes. Locations of fatal pedestrian crashes on urban arterials in darkness were quite similar to overall fatal pedestrian crash locations with respect to SVI.

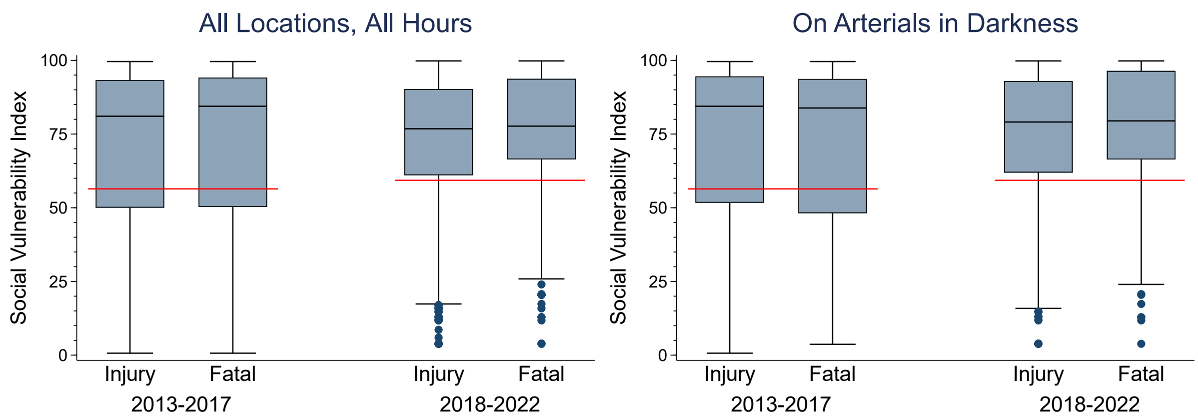


Figure 18. Social Vulnerability Index of locations of pedestrian fatal and injury crashes, Albuquerque, NM, 2013–2022. Note: Red lines represent citywide population-weighted median.

Median characteristics of the locations at which pedestrian crashes occurred are shown in Table 10. Pedestrian crashes tended to occur in locations where the percentage of households without vehicles was much greater than the citywide median. Interestingly, this disparity narrowed from the earlier period to the later period for pedestrian injury crashes, but widened for fatal crashes. Also notably, the median percentage of households residing in large multifamily buildings was much greater in the neighborhoods where pedestrian injury and fatal crashes occurred compared with the citywide median, and increased from the earlier period to the later period. The median ADI and number of jobs per capita were both much higher at locations of pedestrian injury and fatal crashes compared with the citywide median, indicating that crashes involving pedestrians tended to occur in areas oriented toward more commercial activity as opposed to residential neighborhoods. The median distance of pedestrian crashes from the city center was over 4 miles in both periods for all categories of crashes examined. However, the median distance of fatal pedestrian crashes from the city center decreased from the earlier period to the later period, indicating a greater proportion occurring relatively closer to the city center in recent years than in the past.

Table 10. Median characteristics of locations at which pedestrian injury & fatal crashes occurred, Albuquerque, NM, 2013–2022.

	Citywide		Injury & Fatal Crash Locations				Fatal Crash Locations			
			All		Arterials in Darkness		All		Arterials in Darkness	
	2013–17	**2018–22**	**2013–17**	**2018–22**	**2013–17**	**2018–22**	**2013–17**	**2018–22**	**2013–17**	**2018–22**
Social Vulnerability Index	56.4	59.3	81.5	76.8	84.4	79.1	84.4	77.7	83.9	79.5
% Zero-Vehicle HHs	3.8	4.3	12.2	10.2	12.0	9.8	7.9	10.0	6.8	9.3
Unemployment Rate	5.2	3.9	6.2	4.7	6.2	4.7	6.4	4.6	6.4	4.5
% HHs in Buildings w/ 50+ Units	2.1	1.6	5.1	6.3	4.9	6.3	4.2	7.2	5.1	7.4
Median Year Housing Built	1980	1980	1972	1971	1972	1971	1975	1972	1975	1972
Jobs per Capita	0.17	0.18	0.54	0.42	0.43	0.40	0.38	0.40	0.38	0.40
% Jobs–Retail	9.4	11.7	13.7	12.2	13.8	13.1	14.0	13.1	15.0	13.1
% Jobs–Food/Accom/Entertain	11.5	11.0	11.8	11.2	11.9	12.6	12.1	11.2	12.1	11.8
% Workers w/ ≤ HS Education	34.1	35.2	34.7	35.6	35.2	36.3	35.4	36.4	35.2	36.8
Activity Diversity Index	33.0	33.8	57.3	56.6	54.2	55.8	50.4	55.8	50.2	55.8
Residential Density (100s per sq. mi.)	41.5	45.9	43.4	47.6	43.7	49.2	43.4	46.2	43.4	46.5
Distance from City Center (mi)			4.4	4.5	4.7	4.7	4.5	4.3	4.7	4.3

Clustering. Figure 19 illustrates the geographic distribution of fatal pedestrian crashes in Albuquerque, with those in clusters shown in purple and those outside of clusters in green. Overall, 140 of 295 fatal pedestrian crashes (47%) occurred in clusters of pedestrian-involved injury and fatal crashes, indicating that these were places with a high density of pedestrian crashes, whereas the remaining 53% occurred outside of such clusters. The percentage of pedestrian non-fatal injury crashes that occurred in clusters was slightly higher than the corresponding percentage among fatal crashes at 53% (Table 11).

