DEPARTMENT OF TRANSPORTATION

VULNERABLE ROAD USER SAFETY ASSESSMENT

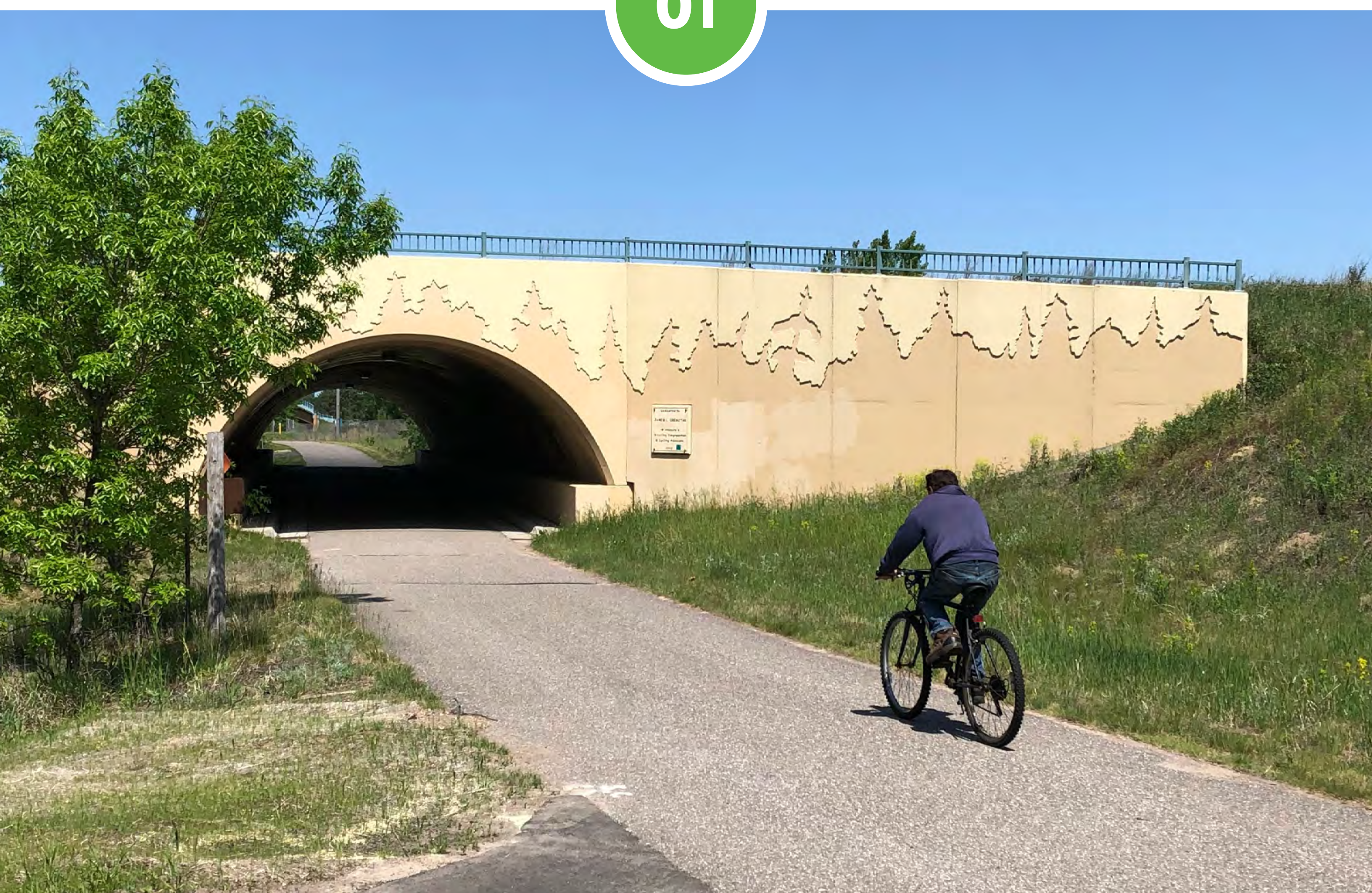
CONTENTS

ABBREVIATIONS

AADT	Annual Average Daily Traffic
ACTT	Advocacy Council on Tribal Transportation
ADA	Americans with Disabilities Act
BIPOC	Black, Indigenous, and People of Color (note that BIPOC and POC are both used in this assessment, based on their inclusion in previous planning efforts)
CHIP	Capital Highway Investment Plan
CRSP	County Roadway Safety Plan
ECHO	Emergency, Community, Health, and Outreach
GIS	Geographic Information System
HIN	High Injury Network
HiPPS	High Priority Pedestrian Safety Improvement Project
HSIP	Highway Safety Improvement Program
KA	Fatal or Serious Injury
MnDOT	Minnesota Department of Transportation
MnSHIP	Minnesota State Highway Investment Plan
MPH	Miles Per Hour
MPO	Metropolitan Planning Organization
PAWS	Priority Areas for Walking Study
PHB	Pedestrian Hybrid Beacon
POC	People of Color (note that BIPOC and POC are both used in this assessment, based on their inclusion in previous planning efforts)
PROWAG	Public Right-Of-Way Accessibility Guidelines
RDC	Regional Development Commission
RRFB	Rectangular Rapid Flashing Beacon
SBSP	Statewide Bicycle System Plan
SMTP	Statewide Multimodal Transportation Plan
SPACE	Suitability of the Pedestrian and Cycling Environment
SPSA	Statewide Pedestrian Safety Analysis
SPSP	Statewide Pedestrian System Plan
SRTS	Safe Routes to School
TCMA	Twin Cities Metropolitan Area
TZD	Toward Zero Deaths
VRUSA	Vulnerable Road User Safety Assessment

INTRODUCTION

01



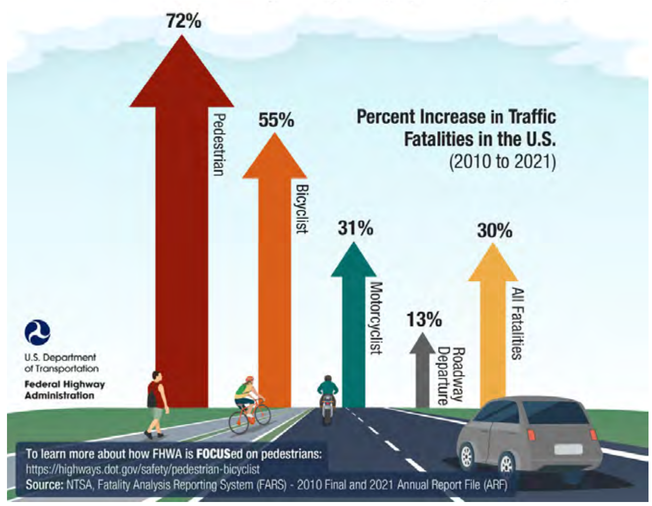
1.1 Purpose of Vulnerable Road User Safety Analysis

Fatalities of the most vulnerable road users in the United States are increasing at a greater rate than all fatalities in the United States. There is an urgent need to take action in response to the current crisis in traffic fatalities by "taking substantial, comprehensive action to significantly reduce fatal and serious injuries on the Nation's roadways," in pursuit of the goal of achieving zero highway deaths. FHWA has encouraged States to prioritize vulnerable road user safety in all Federal highway investments and in all appropriate projects.

To improve the safety of vulnerable road users in the state of Minnesota and satisfy the new federal requirements, the Minnesota Department of Transportation's (MnDOT) Office of Traffic Engineering commissioned a **Vulnerable Road User Safety Assessment** (VRUSA), including development of a High Injury Network for the state and separate studies of bicycling and pedestrian crashes in urban and rural areas within the state. The VRUSA will be amended into the 2020–2024 Strategic Highway Safety Plan as an addendum.

The federal Bipartisan Infrastructure Law, passed in 2021, created a new requirement for states to conduct a VRUSA every five years. Anchored in the Safe System Approach, this assessment uses a data-driven process to identify high risk areas for people walking, biking and rolling across the state and incorporate equity and demographics into the analysis.

While bicyclists and pedestrians are different road users, use different infrastructure in many places, and have different safety concerns, both bicyclists and pedestrians are vulnerable roadway users that are disproportionately likely to be killed or severely injured in the transportation system. Often bicycle and pedestrian countermeasures are planned and implemented in tandem, so it is necessary to have safety analyses of bicycle and pedestrian crash trends to inform these processes.



Bicyclists and pedestrians are vulnerable road users that are disproportionately likely to be killed or seriously injured on the transportation system.

Assessment Approach for Minnesota

There are many established ways to examine crashes to better understand traffic safety patterns. Federal guidance around the new VRUSA recommends the use of a High Injury Network (HIN), predictive, and/or systemic analysis to identify high risk areas for people walking, biking and rolling.

In response, MnDOT developed this assessment to document the agency's robust and multifaceted efforts to understand vulnerable road user safety. This report satisfies the FHWA guidance by presenting findings from both systemic and High Injury Network analysis to identify high risk areas for VRUs. First, the report presents a new Statewide High Injury Network, which accounts for historic crash patterns for people walking, biking, and rolling (VRUs). The High Injury Network was built using data from 4,507 fatal and injury bicyclist, pedestrian, and other vulnerable road user crashes over a five year time period.

In 2021, ahead of the new VRUSA guidance, MnDOT completed a Statewide Pedestrian Safety Analysis (SPSA) to understand challenges facing pedestrians across the state. A Statewide Bicyclist Safety Analysis and the development of a Statewide High Injury Network were completed to complement the preiously completed analysis to fulfill the goals for a VRUSA. Collectively, the results of these three analyses are included in this report to satisfy federal requirements for a data-driven assessment.

Summary findings from MnDOT's 2021 SPSA are included alongside results from a new Statewide Bicyclist Safety Analysis. Both of these analyses are rooted in a systemic framework, helping to identify and document risk factors to proactively direct infrastructure improvements and safety countermeasures to reduce vulnerable road user deaths and injuries. Because the SPSA was completed in 2021, these analyses both use data from 2016—2019 and include 2,643 bicyclist crashes and 4,207 pedestrian and other vulnerable road user crashes. Collectively, these three analyses constitute a robust, data-driven process for identifying higher-risk areas in the transportation system.

The HIN along with pedestrian and bicycle crash reviews provide takeaways which are relevant for road authorities and safety partners across the state. Where possible, analyses were completed for all roads in the state. MnDOT has more comprehensive roadway data elements currently available for their roadway system, so additional analysis was conducted for for state trunk highways. However all communities across the state can learn from the data trends and program of projects and strategies shared in this assessment.

1.2 About this Document

This assessment includes previously completed work with new analysis and engagement to produce a holistic view of safety considerations for VRUs. The following analyses (1) include the past 5 years of data, (2) represent vulnerable road users as defined in federal guidance, (3) use a data-driven approach that incorporates both High Injury Network and systemic elements, and (4) acknowledge human vulnerability and a change in approach to preventing and responding to crashes.

Each of the following chapters outlines the approach and findings for different elements of this assessment. Chapter Two highlights the last five years of crash history in Minnesota, with comparisons between crashes for people walking, biking, rolling, and driving. Chapter Three outlines the new crash data analysis conducted for this assessment in three parts: the HIN, the Statewide Bicyclist Safety Analysis, and the Statewide Pedestrian Safety Analysis. Chapter Four summarizes recent MnDOT and partner engagement around safety for people walking, biking and rolling; as well as new engagement conducted for this assessment. Chapter Five synthesizes these findings with previous MnDOT safety work. Chapter Six presents a program of projects and strategies for walking, biking and rolling safety moving forward.

Definitions

In order to identify high-risk contexts and opportunities for safety improvements, the project team established a number of important definitions and categories for data analysis. Many of these are based on federal or state definitions, as well as data availability for consistent analysis across the state. The resulting definitions and categories used in this assessment are defined in the following sections.

VULNERABLE ROAD USERS

For the purpose of this assessment, the Federal Highway Administration (FHWA) defines vulnerable road users as a **non-motorist coded in crash reporting systems as a pedestrian, bicyclist, other cyclist, or other personal conveyance**. FHWA further clarifies that this category includes highway workers on foot in a work zone and excludes motorcyclists. Therefore, the project team removed crashes that only involved motorists from data analyses. Crash evaluation work included assessment of both highway workers and pedestrians who were initially in a vehicle but exited (typically due to a breakdown).

Crashes in which a person was using a scooter or other mobility device (e.g., shared e-scooter or ADA assistive device) are classified within the data as "Other personal conveyance." Many of these crashes—especially those involving someone using a wheelchair or other assistive scooter or device—are more accurately described as "pedestrian" crashes, for the purposes of this analysis. However, this category of "other personal conveyance" crashes includes a broad range of user types that the reporting officer is otherwise unable to categorize, some of which are considered vulnerable road users (people using e-scooters or assistive devices), and some of which are not (e.g., tractors).

The project team made a targeted effort to categorize "other personal conveyance" crashes based on their likelihood of having been a vulnerable road user.

- Other personal conveyance crashes in which the narrative mentions various permutations of the words "walk", "cycle", "wheelchair", "scooter", and other VRU-related keywords were kept as likely VRU crashes.
- Crashes in which the narrative mentions farm or other road equipment, such as "tractor", "horse", or "combine", were excluded as likely not VRU for the purpose of this study.
- The remainder that could not readily be classified were also kept in the study as "other personal conveyance" crashes.

Throughout this report, vulnerable road users are referred to as ***people walking, biking,*** *and* ***rolling.***

GEOGRAPHY

To create meaningful, manageable geographies, Table 1 defines subsets of urban areas. In this assessment, urban/rural designation utilizes the MnDOT Suitability of Pedestrian And Cyclist Environment (SPACE) dataset. The SPACE tool is a GIS-based spatial analysis tool using publicly available data. An index of 19 social and demographic variables identifies where latent demand and crash risk exist on Minnesota's roadways. Higher SPACE scores represent areas that are likely to have latent demand and a potential need for walking and biking facilities.

