The Research Bureau

TOWARD SAFER STREETS

Identifying Risk Factors for Non-Motorists in Worcester

REPORT 24-09

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EXECUTIVE SUMMARY

IN WORCESTER'S RAPIDLY EVOLVING URBAN LANDSCAPE, SAFEGUARDING THE CITY'S MOST VULNERABLE ROAD USERS — pedestrians, cyclists, and others outside of vehicles — has emerged as a pivotal concern. This report, coinciding with the ongoing actions under the Worcester Now|Next plan, the Mobility Action Plan (MAP), and the Vision Zero initiative, delves into the intricate web of risk factors contributing to the perilous conditions these users face daily. By scrutinizing the physical attributes of Worcester's roadways, traffic patterns, and the socio-economic and demographic profiles of affected communities, this analysis uncovers the underlying causes of VRU crashes. Through comprehensive data analysis and strategic insights, the report aims to guide Worcester's policymakers in crafting targeted interventions that will transform the city's streets into safer, more equitable spaces for all.

This report is divided into three sections that explore these aspects.

PAGES 3-5 | DISCUSSES GENERAL RISKS AND ONGOING ACTIONS ADDRESSING ROAD SAFETY

- Between 2012 and 2019, an average of **184 crashes involving pedestrians or cyclists occurred per year** in Worcester.
- According to a 2022 report, **Worcester had a pedestrian fatality rate of 3.4 per 100,000 residents** — almost double that of Boston.
- The upcoming Mobility Action Plan identifies that **just 62% of the City's sidewalk network is in "good" condition and that bike lanes only cover 7.2 miles of Worcester streets.**

PAGES 5-11 | ANALYZES DEMOGRAPHIC AND SPATIAL DATA TO UNCOVER TRENDS IN PEDESTRIAN CRASHES

- Residents over 65 constituted only 5.8% of all crashes and 13.3% of total City population but 32.4% of fatal crashes. 2.5 times more males were victims of fatal crashes than females.
- **81.8% of arterial road segments were found to contain a severe vulnerable road user crash.** Similarly, greater traffic level, lane count, and lane width were found to increase severe crash rates. Greater shoulder width and the presence of a median decreased crash rates.
- 9.6% of pedestrian and cyclist crashes occurred downtown. Further, **areas which were found to be historically redlined were found to be over four times likelier to contain a severe crash.** Similarly, **city blocks designated for highest environmental justice concern were over seven times likelier to contain a severe crash than not.**
- **71.4% of Worcester's fatal or severe pedestrian and cyclist crashes occurred within 300 feet of a bus stop**. In comparison, 50% of Boston's crashes occurred in the same range.

PAGES 11-12 | ADDRESSES THE ENVIRONMENTAL, SOCIAL, AND FINANCIAL COSTS OF CRASHES

- High crash rates reduce residents' willingness to walk and bike. **According to the Metropolitan Area Planning Council, 60% percent of respondents reported that they would consider biking if they thought their trips would be safer and more comfortable**.
- In peer cities, **implementing Complete Streets redevelopment plans has created new jobs, raised private investment, and increased property development** — in some cities by up to 111%.
- The Bureau estimates that, in terms of damages, medical costs, reduced productivity, and lost-wages, **Worcester's 2019 pedestrian and cyclist crashes costed $493,644,552.**

PAGE 12 | PRESENTS QUESTIONS TO CONSIDER GOING FORWARD

- **What sensitive areas can be identified for speed limit reductions?**
- **How can the City continue to consider community feedback while implementing safety projects?**
- **What plans can be adopted to ensure that sidewalk maintenance and clearing is timely and adequate?**
- **How will the City prioritize high crash bus stops for improvements to prevent future crashes?**

INTRODUCTION

As the City of Worcester continues its rapid development, addressing transportation concerns for vulnerable road users is crucial. Residents and community leaders have prioritized pedestrian safety as essential to Worcester's growth, and with the adoption of Worcester Now|Next, the impending release of the Mobility Action Plan, and ongoing efforts toward a Vision Zero Plan, a report on road safety is timely.

The report starts by outlining current challenges and initiatives aimed at enhancing safety for pedestrians, cyclists, and other vulnerable road users. Subsequent sections present extensive research on crash victims and contributing risk factors, including road attributes and environmental variables. The prevalence of crashes around WRTA stops is highlighted as a critical area of analysis. Additionally, the report addresses the environmental, economic, and demographic impacts of vulnerable road user safety in Worcester. It concludes by summarizing key issues in the City's transportation infrastructure.

UNDERSTANDING THE RISKS

Why is it important to study crashes involving non-motorists? Vulnerable road users (VRUs), which include pedestrians, cyclists, skateboarders, and other road users outside of vehicles, experience a higher risk of fatality and injury from crashes than motorists.[1] **Across the country, VRU crash rates have surged to some of the highest levels seen in decades, totaling an estimated 7,318 pedestrian fatalities in 2023.** Worcester is not exempt from these challenges. **From 2012 to 2019, VRUs in the city experienced an average of 184 crashes annually, accounting for 47.3% of all fatal collisions.**[2] Addressing concerns for these road users is instrumental in combating road danger in Worcester.

Several studies have revealed significant concerns about Worcester's rate of VRU crashes, when compared to other cities in Massachusetts. For example, a 2017 analysis of pedestrian safety conducted by Boston law firm Sweeney Merrigan and data visualization firm 1Point21 Interactive identified Worcester as having the most hazardous intersections in Massachusetts. **The study found 50 intersections in Worcester with more than five pedestrian collisions between 2001 and 2014 — the highest count in the state.** A subsequent report in 2022 by pedestrian safety advocacy group Walk Massachusetts emphasized these concerns. While Worcester reported a lower absolute count of pedestrian fatalities compared to Boston (7 versus 12), **the fatality rate per 100,000**

Chart 1: Overall Road Crashes (2012-2019)

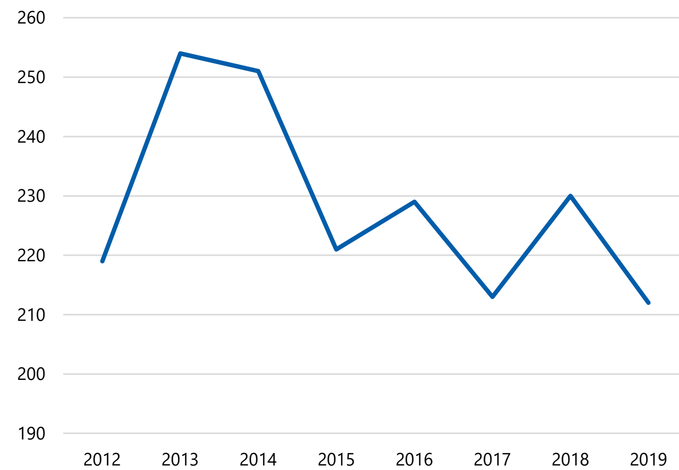
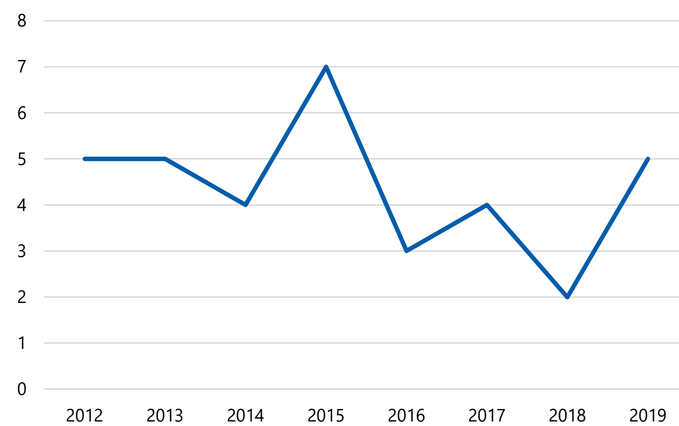


Chart 2: Overall Road Fatalities (2012-2019)



Source: MassDOT Person Level Crash Details, 2012-2019
https://massdot-impact-crashes-vhb.opendata.arcgis.com/

residents was nearly double that of Boston's (3.40 compared to 1.83).

In recent research, much of this risk for non-motorists has been attributed to car-focused development. The May 2024 draft release of Worcester's Mobility Action Plan (MAP) argued that historical development patterns have led to an "overdependence on auto travel," limiting access and safety for road users traveling by other modes. An often-hidden side of this development has been that different communities and demographic groups may experience the City's transportation system in asymmetric and often inequitable ways. MAP demonstrates how Worcester's railroads and highways, for example, segment the city and prevent continuous access to the road network in certain neighborhoods.

Another particularly pernicious effect of this car-centric design is that Worcester's pedestrian infrastructure has been frequently neglected and allowed to deteriorate. **According to MAP, only 62% of the city's sidewalk network was rated in "good" condition** — the best possible rating for a sidewalk's structural condition — with 30% and 8% labeled "fair" and "poor," respectively. The Bureau's 2018 report City on the Move came to similar conclusions, finding that Worcester's sidewalk system extended to only just over half of the total street network. Another potential source of VRU danger in Worcester's current sidewalk network stems from a lack of reliable snow removal. City laws hold property owners responsible for shoveling snow, which can create dangerous walking and biking conditions if owners are forgetful or negligent. All of these limitations present severe challenges to pedestrian mobility in Worcester.