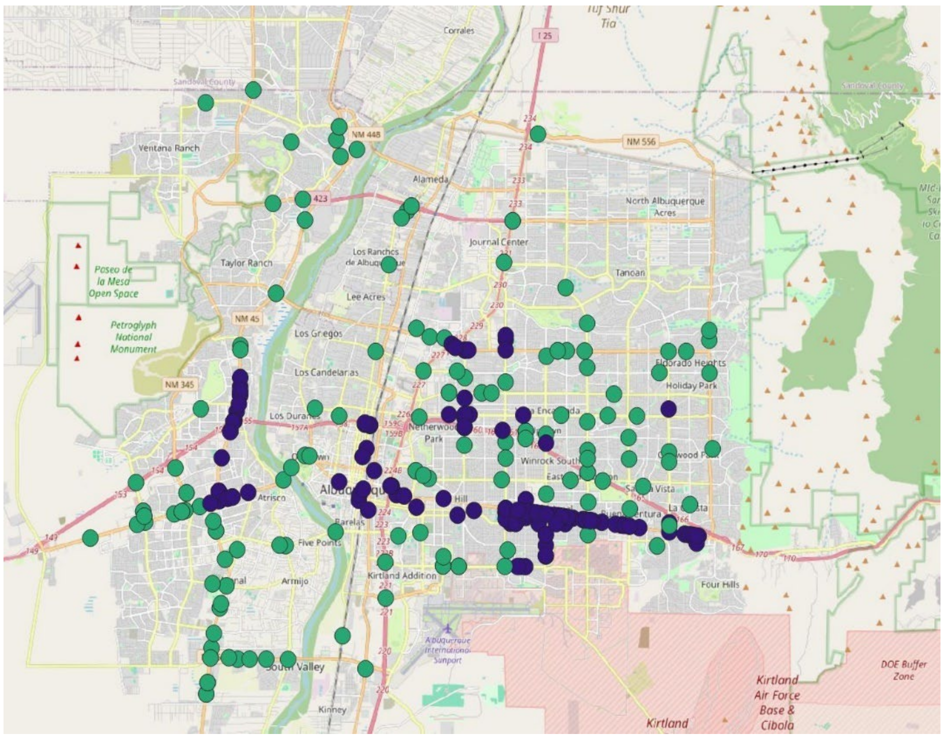


Figure 19. Fatal pedestrian crashes in Albuquerque, NM, 2013–2022 (crashes in clusters shown in purple)

Fatal crashes in clusters were less widely distributed than those not in clusters. Many of the fatal crashes that occurred along arterials were in clusters. However, fatal pedestrian crashes that occurred outside of pedestrian crash clusters had several notable similarities to those that occurred inside of clusters: virtually all (92%) occurred on arterials, 54% occurred in darkness, and 48% occurred in darkness on arterials, very similar to the corresponding percentages among fatal pedestrian crashes that occurred in pedestrian crash clusters (98% on arterials, 44% in darkness, 44% on arterials in darkness). Among non-fatal injury crashes, those that occurred in clusters were much more likely to occur on arterials and slightly more likely to occur in darkness. Fatal crashes were much more likely than non-fatal crashes to occur on arterials and in darkness irrespective of clustering.

Table 11. Pedestrian injury and fatal crashes on arterials and in darkness in relation to clustering, Albuquerque, NM, 2013–2022

		N	% on Arterials	% in Darkness	% on Arterials in Darkness
Fatal	**All**	295	95%	49%	46%
	Inside of Clusters	140	98%	44%	44%
	Outside of Clusters	155	92%	54%	48%
Injury	**All**	2,396	81%	22%	19%
	Inside of Clusters	1,267	88%	24%	22%
	Outside of Clusters	1,129	74%	21%	16%

Table 12 shows rate ratios indicating the relative proportions of pedestrian crashes occurring inside versus outside of clusters in relation to selected neighborhood characteristics. Results are shown for models based on all crashes including fatal crashes and for fatal crashes only, at all hours of the day and during darkness only. Pedestrian crashes were more likely to be clustered in areas with higher levels of social vulnerability, higher activity diversity, older housing, lower unemployment, and higher proportion of households having zero vehicles. Activity diversity was only associated with crash clustering in the model that included injury crashes at all hours of the day, other rate ratios were similar in magnitude and consistent in direction in all four models. Some results were not statistically significant in the model of fatal crashes, likely due to the smaller number of crashes included in that model, but rate ratios in models of fatal crashes were similar or identical to those in corresponding models that included injury crashes in addition to fatal crashes.

Table 12. Rate ratios for characteristics of locations of pedestrian crashes in and out of clusters, Albuquerque, NM, 2013–2022

	Injuries & Fatalities		Fatalities Only	
	All Times	**Darkness Only**	**All Times**	**Darkness Only**
Social Vulnerability Index	**1.02 (1.01–1.02)**	**1.02 (1.01–1.02)**	**1.02 (1.01–1.03)**	**1.03 (1.02–1.05)**
Activity Diversity Index	**1.01 (1.00–1.01)**	1.00 (1.00–1.00)	1.00 (0.99–1.01)	1.00 (0.99–1.01)
Median Housing Age	**1.02 (1.02–1.02)**	**1.02 (1.01–1.02)**	**1.02 (1.01–1.03)**	1.01 (0.99–1.04)
Unemployment Rate	**0.97 (0.96–0.98)**	**0.96 (0.94–0.97)**	**0.96 (0.93–1.00)**	**0.92 (0.88–0.97)**
% Multifamily Housing	**1.00 (1.00–1.01)**	1.00 (1.00–1.01)	1.01 (0.99–1.02)	1.01 (0.99–1.03)
% Zero-Vehicle Households	**1.05 (1.04–1.06)**	**1.05 (1.03–1.06)**	**1.04 (1.01–1.06)**	1.02 (0.98–1.07)

Note: 95% confidence intervals for the IRRs are shown in parentheses. Bolding indicates significance at the 95% level. Median housing age calculated as 2024-median year built.

Findings from Literature Scan and Interview with a City Official

The adoption of Albuquerque's Complete Streets Program in 2015 marked a pivotal shift in the City's transportation safety priorities. Albuquerque's Complete Streets Program was updated in 2019 to include equity considerations that outline how the city will prioritize new projects. Prior to 2019, there was minimal direction on project prioritization and development tended to favor the Downtown District. The 2019 update is a crucial step in expanding the reach of transportation safety throughout the entire city, while prioritizing projects that will benefit the city's most underserved communities. Key countermeasures that have been installed because of the Complete Streets Program include protected bike lanes, daylighting, and midblock crossings with protected pedestrian refuges throughout the whole city. The city of Albuquerque has found inspiration from similar efforts taking place in Oakland, California.