Table 1. *Geographic categories used for this assessment as aggregated to the MnDOT SPACE tool*

GEOGRAPHY	DEFINITION
TCMA – Minneapolis and St. Paul	The cities of Minneapolis and St. Paul *Example: Minneapolis, St. Paul*
TCMA – Other Cities	Remaining cities within the broader Twin Cities Metropolitan Area *Example: Eagan, Roseville, St. Louis Park*
Greater MN Metro Areas	Other metropolitan and large urban areas in the state *Example: Duluth, St. Cloud (and surrounding metropolitan areas)*
Small Urban Communities	Smaller communities that do not have an associated metropolitan area *Example: Alexandria, Bemidji*
Rural Areas	Areas with low population density

SEVERITY

Crash data is reported using the KABCO system of severity recording, defined as follows:

- **K - Fatal:** A fatal injury is any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred. If the person did not die at the scene but died within 30 days of the motor vehicle crash in which the injury occurred, the injury classification should be changed from the injury previously assigned to "Fatal Injury"
- **A – Suspected Serious Injury:** An incapacitating injury is any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury occurred. This category includes: severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconsciousness at or when taken from the accident scene, unable to leave the accident scene without assistance.
- **B – Suspected Minor Injury:** A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include: lump on the head, abrasions, bruises, or minor lacerations.
- **C – Possible Injury:** A possible injury is any injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Possible injuries are those which are reported by the person or are indicated by their behavior, but no wounds or injuries are readily evident. Examples include: momentary loss of consciousness, claim of injury, limping, or complaint of pain or nausea.
- **O – Property Damage Only:** Crash where only property is damaged. No injuries resulted from the crash.

For analysis that looks at severity of crash types, the project team identified fatal (K) and suspected serious injury (A) crashes. These two categories are referred to as "severe" throughout this assessment. For analysis that looks at severity of crash types, the project team focused on severe crashes, which we define as fatal (k) and suspected serious injury (or serious injury, A) crashes. Throughout the report, we use the following labels interchangeably: "severe", "fatal and serious injury", "resulting in death or serious injury", or "life-altering". In tables, the abbreviation "KA" refers to these severe crashes, based on their KABCO initials. The Safe System Approach focuses on reducing and ultimately eliminating these most severe, life-altering crashes, and these are the types of crashes for which state and federal performance measures are set.

1.3 Introduction to Safe System Approach

The Safe System Approach furthers past programs built around the belief that one traffic death is too many. Safe System principles are grounded around the idea that humans make mistakes, and that human bodies have a limited ability to tolerate forces from a crash. As such, transportation systems should be designed so that mistakes do not lead to death. Specifically, the approach focuses on roadway designs that anticipate human mistakes and reduce the risk of a crash, while also minimizing the risk of a serious injury or fatality when crashes do occur.

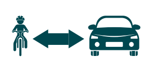
The founding principles of a Safe System Approach (identified in Figure 1) include:

- Deaths and serious injuries are unacceptable
- Humans make mistakes
- Humans are vulnerable
- Responsibility is shared
- Safety is proactive
- Redundancy is critical

Roadway authorities and safety partners committed to a Safe System Approach can focus on improving five elements of the transportation system: safe road users, safe vehicles, safe speeds, safe roads, and post-crash care. By addressing each of these elements with infrastructure, policy and programming solutions, agencies can create a culture of safety.

Figure 1. *Principles and elements of a Safe System Approach*

Data analysis and community engagement both completed for this assessment and completed through other MnDOT processes/projects/efforts are intended to shape specific Safe System countermeasures in future safety planning efforts. Countermeasures rooted in these Safe System principles address safe roads, safe speeds, and safe road users by focusing on:



Separating users in space (e.g., separated bike lanes, walkways, and pedestrian refuge islands)

Separating users in time (e.g., leading pedestrian interval)

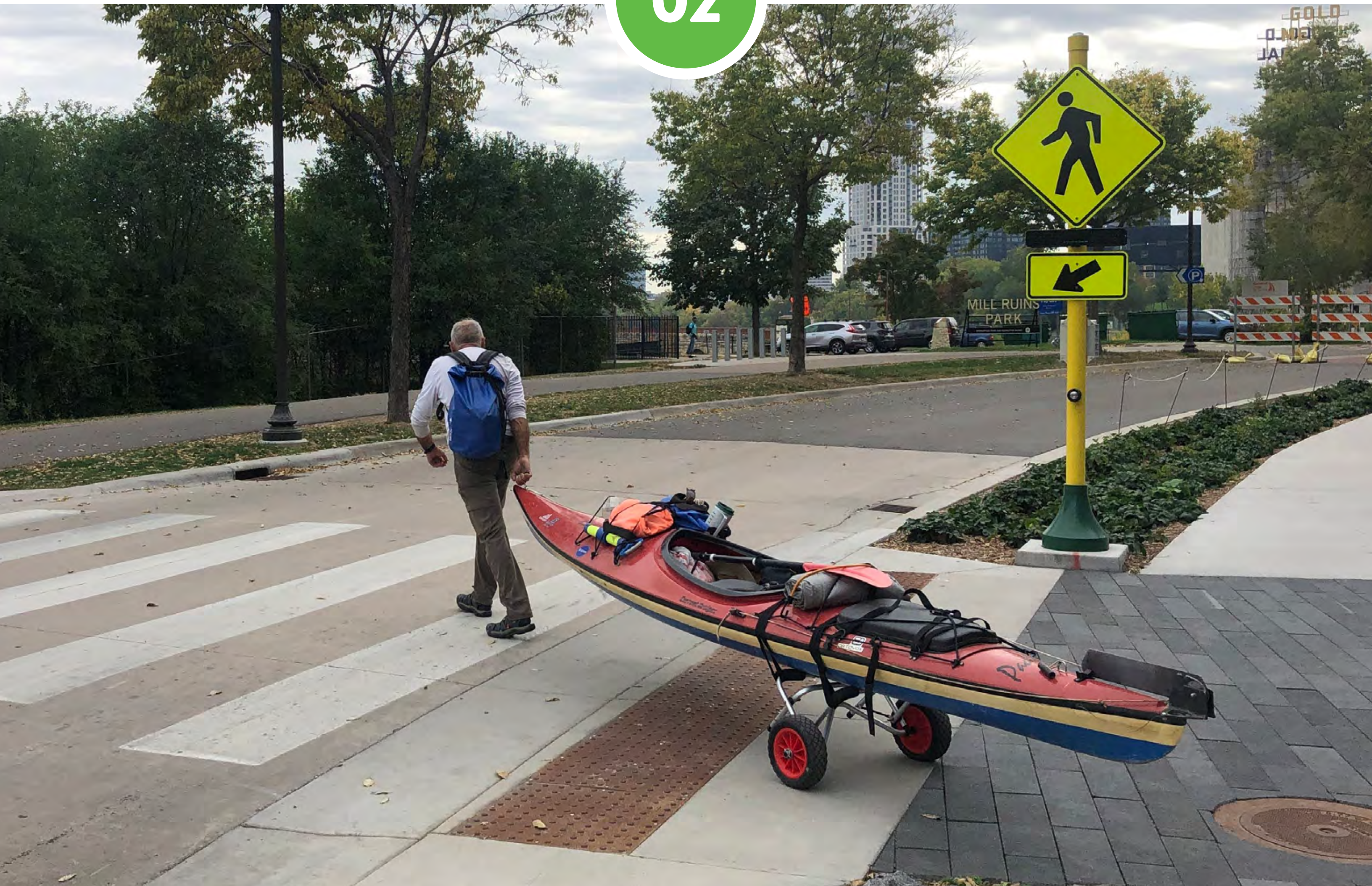
Increasing **driver attentiveness and awareness** (e.g., crosswalk visibility enhancements, pedestrian hybrid beacons, and lighting)

Implementing **physical features to slow traffic** (e.g., self-enforcing roads and road diets)

Implementing **speed enforcing strategies** (e.g., speed safety cameras)

OVERVIEW OF SAFETY TRENDS

02



2.1 Historical Trends

Traffic crashes in Minnesota resulted in **10,448 deaths and serious injuries between 2016 and 2021.** Where crashes are happening, who is involved in crashes, and what types of risks exist for all users of the transportation system are key questions in implementing a Safe System Approach.

This chapter highlights the recent history of traffic crashes in Minnesota. The following sections identify trends in total and serious injury crashes for people walking, biking, rolling, and driving, comparisons between these ways of getting around, and additional factors to consider while interpreting crash history in Minnesota.

Pedestrian Crashes

Pedestrian crashes have generally decreased across the state since 2016, with significant decreases accompanying changed traffic trends from the COVID-19 pandemic in 2020 and 2021. While the severity of pedestrian crashes declined somewhat from 2016 to 2019, the percentage of crashes that resulted in a fatality or serious injury rose in 2020 and 2021.

Figure 2 shows the trend in pedestrian crashes and crash severity from 2016 to 2021.

Bicyclist Crashes

Though the trend is less consistent than with pedestrian crashes, bicyclist crashes have also decreased since 2016. Like pedestrian crashes, the severity of bicycle crashes was generally consistent or declining from 2016 to 2019, before rising again in 2020.

Figure 3 shows the trend in bicyclist crashes and crash severity from 2016 to 2021.

Figure 2. *Trends in pedestrian crashes and crash severity (2016–2021)*

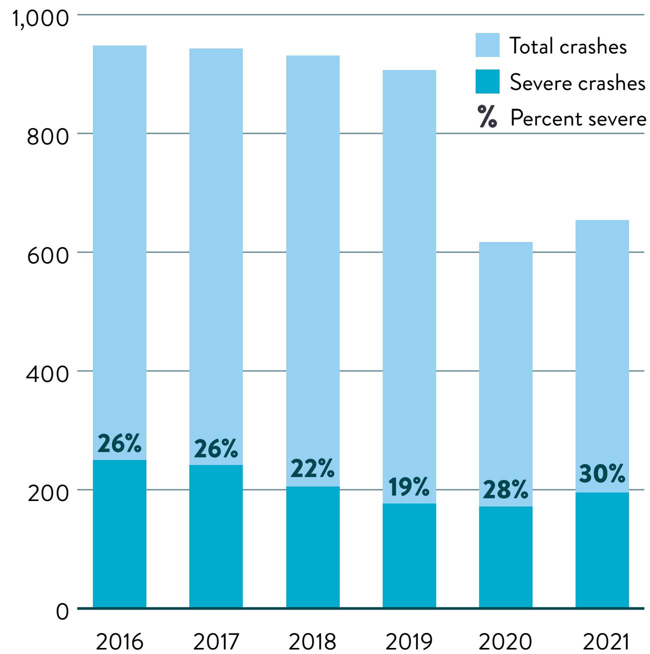
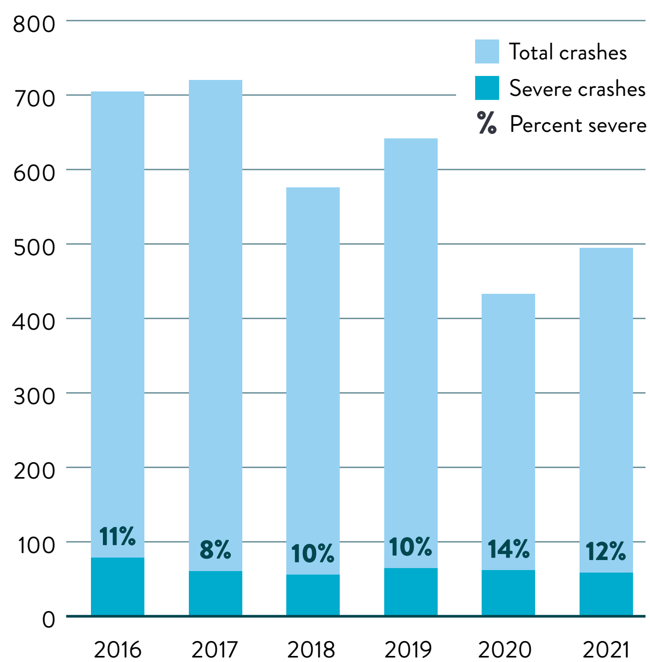


Figure 3. *Trends in bicyclist crashes and crash severity (2016–2021)*



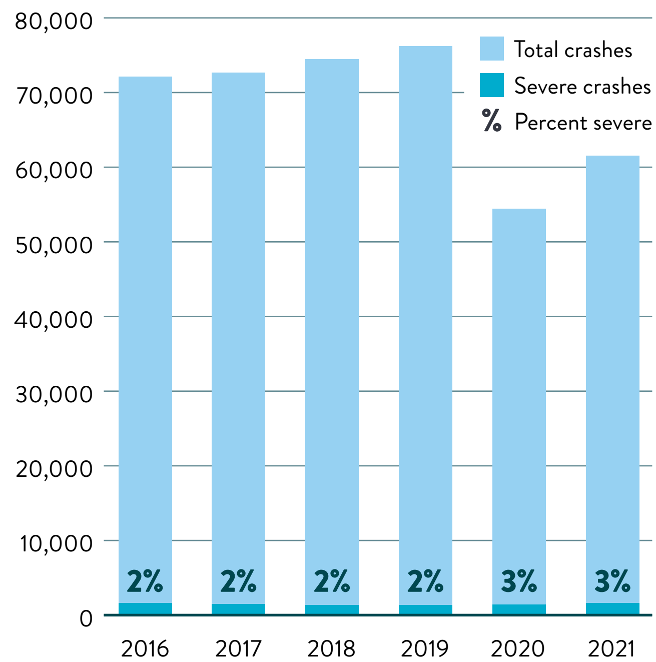
2.2 Comparison to Driver Crashes

Motorist crashes have followed a somewhat different pattern in recent years. After increasing from 2016 to 2019, the total number of motorist crashes decreased signficantly in 2020 with the COVID-19 pandemic. Motorist crashes rebounded in 2021, though still remained lower than pre-pandemic levels.

Throughout that time, severe motorist crashes followed a pattern that is somewhat similar to pedestrian and bicyclist crashes. Severe motorist crashes had been decreasing from 2016 to 2019 but began to increase slightly in 2020 and substantially in 2021. Combined with the decrease in overall number of crashes, this led to an increase in severity rate for motorist crashes from 2% to 3%. While this seems small, a one percentage point increase across tens of thousands of crashes reflects dozens or hundreds more lives significantly altered by severe traffic crashes.

Figure 4 shows the trend in motorist crashes and crash severity from 2016 to 2021.