Worcester's bike infrastructure is also insufficient. **MAP reports that as of 2024, bike lanes covered only 7.2 miles of Worcester's streets and 3.4 miles of off-street paths**. Furthermore, existing bike lanes are often disconnected, leading to a segmented and sparse bike network. See the appendix for a map of bike lanes.

CURRENT INITIATIVES AND PLANS

In recent years, city officials have increasingly pinpointed transportation safety as a central concern for the City of Worcester. For example, Worcester Now|Next called for a Mobility Action Plan. Set to be finalized in 2024, the MAP's most recent draft identifies key projects and scrutinizes avenues to enhance safety, connectivity, equity, and sustainability in Worcester's transportation infrastructure. So far, the plan has developed 46 independent strategies tackling everything from accessibility to safety, with significant input from residents and community leaders.

One such strategy is the continued implementation of the Complete Streets Policy. **Worcester adopted a Complete Streets Policy in 2017, committing the City to implementing guidelines for safe, multimodal street design** from the National Complete Streets Coalition. All subsequent projects ultimately adhere to the Complete Streets model, which includes improved and repaved pedestrian markings, bike lanes, dedicated bus lanes, loading zones, and green infrastructure, among other location-specific safety changes. In 2021, a MassDOT grant prompted the Complete Street Prioritization Plan, which identified and analyzed Worcester's most hazardous and inaccessible streets, developing a clear plan for enhancements.

In order to prepare certain dangerous streets for Complete Streets improvements, a number of pilot projects have already been planned or completed. **In December 2023, a 2.5-mile segment of Mill Street was updated, including repainting crosswalks and street pavement and implementing parking lanes, bicycle lanes, and a road diet** — reducing travel lanes from two to one in each direction. As of 2024, the City is actively completing an equivalent project on Stafford Street, with further plans to implement similar measures on Endicott, Bigelow, Chandler, and Burncoat. After assessing the success of these initial changes, comprehensive Complete Streets projects will be undertaken on each street. Additionally, for other streets not included in the

Chart 3: Total Crashes (2012-2019)

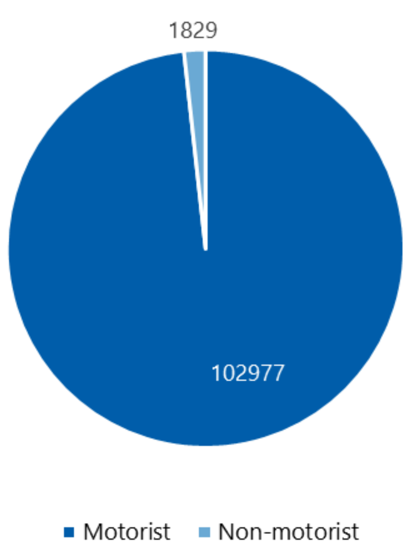
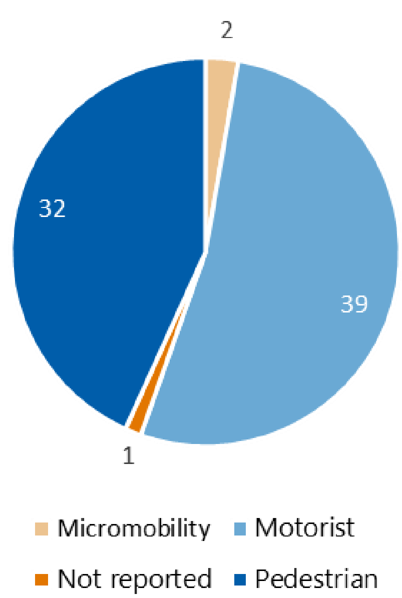


Chart 4: Fatalities (2012-2019)



Source: MassDOT Person Level Crash Details, 2012-2019 https://massdot-impact-crashes-vhb.opendata.arcgis.com/

prioritization list, the Complete Streets Prioritization Plan furnishes a comprehensive toolkit with strategies for policymakers to bolster safety, accommodation, and accessibility.

In October 2023, the City embraced the Vision Zero initiative, an international movement aimed at fully eliminating pedestrian fatalities and severe injuries. Aligned with the objectives of the Complete Streets Plan, Worcester's Vision Zero Action Plan will collect and analyze data to identify locations with higher risks of VRU danger and suggest policy improvements. In early 2024, the City hosted the "State of Our Streets" forum with transportation planners from city planning firm Speck Dempsey to discuss initial steps. Worcester's Vision Zero effort has also implemented a community map where citizens can add comments on issues and suggestions for safety improvements. Beyond the official plans under its purview, Vision Zero has prompted a general reconsideration of road safety. Since December 2023, **City councilors have deliberated a plan proposing reducing Worcester's statutory speed limit from 30 to 25 miles per hour and establishing select "safety zones" with 20 miles per hour limits.** This decision comes on the heels of Vision Zero efforts in Boston, where the default speed limit was similarly reduced in 2017. The results showed a significant reduction in both motorists' real travel speeds, in turn mitigating risks of severe VRU crashes.

Central to the plan for lowering speed limits — and many other initiatives — was the establishment of Worcester's Department of Transportation and Mobility (DTM) in 2022. DTM serves as the architect of the previous projects and coordinates with other regional and municipal organizations to design and implement road safety plans.

ANALYSIS OF CRASHES

In order to mitigate danger for vulnerable road users, the City needs an adequate understanding of the various risk factors in Worcester. This section will present the results of extensive spatial and statistical analysis on who is affected and where and when crashes occur.

WHO IS AFFECTED: DEMOGRAPHIC INSIGHTS

Among vulnerable road users, pedestrians face the highest crash risk. Walking represents the most fundamental mode of human travel and should be encouraged as both an enjoyable and environmentally friendly means of transportation. Given that every journey begins and concludes with some degree of walking, prioritizing pedestrian safety is imperative. But without adequate pedestrian infrastructure, walking can quickly become hazardous. Regrettably, Worcester's crash data underscores the frequent occurrence of perilous pedestrian trips. **Between 2012 and 2019, pedestrians constituted 61.5% of all VRU crashes and 91.4% of fatalities.**

Cyclists accounted for the second-largest portion of VRU crashes at 24.2%. Among those crashes, 60.0% resulted in injury, a rate comparable to that of pedestrians at 63.0%, but only 0.23% resulted in fatality. Still, these figures highlight a need for improved bicyclist infrastructure.

Demographic groups also experience the rate and severity of crashes in different ways. Worcester's seniors, for instance, are much likelier to be killed or severely injured in pedestrian crashes; **residents over 65 constituted only 5.8% of all crashes but 32.4% of fatal crashes.** In comparison, seniors make up 13.31% of the total City population. Although younger VRUs were fortunately less likely to experience fatal crashes, they were nonetheless disproportionately represented in non-fatal crash numbers. Victims aged 0-19 represented

Chart 5: Total Crashes by Age (2012-2019)

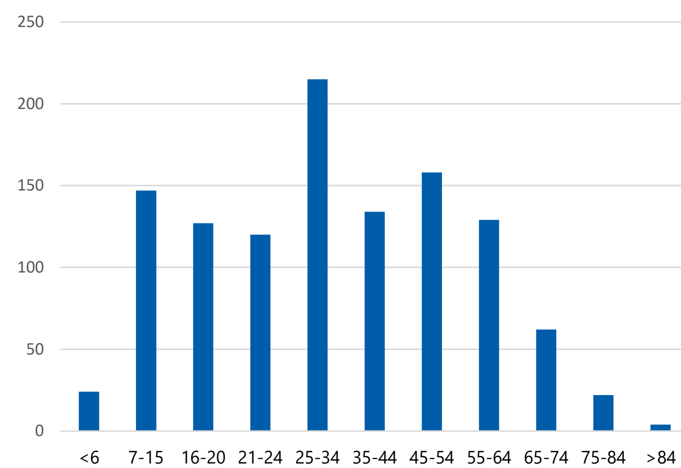
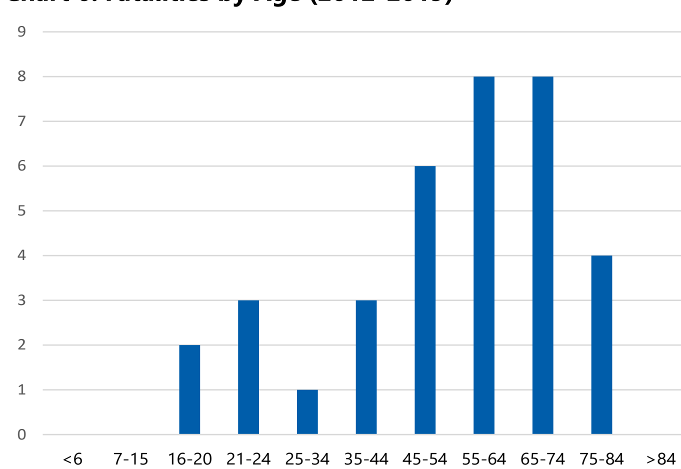


Chart 6: Fatalities by Age (2012-2019)



Source: MassDOT Person Level Crash Details, 2012-2019
https://massdot-impact-crashes-vhb.opendata.arcgis.com/

Chart 7: Total Crashes by Sex (2012-2019)