In 2019, Albuquerque Mayor Tim Keller made a commitment to Vision Zero and set a goal of eliminating deaths through an executive order. This executive order delegated the responsibility of program implementation to the City's public works department and set a goal of eliminating traffic deaths by 2040. In 2021, the City's Public Works Department debuted its Vision Zero action plan. This follows a theme of elected public officials driving roadway safety efforts within the City of Albuquerque through the Department of Public Works (DPW).

Additionally, in 2021, the City of Albuquerque passed legislation that consolidated, revitalized, and rebranded the Greater Albuquerque Bicycling Advisory Committee and Greater Albuquerque Recreational Trails Committee as the Greater Albuquerque Active Transportation Committee (GAATC). The GAATC originally started meeting on an ad-hoc basis but through this centralization process, it has been given a more prominent role within the city, which aims to increase access to active transportation within the city. Currently, GAATC meets monthly and "is composed of nine advocates representing different regions and user groups within the city." GAATC's efforts advise a variety of transportation safety stakeholders throughout the city, including elected officials and governmental agencies, on "projects, policies, and programs" impacting active transportation.

Other guiding plans within the City of Albuquerque's pursuit of Vision Zero include the Albuquerque & Bernalillo County (ABC) Comprehensive Plan, Development Process Manual, and even the Climate Action Plan.

The ABC Comprehensive Plan presents the city's growth, planning, and development priorities. It contains all needed information relating to the city's priority and enhancement areas. All projects implemented within the city must reference and follow the specific priority areas within the ABC Comprehensive Plan. The current version of Albuquerque's ABC Comprehensive Plan was updated in 2017, and an interactive version of the plan is publicly available on the city's website. In May 2024, the

ABC Comprehensive Plan was updated, however, Bernalillo County has not formally adopted the plan (City of Albuquerque, n.d.-a).

Albuquerque's Development Process Manual serves as the city's specification guide for all development projects. All new infrastructure projects are required to meet the specs listed within the Development Process Manual, which contains specs and requirements relating to all possible bike and pedestrian interventions involving the modification of current facilities and infrastructure. In addition to the Development Process Manual, the City of Albuquerque has adapted pedestrian and bicycle safety efforts into the city's Climate Action Plan, which includes a commitment to mode shift concepts to combat climate change. This commitment has led to the City of Albuquerque prioritizing the development of pedestrian and bicycle infrastructure with the hope that residents will feel more comfortable with modes of active transportation.

The City of Albuquerque faces several policy and development challenges including funding, staffing, and old infrastructure. Funding remains the largest barrier for the city. It has been difficult for the City of Albuquerque to participate in grant opportunities like SS4A due to logistical difficulties in meeting requirements for matched funding. Additionally, the DPW is limited due to a workforce deficit of 60%. It is worth noting that despite these challenges, the Albuquerque DPW was successful in navigating the initial rejection of an update to the city's Vision Zero Action Plan in 2023. This is largely due to a department-wide effort to demonstrate a clear prioritization of thematic goals aligned with Albuquerque's ABC Comprehensive Plan.

This prioritization effort is largely informed by the Albuquerque DPW development of a comprehensive High Injury Network (HIN). Through the development of its HIN, the City of Albuquerque has been able to identify areas within its transportation network that require the most attention for the improvement of transportation safety outcomes. This follows a larger effort by the department to develop comprehensive evidence-based approaches to program development and implementation. The HIN has enabled the department to strengthen the decision-making process at the staff level.

In addition to the development of its HIN, the DPW has made a substantial effort to address how the city responds to fatal crashes. This effort is represented by a partnership between the City of Albuquerque DPW, Mid-Region Council of Governments, and the Albuquerque Police Department (APD) at monthly fatal crash review meetings at which the group attempts to identify the causes of crashes and utilizes the APD's Fatal Crash Response Team. In this effort, the DPW utilizes report findings to determine if a crash is preventable or not preventable. When it is determined that a crash is preventable, the DPW will attempt to identify engineering-based solutions that can make Albuquerque roads safer for all users.

The monthly meetings have also been useful in overcoming the challenges caused by the two-year delay that comes with acquiring crash data. The meetings greatly benefit the Albuquerque DPW by allowing them to react in real-time to crashes within the city. The DPW's utilization of the findings represents another step that the city is taking to adapt and normalize Vision Zero considerations in day-to-day operations. Furthermore, the Vision Zero Action Plan has now become a key resource for the development and implementation of new projects throughout the City of Albuquerque.

The City of Albuquerque DWP has also turned to Road Safety Audits (RSAs) to "improve safety and increase multi-modal transportation options" as a part of their Complete Streets improvement effort (City of Albuquerque, n.d.-b). The first RSA took place in 2020 and prioritized Louisiana Boulevard. Louisiana Boulevard was selected because it represents one of the city's most diverse populations and falls within the City of Albuquerque's HIN. This RSA enabled the DPW to engage with residents to identify solutions that would make it easier for residents to walk and bike safely between locations in their neighborhood. The RSA provided key information indicating that bicycle infrastructure was lacking and that residents did not feel that there were enough safe crossing opportunities on Louisiana Boulevard despite it being a primary access route within the city. RSAs have assisted the city in gaining access to Highway Safety Improvement Program funding from the Federal Highway Administration (FHWA). With this funding, Albuquerque will install the city's first separated bike lane on Louisiana Boulevard, in addition to three mid-block crossing points with pedestrian hybrid beacons. The DPW also collaborates with the Mid-Region Council of Governments, which has received formal RSA training from FHWA and has become a valuable resource for the department, to conduct further RSAs.

Combining the efforts behind the RSA on Louisiana Boulevard and the HIN, the City of Albuquerque DPW has identified that 90% of its HIN is represented by principle arterial roadways. With these findings, the City of Albuquerque has been able implement a variety of countermeasures designed to decrease transportation related deaths and fatalities within the HIN. Albuquerque's DPW has made it a priority to make crossing these roads safer for residents by adjusting leading pedestrian intervals and increasing crossing opportunities. The DPW has identified that arterials within the city are over built and has designated arterials as priority within the Vision Zero Action Plan. However, the City of Albuquerque's effort to improve conditions for pedestrians on arterial roadways does come with financial challenges. Much of the infrastructure on arterial roads is outdated and requires major upgrades to traffic signals, wiring, and pedestrian facilities, which make improvements more expensive than typically expected.