Figure 4. *Trends in motorist crashes and crash severity (2016-2021)*

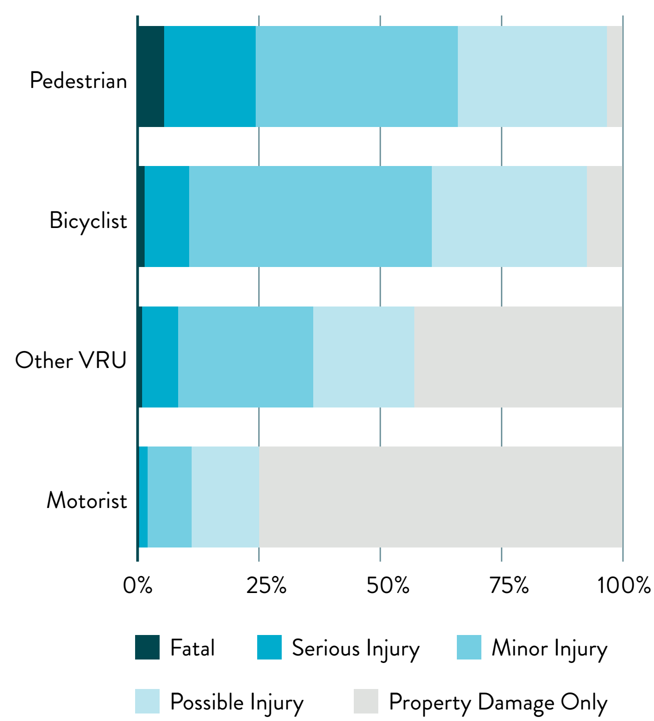


Crash Severity Comparison

Looking at crash severity in more detail reveals clear differences between outcomes for people walking, biking, rolling, and driving. Pedestrian crashes are the most likely to result in a fatality or serious injury. Most bicyclist crashes result in minor injury, but bicyclist crashes still result in higher fatality and serious injury rates than motorists. The motorist-only category is dominated by non-injury, property damage only crashes.

Figure 5 shows the distribution of crash severities across each of the different transportation modes. The disparity between this distribution for motorists and vulnerable road users (pedestrians, bicyclists, and other VRUs) is striking. The two darkest colors, representing fatal and serious injury crashes, fill 25% of the bar for pedestrians; yet these colors are hardly visible for motorists. Conversely, a full 75% of motorist crashes result in property damage only, but it is rare for there to be no injuries when a pedestrian or bicyclist is hit. This disparity shows why a comprehensive assessment of vulnerable road user safety is imperative for a Safe System Approach: when a crash occurs, pedestrians, bicyclists, and other VRUs experience drastically more severe outcomes than motorists.

Figure 5. *Distribution of crash severity by mode (2017–2021)*



These severity trends hold true regardless of where in the state crash data is analyzed. Crashes involving VRUs represent a tiny fraction of overall crashes across the state, but they make up a substantial portion of severe crashes. Trends vary by geography, but even in suburban and smaller urban communities, VRUs make up 19 to 22% of all severe crashes.

Table 2 shows the overrepresentation of walking, biking, and rolling crashes and severe crashes across different community types in Minnesota. The first two columns describe what percent of crashes and severe crashes in the state involve one or more VRUs. Across the state, only 2% of all crashes involve a vulnerable road user, but 16% of severe crashes across the state involve a VRU. In Minneapolis and St. Paul, 39% of severe crashes involve a VRU, compared to only 4% of severe crashes in rural areas.

The second two columns show, when a VRU crash or any crash happens, what percentage of those crashes result in death or serious injury. While only 2% of all crashes are severe, a full 18% are severe when that crash involves a VRU. Minneapolis and St. Paul have the lowest percent of VRU crashes that are severe (14%). By contrast, any given crash in rural areas is already more likely to result in death or serious injury than urbanized areas (6% vs. 1-2%), and VRU-involved crashes are even more likely to be severe (41% vs. 14–22%).

Table 2. *Crash severity by geography (2017–2021)*

GEOGRAPHY	% OF ALL CRASHES THAT INVOLVE VRUs	% OF SEVERE CRASHES THAT INVOLVE VRUs	% OF VRU CRASHES THAT ARE SEVERE	% OF ALL CRASHES THAT ARE SEVERE
TCMA - Minneapolis and St. Paul	5%	39%	14%	2%
TCMA - Other Cities	2%	19%	19%	2%
Greater MN Metro	2%	26%	16%	1%
Small Urban Communities	2%	22%	22%	2%
Rural	1%	4%	41%	6%
Overall Statewide	**2%**	**16%**	**18%**	**2%**

LIGHTING

Crash data from this time range also shows trends in severe crashes aligning with ambient lighting conditions. Specifically, pedestrians are uniquely vulnerable in darkness. Across all geography groups, 53% of severe pedestrian crashes happen in dark conditions (with and without street lights). Only 33% of severe motorist-only crashes and 22% of severe bicyclist crashes happen in darkness.

Table 3 shows the difference in the percentage of fatal and serious injury crashes occurring in the dark by mode and geography type.

EQUITY

There are also trends in where crashes are occurring for different modes based on community demographics around the state. Using Minnesota Department of Transportation's (MnDOT's) Suitability for the Pedestrian and Cycling Environment (SPACE) tool, the project team identified crashes occurring in areas where at least 40% of residents are low income and at least 50% of residents are people of color (POC).

Crashes involving VRUs are more concentrated in majority-POC and low-income areas than motorist-only crashes. Less than 10% of motorist-only severe crashes happen in these areas, whereas 23% of pedestrian severe crashes and 15% of severe bicyclist crashes happen in these areas.

Table 3. *Severe Crashes (KA) in dark conditions (with and without street lighting) by mode and geography (2017–2021)*

GEOGRAPHY	% OF KA PEDESTRIAN CRASHES IN DARKNESS	% OF KA BICYCLIST CRASHES IN DARKNESS	% OF KA OTHER PERSONAL MOBILITY CRASHES IN DARKNESS	% OF KA MOTORIST-ONLY CRASHES IN DARKNESS
TCMA - Minneapolis and St. Paul	53%	27%	9%	44%
TCMA - Other Cities	50%	18%	40%	31%
Greater MN Metro	57%	37%	NA*	28%
Small Urban Communities	50%	19%	14%	29%
Rural	60%	16%	17%	32%
Overall Statewide	**53%**	**22%**	**21%**	**33%**

**There were no severe "Other Personal Mobility" crashes in Greater MN metro areas during the study period, so a percentage in darkness cannot be calculated.*

2.3 Safety Targets for People Walking, Biking, and Rolling

In 2020, MnDOT and partners set a goal of **reducing traffic deaths to 225 or fewer** *and* **serious injuries to 980 or fewer** *by 2025.*

MnDOT has set multiple goals for improving the safety of people walking, biking, and rolling (VRUs) across the state. Through documents like the Strategic Highway Safety Plan (2020) and statewide initiatives like Toward Zero Deaths, MnDOT has set targets for reducing deaths and serious injuries across the statewide transportation system.

In 2020, MnDOT and partners set a goal of reducing traffic deaths (of all modes) to 225 or fewer and serious injuries to 980 or fewer by 2025. This figure was set by stakeholders based on crash data from 2014 to 2018. During that period, Minnesota averaged one traffic-related death every day, and one serious injury every six hours.

With updated crash data, it is clear that Minnesota still has a long way to go to acheive these goals. Table 4 shows the number of fatal and serious injury crashes across Minnesota broken out by mode from 2016 to 2021.

The following chapters of this assessment provide more insight into the types of crashes, crash locations, and key contexts that should be the focus of future safety efforts moving forward. Partners around the state can benefit from these analyses to build a Safe System Approach to fatal and serious crash reduction in every Minnesotan community.

Key Takeaways

These findings highlight that there has been some decrease in crashes for vulnerable roadway users since 2016, but the percentage of crashes that resulted in a fatality or injury rose in 2020 and 2021. Pedestrian crashes are most likely to result in a fatality or serious injury.

One key takeaway is that pedestrian crashes are uniquely vulnerable in darkness. There is a need to address lighting conditions for all vulnerable road users, with a particular emphasis on pedestrians. Another key takeaway is that crashes involving VRUs are more concentrated in majority-POC and low-income areas than motorist-only crashes. This highlights a need to use socioeconomic data to prioritize infrastructure that is safe and comfortable for people of all ages and abilities during all hours of the day.

Table 4. *Severe Crashes by mode (2016–2021)*

MODE	2016	2017	2018	2019	2020	2021
Pedestrian	250	241	205	176	171	195
Bicyclist	79	61	56	65	62	59
Other VRU	9	6	4	9	5	10
Motorist	1,603	1,500	1,362	1,324	1,399	1,597
Total	**1,941**	**1,808**	**1,627**	**1,574**	**1,637**	**1,861**

SUMMARY OF DATA ANALYSIS

03

3.1 Introduction

Minnesota Department of Transportation (MnDOT) has been focused on the safety of people walking, biking, and rolling (VRUs) for many years. Chapter 5, Recent MnDOT VRU Initiatives, will discuss in more detail the efforts that MnDOT has taken to identify issues and create solutions for the most vulnerable users of its transportation system.

In one of their most robust data-driven efforts to better understand issues facing these Minnesotans, MnDOT completed the SPSA in 2021. This initiative was a statewide, systemic safety study to identify conditions that create higher risk of deaths or serious injuries for people walking. The result was an understanding of the state's top pedestrian safety risk factors, and a set of recommendations intended to proactively identify safety countermeasures for these contexts.

When the FHWA required this assessment, MnDOT identified two additional analyses—the High Injury Network (HIN) Analysis and Bicyclist Safety Analysis—to complement previous work around understanding systemic pedestrian issues. This chapter presents the results of (1) the High Injury Network Analysis and (2) Bicyclist Safety Analysis alongside (3) a summary of results from the 2021 SPSA. Collectively, these three analyses provide a more comprehensive assessment of vulnerable road user safety that (1) includes the past 5 years of data, (2) represents VRUs as defined in the federal guidance, (3) uses a data-driven approach that incorporates both High Injury Network and systemic elements, and (4) follows the Safe System Approach of targeting the system as a whole.

3.2 High Injury Network Analysis

Overview

HINs are a simple and effective tool for identifying where severe crashes occur, and which areas to prioritize for safety countermeasures. They strike a balance between a reactive and proactive approach by identifying not only high-crash hot spots, but also clusters of crashes that may share similar risk factors. This approach provides a better understanding of how particular roadways and roadway risk factors contribute to safety concerns across the roadway system.

MnDOT created an HIN as a part of this effort to supplement other systemic safety research. The resulting network can help MnDOT prioritize future safety improvements and provide technical assistance to communities looking to improve safety for VRUs on their local networks.

This chapter describes how the statewide HIN was built and the results of that analysis. This section covers all vulnerable road users, including VRUs, such as with wheelchairs or mobility scooters.

Approach

MnDOT built the HIN using a dataset of over 7,000 crashes involving people walking, biking, or rolling from 2017 to 2021 (unlike the Bicyclist Safety Analysis, as noted in that section's approach). The HIN represents only fatal and injury crashes, with fatal and serious injury crashes weighted more heavily than minor injury crashes. Possible injury and property damage only crashes are excluded from the analysis. This technique is in line with a Safe System Approach that places an emphasis on life-altering crashes.

The number of crashes by mode, used in the development of the HIN, is shown in Table 5.

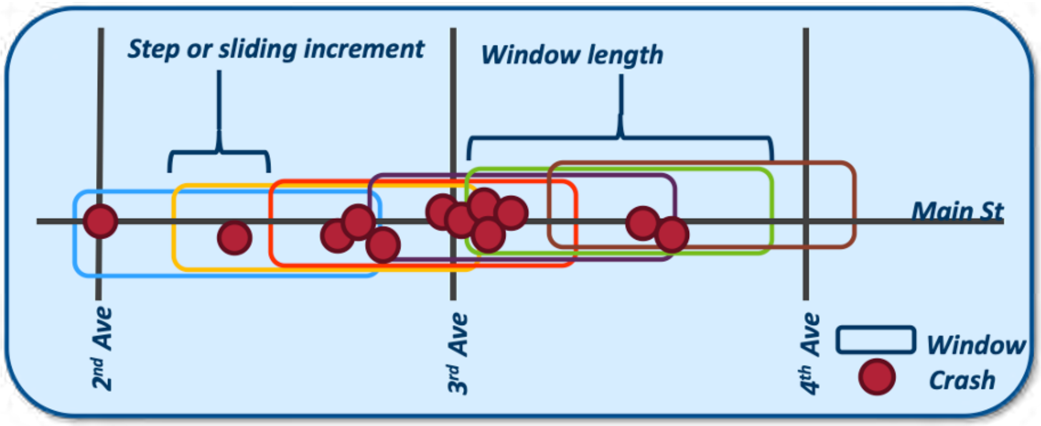
The HIN used a sliding window analysis (shown in Figure 6 on the following page) to understand roadways that may not contain a crash but are situated between crash locations and likely share similar characteristics. The analysis includes two different window lengths based on the urban/rural designations in MnDOT's Suitability of the Pedestrian and Cycling Environment (SPACE) data set. This difference is meant to account for different crash densities, roadway characteristics, and land uses across the urban–rural gradient. For large metropolitan urban areas (e.g., Minneapolis-St. Paul, Rochester, Duluth, St. Cloud, Fargo-Moorhead, Mankato), MnDOT used one-mile window lengths with 1/10-mile step increments. For smaller urban communities (e.g., Bemidji, Brainerd, Alexandria, Willmar, and Red Wing), as well as rural areas, MnDOT used two-mile window lengths and ¼-mile step increments.

Table 5. *Number of crashes by mode and severity included in the High Injury Network, 2017–2021*

MODE	FATAL AND SERIOUS INJURY	MINOR INJURY	POSSIBLE INJURY AND PROPERTY DAMAGE ONLY (EXCLUDED)	TOTAL INCLUDED	PERCENTAGE OF INCLUDED CRASHES
Bicyclist	302	1,431	1,133	1,733	38%
Pedestrian	981	1,675	1,395	2,656	59%
Other – Personal Conveyance (Possible Vulnerable Road User)	29	89	272	118	3%
Subotal – Crashes Included in HIN	**1,312**	**3,195**	**2,800**	**4,507**	**100%**

In larger urban metro areas, where sample sizes allow, separate pedestrian and bicyclist networks were developed and then combined, to better represent the distinct needs of different users. For example, Figure 7 shows the different sliding windows scores for pedestrian versus bicyclist crashes in Duluth. In small urban communities and rural areas, all crashes involving people walking, biking and rolling are combined into a single network since sample sizes are usually smaller.

Figure 6. Sliding windows used to measure crash density along a network



MnDOT also took steps to understand which type of roadways and contexts the HIN is located in. The project team compared HIN analysis results to MnDOT's trunk highway network to identify which segments of the HIN are on state-owned roadways. The analysis also joined the HIN to MnDOT's [SPACE data set] to evaluate the HIN through this lens.

Additional details on the crash data, analysis thresholds, and other considerations for communities looking to use the HIN data are available in Appendix A.