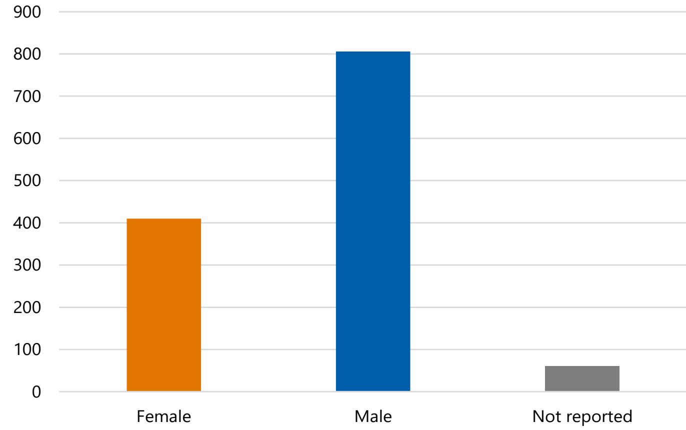
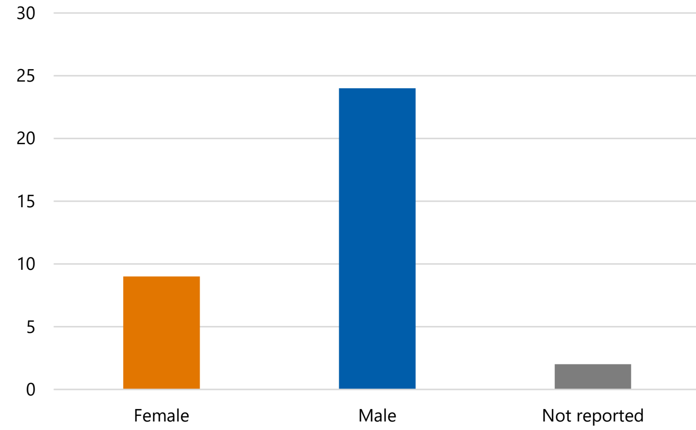


Chart 8: Fatalities by Sex (2012-2019)



Source: MassDOT Person Level Crash Details, 2012-2019 https://massdot-impact-crashes-vhb.opendata.arcgis.com/

27.2% of all crashes but only 16.1% of the overall population, according to American Community Survey data.

Additionally, sex presented as a significant modifier for VRU crash prevalence and outcomes. **Males were overrepresented in Worcester's crash data, with 20.2% more VRU crashes involving males than females**. The difference was even more extreme among fatal crashes, where 2.5 times more males were reported than females.

Numerous studies have found that crashes are also commonly stratified by economic status. For example, one study of Californian cities found that **residents in poor urban centers are disproportionately affected by crashes.** A common explanation for this trend relies on differences in car ownership rates, with lower-income households being more likely to commute by walking or taking public transportation. Based on the Bureau's 2018 *City on the Move* and 2023 *Resurging Regional Ridership* reports and previous WRTA customer satisfaction surveys, two-thirds of transit riders reported incomes below $25,000, and only 8% said they would drive if buses were not available. As will be discussed later, this report finds that WRTA stops are high-risk areas for VRU crashes, presenting disproportionate danger for certain socioeconomic and demographic groups.

Although full demographic data on VRU crash victims was not readily available for Worcester specifically, existing research has demonstrated that, controlling for other factors, the race and ethnicity of crash victims alone are not typically associated with differences in crash prevalence. However, as explored in the next section, the City's majority non-white geographic communities are found to have significantly higher rates of VRU crashes, suggesting that disparities in crash outcomes are likely due to environmental conditions rather than behavioral differences.

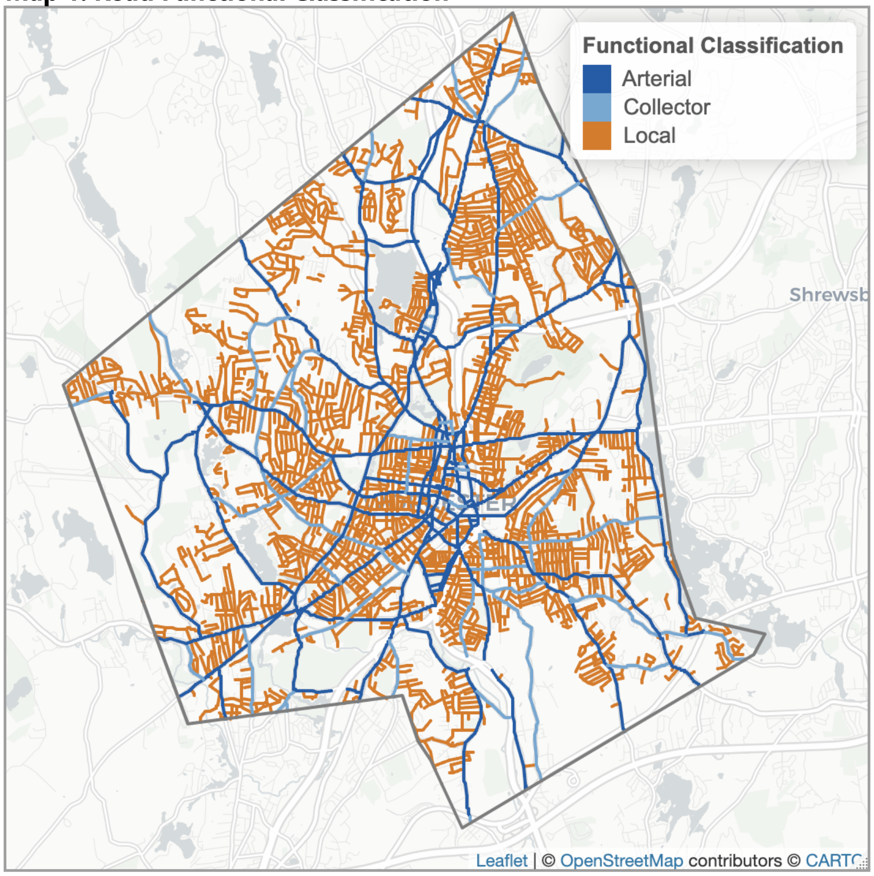
DANGEROUS INFRASTRUCTURE

A better understanding of what makes Worcester's road system dangerous can help the City better effectively target and design road safety measures. Worcester already benefits from extensive reports on crash hotspot intersections and dangerous corridors from MassDOT and the DTM, many of which have been covered here. This section hopes to furnish City officials with a general sense of the factors contributing to VRU danger. To accomplish this, the Bureau first tested the prevalence of crashes across road segments' physical structure and characteristics.[3] As a baseline, the Bureau's own analysis shows that 26.1% of all Worcester road segments were associated with containing at least one crash and 4.4% with a fatality or serious injury.

Two key variables explain much of the variation in crashes on Worcester streets. First, the majority of crashes involving vulnerable road users occurred on arterial roadways — the streets primarily serving travel between Worcester and surrounding communities. Generally, arterial roads are characterized by having more lanes, higher speeds, and greater vehicle volumes than local streets but more pedestrian access and traffic than highways. Accordingly, the US Department of Transportation has identified them as commonly dangerous for VRUs. Consequently, **it was found that principal and minor arterial roads accounted for only 20.9% of the total City-operated street network but 81.8% of all VRU fatalities or serious injuries.** Local roads constituted the majority of the network and the second largest portion of severe crashes, with 71.6% and 15.1%, respectively, and collectors — streets distributing traffic from arterial to local roadways — made up the rest.[4]

Closely tied to road classification, the second major variable is traffic rates. **Arterial roads with an average annual daily traffic (AADT) rate of over 10,000**

Map 1: Road Functional Classification



Source: MassDOT 2019 Road Inventory
https://geo-massdot.opendata.arcgis.com/datasets/10a2766a607345928c6a66ffb479c937/about

vehicles were found to have over triple the rate of severe crashes (9.1% to 2.7%). Given the lack of variance in AADT rates among local roads, this same analysis was not useful. For collectors, however, the effect of AADT was significant and great: the rate of severe crashes was over ten times higher among road segments with AADT over 10,000 vehicles (13.2% vs. 1.3%). The rest of this section tests other road attributes, controlling for road classification when possible, to identify the existence and extent of risk factors on each street type.

Following academic literature and other findings informing Complete Streets Policy, streets with more lanes were associated with a significant increase in the rates and severity of VRU crashes. The Bureau's model found that **arterial road segments with three or more total travel lanes across both directions were over two times likelier than arterial roads with less than two lanes to contain a VRU crash resulting in death or fatality (12.1% vs. 5.4%).** Besides six- and eight-lane roads — which were too uncommon for meaningful analysis — **each lane reduction was shown to decrease the odds of a crash**. Given small sample sizes among local roads and collectors, an identical analysis was not conducted.

Similar to lane count, **differences in lane and pavement width have been shown to account for other VRU danger trends**. While delivering Worcester's Vision Zero "State of Our Streets" speech, transportation planner Jeff Speck claimed that engineering movements to widen lanes to twelve feet have been greatly counterproductive to road safety and urban vitality in American cities. Many studies have corroborated this, finding that wider lanes bring no significant improvements in mitigating motorist crashes but are greatly harmful to VRUs. While a comparison of Worcester's arterial roadways showed a decrease in severe crashes, **local roads saw a sharp increase in severe crashes between 10- and 12-foot lanes (13.8% vs. 8.7%).**[5] Too little data existed for collectors. When cities widen lanes, sidewalks are often shortened as a consequence. With smaller sidewalks and bigger streets, VRU exposure and the potential for collisions skyrockets. Simultaneously, wider lanes give drivers an inflated perception of appropriate speeds. Together, these factors create the exact conditions for severe VRU crashes.