Additionally, the City of Albuquerque has encountered public resistance to infrastructure projects within the city. To alleviate the impacts of this challenge, the city has relied on its network of community pedestrian and bicycle advocates to educate and inform their neighbors about the benefits associated with said projects. Also, the DPW has used its efforts with automated enforcement to create a media campaign showing the importance of speed reduction in Albuquerque. By being able to demonstrate that decreases in speed saves lives, the city has been able to develop evidence-based messaging for the residents of Albuquerque.

Despite these efforts, fatalities, and injuries at nighttime on arterial roads still represent a crucial challenge for the City of Albuquerque. Even with the focus on lighting on the city's arterials, an obligation of the Development Process Manual, pedestrian and bicycle fatalities disproportionately occur during darkness on arterial roads.

Discussion

Systems Analysis Using AcciMapping

The AcciMap approach is a systems-based tool used to analyze interconnected events, conditions, and decisions that result in an “accident,” such as a motor vehicle collision. At the outset of the project, the team used the AcciMapping approach to hypothesize the causes and contributing factors for a single fatal pedestrian crash that occurred on an urban arterial road, Martin Luther King Jr Boulevard during nighttime in Chapel Hill, NC. While all the details of a single crash may not be completely generalizable to all similar crashes nationwide, analysis at multiple levels allowed the team to uncover factors that may be present in other crashes and worthy of further exploration. This exercise also helped frame research questions to further explore in the case studies.

In this AcciMapping exercise, the group reviewed the crash report and death certificate for the pedestrian fatality, reviewed relevant media reports and obituary notices, reviewed a video of the crash, performed a state and local policy scan, and conducted a crash site visit. Over a series of workshops, through an iterative process, the research team generated an AcciMap for the incident. The structure of the AcciMap moves from the most immediate causes at the bottom of the map (e.g., vehicle speed at impact, presence/quality of lighting, or road user actions) up to the more distal contributing factors at the local, state, and federal levels, and ultimately, to culture and societal norms implicated in the causal pathway. The discussions that occurred in developing the AcciMap point to the potential for use of this tool. Crash reports provide information about the most proximal factors (i.e., the lower part of the maps). In the AcciMapping workshops, the team presented information on policies, including those governing land use, roadway design, speed limit setting, and transportation funding, and used any relevant information to build the causal chains from these factors to the pieces of the map immediately preceding the crash. In doing so, the exercise moves beyond a simple analysis of the specific crash event to also explore more of the factors from the transportation and wider regulatory and social systems that contribute to this single crash. Understanding the systemic causes then allows uncovering how these factors may be contributing to larger trends in roadway safety, while identifying potential interventions.

The AcciMap exercise pointed to a number of contributing factors at various levels that led to the incident on MLK Jr Blvd. These included the following:

- ***Environmental factors*** such as poor visibility and lack of safe pedestrian crossings
- ***Local-level factors*** such as limited control over the roadway, poor sidewalk maintenance, and the prioritization of auto infrastructure over pedestrian infrastructure
- ***State-level factors*** such as the lack of policies, funds, and action to support pedestrian infrastructure, state prioritization of motor vehicle throughput over safety, and state alcohol sales policies
- ***Federal-level factors*** such as insufficient funding for pedestrian projects, inadequate vehicle regulations oriented towards pedestrian safety, and the prioritization of motor vehicle throughput over safety
- ***Societal factors*** such as societal acceptance of traffic injuries and fatalities, pedestrian risk-taking behaviors, economic inequalities, and substance use and abuse

These factors were all identified in the causal chains in the map for this single crash; however, they are not unique to the analyzed crash.

Case Studies

To complement the systems analysis, the team next developed a case study approach to further investigate circumstances driving the increase in pedestrian fatalities on urban arterials at night. Case study analyses explored safety outcomes and efforts at the city level for locations with differing trends in pedestrian fatalities and varying approaches to pedestrian safety policy. The cities of Charlotte, NC; Memphis, TN; and Albuquerque, NM, were selected for case study analyses. Analyses of crash data, policy scans, and interviews with city officials examined neighborhood characteristics of pedestrian crash locations, clustering trends in pedestrian crashes, and the policy landscape related to pedestrian safety in each city.

Results of the analysis of data from pedestrian fatal and injury crashes revealed several similarities across the three cities. Consistent with national data, a large majority of pedestrian fatalities occurred on arterial roads in all three cities and about half occurred in darkness. A far greater proportion of pedestrian fatalities than non-fatal injury crashes occurred on arterial roads in darkness. In all cities, neighborhoods with higher levels of social vulnerability, a greater proportion of multifamily housing units, a greater proportion of jobs in the arts/entertainment/food/accommodations category, and an older housing stock were associated with higher rates of pedestrian crashes both overall and specifically on arterials in darkness. Focusing on fatal crashes, social vulnerability was the only neighborhood characteristic significantly associated with higher fatal crash rates in all three cities. Higher social vulnerability was associated with higher fatal crash rates both at all hours of the day and specifically on arterials in darkness, with similarly sized and strong associations observed in all three cities.

In all cities, injury and fatal pedestrian crashes occurred in more vulnerable neighborhoods at all times of the day and in darkness. Interestingly, the analysis of neighborhood characteristics indicated a median SVI of roughly 0.75 for pedestrian fatalities (both overall and in darkness) in all three case study cities, despite each city having a very different level of social vulnerability overall (~0.35 for Charlotte, ~0.70 for Memphis, and ~0.55 for Albuquerque). In both Albuquerque and Charlotte, the analysis of neighborhood characteristics indicated less variability in the SVI score of pedestrian fatal crashes in 2018–2022 compared to the 2013–2017 period. That is, results suggest fatal pedestrian crashes are becoming more concentrated in areas of greater disadvantage in more recent years.