Figure 7. Scores from the pedestrian (left) and bicyclist (right) sliding windows analysis in Duluth

Image from Safe Streets Research & Consulting

Findings

The HIN captures about 30% of the state's total walking, biking, and rolling crashes on about 352 miles of HIN statewide, or about 0.2% of the state's overall road mileage. This amount varies by year, mode, severity, and geography. A smaller share of crashes during pandemic years (2020 and 2021) are on the HIN than crashes in previous years. Nearly 33% of crashes involving people walking and rolling are on the HIN, compared with 26% of crashes involving people biking. Over 27% of fatal crashes and nearly 36% of serious injury crashes are on the HIN.

Large metro areas have separate pedestrian and bicyclist HINs. There is relatively little overlap between the two, underscoring the importance of looking at walking, biking, and rolling safety separately when there are sufficient crash numbers to do so.

LOCATION TRENDS

The HIN within Minneapolis and St. Paul captures nearly 50% of crashes, but only about 2% of rural crashes are on the HIN. In these rural areas, proactive or risk factors may prove more effective in these rural, low-volume areas. Variations by geography reflect the general urban character of walking, biking, and rolling crashes in general—over 75% of crashes involving VRUs happen in the TCMA (Twin Cities Metropolitan Area). The cities of Minneapolis and St. Paul account for 113 miles of the HIN, with another 100 miles of HIN located in the rest of the metro region.

The analysis also found that HIN segments are concentrated in places with medium and high SPACE scores, as shown in Table 6. Higher SPACE scores represent areas that are likely to have latent demand and a potential need for walking and biking facilities. This finding is supported by the presence of HIN segments that also highlight a need for more protective walking and biking facilities.

Note that the SPACE dataset includes a surface of half-mile hexagon tiles covering the entire state, allowing MnDOT to normalize crash statistics by area within geography classifications. In Table 6 and following tables that include SPACE data, these areas are what is meant by "Hex" or "Hexagon."

Table 6. *Presence of HIN by SPACE score*

SPACE SUITABILITY SCORE	HEXAGONS WITH 1+ HIN SEGMENTS	HEXAGONS WITH NO HIN SEGMENTS	PERCENTAGE OF HEXAGONS WITH 1+ HIN SEGMENTS
0–39	49	302,093	0%
40–44	57	110,965	0.1%
45–44	152	62,227	0.2%
50–54	144	32,213	0.4%
55–59	135	10,404	1.3%
60–64	104	2,672	3.7%
65–69	108	601	15.2%
70–74	68	130	34.3%
75–79	40	63	38.8%
80–100	11	27	28.9%
Total	**868**	**521,395**	**0.2%**

The HIN is effective at capturing crashes involving VRUs at signal-controlled intersections, with 49% of all crashes and 59% of severe crashes on the HIN. Other location types (unsignalized intersections (22%), midblock (16%)) have lower concentrations on the HIN.

The higher inclusion of signalized intersection crashes may reflect higher vehicular traffic volumes and higher walking, biking and rolling activity at signalized intersections, as well as the general clustering of signalized intersections in denser, urbanized areas.

Among bicyclist crashes, crashes involving a driver going forward and the bicyclist crossing the roadway were much better captured by the HIN than crashes in which the driver was turning or the bicyclist was riding with or against traffic. The HIN best captures pedestrian crashes occurring at signalized intersections in which the driver was going forward or turning left.

These findings have important implications for how the HIN is used, since we know the HIN is capturing certain types of crashes better than other crash and location types. Systemic network screening or other tools should be used in tandem with the HIN to help agencies target crash types that are poorly represented on the HIN.

EQUITY

The HIN's spatial distribution reflects the underlying inequities in traffic crashes. Crashes involving people walking or biking are overrepresented in neighborhoods where residents are lower income and majority people of color.[1] Using this data from the SPACE data set, the HIN stands out with greater concentrations in these areas.

One notable concern when interpreting these crash data and the resulting HIN is the incomplete data reported in Tribal communities. DPS MNCRASH data set generally undercounts crashes in Tribal areas, and as a result, the HIN may underestimate crash concentrations. This issue is noted in Chapter 5 as an important focus area for future safety investment.

Using the Network

The HIN is one of many tools to assist MnDOT and local agencies with planning and engineering for the safety of VRUs. The HIN can help communities identify segments with the greatest concentration of crashes needing further investigation and safety improvements.

An online interactive Data Dashboard, created as a part of this assessment, provides partners with a way to view the results of the HIN analysis. If communities around the state want to investigate further into findings, they can request the underlying sliding windows data to identify their own thresholds and local HIN. Systemic and predictive analyses can also be used to screen both the HIN and other streets for risk factors.

1. Low income is defined as incomes less than 185% of the federal poverty level. People of color are defined using Census data as anyone who is not white, non-Hispanic.

3.3 Bicyclist Safety Analysis

Overview

Building off the existing 2021 SPSA and the HIN completed for this effort, MnDOT conducted a third analysis: a Statewide Bicyclist Safety Analysis. This statewide, data-driven, systemic safety study aimed to identify conditions that contribute to higher risk of death or serious injury for people biking. Using the findings from this analysis, MnDOT can proactively identify areas that would benefit from bicyclist safety engineering countermeasures.

This section provides information regarding the analysis approach (which closely resembles the 2021 SPSA methodology), a descriptive analysis of bicyclist crashes and related systemic roadway and contextual risk factors, and a multivariate crash tree analysis which identifies combinations of systemic factors commonly linked to areas where bicyclist crashes are more likely to occur. Identified conditions include not only existing roadway design features but also surrounding contextual features, such as existing non-motorized trip attracting land uses or the presence of public transit facilities.

Approach

This Bicyclist Safety Analysis closely follows the methodology of MnDOT's 2021 SPSA. The descriptive and systemic analyses combined bicycle crashes from 2016 to 2019 with roadway and environmental characteristics to create a data set for analysis, consistent with the time range included in the pedestrian report. Crash data include variables about injury severity, lighting, functional classification of the roadways, development intensity, SPACE scores and related factors, and bicycle infrastructure. Given some data limitations, some of the detailed analysis focuses on MnDOT's trunk highway network.

The 2021 SPSA included a robust data collection and consolidation process. The study team reprocessed the data using the methods documented in the data collection section of the SPSA. Please refer to that document for a detailed summary regarding data usage and limitations.

While the crash data provided notable insights, several characteristics or trends in crashes were not discernible from the data. To supplement the data, the study team scanned crash narratives from police reports of bicycle crashes. These provided clearer details in some cases, especially related to pre-crash positioning of bicyclists and vehicles, as well as sidewalk bicycling. While officer narratives are not always the most reliable source of information for pedestrian and bicyclist crash factors, keyword searching on their narratives proved useful to add nuance where roadway data are limited or coded crash report variables are ambiguous.

DESCRIPTIVE CRASH ANALYSIS

The descriptive crash analysis consists of tabulations on key variables of interest to identify attributes linked to crashes and crash severity. The project team used frequency tables to identify variables for further analysis through the development of crash trees. The descriptive analysis reviewed factors including the following:

- Injury severity
- Lighting condition
- Functional classification (of the road on which the crash occurred)
- Location type (segment vs. intersection; intersection signalization)
- Area land development intensity
- Suitability of Pedestrian and Cyclist Environment (SPACE) scores and their contributing factors tabulated to the SPACE score hexagons, including demographics and intersection risk ratings
- Variables from the Minnesota Pollution Control Agency Environmental Justice data (as aggregated to the SPACE tool) such as the racial and income demographics of areas surrounding crash locations
- Location types, specifically if a crash occurred on a trunk highway or off the trunk highway network
- Bicycle facility type (2007 data)

SYSTEMIC CRASH TREE ANALYSIS

Crash tree diagrams are a type of frequency analysis that divides crashes into progressively more detailed categories as variables are added (e.g., urban vs. rural, intersection vs. midblock, and arterial vs. residential). Crash trees are built around a single transportation mode, and then high priority types of crashes within that mode are built into separate "branches" on the tree. Priority crash types are usually defined by whichever comprises the largest shares of fatal and serious injury crashes in the system. Figure 8 shows the general crash tree development process.

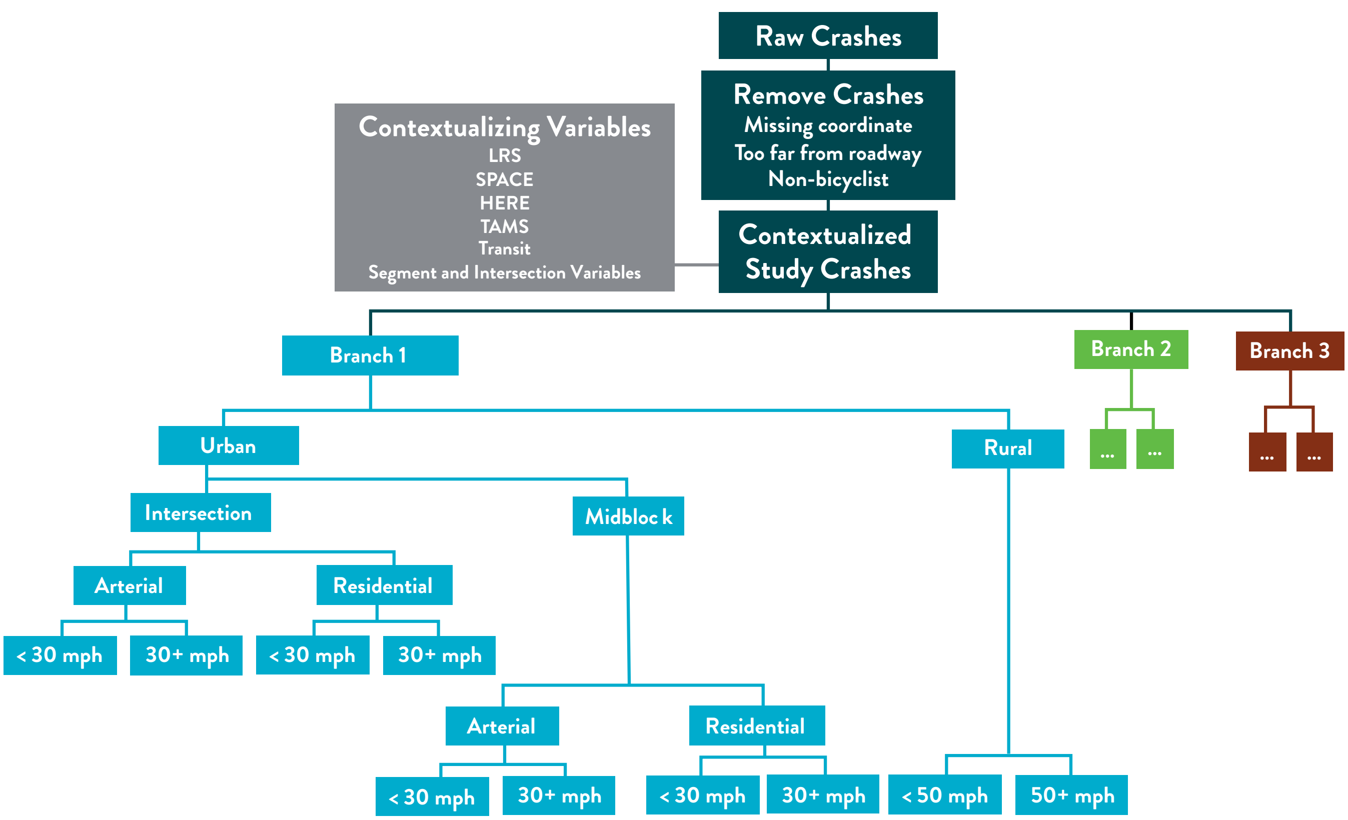
Crash tree diagrams can identify potential combinations of roadway, land use, and operational characteristics associated with high crash histories. The crash trees constructed in this assessment are not only informed by the data stored within the DPS MNCRASH database, but also include available statewide contextual data that can help practitioners and researchers better understand the combinations of variables and the relationship to crash outcomes.

This type of analysis is considered "systemic" because it helps to identify the types of locations where crashes are relatively more common or more severe, so that proactive safety countermeasures can be considered in these types of locations.

This analysis and the 2021 SPSA both used crash types as the foundation of the crash trees to identify similar crash circumstances that could be addressed using related safety countermeasures. Due to the smaller sample size of bicycle crashes, the project team constructed the bicyclist crash types using the bicyclist and motorist pre-crash movements.

Additional detail on the methodology and data considerations is available in Appendix B.

Figure 8. *Generalized example of the crash tree process and structure*



Findings

DESCRIPTIVE CRASH ANALYSIS

The project team created frequency tables to identify common attributes associated with crashes. Through review of these frequency tables, MnDOT identified the key variables, described in the following subsections, that can be used for further analysis through crash trees.

Injury Severity

Table 7 shows the distribution of all bicycle crashes by injury severity, following the "KABCO" severity scale. Throughout this report, mostly in table headers, the acronym "KA" is used to refer to fatal crashes and serious injury crashes.

In total, there were 2,643 reported bicycle crashes between 2016 and 2019. Roughly 10% of those crashes were reported to be fatal or to result in a serious injury. Most of the reported bicycle crashes resulted in a possible or confirmed injury, an expected result due to the overall vulnerability of people biking within space shared with motorists. Property damage only crashes accounted for only 6% of crashes.

Injury severities other than fatalities also likely include some degree of both underreporting and misclassification—previous research found crash reporting levels in police crash data range from 7 to 46%,[1] and the San Francisco Department of Public Health found miscoding between a meaningful percentage of serious and minor injuries.[2] Future efforts to link police crash data with hospital or other public health data may provide a more accurate assessment of bicyclist crash severity across the state.

10% of bicycle crashes resulted in a fatality or serious injury.

Table 7. *All bicycle crashes by severity, 2016–2019*

CRASH SEVERITY	# CRASHES	% CRASHES
Fatal (K)	30	1%
Serious Injury (A)	231	9%
Minor Injury (B)	1,370	52%
Possible Injury (C)	847	32%
Property Damage Only (O)	165	6%
Total	**2,643**	

Percentages may not sum to 100% due to rounding

Area Land Development Intensity

Table 8 shows the distribution of crashes by severity across the different land use designations around the state, based on categories in the SPACE dataset. The greatest portion of bicyclist crashes (41%) occurred within Minneapolis and St. Paul, while fatal or serious injury crashes occurred more often within other cities in the TCMA (36%) than any other geography group.