The width of street shoulders was tested in a similar vein, with previous research having found decreased rates of crashes among rural roads with wider shoulders. Using

Visual 1: Description of Road Attributes on Main Street (2019)

Source: Google Maps

the same method as for lane width, **only 3.1% of roads with right-side shoulders greater than five feet wide were found to have a severe crash, as compared to 10.1% with right-side shoulders less than five feet.**

In 2019, only 35.7% of Worcester's roads were rated in "good" structural condition.[6] Testing for crashes among arterial streets, road segments labeled "intolerant," "deficient," or "fair" were less likely to contain a crash resulting in a fatality or serious injury (6.8% vs. 8.3%). Worcester's local roads and collectors demonstrated no statistical significance for either category. Interestingly, a "good" pavement score was associated with the highest rate of severe crashes (8.6%, on average), although those roads were only the third most likely to contain a crash at all. In a study on Texas roads, a similar conclusion was attributed to better-paved roads providing more suitable conditions for speeding. In response, the City may consider improving signage and implementing speed management strategies when re-paving roads.

Turning to pedestrian infrastructure, the effect of street medians was also tested. **The presence of any type of median was associated with a decrease in severe VRU crashes on Worcester's roads (4.6% vs. 9.3%).** Other studies have demonstrated, however, that the rigidity of street medians — the amount that a median restricts or directs pedestrian crossing — better explains reduced crash rates. **Indeed, with the presence of "semi-rigid" or "rigid" medians, severe crash rates decreased by almost a third (10.1% vs. 3.3%).**[7]

Other variables related to road attributes — based on community observations or existing literature — did not provide meaningful analysis. When testing the width or presence of sidewalks on arterial streets, for example, analysis consistently shows that road segments with narrow sidewalks have far lower rates of VRU crashes. Instead of indicating that larger sidewalks are dangerous for VRUs, this finding probably reflects that sidewalks are unsurprisingly high-traffic areas for non-motorists and that VRUs are far less likely to travel on streets without sidewalks. **However, this report does find at least 125 instances of "sidewalk gaps,"** where a street block that is reasonably intended for non-motorist travel lacks continuous sidewalk coverage from surrounding streets. Particularly for residents with mobility challenges, sidewalk gaps can result in a disrupted journey or force pedestrians onto the road. A limited analysis by the Bureau demonstrated no statistical significance for differences in crash rates, but a larger study of pedestrian crash outcomes in Florida found that the likelihood of a crash was tripled along sidewalk gaps.

A similar logic prevents us from testing listed speed limits, which do not necessarily represent drivers' actual speeds. However, as mentioned, other Vision Zero reports have demonstrated that higher recorded speed values are strongly associated with increased crash likelihood and severity.

COMMUNITY RISKS: ENVIRONMENTAL FACTORS

Beyond testing crashes across road features, other analysis was conducted to measure the incidence of VRU crashes within and around neighborhoods, communities, and buildings. This builds on the Bureau's earlier analysis of who is affected by VRU crashes, giving spatial insight into how Worcester's built transportation environment affects the City's communities.

Across the City, a plurality of VRU crashes occur downtown. Previous research has shown urban centers to have particularly high rates of non-motorist activity. Further, 9.57% of VRU crashes — the most of any tract in the City — occur downtown. Likely due to the large concentration of businesses and workplaces, 25.5% of VRUs involved in crashes downtown lived outside Worcester.

Extending to the rest of the city, the Bureau reinterprets data from a 2022 report titled *Static Income, Rising Costs*. Part of that report studied the consequences of 1930s redlining, the discriminatory practice of refusing access to credit based on the racial or ethnic composition of a neighborhood. The report found lasting negative effects on both the proportion of renter-occupied units and levels of social vulnerability — a measure of vulnerability to environmental, social, and financial shocks. Based on the Bureau's digitization of a 1936 redlining map, this report further measures VRU danger across these historically disadvantaged areas. Beyond downtown, which again presented as the most dangerous neighborhood, rates of severe VRU crashes were perfectly stratified by degree of historic redlining. **Specifically, 6.4% of road segments in the two "hazardous" neighborhoods had at least one severe crash, compared to only 1.5% in the neighborhood rated "best."**

Using data from Massachusetts' environmental justice initiative, the Bureau also directly examined crash rates across various demographic and socioeconomic communities. To spatially measure social vulnerability, the Office of Environmental Justice and Equity flags census blocks based on specific risk criteria: median income below 65% of the state average, a non-white population over 40%, or over 25% of households reporting limited English proficiency. By incorporating these variables, this analysis explores the impact of Worcester's transportation infrastructure on disadvantaged populations. The Bureau's findings indicate that each additional environmental justice flag assigned to a community correlates with higher rates of both overall crashes and incidents resulting in deaths or serious injuries. **In block groups meeting all three environmental justice criteria, 7.9% of road segments reported crashes resulting in fatality or major injury.** In contrast, 1.0% of roadways in areas not meeting these criteria contained at least one severe crash.

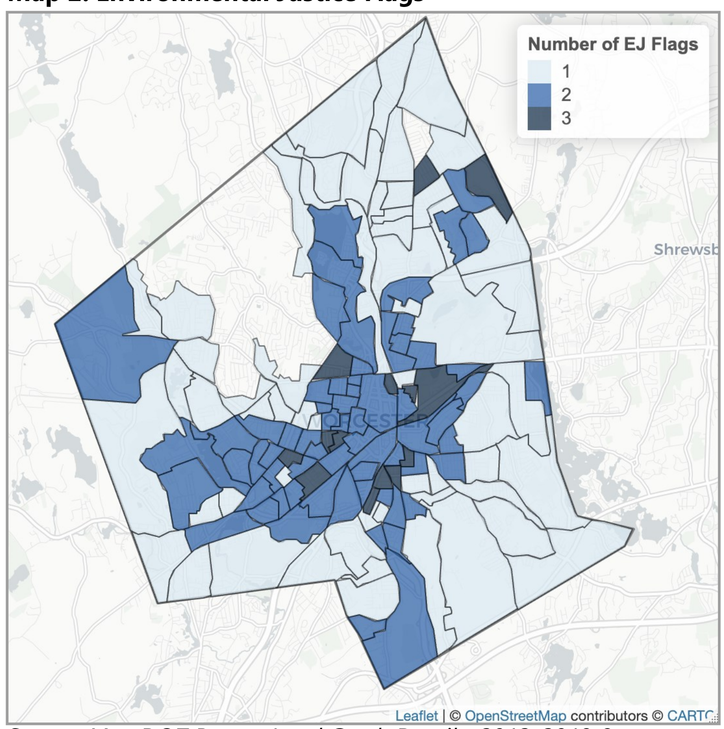
Table 1: Road Segments in Previously Redlined Zones

Redlining Label	Count	Percent Containing Crashes	Percent Containing Severe
Business	208	62.50%	12.02%
Hazardous	752	42.02%	6.38%
Definitely Declining	3547	28.33%	5.78%
Still Desirable	3476	22.04%	2.93%
Best	342	18.42%	1.46%

Table 2: Road Segments in Environmental Justice Blocks

EJ Flags	Count	Percent Containing Crashes	Percent Containing Severe
3	709	40.48%	7.90%
2	3632	39.32%	6.72%
1	3901	14.56%	2.15%
No flag	687	6.55%	1.02%

Map 2: Environmental Justice Flags



Source: MassDOT Person Level Crash Details, 2012-2019 & Executive Office of Energy and Environmental Affairs *https://www.mass.gov/info-details/massgis-data-2020-environmental-justice-populations*

Further contextualizing these findings, both areas with environmental justice flags and redlined neighborhoods had a much higher proportion of arterial roads and higher mean AADT values. These results underscore the disparities in road safety outcomes among communities who have been historically disadvantaged, highlighting the urgent need for targeted interventions to improve safety and equity in transportation infrastructure.

Other variables under study included the areas around schools or establishments serving alcohol, chosen following methodology from the Federal Highway Administration's Highway Safety Improvement Program. **Among arterial road segments within 600 feet of Worcester schools, the rate of severe VRU crashes doubled (6.7% vs. 13.9%).** While the overall mean age of VRU crashes around schools was almost identical to Citywide averages, **the data does show that a higher proportion of these road segments involved residents younger than 18 (3.8% vs. 1.5%).** Around establishments serving alcohol, the increase in severe crashes was also slightly higher (7.3% vs 8.9%).

COMMUNITY RISKS: CRASHES NEAR WRTA STOPS

WRTA stops have also been identified as key targets for preventative measures. According to a 2023 MassDOT vulnerable road user safety assessment, between 2016 and 2020, 41% of fatal or serious pedestrian crashes statewide and 50% of Boston crashes occurred within 300 feet of a bus stop. **In comparison, between 2016 and 2019, the Bureau finds that 71.4% of Worcester's fatal or serious crashes occurred within the same range of WRTA stops.**[8] This disparity, paired with both the previously described demographic and socioeconomic characteristics of WRTA passengers, warrants deeper analysis.