In all cities, many fatal pedestrian crashes occurred in clusters close to locations where other pedestrian crashes occurred, between 33% and 47% depending on the city. However, a majority of fatal pedestrian crashes occurred outside clusters on streets not known to be dangerous for pedestrians. There were some similarities in the neighborhood characteristics of crash locations in fatal crashes located in clusters compared to outside clusters. Compared to those outside clusters, fatal crashes inside clusters tended to occur in neighborhoods with an older housing stock (all case study cities), in areas with higher levels of social vulnerability (in Memphis and Albuquerque only), and in areas with greater proportions of zero-vehicle households (Charlotte and Albuquerque only).

The policy scan in Charlotte, Memphis, and Albuquerque identified some crucial challenges to improving pedestrian safety. These included the high cost of fixing the arterial networks, tensions between roads designed for vehicle thoroughfare and pedestrian safety, local challenges of implementing interventions on state-controlled roads, and public resistance to change. All cities faced financial challenges with the scale of changes needed to upgrade the arterial network. Cities reported that they have already executed lower cost and easier to implement countermeasures, indicating that the remaining potential improvements are larger in scale and more costly. A key pedestrian safety challenge cities face is state ownership of many of the arterial roads where pedestrian fatalities occur. Charlotte has overcome this challenge by taking over ownership of many arterial roads from NCDOT. This has given the City of Charlotte more latitude to make changes directly for pedestrian safety, such as reducing speed limits.

An overarching theme in the policy scans of the three different cities was the importance of cultural attitudes towards active travel and safety. In Memphis, the policy scan indicated that pedestrian injury tended to be framed as an individual behavioral problem, rather than a systemic issue, and reported public resistance to infrastructure projects aimed at improving pedestrian safety. By contrast, interviewees in Charlotte reported a pro-safety culture with support from both the City Council and larger constituency for safety improvements. Both Charlotte and Albuquerque have explicit targets to reduce private car use and increase active travel, which provides further incentive for these cities to improve safety infrastructure.

Comparison with Other Work

Findings from this analysis concur with recent cross-sectional work illuminating associations between pedestrian fatalities and various measures of neighborhood disadvantage in many places in the United States, both overall (Roll & McNeil, 2022; Younes et al., 2023) and specifically at night (Mwende et al., 2024). Across all three case studies included in this analysis, higher levels of neighborhood social vulnerability were consistently associated with increased pedestrian fatal crash rates both during all times of the day and specifically on arterials during darkness. There are many mechanisms linking neighborhood disadvantage to pedestrian fatality risk, including less access to vehicles with the latest safety technology for the resident population (or any vehicles at all), potential differences in safety transportation infrastructure quality (Morency et al., 2012; Nicoletti et al., 2022; United States Government Accountability Office, 2022), and access to timely high-quality trauma care (Carr et al., 2017).

Similar to Mansfield et al. (2018), findings from case study analyses indicate that pedestrian crash and fatality rates were higher in neighborhoods with both a greater proportion of jobs in the arts/entertainment/food/accommodations category and a greater diversity of activity mix (a measure of the relative amounts of different types of jobs present in a place). As noted by Mansfield and colleagues, high retail and entertainment/food/accommodations employment density is likely associated with pedestrian exposure and may also be associated with other risk-increasing factors, such as proximity to establishments that serve alcohol. In a study focused on one of the selected cities for this project, Albuquerque, NM, Long & Ferenchak (2021) found that nighttime pedestrian fatality and severe injury rates within a quarter mile of alcohol establishments were higher than other commercial areas of the city. While these cross-sectional studies are helpful in determining associations, the causal mechanisms linking activity mix, entertainment/food/accommodations employment density, and pedestrian fatalities are unclear and require additional research.

One hypothesis that grew out of the AcciMap exercise relates to the suburbanization of poverty, as lower income populations both have less vehicle access and are more likely to live along higher-speed arterial roads. Case study analyses also lend support to hypotheses linking increasing trends in pedestrian fatalities to population trends in the suburbanization of poverty. Using data from Los Angeles, Chicago, Houston, Pheonix, Dallas, San Antonio, Detroit, Baltimore, and Milwaukee, Sanchez Rodriguez and Ferenchak (2023) found that pedestrian fatalities more often occurred in neighborhoods with high levels of poverty, and the authors uncovered a trend of fatalities moving away from downtown areas towards the suburbs in more recent years (2017–2020) compared to previous years (1999–2002). The authors noted that many of the areas with increasing pedestrian fatalities in more recent years tended to have lower densities and less pedestrian activity overall, suggesting a growing need for pedestrian safety interventions in more suburban locations where the need to accommodate pedestrians had not necessarily been prioritized previously.

Findings from the neighborhood characteristics analysis of this study confirm associations between fatal pedestrian crashes and high levels of neighborhood social vulnerability in three additional cities. While time periods differ from the Sanchez Rodriguez and Ferenchak (2023) study, this study's cluster analysis confirms clusters of pedestrian crashes both in downtown areas and in more suburban locations. Finally, findings from the policy scan highlight important cultural barriers to pedestrian safety infrastructure implementation on more suburban arterial locations. These findings back up results from the AcciMap exercise, where the crash analyzed occurred on a state road where the purpose of vehicle throughput comes into conflict with the land uses and activity lining the roadway. Overall, culturally, many of these roads are perceived as thoroughfares for vehicles, and infrastructure changes face public resistance.

These results concur with recent research that highlights the role of traffic safety culture on safety related trends (Kumfer et al., 2024). Traffic safety culture refers to the "shared belief of a group of people, which influences road user behaviors and stakeholder actions that impact traffic safety (Austin et al., 2021). Findings from the Accipmap exercise on-site visit confirmed a local culture of risk acceptance among pedestrians. Findings from the case study interviews indicated a resistance to prioritizing pedestrian safety infrastructure over travel efficiency among both residents and transportation organizations in two of the three case study cities. Taken together, these indicate that much work needs to be done to change social norms and organizational cultures in order build a healthier traffic safety culture in some areas. However, in the other case study city, Charlotte, interviewees reported more positive traffic safety cultures. A better understanding of how and why traffic safety cultures differ, and how and why they change may help to further illuminate contributors to differences in pedestrian safety trends.