When looking at bicyclist crashes that occurred within Minneapolis and St. Paul and other cities of the TCMA, most crashes (76%) and most fatal or serious injury crashes (68%) occurred in the TCMA, which is likely linked with the number of people riding bikes; more bicyclists are expected to ride in urban areas, so it follows that there would be more crashes.

Small urban communities (defined as rural downtown in SPACE) had the third largest share of crashes (13%) and fatal and serious injury crashes (13%). While bicycle riding is less frequent (lower levels of exposure) in small urban communities relative to denser metro areas, this may be an indication of high crash risk in these areas of the state.

1. Doggett, S., Ragland, D. R., & Felschundneff, G. (2018). Evaluating Research on Data Linkage to Assess Underreporting of Pedestrian and Bicyclist Injury in Police Crash Data. Available at: https://safetrec.berkeley.edu/publications/evaluating-research-data-linkage-assess-underreporting-pedestrian-and-bicyclist-injury

2. San Francisco Department of Public Health-Program on Health, Equity and Sustainability. (2017). Vision Zero High Injury Network: 2017 Update – A Methodology for San Francisco, California. San Francisco, CA. Available at: https://www.sfdph.org/dph/files/EHSdocs/PHES/VisionZero/Vision_Zero_High_Injury_Network_Update.pdf

Table 8. *Bicycle crashes by land development (SPACE), 2016–2019*

AREA LAND DEVELOPMENT INTENSITY	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA	CRASHES PER HEX	KA CRASHES PER HEX	% SQUARE MILEAGE
TCMA - Minneapolis and St. Paul	1,079	41%	84	32%	8%	137.6	10.7	0%
TCMA - Other cities	916	35%	94	36%	10%	11.4	1.2	2%
Small urban communities	339	13%	35	13%	10%	3.7	0.4	2%
Greater MN metro	238	9%	23	9%	10%	17.5	1.7	0%
Rural	71	3%	25	10%	35%	0.0	0.0	96%
Total	**2,643**		**261**		**10%**	**0.5**	**0.0**	

Percentages may not sum to 100% due to rounding

Only 3% of all crashes occurred in rural areas, but 10% of fatal and serious injury crashes occurred in rural areas, and more than a third (35%) of all bicycle crashes that occurred in rural areas resulted in a fatality or serious injury. While it is possible that some of this disparity may be because of lower reporting rates of non-severe crashes in rural areas, a significant factor in rural areas is speed. An overwhelming majority of rural crashes (80%) and rural severe crashes (72%) occurred on streets with a posted speed limit of 50 mph or greater.

35% *of all bicycle crashes that occurred in* **rural areas** *resulted in a* **fatality or serious injury.**

Month

In general, warmer months (May through September) had more bicycle crashes. This finding aligns with bicyclist volume seasonality: volumes of people biking are highest during warmer months and lowest during colder and snowier months. As such, months with higher bicyclist volumes (exposure) are expected to have the highest bicyclist crash frequencies.

The share of fatal and serious injury bicyclist crashes follows the same trend—there are generally more fatal and serious injury crashes in warmer months than colder months. March is the outlier, with 4% of all crashes but 14% of fatal or serious injury crashes. This may indicate other risks, including environmental risks from ice or snow posed to road users (e.g., narrower roadways, reduced traction, and longer braking distances), darker lighting conditions, or visibility challenges related to snowfall during this time of year.

Lighting Condition

Table 9 shows how bicycle crashes and crash severity vary with lighting conditions. Compared to dark and low-light conditions, most of the crashes happened in well-lit conditions, although fatal and serious injury crashes are slightly overrepresented in dark and low-light conditions. Both findings align with what is expected, as there are more people biking during daylight hours, but low lighting impairs visibility of people biking.

Out of all crashes that occurred in darkness where there were no streetlights, 23% of the crashes resulted in a serious injury or fatality. Similarly, 14% of all crashes that occurred in dark hours at locations where streetlights were not on resulted in fatalities or serious injuries. Dark conditions with no street lighting, as well as sunrise and sunset hours appear to carry higher risk of severe outcome for people riding bicycles, with 23%, 16%, and 17%, respectively, of these crashes resulting in a fatality or serious injury.

While crashes occurring in dark, unlit conditions and crashes occurring during sunrise and sunset are disproportionately severe, the vast majority of bicyclist crashes (77%) and severe crashes (72%) happen during daylight hours.

There are slight differences between urban and rural outcomes in the link between lighting and crash severity. In urban areas, dark conditions without streetlights appear to be the riskiest: 19% of crashes that occurred in these conditions resulted in a severe outcome, compared to 12% for sunrise and sunset and 11% for dark conditions with streetlights. In rural areas, however, sunrise and sunset times appear to be a much more prevalent risk factor, with 42% of those crashes resulting in a severe outcome.

Table 9. *Bicycle crashes by lighting condition, 2016–2019*

LIGHTING CONDITION	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA
Daylight	2,034	77%	189	72%	9%
Dark (Street Lights On)	391	15%	39	15%	10%
Sunset	105	4%	17	7%	16%
Sunrise	46	2%	8	3%	17%
Dark (No Street Lights)	26	1%	6	2%	23%
Dark (Unknown Lighting)	18	1%	1	0%	6%
Unknown	15	1%	0	0%	0%
Dark (Street Lights Off)	7	0%	1	0%	14%
Other	1	0%	0	0%	0%
Total*	**2,643**		**261**		**10%**

Percentages may not sum to 100% due to rounding

Age

The analysis found that most crashes and the most severe bicycle crashes involved younger bicyclists. Bicyclists aged 10 to 14 accounted for the largest share of crashes (13% to 14%) and bicyclists aged 15 to 19 accounted for the largest share of fatal and serious injury crashes (15%), as shown in Table 10.

When comparing the distribution of victims by age to the state's population by age, younger bicyclists are much more likely to be involved in a crash and a severe crash compared to older populations. Bicyclists aged 10 to 14 were the most overrepresented in crashes, and bicyclists aged 15 to 19 were the most overrepresented in fatal and serious injury crashes. This highlights the vulnerability of people biking, especially for Minnesota's youth.

Table 10 shows that the distribution of driver ages was slightly more dispersed than that of bicyclist ages, though drivers aged 20 to 34 were more likely to be involved in a crash with a bicyclist than other age groups. Drivers aged 20 to 29, 35 to 39, and 55 to 59 were most frequently involved in fatal or severe crashes with a bicyclist. Driver representation relative to the state's population was less skewed than bicyclist representation; however, younger drivers were overrepresented. Note that the population distribution column refers to the entire state's population, not specifically licensed drivers.

Younger bicyclists are much more likely to be involved in a crash and a severe crash compared to older populations.

Table 10. *Bicyclist crashes by age, 2016-2019*

AGE	# OF CRASHES	% OF TOTAL BICYCLE CRASHES	# OF FATAL OR SERIOUS INJURY CRASHES	% OF FATAL OR SERIOUS INJURY CRASHES	% POPULATION
Under 5	13	0%	0	0%	6.2%
5 to 9	90	3%	6	4%	6.4%
10 to 14	359	13%	11	7%	6.6%
15 to 19	367	14%	22	15%	6.4%
20 to 24	262	10%	17	11%	6.1%
25 to 29	269	10%	14	9%	6.8%
30 to 34	228	9%	12	8%	6.8%
35 to 39	149	6%	8	5%	6.8%
40 to 44	125	5%	7	5%	6.1%
45 to 49	132	5%	8	5%	5.8%
50 to 54	169	6%	10	7%	6.1%
55 to 59	152	6%	12	8%	6.9%
60 to 64	116	4%	9	6%	6.6%
65 to 69	67	3%	5	3%	5.4%
70 to 74	43	2%	1	1%	4.1%
75 to 79	18	1%	3	2%	2.9%
80 to 84	8	0%	1	1%	2.0%
85+	5	0%	0	0%	2.0%
Unknown	104	4%	5	3%	
Total	**2,676**		**151**		

Percentages may not sum to 100% due to rounding

Crash Location

Nearly three-quarters of crashes involving people bicycling occurred at an intersection, as shown in Table 11. Overall crashes and severe crashes occurred most frequently at stop-controlled intersections (40% of all crashes; 39% of severe crashes). Detailed information related to the type of stop control (all-way or two-way) is not available, but we can infer from functional class combinations and from spot-checking street view imagery that most crashes happening at stop-controlled intersections are happening at partial stop-controlled intersections; where an arterial is uncontrolled and only the cross-streets have stop signs.

One potential systemic issues across the state for bicyclists relates to people biking along calmer streets (often residential streets) who need to cross major streets that are often controlled with a two-way stop sign. Crash data supports this theory: 47% of all bicyclist crashes and 55% of severe bicyclist crashes at stop-controlled intersections report the bicyclist as crossing traffic or a roadway. Furthermore, nearly all those crashes are at an intersection where the lowest functional classification was a residential street. This lack of crossing accommodations at lower-stress streets likely contributes to bicyclists attempting to cross a major street and being struck by a motorist who does not have a traffic control device.

*Nearly **75%** of crashes involving people bicycling occurred at an **intersection.***

Signalized intersections accounted for the largest share of overall crashes (34%) and the second largest share of fatal or serious injury crashes (28%). However, these crashes tended to be slightly less severe than other location types, with 8% of crashes resulting in a severe outcome, compared to 10% at stop-controlled intersections and 13% at segment locations.

Analyzing the crash data further shows differences between these trends in rural and urban areas. For example, rural areas often have more higher-speed lane miles as a proportion of the total area, which may help explain why 29% of rural segment crashes involving someone bicycling result in a fatal or severe outcome, compared to just 9% of segment locations in urban areas. Crashes that occurred at stop-controlled intersections were also more likely to be severe in rural areas than in urban areas.

Table 11. *Bicycle crashes by location, 2016–2019*

CRASH LOCATION	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA
Intersection with Stop Sign	1,048	40%	103	39%	10%
Intersection with Signal	910	34%	72	28%	8%
Segment	552	21%	72	28%	13%
Intersection with Other/ Unknown Control	133	5%	14	5%	11%
Total	**2,643**		**261**		**10%**

Percentages may not sum to 100% due to rounding

Trunk Highways

Trunk highways are state-operated roadways that range from freeways and interstates down to urban arterials and small-town main streets. Most bicyclist crashes (87%) and severe bicyclist crashes (85%) happen off the trunk highway system. Although only 15% of crashes happened on the trunk highway system, these roads represent only 8% of the state's roadway miles—meaning that crashes are more concentrated on trunk highways than on other streets.

This is noteworthy because there is a relatively smaller network across which safety countermeasures could be deployed, making this system a good opportunity to demonstrate systemic safety measures.

The project team conducted a deeper analysis of several variables within the trunk highway system, with results presented here.

Volume on Trunk Highways

Most trunk highway bicyclist crashes and severe bicyclist crashes happened on mid-range AADT streets (5,000 to 20,000 vehicles per day), similar to patterns off the trunk highway system as well. Trunk highway severe bicyclist crashes were slightly more likely to occur on high volume streets (20,000-25,000 and 30,000+) than severe bicyclist crashes off the trunk highway system. Low volume (<3,000 AADT) trunk highway bicyclist crashes were disproportionately severe, comprising 6% of bicyclist trunk highway crashes and 13% of severe bicyclist trunk highway crashes. These patterns may reflect the distribution and purpose of the trunk highway system: while these streets are more often high volume, the lowest volume trunk highways where bicyclist crashes happen may be in rural areas where speeds are high. Further, the relative proportion of bicyclist crashes on mid-AADT streets may reflect bicyclist discomfort with and avoidance of the highest volume streets.

Location Type on Trunk Highways

Of the 343 crashes along the trunk highway network, more than three-quarters of crashes occurred at some kind of intersection—a slightly higher share than the nearly three quarters of all bicyclist crashes. Of those trunk highway intersection crashes, 52% occurred at signals, and 24% were at partial-stop or all-way stop-controlled locations. A larger share of bicyclist crashes occurred at stop-controlled intersections off the trunk highway network (42%) compared to stop-controlled intersections along the trunk highway network (24%).

Through Lanes on Trunk Highways

For both on and off trunk highways, overall crashes and severe crashes involving people bicycling occurred most frequently along or at streets with two through lanes, followed by four through lanes. Interestingly, most of the crashes along two-lane roads occurred on 30 mph streets both on and off the trunk highway, as well as in urban and rural areas.

Other research (e.g., the recent NCHRP 1036 publication about roadway cross section reallocation) has shown that having more through lanes (e.g., a 4-lane road versus a 2-lane road) is typically associated with worse crash outcomes for VRUs. But without the ability to normalize by bicycle volumes/exposure or route choice, this pattern likely reflects both the overall network having a larger share of two-lane streets as well as bicyclists' route preference for calmer, lower-stress streets.

Geography Type along Trunk Highways

Similar to overall crashes, most bicyclist crashes across all analysis geography groups happened off the trunk highway system. However, the distribution of trunk and non-trunk crashes differs by geography in interesting and informative ways. Non-trunk crashes are relatively more concentrated in the TCMA (both Minneapolis and St. Paul, and the surrounding suburbs). Meanwhile most severe crashes both on and off the trunk highway network occurred in the TCMA other cities category.

A larger share of trunk highway crashes occurred in small urban communities (33%) compared to TCMA and greater MN metro areas (9% to 13%). Crashes in the Twin Cities and in rural areas had a similar severity rate between trunk highway crashes and non-trunk crashes (10-11% and 35% respectively). In Greater MN metro areas, only 13% of crashes happened on trunk highways, but they were disproportionately severe (23% on trunk highways vs. 8% non-trunk). Conversely, trunk highway crashes in small urban communities were relatively less severe than non-trunk crashes in the same geography (5% vs. 13%).

This may reflect the roles that trunk highways play in different community types. When the trunk highway turns into a small town main street, speeds are lowered and there are other visual cues to help drivers slow down, resulting in a lower crash severity rate in spite of increased crashes overall. Trunk highways through larger urban areas outside the Twin Cities function as high-speed and high-volume principal arterials while also serving a significant local access need.

Sidewalks along Trunk Highways

Sidewalk data are collected and maintained for locations along MnDOT trunk highways or overpasses that cross trunk highways as part of MnDOT's compliance with the Americans with Disabilities Act. Sidewalk data are not reliably available off the trunk highway network. To obtain sidewalk related data for this analysis, the analysis also considered officer-reported position and action of the bicyclist as well as sidewalk-related keywords from the officer narratives to classify crashes potentially related to sidewalk-riding.