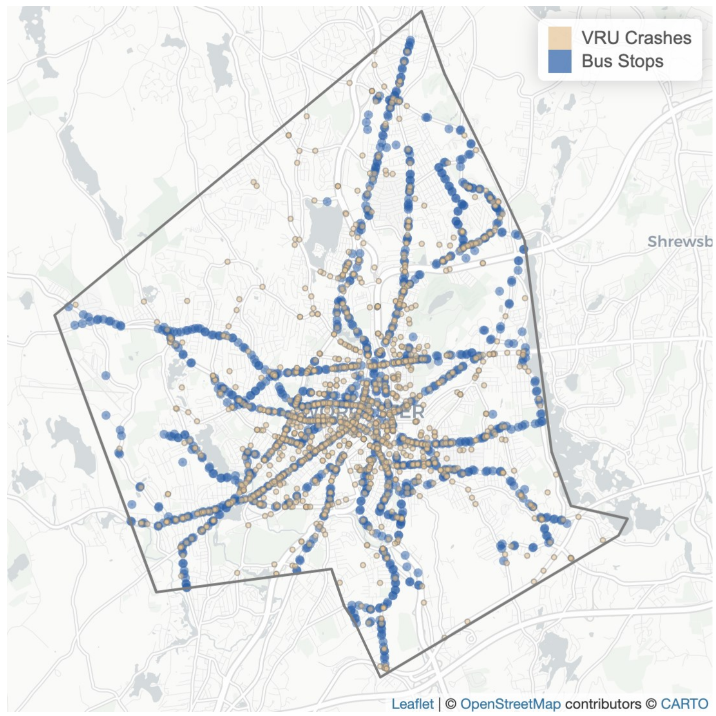
The Bureau completed its own crash stop analysis within 150 feet of WRTA bus stops, considering the close proximity of bus stops to each other within Worcester. **Roughly three times as many arterial road segments near a WRTA stop contained at least one severe VRU crash than segments without a stop (11.4% vs. 3.7%).** Among local roads, the difference jumped to over five times (7.3% vs. 1.4%) and collectors nearly twelve times as many (8.1% vs 0.7%). These statistics become more alarming when considering that across the City, those road segments comprise only 28.7% of all centerline miles.

WRTA stops' surroundings also affect their danger. Following previous findings, the presence of a school or bar was associated with increased risk and severity of pedestrian crashes. **The Bureau's analysis reveals that WRTA stops within 600 feet of schools were more likely to contain any crashes (63.7% vs. 42.9%) and, on average, had roughly two times more severe crashes on average than stops without schools nearby (0.21 vs. 0.11 crashes).** A similar effect was found among stops within 600 feet of establishments serving alcohol, with both a greater incidence of crashes and a slightly higher number of severe crashes on average (62.2% vs. 44.0%) (0.13 vs. 0.11 crashes).

Table 3: WRTA Stops in Environmental Justice Blocks

EJ Flags	Count	Average Number of Crashes	Percent Containing Crashes	Percent Containing Severe
3	77	2.22	62.34%	16.88%
2	492	1.56	52.03%	15.45%
1	433	0.82	35.33%	8.55%
No flag	18	0.56	27.78%	11.11%

Map 3: WRTA Stop Locations and VRU Crashes



Source: MassDOT Person Level Crash Details, 2012-2019, Executive Office of Energy and Environmental Affairs, & MassDOT Open Data *https://geo-massdot.opendata.arcgis.com/maps/9f0b255b1a314b70a396d93d4425f531*

Returning to the environmental justice framework, the Bureau's analysis is also able to demonstrate that bus stops primarily serving communities with residents who are low-income, minority-identifying, and non-English-speaking are disproportionately dangerous. With each environmental justice indicator attributed to a census block, data shows that the rate of crashes at stops increases. **WRTA stops within a census block flagged for all three risk categories almost four times more crashes on average than stops not flagged for any category (2.2 vs. 0.56 crashes).**

THE CITY'S POST-COVID INITIATIVES

As the City begins implementing new initiatives and fully comprehending the effects of the COVID-19 pandemic on its transportation infrastructure, a comparison of VRU crashes in this period is worthwhile.[9] WRTA stops stand out as a particularly important area for analysis here, too. In response to the pandemic and long-term declining ridership, the WRTA began suspending fares in 2020. A subsequent report by the Bureau found that among eleven other RTAs, not only was the WRTA able to meet pre-pandemic ridership levels by November 2022, but it surpassed them by 149.1%. Despite this surge, crash data shows an initial decrease in crashes around WRTA stops following the pandemic. Between 2012 and 2019, an average of two fatal crashes per year within 150 feet of bus stops. **In comparison, from 2021 to 2023, the rate dropped to one crash per year, with all incidents occurring in 2023.**

A closely monitored redesign that took place after the Bureau's analysis period was the Kelley Square remodel. Although not part of the City's Complete Streets initiative, this project included numerous VRU safety implementations. The infamous seven-way intersection was replaced by a roundabout featuring shortened crosswalks, pedestrian medians, and widened sidewalks, with bike lanes installed on surrounding streets. According to crash data, these changes have been successful. Between 2012 and 2019, 30 crashes involving VRUs were recorded within 300 feet of Kelley Square, averaging 3.75 crashes per year. **In comparison, from 2021 through 2023, only four crashes were reported, averaging 1.3 crashes per year.** While these results are preliminary and the sample sizes are small, they indicate the early success of the Kelley Square remodel and hold promise for future road safety projects.

THE COSTS OF CRASHES

Beyond the immeasurable cost of human life, crashes involving vulnerable road users (VRUs) impose a host of environmental, social, and economic burdens on Worcester communities. These crashes create ripple effects that impact sustainability efforts, quality of life, and economic stability. Addressing VRU safety is not solely about preventing tragedies; it is about fostering healthier, more vibrant, and economically resilient communities. This section delves into the multifaceted consequences of VRU crashes, illustrating the pressing need for improved safety measures across various domains.

SUSTAINABILITY AND ENVIRONMENT

High rates of VRU crashes can significantly dampen sustainability efforts in Worcester. Residents' perceptions of safety risks — particularly from seniors — often reduce their willingness to walk, bike, or take public transportation. In a survey from the Metropolitan Area Planning Council, **60% percent of respondents reported that they would consider biking if they thought their trips would be safer and more comfortable**. Another survey by the City's 2020 Green Worcester Plan found that **61% of residents thought creating safer and more attractive conditions for bicyclists and pedestrians should be a major priority**. Currently, however, when people are unable to justify the potential danger of walking or biking, they may choose less environmentally friendly means of transportation instead. A bulk of research has shown that greater traffic fatalities strongly deter walking. Worcester residents accurately perceive the increased danger of walking, and as a result, the City's roads are more congested than they need to be. Prioritizing safe and green transit is a fundamental step toward ensuring a sustainable future for Worcester.

IMPROVING QUALITY OF LIFE

People are happier when their roads are safer. A study on walkability in Dublin found that survey respondents in highly walkable areas reported being more satisfied with their neighborhood's appearance and personally happier and healthier than those in car-dependent areas. Another study in Durham, New Hampshire, found that **residents in walkable neighborhoods had larger social networks and were more frequently involved in community activities.** This was especially true for seniors, who are less likely to drive and more vulnerable to severe injuries or fatalities from crashes. Enhancing walkability in Worcester would provide significant benefits for senior pedestrians, improving their safety and quality of life.

Road safety has also been identified as a key means of supporting local development. A report by Smart Growth America found that increasing VRU safety was likely associated with broad economic gains. In many communities adopting Complete Streets programs, the surrounding areas saw increased employment, property values, and private sector investment. In a study of Complete Streets implementation in Orlando, Florida, between 2008 and 2015, Smart Growth America found that along the remodeled corridor, 77 new businesses opened, 560 new jobs were created, and on-street parking increased by 41%. **In a similar study of Dubuque, Indiana, property values around Complete Streets rose 111%**. Another meta-analysis of 23 other studies found that even when new VRU infrastructure reduced on-street parking — a common fear from those opposing road safety projects — new travel facilities typically had an overall positive effect on the local economy. Worcester's residents want to bike and walk and will more easily engage in the community when given the chance. Improving street safety goes hand-in-hand with the City's current focus on attracting and retaining residents.

THE FINANCIAL COSTS OF VRU CRASHES

Beyond lost economic development, however, crashes themselves carry an enormous financial burden for the City. Given that crashes involving VRUs are more likely to result in death or injury and disproportionately affect victims in their peak productive years, they typically result in high costs from damages, medical procedures, and lost wages. In the long term, economists and medical researchers have leveraged the Quality-adjusted Life Year (QALY) model, an average measure of the lasting medical and financial burdens accrued by a disease or injury, to approximate the comprehensive lifetime costs of crashes. Based on derivations from MassDOT and the Federal Highway Administration and using data from the last year with fully complete crash outcome data (2019), **the Bureau estimates that Worcester's VRU crashes in that year alone cost roughly $493,644,552 in 2024 dollars — about 0.97% of the Worcester metro area's GDP.**[10]

CONCLUSION

As Worcester continues to develop and grow, addressing transportation safety for vulnerable road users is critical. This report highlights the challenges and initiatives in place to enhance safety, with particular attention to the prevalence of crashes around WRTA stops and the impact on various demographic and socioeconomic groups. Analysis reveals significant risks and disparities, underscoring the need for targeted interventions. Ongoing efforts by the Department of Transportation and Mobility like the Mobility Action Plan, Complete Streets framework, and Vision Zero initiative demonstrate Worcester's commitment to creating a safer and more equitable transportation system. These plans aim to address the current deficiencies in pedestrian and bike infrastructure and implement comprehensive safety strategies.