Limitations

While the site and crash circumstances in the AcciMap analysis shared common features of many crashes on urban arterials, the AcciMap exercise focused on a single crash. The results of the analysis were used to develop topics related to potential causes and contributing factors for the rise in pedestrian fatalities in these circumstances. However, results from analyzing a single crash cannot be completely generalized to the wider trends across the country. There are elements of the crash used in the AcciMap exercise that may be unique to the location and surrounding circumstances and thus not reflective of factors nationwide. The team must be careful to note that AcciMapping serves as an exploratory tool to uncover potential, systemic factors related to these types of crashes rather than finding conclusive evidence.

A potential threat to the reliability of case study analyses is data completeness. Not all pedestrian crashes are reported to the police, and there may be differences in the propensity to report pedestrian crashes over time in each case study city, which may change over time. Further, neighborhood characteristics may affect whether a pedestrian crash is reported to the police. Misclassification is another threat to studies focused on pedestrians. In a study that utilized multiple sources of data to examine pedestrian deaths in New Jersey in 2012, Noland et al. (2017) found substantial evidence of misclassification of whether crash victims were pedestrians. The authors reported that several fatalities classified in FARS as pedestrians should not have been classified as pedestrians, and several pedestrian fatalities identified in the state DOT's crash database were missing from FARS (Noland et al., 2017).

Another key limitation of case study city analyses is the lack of data on pedestrian exposure. To our knowledge, there is not sufficient quality data detailing pedestrian exposure that would be appropriate to use as denominators in rate calculations. Analyses computed rates based on the resident and daytime population, and attempted to account for pedestrian exposure by including variables likely to be associated with it, such as population density, zero-vehicle households, and job-related characteristics in each neighborhood.

Implications

Critical data in road safety include crashes, traffic volumes, and road characteristics (World Health Organization, 2023). All three of these represent a challenge when it comes to pedestrian safety research. Firstly, in order to create a reliable collision and exposure dataset to address pedestrian safety, it is necessary to improve data, such as linking hospital and/or police report data and crash data, which could be immensely helpful to address pedestrian deaths and injuries. Additionally, overcoming the systematic biases in crash reporting is required. Even if the underlying cultural and economic factors that may underpin underreporting of pedestrian crashes in particular cannot be addressed, some temporary measures may help to improve the situation. A specialized field study in a given location, for example, might assess the amount of under-reporting (or the real ratio of pedestrian to other collisions), which could then be used as a correction factor to estimate the true magnitude of pedestrian fatalities, injuries, and costs (Job, 2020).

Secondly, it is necessary to evaluate the interventions with rigorous study designs to support evidence-based decision-making. Although much progress has been made in understanding pedestrian behaviors and the risk that pedestrians are exposed to in traffic, not enough success has been achieved in reducing pedestrian crashes in both motorized and less-motorized areas. Additionally, while many evaluation results are reported about interventions in the literature, it is not always possible to know with sufficient confidence what works and what does not. It is necessary to consider the specific road users before deciding on and implementing interventions. Education and communication efforts should target the specific audience. Road safety strategies are based on data, but there remains insufficient high-quality systematic evaluation of road safety interventions and their effectiveness on pedestrian injuries (Namatovu et al., 2022). Rigorous evaluations of built-environment interventions, including randomized controlled trials, quasi-experimental research, and controlled pre-post studies, are needed to assess their effectiveness on both active transportation and pedestrian injuries (Stoker et al., 2015).

Furthermore, in order to achieve continuous improvement in pedestrian crash injury avoidance, evidence-based policies must adopt a systematic approach and include the relationship between road safety policy, transportation planning, environmental design, and health. Policies to encourage walking and those to increase pedestrian safety should not be implemented separately. Interventions must use an environmental design approach in order to achieve a system that is forgiving of human error (Wegman et al., 2015). Integrating road safety into larger urban policies is important and should entail collaboration among decision-makers, practitioners, and researchers. Additionally, decisions related to pedestrian safety should be data-driven and evidence-based and take a long-term view involving consultation and consensus with decision-makers, citizens, and politicians, but this is often in conflict with the political need for quick results.

Next, multidisciplinary collaboration between researchers and practitioners is the key to success in reducing pedestrian fatalities as an ultimate goal. As for many other public health issues, collaboration between researchers, public health professionals, decision makers, and practitioners is essential to achieve success in injury reduction. Moreover, a Safe System approach, which addresses infrastructure, human behavior, responsible oversight of the vehicle and transportation industries, and emergency response, requires collaboration across disciplines (Finkel et al., 2020). Broad collaboration is also essential to plan and implement an evaluation process early into intervention projects. However, the decision-making process related to road safety is often heavily influenced by public opinion. The management of road safety will be most successful if policy makers are involved in the research process from the start and vice versa.

References

Austin, E., Otto, J., Green, K., Watson, H., Ward, N. J., Dively, K., & Montana State University (Bozeman, Mont.)–Center for Health and Safety Culture. (2021). *Guidance for Evaluating Traffic Safety Culture Strategies* (FHWA/MT-21-001/8882-309-14). Federal Highway Administration. https://doi.org/10.21949/1518313

Birant, D., & Kut, A. (2007). ST-DBSCAN: An algorithm for clustering spatial–temporal data. *Intelligent Data Mining*, *60*(1), 208–221. https://doi.org/10.1016/j.datak.2006.01.013

Bogel-Burroughs, N. (2019, October 22). Deadliest Year for Pedestrians and Cyclists in U.S. Since 1990. *The New York Times*. https://www.nytimes.com/2019/10/22/us/pedestrian-cyclist-deaths-traffic.html

Branford, K., Naikar, N., & Hopkins, A. (2009). Guidelines for AcciMap analysis. In Hopkins, A. (Ed.), *Learning from High Reliability Organisations* (pp. 193–212). CCH Australia, Limited.