Table 12 summarizes crashes that occurred at or along trunk highways by the presence of a sidewalk and other possible indicators of sidewalk riding present in the crash data.

Bicyclist crashes along trunk highways most frequently occurred if the bicyclist was using the sidewalk or crosswalk connected to a sidewalk (40%) rather than riding within the road. Most trunk highways lack low-stress on-street bicycle facilities designed to encourage bicyclists of all ages and abilities to ride within the road or in dedicated facilities rather than on the sidewalk.

Only 4% of sidewalk riding bicyclist crashes on trunk highways were severe, compared to 11% of trunk highway crashes overall.

Importantly, these 40% were disproportionately mild (only 4% resulting in death or serious injury) relative to non-sidewalk riding crashes along trunk highways with and without sidewalks (13% and 20% respectively). This finding suggests that sidewalk riding may be protective when adequate bicycle facilities are not present. Therefore, MnDOT should focus on providing high quality separated bicycle facilities along and across trunk highways. In the meantime, enforcement of anti-sidewalk riding laws may have a counterproductive effect on bicyclist safety.

Furthermore, the need for these low-stress facilities is not just preference-based: most severe trunk highway crashes occurred along segments where no sidewalk was present (50% of all trunk highway severe crashes). Many of these crashes would likely have been prevented if the bicyclist had been separated from vehicular traffic.

Additionally, analysis results about sidewalk riding—both the large numbers of crashes happening under possible sidewalk riding conditions, as well as the relatively lower severity rate of these possible sidewalk riding crashes—can inform decisions about education and enforcement as well as engineering.

Table 12. *Bicyclist crashes at/along trunk highways by presence of sidewalk and if the bicyclists may have used the sidewalk before the crash (excludes crashes off trunk highways), 2016–2019*

PRESENCE OF SIDEWALK (TRUNK HIGHWAYS ONLY)	POSSIBLE SIDEWALK USAGE FLAG	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA
No Sidewalk	No	94	27%	19	50%	20%
	Yes	9	3%	0	0%	0%
Sidewalk	No	104	30%	14	37%	13%
	Yes	136	40%	5	13%	4%
Total		**343**		**38**		**11%**

Percentages may not sum to 100% due to rounding

Table 13. *All bicycle crashes by functional classification, 2016–2019*

FUNCTIONAL CLASS*	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA	% ROADWAY MILEAGE	CRASHES PER 100 MILES	KA PER 100 MILES
Minor Arterial	1,383	52%	121	46%	9%	9%	10.8	0.9
Major Collector	495	19%	44	17%	9%	12%	2.8	0.2
Local	437	17%	53	20%	12%	69%	0.4	0.1
Principal Arterial	272	10%	30	11%	11%	4%	4.8	0.5
Minor Collector	55	2%	12	5%	22%	6%	0.6	0.1
Unknown	1	0%	1	0%	100%			
Total	**2,643**		**261**		**10%**		**1.79**	**0.18**

** Local roads tend to prioritize access at the expense whereas Arterials prioritize mobility at the expense of access. Collectors attempt to balances these competing transportation needs.*

Percentages may not sum to 100% due to rounding.

Functional Classification

Table 13 shows the distribution of bicyclist crashes and severe crashes by functional classification of the roadway. More than half (52%) of all bicyclist crashes and 46% of severe crashes occurred on minor arterials. Local streets had the second largest share of crashes that resulted in a severe outcome (12%).

Local roadways and major collectors had the next two largest shares of total and severe crashes for people bicycling, behind minor arterials. When looking at crashes on a per mile basis, minor arterials rise to the top for total and severe crashes, followed by principal arterials. When looking at the percentage of crashes that resulted in a severe outcome, minor collectors, local streets, and principal arterials had the largest share of crashes.

The largest portion of crashes (29%) and severe crashes (24%) occurred at intersections between minor arterials and local streets, followed by major collectors and local streets (14% of all intersection crashes). Exploring the pre-crash action of the person bicycling at both locations, nearly half of all crashes (48%) and more than half of severe crashes (56%) indicate the bicyclist was riding across traffic or a roadway. Looking only at crashes at these locations with this crossing pre-crash action, 60% of crashes and 68% of severe crashes were at an intersection with some type of stop control (most likely partial stop control). This indicates serious safety issues at locations in which bicyclists are attempting to cross a major street but do not have a traffic control or crossing enhancement to facilitate a safe crossing.

The data also suggest safety concerns at larger intersections—where a minor arterial meets another minor arterial or major collector. These combinations contribute 25% of all bicyclist crashes and 23% of severe bicyclist crashes. Even at signalized intersections, careful attention to design is needed to provide safe passage for people biking.

Through Lanes

Most crashes involving someone riding a bicycle occurred on two- and four-lane roadways, and these roadways had the most severe crashes as a share of all bicycle crashes. This could be because there are safety issues associated with many of these roadways, or it could be because two- and four-lane roadways make up the larger shares of the network.

Similar trends emerge when separating by urban and rural context. In general, more crashes occurred on roadways with two or four lanes, and in rural areas, crashes were concentrated on two-lane roads and were more likely to be severe than those on other roadways. In the TCMA other cities and greater MN metro categories, in contrast, crashes on roadways with five or more lanes tended to be the most severe. These patterns likely reflect the interaction of roadway design, vehicle speed, and countermeasure presence in each area.

Speed Limit

Vehicle speed is a common risk factor for bicycle crashes and crash severity. While posted speed limit is not always indicative of prevailing vehicle speed, it is used as a proxy in this analysis. Most crashes (58%) and severe crashes (52%) occurred in places where there are 30-mph speed limits. This could be because there are many roadways where the posted speed limit is 30 mph, because roadways where vehicle speeds are 30 mph are perceived by cyclists as “low enough” stress roadways, or other reasons. There are, however, notably fewer crashes and severe crashes on roadways signed at 25 mph or lower. Note that this crash analysis used data that preceded the Minnesota law (Minnesota Statute 169.14) that allows cities to more easily lower speed limits on municipal roads. The Cities of Minneapolis and St. Paul lowered speed limits on streets under their respective ownership after the new Statute was passed.

Crashes were more likely to be severe on higher-speed roadways, with the likelihood of a severe crash increasing as posted speed increased. For example, 7% of crashes were severe at 35 mph, compared to 11% at 40 mph and 16% at 50 mph or more. While this finding is expected, as higher-speed crashes release more energy during the crash, resulting in more serious injuries—it also underscores the safety benefits of lower speeds.

In general, the same trends were present across the urban–rural spectrum, with some differences. First, compared to TCMA, more of the crashes that occurred on high-speed segments in rural areas were likely to result in a serious injury or death. This differential should be further investigated to understand its cause.

For example, many non-truck highway rural roads have speed limits above 50 mph but are very narrow with no shoulders, affording no space for safe or comfortable passing when bicycling with traffic on these roads. Lack of enforcement or environmental cues to tell drivers to slow down could further exacerbate this problem, by making prevailing motorist speeds on rural roads even faster than the signed speed limit. However, when the speed limit is 50 mph, the legal traffic conditions are already deadly for VRUs. Proven safety countermeasures aimed at speed reduction, paired with a reduction in speed limits, are necessary.

There may also be connections with post-crash care that result in a higher likelihood of a serious injury or fatality given the time that it takes for the injured person to be brought to or reached by adequate emergency care. These and other factors need to be investigated and understood to be addressed.

Table 14. *Bicycle crashes by speed limit, 2016–2019*

POSTED SPEED LIMIT (MPH)	# CRASHES	% CRASHES	# KA CRASHES	% KA CRASHES	% CRASHES RESULTING IN KA
<25	34	1%	0	0%	0%
25	45	2%	3	1%	7%
30	1,545	58%	137	52%	9%
35	287	11%	19	7%	7%
40	228	9%	24	9%	11%
45	144	5%	22	8%	15%
50+	295	11%	48	18%	16%
Unknown	65	2%	8	3%	12%
Total*	**2,643**		**261**		**10%**

Percentages may not sum to 100% due to rounding

Traffic Volume

Vehicle AADT is not available for all streets across the state. Accordingly, 16% of all bicycle crashes and severe crashes occurred along streets that lack documented AADT. The majority of the street network with available AADT comprises streets with an AADT less than 3,000 vehicles per day, accounting for 84% of the network mileage but only 9% of crashes. Even if all crashes that do not have available AADT occurred along streets with less than 3,000 vehicles per day, that will still result in a lower bicycle crash per mile rate (6.5 crashes per 100 miles) and severe crashes per mile (0.8 KA crashes per 100 miles) than most other AADT categories.

However, the AADT findings also appear to corroborate the findings about functional classification noted previously—crashes that occurred along streets with an AADT of less than 3,000 (e.g., local streets) were equally likely to result in death or serious injury as crashes that occurred along roads with an AADT between 30,000 and 34,999 (e.g., minor arterials).

Digging deeper, it is evident that not all low-volume streets are equal. In the Twin Cities and in Greater MN metropolitan areas, 7% of crashes and 5% of severe crashes happen on low volume streets. In rural areas and small urban communities, low volume streets contribute 23% of bicyclist crashes and 42% of severe crashes. This finding may correlate with faster motorist speeds on rural roads.

Furthermore, lower-volume streets had a larger share of crashes that involved a person biking who was less than 18 years of age. One in three crashes (33%) that occurred along a street with less than 5,000 AADT involved a youth bicyclist, compared to 20% for streets with an AADT greater than 15,000. When looking at these lower-volume streets (less than 5,000 AADT), more than half of all crashes in small urban communities involved a youth bicyclist, followed by Greater MN metro (36%), TCMA (26%), and rural (14%).

Destinations

The 2021 SPSA crash tree analysis found that most of the pedestrian crash types studied were highly associated with destinations that attract walking trips, such as entertainment establishments, retail, and restaurants. Table 15 summarizes bicyclist crashes that are within 100 meters[1] of any of those destinations. According to the analysis, destinations have some correlation with crashes, as 42% of all crashes were within 100 meters of one of the target destinations; however, only 34% of severe crashes were within this buffer; crashes that occurred along streets with an AADT of less than 3,000 (e.g., local streets) were equally likely to result in death or serious injury as crashes that occurred along roads with an AADT between 30,000 and 34,999 (e.g., minor arterials).

1. *The 2021 SPSA also used 100 meters as the distance threshold.*

Table 15. *Bicycle crashes within 100 meters of an entertainment, retail, or restaurant establishment, 2016–2019*

WITHIN 100 METERS OF ENTERTAINMENT, RETAIL, OR RESTAURANT	# CRASHES	% CRASHES	# KA	% KA	% KA OF ALL CRASHES
No	1,542	58%	172	66%	11%
Yes	1,101	42%	89	34%	8%
Total	**2,643**		**261**		**10%**

Percentages may not sum to 100% due to rounding

SPACE Score

The project team examined the distribution of crashes by SPACE score and found that higher numbers of crashes occurred in areas with mid-range SPACE scores, as shown in Figure 9. The percentage of high-severity crashes did not follow this pattern (shown in Figure 10), and the relationship is opposite between the percentage of severe crashes and SPACE score. Both of these patterns are consistent with findings from the 2021 SPSA—that most crashes happen in mid-scoring areas, but crashes in the lowest-scoring areas are disproportionately severe. This aligns with prior analyses on severity of bicyclist crashes in rural areas.

This relationship may be due to lower motor vehicle speeds in locations with higher SPACE scores (for example, due to congestion, existing roadway design, or lower posted speed limits) or greater motorist expectation that people biking are present. Roadway miles are distributed differently, with more miles present in lower-scoring areas. The concentration of crashes in medium- and high-scoring areas on a per-mile basis may be even higher than a simple frequency distribution suggests. Further research would be needed to better understand the relationship between SPACE score and bicyclist safety.

Most crashes happen in mid-scoring SPACE areas, but ***crashes in the lowest-scoring areas are disproportionately severe.***

Figure 9. *Distribution of bicyclist crashes by severity and SPACE score, 2016–2019*

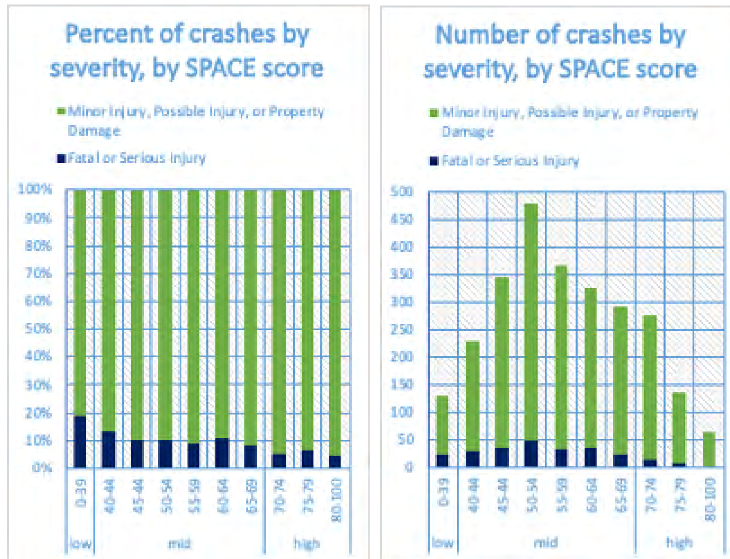
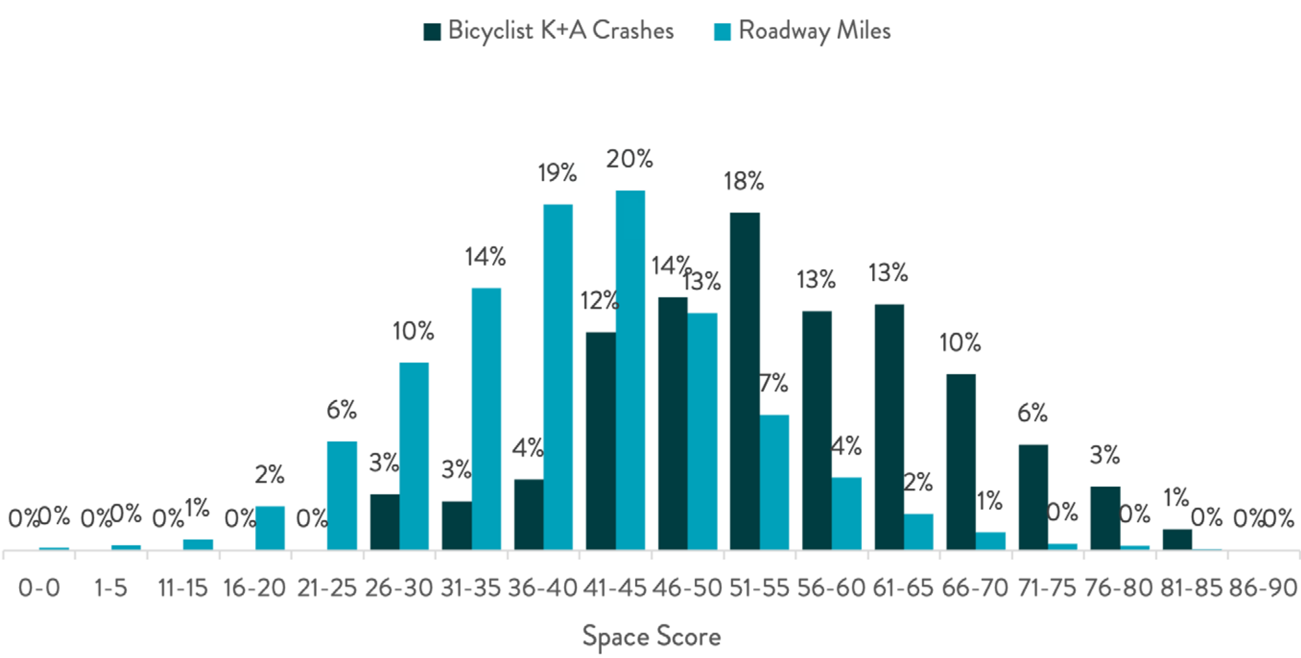