The analysis of crash data and contributing risk factors identifies key areas for improvement, including road design and traffic management. Environmental and demographic analyses further emphasize the need for equitable safety measures across all neighborhoods. While early redesign projects show promise, continuous monitoring and adaptation are necessary to ensure long-term success. Additionally, the cost of crashes extends beyond human life, affecting environmental sustainability and quality of life. Prioritizing safe, accessible, and green transportation options is essential for Worcester's sustainable future.

Worcester's path to becoming a safer city for all road users requires a multifaceted approach, leveraging data-driven insights, community input, and a commitment to equitable and sustainable development. To accomplish this, the City should continue its commitment to Vision Zero. These insights will help Worcester create a more inclusive and resilient transportation system that supports its growth and the well-being of its residents.

QUESTIONS TO CONSIDER

If the City decides to adjust statutory speed limits, how can sensitive areas requiring further speed limit reductions be identified? Speed of vehicles impacts the severity of crashes. While reducing the number of crashes is the ideal, speed's relation to severity should be taken into consideration as well.

What level of community involvement is appropriate? The City has held Vision Zero events and has asked for community feedback online for this project. After the plan's completion, in what ways will the City continue to request feedback for other projects?

How can the City better ensure that sidewalk maintenance and clearing is timely and adequate? Clearing snow off of sidewalks is generally the responsibility of the abutting property owner, rather than the city. But, obstructed sidewalks—whether snow, debris, or other issues—can force pedestrians into the road to proceed, increasing the danger of a road crash. In what ways can the City better ensure that sidewalks remain clear for pedestrians?

In the appendix, table 4 references the top 10 WRTA bus stops where VRU crashes have occurred. **Going forward, how can City policymakers prioritize these bus stop areas for infrastructure improvements to prevent future crashes?** For example, do these (and other) stops have adequate lighting and crosswalks necessary for the safety of pedestrians? **Along the same lines, could the City and the WRTA analyze bus stop locations and proximity to one another, to optimize locations in a way that could minimize future crashes near them?**

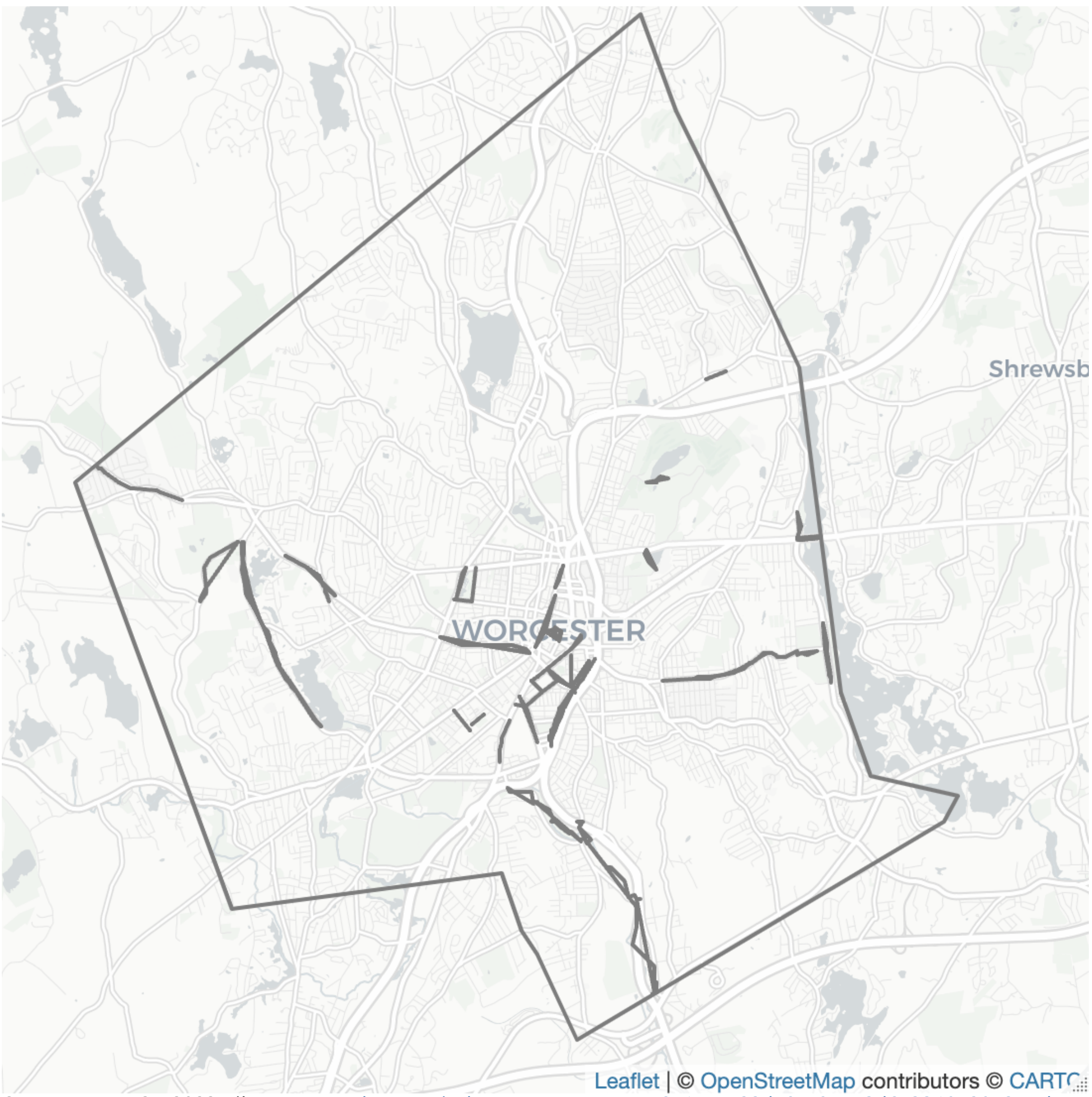
This report is supported by a grant from the Barr Foundation. The opinions expressed in this report do not necessarily reflect the views of the Barr Foundation.

APPENDIX

Table 4: Top 10 WRTA Stops by Crashes

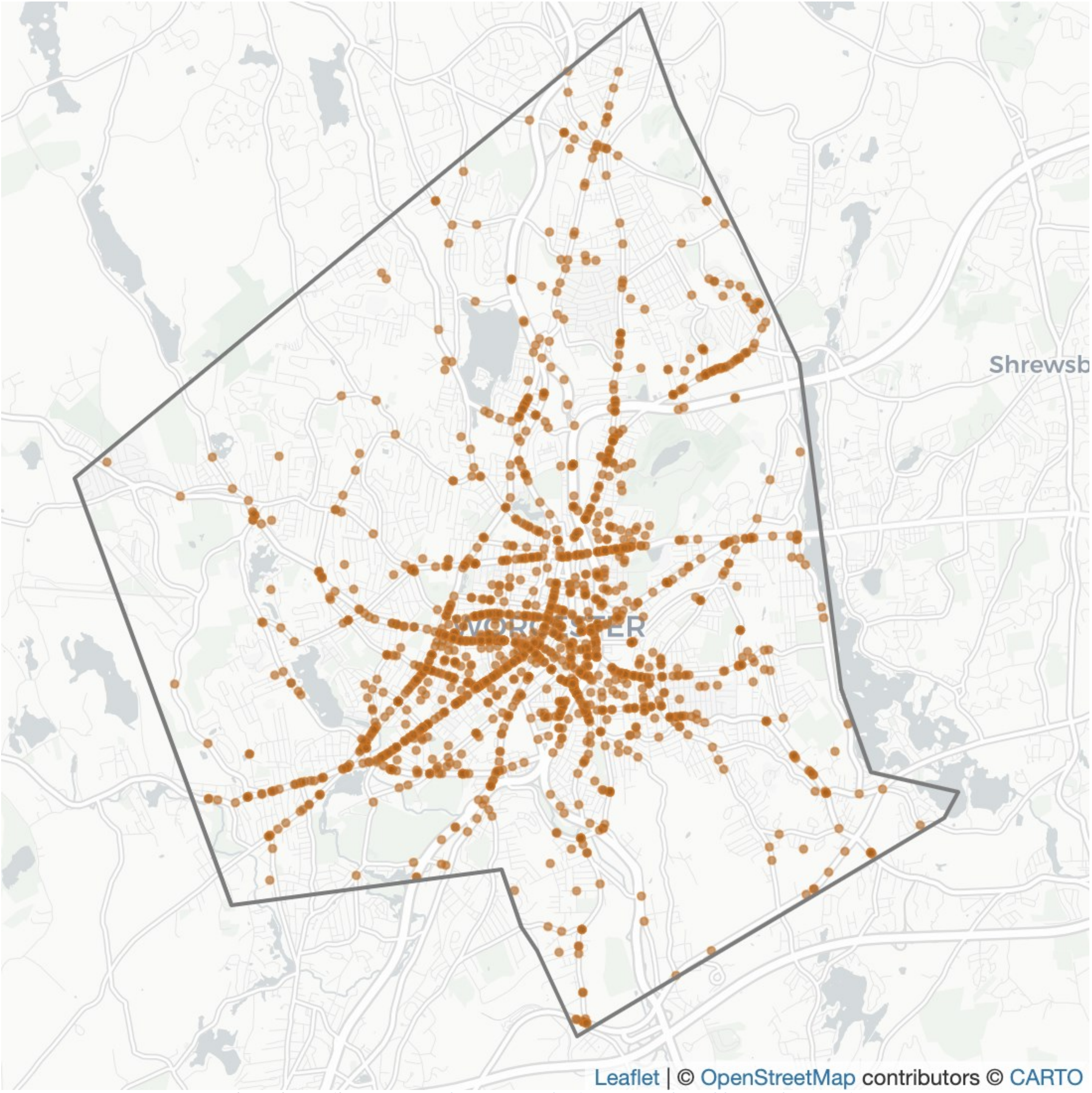
Stop Name	Avg. Crashes / Year	Avg. Severe Crashes / Year
BELMONT ST + EDWARD ST	5.88	0.38
CHANDLER ST + WELLINGTON ST	3	0.25
CHANDLER ST + QUEEN ST	2.62	0.5
QUEEN ST + CHANDLER ST	2.5	0.5
CHANDLER ST + IRVING ST	2	0
PLEASANT ST + RUSSELL ST	1.88	0.12
CHANDLER ST + DEWEY ST	1.62	0
CHANDLER ST + MAIN ST	1.62	0.12
MAIN ST + BENEFIT ST	1.62	0
PARK AVE + MAY ST	1.62	0.12