Carr, B. G., Bowman, A. J., Wolff, C. S., Mullen, M. T., Holena, D. N., Branas, C. C., & Wiebe, D. J. (2017). Disparities in access to trauma care in the United States: A population-based analysis. *Injury*, *48*(2), 332–338. https://doi.org/10.1016/j.injury.2017.01.008

Chong, S.-L., Chiang, L.-W., Allen, J. C., Fleegler, E. W., & Lee, L. K. (2018). Epidemiology of Pedestrian–Motor Vehicle Fatalities and Injuries, 2006–2015. *American Journal of Preventive Medicine*, *55*(1), 98–105. https://doi.org/10.1016/j.amepre.2018.04.005

City of Albuquerque. (n.d.-a). *ABC Comprehensive Plan*. City of Albuquerque. Retrieved August 15, 2024, from https://www.cabq.gov/planning/plans-publications/abc-comprehensive-plan

City of Albuquerque. (n.d.-b). *Vision Zero*. City of Albuquerque. Retrieved November 20, 2024, from https://www.cabq.gov/vision-zero

City of Charlotte. (2007). *Urban Street Design Guidelines*. https://www.charlottenc.gov/files/sharedassets/city/v/1/growth-and-development/documents/dev-center-fees/manual/usdg-full-document.pdf

City of Charlotte. (2011). *Transportation Action Plan – Policy Document: 5 Year Update*. https://localdocs.charlotte.edu/Transportation/TransActionPolicy/TAPPolicy/2011_TAPUpdate.pdf

City of Charlotte. (2019). *Road to Vision Zero – Safer Streets for Charlotte: 2019-2030 Action Plan*. Department of Transportation. https://www.charlottenc.gov/files/sharedassets/city/v/1/city-government/departments/documents/vision-zero-action-plan.pdf

City of Charlotte. (2022a). *Charlotte Strategic Mobility Plan: Our Blueprint for Safe and Equitable Mobility*. https://www.charlottenc.gov/files/sharedassets/city/v/1/growth-and-development/documents/smp/charlotte-strategic-mobility-plan_final-plan_adopted-06.27.2022_reduced.pdf

City of Charlotte. (2022b). *Charlotte Streets Map*. https://charlotte.maps.arcgis.com/apps/webappviewer/index.html?id=07aa32663a3e4a84aab2d2c434b1d09e

City of Charlotte. (2023). *Charlotte Streets Manual—Amendment Draft*. https://www.charlottenc.gov/files/sharedassets/city/v/1/growth-and-development/documents/smp/2023/charlotte-streets-manual_amended-draft_marked_june-2023_formatted.pdf

City of Charlotte. (2024). *City of Charlotte Adopts Fiscal Year 2025 Budget*. https://www.charlottenc.gov/CS-Prep/City-News/FY-2025-Budget

City of Memphis. (2013). *An Order Establishing a Complete Streets Policy for the City of Memphis*. https://bikepedmemphis.wordpress.com/wp-content/uploads/2014/12/executive-order-01-2013.pdf

City of Memphis. (2015). *Complete Streets Project Delivery Manual*. https://bikepedmemphis.wordpress.com/plans-and-publications/complete-streets-project-delivery-manual/

City of Memphis. (2019). *Memphis 3.0 Comprehensive Plan*. https://www.memphis3point0.com/

City of Memphis. (2020). *Complete Streets Plan Update*. https://100a0d59-51a0-4e58-a4fe-68ac607f7fbc.usrfiles.com/ugd/100a0d_b820e52ccea9460f9d5624f1c3f567ac.pdf

Finkel, E., McCormick, C., Mitman, M., Abel, S., & Clark, J. (2020, October). *Integrating the Safe System Approach with the Highway Safety Improvement Program: An Informational Report*. Federal Highway Administration (FHWA). https://safety.fhwa.dot.gov/hsip/docs/fhwasa2018.pdf

Holian, M. J. (2019). Where is the City's Center? Five Measures of Central Location. *Cityscape: A Journal of Policy Development and Research, 21*(2), 14. https://www.huduser.gov/portal/periodicals/cityscpe/vol21num2/article12.html

ITE. (2021). *Trip Generation Manual* (11th Edition). ITE.

Job, R. (2020). Policies and interventions to provide safety for pedestrians and overcome the systematic biases underlying the failures. *Frontiers in Sustainable Cities, 2*. https://doi.org/10.3389/frsc.2020.00030

Kumfer, W., LaJeunesse, S., Heiny, S., West, A., Weisenfeld, J., Otto, J., Ward, N., Dively, K., Hanson, B., McAndrews, C., Lavrenz, S., Kash, G., & Brown, C. T. (2024). *Traffic Safety Culture Research Roadmap* (National Cooperative Research Program). Transportation Research Board. https://doi.org/10.17226/27488

Long, B., & Ferenchak, N. N. (2021). Spatial equity analysis of nighttime pedestrian safety: Role of land use and alcohol establishments in Albuquerque, NM. *Transportation Research Record: Journal of the Transportation Research Board*, *2675*(12), 622–634. https://doi.org/10.1177/03611981211030263

Mansfield, T. J., Peck, D., Morgan, D., McCann, B., & Teicher, P. (2018). The effects of roadway and built environment characteristics on pedestrian fatality risk: A national assessment at the neighborhood scale. *Accident; Analysis and Prevention*, *121*, 166–176. https://doi.org/10.1016/j.aap.2018.06.018

Miro. (2023). *Miro online whiteboard*. Miro. https://miro.com/

Morency, P., Gauvin, L., Plante, C., Fournier, M., & Morency, C. (2012). Neighborhood social inequalities in road traffic injuries: The influence of traffic volume and road design. *American Journal of Public Health*, *102*(6), 1112–1119. https://doi.org/10.2105/AJPH.2011.300528

Mwende, S. I., Kwigizile, V., Oh, J.-S., & Van Houten, R. (2024). Investigating Racial and Poverty-Level Disparities Associated with Pedestrian Nighttime Crashes. *Transportation Research Record: Journal of the Transportation Research Board*. https://doi.org/10.1177/03611981241233294

Namatovu, S., Balugaba, B. E., Muni, K., Ningwa, A., Nsabagwa, L., Oporia, F., Kiconco, A., Kyamanywa, P., Mutto, M., Osuret, J., Rehfuess, E. A., Burns, J., & Kobusingye, O. (2022). Interventions to reduce pedestrian road traffic injuries: A systematic review of randomized controlled trials, cluster randomized controlled trials, interrupted time-series, and controlled before-after studies. *PLOS ONE*, *17*(1), e0262681. https://doi.org/10.1371/journal.pone.0262681

National Academies of Sciences, Engineering, and Medicine. (2020). *Identification of Factors Contributing to the Decline of Traffic Fatalities in the United States from 2008 to 2012*. The National Academies Press.