Figure 10. *Distribution of severe bicyclist crashes and roadway mileage by SPACE score, 2016–2019*



Equity

The Minnesota Pollution Control Agency (MPCA) defines Areas of Concern as a proxy for environmental justice: areas where 50% or more of resides are people of color (POC) and 40% or more of households are low income fall under this definition. Areas where 50% or more of residents are people of color (POC) and 40% or more of households are low income are considered equity target areas under this definition. This represents only a small portion of the state, and most of these identified areas are within Minneapolis and St. Paul. Therefore, while most bicyclist crashes occur outside of these Areas of Concern, this does not mean that Minnesota does not have inequities in bicyclist crashes or safety. However, this does not mean that Minnesota does not have inequities in bicyclist crashes or safety.

Within Minneapolis and St. Paul, a sizeable percentage of severe bicyclist crashes happen in equity-identified communities (more than 40% low income or majority people of color). Further, the concentration of bicyclist crashes in these areas relative to the state at large is much higher. Put another way, even though smaller numbers of severe bicyclist crashes are happening in these areas, people who live in these areas—who are more likely to be low income or people of color—are exposed to greater risk of bicyclist crashes.

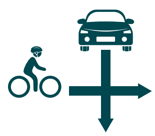
In small urban communities, the concentration of severe bicyclist crashes among areas with high poverty rates and majority POC residents are about six times higher than in areas with neither of these conditions present. Further investigation is needed, including testing different equity-related demographic thresholds, to fully evaluate disparities in bicyclist injuries and fatalities.

People with lower incomes and people of color are exposed to a greater risk of bicyclist crashes.

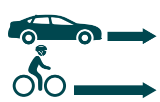
SYSTEMIC CRASH ANALYSIS

The results from this analysis identify the types of locations where crashes are relatively more common or relatively more severe. With this information, MnDOT and partners are more prepared to identify proactive safety countermeasures to apply in these types of locations.

The systemic analysis separated crashes into two significant groups to understand risky conditions:



1) crashes involving a person **biking across traffic** or a roadway while a motor vehicle moved forward, and



2) crashes involving a person **biking with traffic** or a roadway while a motor vehicle moved forward.

The following results are shared according to these groupings.

Group 1: Biking Across Traffic with a Motor Vehicle Moving Forward

Crashes involving a person biking across traffic or a roadway and the motorist proceeding forward accounted for the largest share of bicyclist crashes (791, or 30%) and severe crashes (91, or 35%). Roughly 12% of crashes in the crash type resulted in a fatal or severe crash, which is marginally more severe than the overall average of 10% for all crashes involving someone bicycling.

Figure 11 lists the factors used to categorize crashes in Group 1.

Location Type

Most crashes in this group occurred in urban areas (TCMA or Greater MN metro), accounting for 81% of crashes and 76% of severe crashes. Meanwhile 17% of these crashes occurred in small urban communities, and 2% occurred in rural areas. This is expected due to substantially higher exposure rates in urban areas compared to rural geographies, while there are low to moderate levels of people bicycling in small urban communities.

Location type and intersection control proved to be important factors for this group. Most (84%) of crashes in Group 1 occurred at an intersection, while the remaining occurred at midblock/segment locations. Crashes were more concentrated at intersection locations for urban and small urban communities, which can be expected as there was a higher density of intersections in these geography types compared to rural areas.

Looking at crashes in urban areas, most crashes occurred at stop-controlled intersections (35% of all crashes; 31% severe crashes) followed by signalized intersections (30% of all crashes; 31% severe crashes). For both rural and small urban communities, most crashes and severe crashes occurred at stop-controlled intersections, which may reflect the smaller share of intersections in these geographies that have a traffic signal.

Functional Classification

Functional classification plays a large role in where crashes have occurred in this group for all geography types. To increase the sample sizes for each step of the crash tree process, all collector and arterials were classified as "Major," while all residential streets were assigned "Local."

Across all geography types, crashes were concentrated along or at intersections with major streets. The largest share of crashes (29%) and fatal/serious injury crashes (30%) occurred at signalized intersections at a major intersection within urban areas. These are likely locations that have higher bicyclist volumes and may be easier for bicyclists to cross than other major intersections but have risk factors that contribute to a higher share of crashes and severe crashes.

Stop-controlled intersections at major streets within urban areas had the second largest share of crashes (25%) and fatal/serious injury crashes (22%). Unlike at signalized intersections, most of these crashes (83%) occurred between a major and a local street. This is likely due to where and how stop signs are used to control traffic at locations involving local functional classifications. Signals are less likely to be used than stop signs where local roads intersect with higher functional class roads. However, some bicyclists (less confident or younger) may choose to ride along slower streets (often lower speed and lower volume) but may be required to cross major streets that do not have traffic signals or crossing enhancements to facilitate a safe crossing.

Figure 11. *Variables included in the Group 1 crash tree*

Group 2: Biking with Traffic with a Motor Vehicle Moving Forward

Crashes involving a person biking with traffic and the motorist proceeding forward accounted for the second largest share of bicyclist crashes (285, or 11%) and severe crashes (45, or 17%). Roughly 16% of crashes in this group resulted in a fatal or serious crash, which is marginally more severe than the overall average of 10% for all bicyclist crashes.

Figure 12 lists the factors used to categorize crashes in Group 2.

Location Type

Like the first group, most crashes in Group 2 occurred within urban areas (86%), including two-thirds (66%) of severe crashes. Rural areas accounted for the next largest share, with 8% of crashes and 22% of severe crashes. This crash type was relatively less common in small urban communities, with 6% of crashes and 11% of severe crashes.

In urban areas, crashes were concentrated at intersection locations with nearly two-thirds of all crashes (61%) and nearly half of all severe crashes (47%) in this group. When looking at the marginal share of crashes within urban areas by location type, crashes occurred most often at intersections (72%).

Small urban community crashes were slightly more likely to happen at intersections (47%) than along segments. By contrast, rural area crashes were not concentrated at intersections - a full 79% of rural area crashes occurred along segment locations. This may reflect the lower number of intersections within these geography types, or the lack of facilities that provide adequate separation between moving traffic and people biking in these areas.

Traffic Control

When diving deeper and looking at location type and traffic control, crashes were concentrated at urban stop-controlled intersections (32%), followed by urban signalized intersections (23%) and urban segment locations (24%). Of the remaining 21% of rural crashes not happening along segments, 17% happened at partial- or all-way stop controlled intersections, and one crash happened at a signalized intersection. Thirty five percent (35%) of small urban community crashes happened at signalized intersections, with the remainder of non-segment crashes located at either stop-controlled intersections or having other/unknown control.

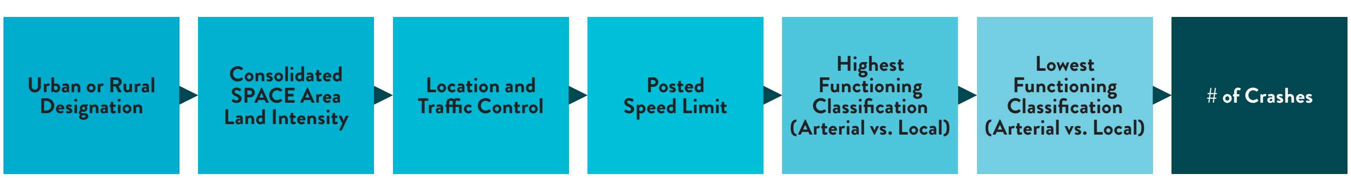
Functional Class

Looking at functional classification groupings (major vs. local), urban crashes occurred most frequently at signalized intersections between major streets (13%) followed by stop-controlled intersections between major and local streets (12%), both at locations with a 30-mph speed limit. The third most frequent location was at urban segment locations along major streets with a posted speed limit of 30 mph (11%).

Speed Limit

Posted speed limit reflects the statutory speed limits throughout the state (50 mph in rural areas and 30 mph in urban areas). Crashes in urban areas occurred most often at locations with a 30-mph speed limit, and crashes in rural areas occurred at locations with a posted speed limit of 50 mph. Interestingly, most crashes within small urban communities occurred at stop-controlled intersections at 30-mph streets, though the sample size was only six crashes.

Figure 12. *Variables included in the Group 2 crash tree*



3.4 Pedestrian Safety Analysis

Overview

Like the bicyclist safety analysis, this statewide, data-driven, systemic safety study aimed to identify conditions that contribute to higher risk of death or serious injury for people walking or rolling. Although called the "Statewide Pedestrian Safety Analysis", the study also included other vulnerable road user crashes as described elsewhere in this report. The findings from this analysis reveal the types of locations that may benefit from pedestrian safety engineering countermeasures. This section briefly summarizes the approach and key findings. A detailed description of the study's methodology and results can be viewed in the 2021 SPSA report.

Approach

As noted in the previous section, the previously described Bicyclist Safety Analysis was modeled on the 2021 SPSA. The descriptive and systemic analyses combined pedestrian and other vulnerable road user crashes from 2016 to 2019 with roadway and environmental characteristics to create a data set for analysis. At the time of this study, these represented the most recent years of data available while avoiding 2015 and earlier data due to a change in the state's crash reporting system that made older data incomparable to newer data.

Crash data include variables about injury severity, lighting, functional classification of the roadways, development intensity, SPACE scores and related factors, and sidewalks (where available). Please refer to the full SPSA report for a detailed summary regarding data usage and limitations.

Key Findings

- The rate of pedestrian crashes with confirmed injuries—and pedestrian crashes overall—was **over twice as high** on trunk highways as non-trunk roadways.
- **Over half** of pedestrian crashes with confirmed injuries, and crashes overall, occurred on Minor Arterials, while **only seven percent** of Minnesota roads are estimated to be of this type.
- **Approximately three-fourths** of pedestrian crashes with confirmed injuries, and crashes overall, occurred in the Minneapolis—St. Paul Metropolitan Region.
- Areas with lower income and higher percentages of people of color have a **disproportionately higher** number of pedestrian crashes.
- **Approximately one-third** of pedestrian crashes occurred at intersections with signals. This is the highest percentage of any roadway location type.
- Pedestrian-oriented land uses, such as commercial land use and public transit stops were associated with a **higher number** of pedestrian crashes for most crash types.

Statewide Pedestrian Safety Analysis Final Report (2021)

In 2021 MnDOT conducted a statewide, systemic safety analysis to identify conditions that create higher risk of pedestrian deaths or serious injuries. The result was an understanding of the state's top pedestrian safety risk factors, and a set of recommendations intended to proactively identify safety countermeasures for these contexts.

Top pedestrian safety risk factors identified in the plan include:

- State highways
- Minor arterials
- Four or more through lanes
- Signalized intersections
- Posted speed limits of 30 mph or more
- Shopping, restaurant, or entertainment destinations (e.g., theaters, stadiums)
- Transit stop nearby (within 500 feet)
- Greater density of people experiencing low incomes
- Greater density of people of color (POC)

Plan recommendations include:

- Collect additional key pedestrian safety data
- Adjust policies and programs to improve pedestrian safety
  - » Adopt and communicate about a speed management policy for MnDOT roads
  - » Adjust the project delivery process to facilitate system-wide proactive pedestrian safety improvements, for example through routine resurfacing
- Deploy systemic pedestrian safety countermeasures
  - » Install low-cost, rapid-implementation pedestrian safety countermeasures systemically at higher risk locations, for example: leading pedestrian intervals, high-visibility crosswalks, and pedestrian crossing islands
- Identify priority locations for longer-term improvements (e.g., roadway reallocation)
- Develop a statewide pedestrian safety action plan to target statewide approaches for reducing or eliminating pedestrian deaths and serious injuries in the state
- Create district-specific systemic pedestrian safety design and implementation guidebooks

Executive Summary

Top Pedestrian Safety Risk Factors

- State highways
- Minor arterials
- 4 or more through lanes
- Signalized intersections
- Posted speed limits of 30mph or more
- Shopping, restaurant, or entertainment destinations (e.g., theatres, stadiums)
- Transit stop nearby
- Greater density of people experiencing low incomes
- Greater density of people of color

Pedestrian Safety

MnDOT conducted a statewide, data-driven, systemic safety study to identify conditions that contribute to higher risk of pedestrian death or serious injury. Proactive application of pedestrian safety engineering countermeasures is recommended.

Detailed findings and recommendations from the Statewide Pedestrian Safety Study are available in the full report.

Roadway Factors

State Highways

State highways or trunk highways[1] had over **2x** as many pedestrian fatal and injury crashes per mile as all other roadways.

Intersections

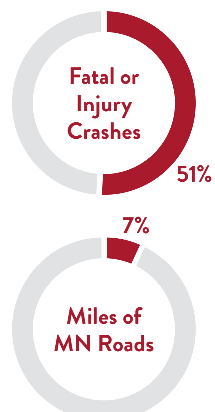
Approximately **2/3** of pedestrian fatal or serious injury crashes happened at intersections.