Map 4: Bike Lanes, 2023 Massachusetts Bike Inventory



Source: MassDOT 2023 Bike Inventory *https://gis.data.mass.gov/maps/641e45522d784c87a43d673310a20427/about*

Map 5: Pedestrian Crash Locations in Worcester, (2012-2019)



Source: MassDOT Person Level Crash Details, 2012-2019 https://massdot-impact-crashes-vhb.opendata.arcgis.com/

METHODOLOGY

Data and street variable characteristics were sourced from MassDOT's catalog of Road Inventory datasets. For the pre -COVID analysis, the 2019 Road Inventory release was used for all years of analysis (2012-2019). The Bureau acknowledges that this may present error in a small selection of crashes where there is inconsistency between descriptions of street segments at the time of crash versus as reported in the 2019 Road Inventory dataset but holds that these differences are minor, if at all present.

The data were downloaded from MassDOT's open data portal and uploaded into RStudio. With R, VRU crash data points were spatially joined with the nearest road segment within 25 feet. Given that road segment sizes were not normalized (ranging from 0.00000063 to 4.46 centerline miles), analyzing the count of pedestrian crashes at this stage was not statistically valuable. As a result, all analysis in the road attributes section is categorized by whether there was at least one pedestrian crash within the time range, giving a better sense of the different attributes' effects, insulated from road segment size. Each variable was additionally modified to a binary configuration to allow coherent significance testing.

The data were then divided into separate sets, depending on functional classification. Generalized binomial regression models were then applied to each variable and category. The results for arterial roads, collectors, and local roads are presented in Tables 5-7 on the next page. Citywide analysis is shown in Tables 8 Statistical significance — here, an expression of the probability of a variable's association with changing severe crash rates — is determined by the p-value. This report accepts p-values below 0.1 as statistically significant. Alternatively, the odds ratio measures the strength of that association, with a value over one indicating a severe crash is more likely to happen in the presence of that variable. Odds ratios are calculated by exponentiating the coefficient of the regression model where the binary value equals one (the variable is "true"). The formula is: Odds Ratio = $e^{\text{coeffcient}}$. The probabilities used in the report are then calculated using the statistic's odds ratio, with the formula: Probability = Odds Ratio / 1+Odds Ratio.

LIMITATIONS

First, the analysis relies on reported crashes, which may not account for all incidents, particularly minor ones that go unreported. Therefore, while the data likely captures the most significant crashes, there may still be an undercount of less severe incidents that could influence the overall analysis.

Another limitation involves the spatial joining of VRU crash data points with the nearest road segment within 25 feet. This proximity assumption might not accurately reflect the actual location or conditions contributing to the crash but provides a general approximation for analysis., possibly overlooking specific localized factors affecting crash occurrences.

Furthermore, converting variables to a binary format, while necessary for coherent significance testing, may oversimplify the relationship between road attributes and crash rates. Crashes often result from a combination of factors, including road conditions, weather, and driver behavior. The binomial regression model assumes that each crash can be categorized as being influenced by a specific road attribute which may not fully capture the complexity of crash causation.

The choice of a p-value threshold of 0.1 for determining statistical significance is another consideration. While this threshold allows researchers to identify potential associations that may warrant further investigation or confirmation in future studies, it also increases the likelihood of Type I errors, where associations are found that do not exist. This approach emphasizes the need for cautious interpretation of results and highlights areas for further practitioner research and exploration.

Table 5: Generalized Binomial Regression Models on Arterial Roads

Variable	Coefficient	Std. Error	Z Value	P Value	Odds Ratio
Terrain (Level y/n)	0.057	0.46	0.123	>0.1	1.058
AADT (10,000+ y/n)	1.286	0.218	5.892	<0.01 (***)	3.618
Structural Cond. ("good" y/n)	-0.218	0.132	-1.654	<0.1 (*)	0.804
Lanes (2+ y/n)	0.313	0.051	6.167	<0.01 (***)	1.367
Lane Width (10 ft./12 ft.)	-0.992	0.181	-5.482	<0.01 (***)	0.371
Shoulder Width (5+ ft. y/n)t	-0.708	0.346	-2.043	<0.05 (**)	0.493
Sidewalk Gap (y/n)	-12.066	333.646	-0.036	>0.1	0
EJ Flag (2 + y/n)	0.898	0.15	5.973	<0.01 (***)	2.455
School Presence (y/n)	0.815	0.173	4.708	<0.01 (***)	2.259
Bar Presence (y/n)	0.218	0.213	1.022	>0.1	1.243
WRTA Presence (y/n)	1.191	0.148	8.064	<0.01 (***)	3.29

Table 6: Generalized Binomial Regression Models on Local Roads

Variable	Coefficient	Std. Error	Z Value	P Value	Odds Ratio
Terrain (Level y/n)	0.057	0.46	0.123	>0.1	1.058
AADT (10,000+ y/n)	1.286	0.218	5.892	<0.01 (***)	3.618
Structural Cond. ("good" y/n)	-0.218	0.132	-1.654	<0.1 (*)	0.804
Lanes (2+ y/n)	0.313	0.051	6.167	<0.01 (***)	1.367
Lane Width (10 ft./12 ft.)	1.237	0.459	2.693	<0.01 (***)	3.446
Shoulder Width (5+ ft. y/n)t	-12.878	523.624	-0.025	>0.1	0.493
Sidewalk Gap (y/n)	-0.169	0.515	-0.329	>0.1	0.844
EJ Flag (2+ y/n)	1.83	0.289	6.336	<0.01 (***)	6.235
School Presence (y/n)	1.522	0.214	7.111	<0.01 (***)	4.584
Bar Presence (y/n)	0.734	0.34	2.161	<0.05 (**)	2.083
WRTA Presence (y/n)	1.72	0.198	8.694	<0.01 (***)	5.583

Table 7: Generalized Binomial Regression Models on Collectors

Variable	Coefficient	Std. Error	Z Value	P Value	Odds Ratio
Terrain (Level y/n)	-0.357	0.433	-0.823	>0.1	0.7
AADT (10,000+ y/n)	2.419	0.377	6.419	<0.01 (***)	11.237
Structural Cond. ("good" y/n)	-0.328	0.379	-0.866	>0.1	0.72
Lanes (2+ y/n)	0.455	0.313	1.454	>0.1	1.576
Sidewalk Gap (y/n)	-11.17	882.743	-0.013	>0.1	0
EJ Flag (2+ y/n)	1.5	0.435	3.452	<0.01 (***)	4.482
School Presence (y/n)	1.051	0.405	2.596	<0.01 (***)	2.86
Bar Presence (y/n)	2.939	0.434	6.777	<0.01 (***)	18.902
WRTA Presence (y/n)	2.541	0.492	5.169	<0.01 (***)	12.694

Table 8: Generalized Binomial Regression Models (Citywide)

Variable	Coefficient	Std. Error	Z Value	P Value	Odds Ratio
Median (y/n)	-1.054	0.239	-4.409	<0.01 (***)	0.348
Rigid Median (y/n)	-1.21	0.395	-3.062	<0.01 (***)	0.298

NOTES TO THE TEXT

[1] (page 3) Although many other studies include motorcyclists in this definition, the Bureau excluded them from this analysis in favor of a more specific study of the infrastructure affecting pedestrians and micromobility users.