NHTSA. (n.d.). *Fatality Analysis Reporting System | NHTSA* [Text]. Retrieved October 23, 2024, from https://www.nhtsa.gov/crash-data-systems/fatality-analysis-reporting-system

Nicoletti, L., Sirenko, M., & Verma, T. (2022). Disadvantaged communities have lower access to urban infrastructure. *Environment and Planning B: Urban Analytics and City Science*, *50*(3). https://doi.org/10.1177/23998083221131044

Noland, R. B., Sinclair, J. A., Klein, N. J., & Brown, C. (2017). How good is pedestrian fatality data? *Journal of Transport & Health*, *7*(Part A), 3–9. https://doi.org/10.1016/j.jth.2017.04.006

OECD. (2024). *Casualties by age and road user (Edition 2023)* [Dataset]. Organisation for Economic Co-operation and Development. https://doi.org/10.1787/9be30350

Parajuli, S., Cherry, C. R., Zavisca, E., & Rogers, W. (2024). Are Pedestrian Crashes Becoming More Severe? A Breakdown of Pedestrian Crashes in Urban Tennessee. *Transportation Research Record*, *2678*(6), 523–541. https://doi.org/10.1177/03611981231198475

Road to Zero Task Force. (2019). *Town of Chapel Hill Pedestrian Safety Action Plan*. Town of Chapel Hill.

Roll, J., & McNeil, N. (2022). *Pedestrian injuries by social equity factors in Oregon: Measuring statewide pedestrian injury disparity using common data* (TRBAM-22-01315). Article TRBAM-22-01315. Transportation Research Board 101st Annual MeetingTransportation Research Board. https://trid.trb.org/View/1996394

Sanchez Rodriguez, O., & Ferenchak, N. N. (2024). Longitudinal Spatial Trends in U.S. Pedestrian Fatalities, 1999–2020. *Transportation Research Record*, *2678*(5), 904–916. https://doi.org/10.1177/03611981231190637

Schneider, R. J., Sanders, R., Proulx, F., & Moayyed, H. (2021). United States fatal pedestrian crash hot spot locations and characteristics. *Journal of Transport and Land Use*, *14*(1), Article 1. https://doi.org/10.5198/jtlu.2021.1825

Stoker, P., Garfinkel-Castro, A., Khayesi, M., Odero, W., Mwangi, M. N., Peden, M., & Ewing, R. (2015). Pedestrian Safety and the Built Environment: A Review of the Risk Factors. *Journal of Planning Literature*, *30*(4), 377–392. https://doi.org/10.1177/0885412215595438

Tefft, B. C., Arnold, L. S., & Horrey, W. J. (2021). *Examining the increase in pedestrian fatalities in the United States, 2009-2018* [Research Brief]. AAA Foundation for Traffic Safety.

Tennessee Department of Transportation. (n.d.). *Transportation System Overview*. Retrieved November 20, 2024, from https://www.tn.gov/tdot/about/transportation-system-overview.html

Tennessee Department of Transportation. (2018). *Guidance on Setting Speed Limits*. https://www.tn.gov/content/dam/tn/tdot/traffic-engineering/TOM%201801.pdf

Town of Chapel Hill. (n.d.). *Vision Zero Chapel Hill*. Town of Chapel Hill. Retrieved March 22, 2023, from https://www.townofchapelhill.org/residents/transportation/bicycle-and-pedestrian/road-to-zero

Tyndall, J. (2021). Pedestrian deaths and large vehicles. *Economics of Transportation*, *26–27*, 100219. https://doi.org/10.1016/j.ecotra.2021.100219

United States Government Accountability Office. (2022). *National Highways: Analysis of Available Data Could Better Ensure Equitable Pavement Condition* (Report to Congressional Committees GAO-22-104578). United States Government Accountability Office. https://www.gao.gov/assets/d22104578.pdf

U.S. Census Bureau. (n.d.-a). *U.S. Census Bureau QuickFacts: Albuquerque city, New Mexico; Memphis city, Tennessee*. Retrieved September 20, 2024, from https://www.census.gov/quickfacts/fact/table/albuquerquecitynewmexico,memphiscitytennessee/PST045223

U.S. Census Bureau. (n.d.-b). *U.S. Census Bureau QuickFacts: Charlotte city, North Carolina*. https://www.census.gov/quickfacts/fact/table/charlottecitynorthcarolina/PST045219

U.S. Census Bureau. (n.d.-c). *U.S. Census Bureau QuickFacts: Memphis city, Tennessee*. https://www.census.gov/quickfacts/fact/table/memphiscitytennessee/PST045219

Wegman, F., Berg, H.-Y., Cameron, I., Thompson, C., Siegrist, S., & Weijermars, W. (2015). Evidence-based and data-driven road safety management. *IATSS Research*, *39*(1), 19–25. https://doi.org/10.1016/j.iatssr.2015.04.001

World Health Organization. (2023). *Pedestrian safety: A road safety manual for decision-makers and practitioners*. World Health Organization.

Younes, H., Noland, R. B., Von Hagen, L. A., & Meehan, S. (2023). Pedestrian- and bicyclist-involved crashes: Associations with spatial factors, pedestrian infrastructure, and equity impacts. *Journal of Safety Research*, *86*, 137–147. https://doi.org/10.1016/j.jsr.2023.05.005