[2] (page 3) 2020 to 2024 were not included in this calculation as much of the data on injury or fatality are unresolved for those years. MassDOT's disclaimer: "any crash records or data provided for the years 2020 and later are subject to change at any time and are not to be considered up-to-date or complete." More info can be found here. Unless stated otherwise, all crash calculations are performed with data from 2012 to 2019.

[3] (page 6) In order to adequately compare the distribution of VRU crashes across road segment geometries without normalized shapes and lengths, binary variables were used to indicate the presence and severity (one corresponding to fatal [K] or severe [A] severity classification) of a crash within 25 feet of a road segment. Accordingly, the following statistics are presented in terms of the rate of crashes among road segments of a given characteristic. Unless stated otherwise, data for this section were sourced from MassDOT's 2019 Road Inventory and filtered for segments operated and maintained by the City of Worcester. For a similar methodology, see MassDOT's IMPACT Phase II report.

[4] (page 6) Here and in the rest of the report, "severe crash" means a VRU crash resulting in fatality, "Non-fatal injury - Incapacitating," or "Suspected Serious Injury," according to MassDOT labeling.

[5] (page 7) Considering research showing wider lanes are typically a result of interstates feeding into city roads, this analysis was conducted using all roads within the geographic bounds of the City. Additionally, divided roads were filtered from this analysis, given inconsistency in labeling for lane width.

[6] (page 8) Road segments were scored either "Good," "Fair," "Deficient," or "Intolerable."

[7] (page 8) Unfortunately, the presence of medians was too infrequently distributed across City-operated roads and functional classification factors for valuable testing. However, an illustrative test incorporating state roads and controlling for AADT was conducted instead.

[8] (page 10) Figuring that a 300-foot radius was too large to capture the specific effect of a WRTA stop's presence in an exclusively urban environment, the rest of this analysis uses 150 feet as a baseline.

[9] (page 11) MassDOT crash data used in this section are not fully complete, and all analysis should be considered preliminary.

[10] (page 12) This amount was calculated using the Massachusetts per-capita income comprehensive crash unit cost values. The baseline crash unit and QALY unit costs were inflation-adjusted using the consumer price index and median usual weekly earnings index, respectively. Summing those two categories, 2024 comprehensive costs for each crash severity type were calculated as: K: $20,233,514.4; A: $23,834,674.9; B: $354,194.6; C: $228,373.8; O: $22,088.1. Those values were multiplied by the count of each severity group, determined with MassDOT's 2019 Person Level Crash Details dataset to be: K: 5; A: 15; B: 65; C: 51; O: 13. Final values were summed to obtain the total cost.

BIBLIOGRAPHY AND FURTHER READING

Abou-Senna, H., Radwan, E., & Mohamed, A. (2022). Investigating the correlation between sidewalks and pedestrian safety. *Accident Analysis & Prevention*, *166*, 106548. https://doi.org/10.1016/j.aap.2021.106548

Blečić, I., Congiu, T., Fancello, G., & Trunfio, G. A. (2020). Planning and Design Support Tools for Walkability: A Guide for Urban Analysts. *Sustainability*, *12*(11), Article 11. https://doi.org/10.3390/su12114405

Chakravarthy, B., Anderson, C. L., Ludlow, J., Lotfipour, S., & Vaca, F. E. (2010). The Relationship of Pedestrian Injuries to Socioeconomic Characteristics in a Large Southern California County. *Traffic Injury Prevention*, *11*(5), 508–513. https://doi.org/10.1080/15389588.2010.497546

City of Worcester (Director). (2024, March 18). *State of Our Streets Forum—Worcester Vision Zero, February 29, 2024*. https://www.youtube.com/watch?v=JQTuW28hU38

Crash Costs for Highway Safety Analysis | Mass.gov. (n.d.). Retrieved July 10, 2024, from https://www.mass.gov/info-details/crash-costs-for-highway-safety-analysis

Ewing, R., & Dumbaugh, E. (2009). The Built Environment and Traffic Safety: A Review of Empirical Evidence. *Journal of Planning Literature*, *23*(4), 347–367. https://doi.org/10.1177/0885412209335553

Godley, S. T., Triggs, T. J., & Fildes, B. N. (2004). Perceptual lane width, wide perceptual road centre markings and driving speeds. *Ergonomics*, *47*(3), 237–256. https://doi.org/10.1080/00140130310001629711

Green Worcester Plan | City of Worcester, MA. (n.d.). Retrieved July 10, 2024, from https://www.worcesterma.gov/sustainability-resilience/green-worcester

Hu, W., & Cicchino, J. B. (2020). Lowering the speed limit from 30 mph to 25 mph in Boston: Effects on vehicle speeds. *Injury Prevention: Journal of the International Society for Child and Adolescent Injury Prevention*, *26*(2), 99–102. https://doi.org/10.1136/injuryprev-2018-043025

King, D. A., Smart, M. J., & Manville, M. (2022). The Poverty of the Carless: Toward Universal Auto Access. *Journal of Planning Education and Research*, *42*(3), 464–481. https://doi.org/10.1177/0739456X18823252

Leyden, K. M., Hogan, M. J., D'Arcy, L., Bunting, B., & Bierema, S. (2024). Walkable Neighborhoods: Linkages Between Place, Health, and Happiness in Younger and Older Adults. *Journal of the American Planning Association*, *90*(1), 101–114. https://doi.org/10.1080/01944363.2022.2123382

Li, Y., Liu, C., & Ding, L. (2013). Impact of pavement conditions on crash severity. *Accident; Analysis and Prevention*, *59*, 399–406. https://doi.org/10.1016/j.aap.2013.06.028

Miller, G. F., Florence, C., Barnett, S. B., Peterson, C., Lawrence, B. A., & Miller, T. (2022). Monetized Estimated Quality-adjusted Life Year (QALY) Losses for Non-fatal Injuries. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention*, *28*(5), 405–409. https://doi.org/10.1136/injuryprev-2021-044416

Pedestrian Traffic Fatalities by State: 2023 Preliminary Data (January-December) | GHSA. (n.d.). Retrieved July 10, 2024, from https://www.ghsa.org/resources/Pedestrians24

Potts, I. B., Harwood, D. W., & Richard, K. R. (2007). Relationship of Lane Width to Safety on Urban and Suburban Arterials. *Transportation Research Record*, *2023*(1), 63–82. https://doi.org/10.3141/2023-08

REPORT: Fatal Pedestrian Crashes in MA (2022)—WalkMassachusetts. (n.d.). Retrieved July 10, 2024, from https://walkmass.org/fatal-pedestrian-crashes-in-ma-2022/

Rogers, S. H., Halstead, J. M., Gardner, K. H., & Carlson, C. H. (2011). Examining Walkability and Social Capital as Indicators of Quality of Life at the Municipal and Neighborhood Scales. *Applied Research in Quality of Life*, *6*(2), 201–213. https://doi.org/10.1007/s11482-010-9132-4

Safer Streets, Stronger Economies—Smart Growth America. (n.d.). Retrieved July 10, 2024, from https://smartgrowthamerica.org/resources/evaluating-complete-streets-projects-a-guide-for-practitioners/

Safety, M. T. (2024, March 12). *MassDOT Vulnerable Road User Safety Assessment*. ArcGIS StoryMaps. https://storymaps.arcgis.com/stories/8b36ed2f1f3749b7ac085c0ca5b8efa7

The 496 Most Dangerous Intersections for Pedestrians in MA. (n.d.). Sweeney Merrigan Law, LLP. Retrieved July 10, 2024, from https://www.sweeneymerrigan.com/boston-pedestrian-accident-lawyer/walking-in-ma-study/

Total Gross Domestic Product for Worcester, MA-CT (MSA). (2023, December 18). https://fred.stlouisfed.org/series/NGMP49340

Vanterpool, V. (2018, August 28). Pioneering Study Affirms Vision Zero Focus on Speed Management. *Vision Zero Network*. https://visionzeronetwork.org/pioneering-study-affirms-vision-zero-focus-on-speed-management/

Volker, J. M. B., & Handy, S. (2021). Economic impacts on local businesses of investments in bicycle and pedestrian infrastructure: A review of the evidence. *Transport Reviews*, *41*(4), 401–431. https://doi.org/10.1080/01441647.2021.1912849

White, D., Raeside, R., & Barker, D. (2000). ROAD ACCIDENTS AND CHILDREN LIVING IN DISADVANTAGED AREAS: A LITERATURE REVIEW. *CM 4604*. https://trid.trb.org/View/657259

Why 12-Foot Traffic Lanes Are Disastrous for Safety and Must Be Replaced Now. (2014, October 6). *Bloomberg.Com*. https://www.bloomberg.com/news/articles/2014-10-06/why-12-foot-traffic-lanes-are-disastrous-for-safety-and-must-be-replaced-now

Zegeer, C. V., Deen, R. C., & Mayes, J. G. (1981). EFFECT OF LANE AND SHOULDER WIDTHS ON ACCIDENT REDUCTION ON RURAL, TWO-LANE ROADS. *Transportation Research Record*, *806*. https://trid.trb.org/View/173310

Zegeer, C. V., Richard Stewart, J., Huang, H., & Lagerwey, P. (2001). Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Analysis of Pedestrian Crashes in 30 Cities. *Transportation Research Record*, *1773*(1), 56–68. https://doi.org/10.3141/1773-07