Signalized Intersections

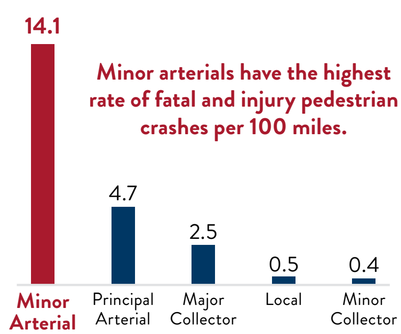
Over **1/3** of pedestrian fatal or serious injury intersection crashes occurred at signalized intersections, despite these comprising a much smaller share of all intersections.

Minor Arterials

51% of pedestrian fatal and injury crashes and 53% of pedestrian crashes overall, occurred on Minor Arterials[2], while only 7% of Minnesota roads are estimated to be of this type.

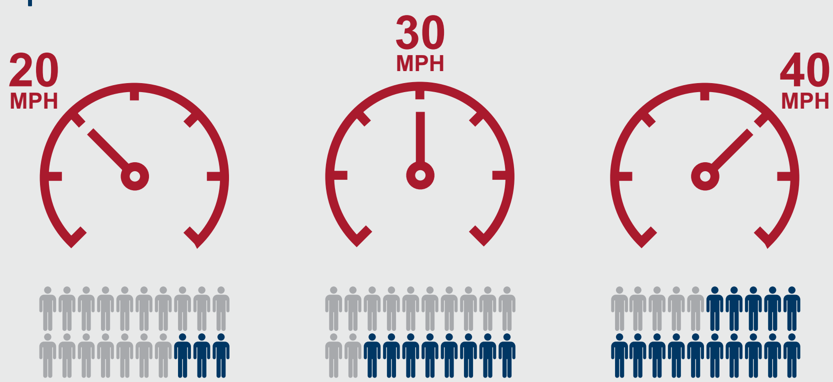


Minor arterials had over **28x** as many pedestrian injury and fatal crashes per mile as local roads.



1. Trunk highways are state-operated roadways, ranging from freeways and interstates to urban arterials to small town main streets.
2. Minor arterials are roads that serve a mix of local access needs and through-travel needs. Read more about roadway functional classification in Minnesota here.

Speed



13% Likelihood of fatality or severe injury

40% Likelihood of fatality or severe injury

73% Likelihood of fatality or severe injury

Source: Tefft, Brian C. Impact speed and a pedestrian's risk of severe injury or death. Accident Analysis & Prevention. 50. 2013.

Over half of pedestrian fatal or serious injury crashes occur where the posted speed limit is 30 mph. If a pedestrian is struck by a motorist traveling the speed limit, they have a 40% chance of dying or having a life-altering serious injury. Roadway design and other factors also affect how fast people drive, and typical travel speeds may in fact be higher than the posted speed limit.

Other Factors

Area Land Development Intensity

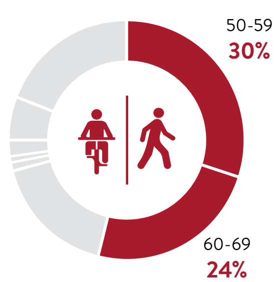
Approximately **3/4** of pedestrian injury crashes statewide occur in the Twin Cities Metro area.

Transit

Over **40%** of fatal and injury pedestrian crashes statewide occurred within 500 feet of a transit stop.[2]

SPACE Score

54% of fatal and injury pedestrian crashes occur in areas with mid-range Suitability of Pedestrian and Cycling Environment (SPACE)[1] scores (50-69).



Equity

Areas with high poverty rates have **3.9x** as many fatal and injury pedestrian crashes per square mile as high income/low poverty areas.

Areas where a majority of residents are Black, Indigenous, and People of Color have almost **9x** as many fatal and injury pedestrian crashes per square mile as majority white areas.

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3. The SPACE score is a measure of latent demand for walking and biking and environmental justice or underserved communities.
4. Transit stops and stations are common destinations for people walking and rolling. Their presence is correlated with high pedestrian volumes. Transit in and of itself does not cause pedestrian crashes. Most pedestrian crashes (75%) happened in the Twin Cities Metro area, which also contains most of the transit stops in the state. Limited transit data were available for systems outside the Twin Cities Metro area. These findings are consistent with other studies that show pedestrian crashes are disproportionately common near transit stops, e.g. Ukkusuri et al. 2021 https://doi.org/10.1016/j.ssci.2011.09.012.

Common Crash Circumstances

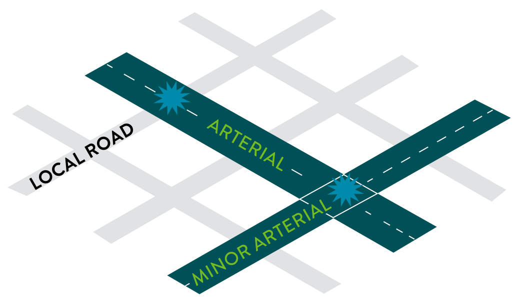
These findings are the result of a crash tree analysis to identify roadway factors that are linked to pedestrian fatal and serious injury crashes. Some of these findings mirror common roadway and travel patterns in the state; for example, many pedestrian crashes happen on lower speed roads because that is where people are more likely to walk.

Motorist going straight + Signalized intersection

- **1 in 7 pedestrian fatal and serious injury crashes**
- **96%** of crashes in this branch occur in **urban areas**
- **Over 2/3** of these crashes occurred at an intersection where:
  - » Intersections with a posted speed limit of **35 mph or below**
  - » **Minor arterial** on intersection approach
  - » Near **transit stops**
  - » Near **food, entertainment, or commercial establishments**

Motorist going straight + Unsignalized intersection

- **1 in 4 pedestrian fatal and serious injury crashes**
  - Severe outcomes were linked to locations where roads with different functional classes meet at an intersection, often with partial stop control. For example, a pedestrian attempting to cross an uncontrolled arterial at an intersection with a stop-controlled local road.

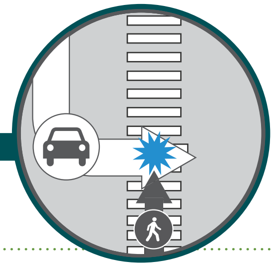


- **These crashes occur in almost all land use contexts,** with and without transit, shopping, restaurants, and entertainment.

Motorist going straight + Not at intersection + Pedestrian crossing

- **1 in 8 pedestrian fatal or serious injury crashes**
- These crashes most often occur in **urban areas** with a **30-35 mph** speed limit on **2 lane** streets **not near** transit, shopping, entertainment, or restaurants.
- **1/4** of fatal or serious injury pedestrian crashes in this branch occur in **rural areas**.

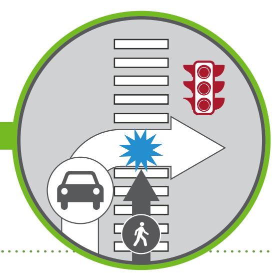
Motorist turning left + Signalized intersection



- **Nearly 1 in 10 pedestrian fatal and serious injury crashes**
- **Over 2/3** of fatal or serious injury pedestrian crashes occurred at an intersection where:
  - » Intersections with a posted speed limit of **35 mph or below**
  - » **Minor arterial** on intersection approach
  - » Near **transit stops**
  - » Near **food, entertainment, or commercial establishments**

SPEED LIMIT 35

Motorist turning right + Signalized intersection



- **1 in 50 pedestrian fatal or serious injury crashes**
- These crashes most often occur in **urban areas** with a **30-35 mph** speed limit at intersections with a **minor arterial** road near **shopping, entertainment, or restaurants**.

RESOURCES

Statewide Pedestrian Crash Analysis Full Report

MnDOT Pedestrian Design and Engineering Guidance

MnDOT Traffic Engineering Manual, Chapter 13: Non-Motorized Facilities

MnDOT Statewide Pedestrian System Plan

FHWA-HEP-16-005: Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts

COUNTERMEASURES AND BEST PRACTICES

Minnesota's Best Practices for Pedestrian/Bicycle Safety

FHWA STEP Guide

NCHRP Report 926: Guidance to Improve Pedestrian and Bicycle Safety at Intersections

MnDOT Best Practices Synthesis and Guidance in At-Grade Trail-Crossing Treatments

DEPARTMENT OF TRANSPORTATION

District Safety Plans (2016)

MnDOT updated the District Safety Plans in 2016 to identify urban and rural roadway facilities at high priority locations for safety investments. The plans identified safety projects that would give drivers a common set of roadway characteristics at similar locations across the state, identified for their sustained high crash rate or high crash risk.

The resulting plans, developed for each MnDOT district, provide a statewide and district-level overview of:

- Frequently occurring ("focus") crash types, with associated roadway and traffic characteristics
- Prioritized highway segments, curves, and intersections based on sustained high crashes or systemic risk assessment
- Prioritized list of safety strategies to reduce focus crash types
- Suggested safety projects and strategies at priority locations

Crashes involving people walking and biking were specifically identified in urban areas on trunk highways. MnDOT evaluated each intersection according to seven risk factors, prioritizing those with the highest number of risk factors present. These locations are a focus of the District Safety Plan recommendations due to the high opportunity for reducing severe crashes throughout the state highway system.

The effort identified two sets of locations: those known to have a sustained high number of crashes, and those with characteristics determined to be high risk for crashes. The 212 known intersections identified as high-crash locations account for only 3% of all intersections, and 10% of all severe crashes on the state highway system. Crashes outside the sustained high-crash locations are highly dispersed, yet not random. A more thorough systemic risk assessment was applied to the state roadway system to identify and prioritize high-risk locations based on roadway and traffic characteristics.

These plans identified characteristics associated with sustained high-crash intersections, as well as the safety countermeasures recommended to address these locations. Countermeasures include primarily upgrading signs, markings, and streetlights at rural two-lane intersections; reduced conflict intersections at expressway intersections; and addition of confirmation lights and countdown timers at urban signal-controlled intersections.

The plans also identified characteristics associated with high-risk locations. In urban areas where bicycle and pedestrian crashes were assessed, most projects included improved access management, confirmation lights at signalized intersections, and pedestrian facilities.

Table 16. *Urban Segment and Intersection Risk Factors*

	MINIMUS	MAXIMUS
URBAN SEGMENTS		
ADT	9,000	Unlimited
Road Geometry	Multi-Lane (4+)	
Access Density	36	Unlimited
Speed Limit	35	45
Primary Land Use	Urban or Suburban Retail	
Severe HO +RE +SSP + SSO Crash History	0.019	
URBAN INTERSECTIONS – RIGHT ANGLE		
Cross Product	3,000,000	Unlimited
Traffic Control	Signal	
Major Corridor Speed	40	Unlimited
Skew	5	Unlimited
Adjacent Curve	Present	
Primary Land Use	Urban or Suburban Retail	
Severe Right Angle Crash History	0.006	
URBAN INTERSECTIONS – PED/BIKE		
Cross Product	3,000,000	Unlimited
Traffic Control	Signal	
Major Corridor Speed	35	Unlimited
Skew	5	Unlimited
Adjacent Curve	Present	
Primary Land Use	Urban or Suburban Retail	
Severe Ped/Bike Crash History	0.001	

3.5 Data Analysis Findings

This assessment provides additional data-driven insight into the challenges facing people walking and biking around the state. The full analysis results from the High Injury Network (HIN) and Bicyclist Safety Analysis are documented in Chapter 3. Key safety themes that can influence future investment in walking and biking safety are listed here.

High Injury Network Analysis

The sliding window analysis of crash data from 2017 to 2021 highlighted key safety takeaways for reducing fatal and (especially severe) injury crashes. Specifically:

- **Modal Differences:** Where there are sufficient crash numbers to review (in large metro areas) pedestrian and bicycle HINs highlight different areas of risk for people walking and biking.
- **Demand:** HIN segments are concentrated in areas with medium to high Suitability of the Pedestrian and Cycling Environment (SPACE) scores, or areas with latent demand and a potential need for walking and biking facilities.
- **Equity:** Crashes involving people walking or biking are overrepresented in neighborhoods where residents are lower income and majority POC. Crash data in Tribal communities are lacking, so the HIN may underestimate risk on Tribal lands.
- **Geographic Coverage:** The HIN is heavily concentrated in Minnesota's densest, most urbanized areas.
- **Crash Types:** The HIN does a better job of capturing signalized intersection crashes than crashes at unsignalized or midblock locations. Other safety analysis results should be used to help understand safety in these areas less covered by the HIN.

Bicyclist Safety Analysis

The descriptive and systemic crash analyses provide additional context on bicycle crashes specifically, mirroring the timeframe (2016 to 2019 crashes), extent, and methodology of the Statewide Pedestrian Safety Analysis completed in 2021. See the Minnesota SPSA Final Report for results.

DESCRIPTIVE CRASH ANALYSIS

Analyzing trends in bicycle crash data highlighted the following takeaways:

- **Severity:** Around 10% of reported bicycle crashes statewide resulted in a fatality or serious injury. In rural areas, more than a third of all bicycle crashes resulted in a fatality or serious injury. Dark conditions with no street lighting and sunrise/sunset hours appear to be especially severe for people riding bicycles.
- **Age:** Youth are overrepresented in bicycle crashes. People riding bikes aged between 10 and 14 accounted for the largest share of victims and bicyclists aged between 15 and 19 accounted for the largest share of fatal and serious injury victims.
- **Location:** Nearly three quarters of crashes involving people bicycling occurred at an intersection. Overall crashes and severe crashes occurred most frequently at partial stop-controlled intersections between a larger, busier arterial and a smaller local street.
- **Trunk highways:** Fifteen percent of all bicyclist crashes happen on trunk highways, even though these represent only 8% of Minnesota's roadway miles. Crashes in small urban communities and rural areas were relatively more likely to happen on trunk highways. Trunk highway crashes in Greater MN metro areas were disproportionately severe.
- **Sidewalks:** Bicyclist crashes that occurred along trunk highways most frequently occurred if the bicyclist was using the sidewalk; however, these crashes were much less severe than crashes occurring where no sidewalk was present.
- **Functional Classification:** More than half of all bicyclist crashes and 46% of fatal/serious injury crashes occurred on minor arterials.

- **Speed:** Crashes were more likely to be severe on higher speed roadways, with the likelihood of a severe crash increasing as posted speed increased. However, most crashes occurred on roads with 30-mph speed limits; 30 mph is fast enough to present real danger for vulnerable road users.
- **Demand:** Higher numbers of crashes occurred in areas with mid-range SPACE scores (showing some latent demand). As SPACE scores increase (more latent demand), the relative percentage of severe crashes decreases.
- **Equity:** The concentration of bicyclist crashes in areas with 40% or more residents who are low income and/or a majority POC is much higher than the state at large. In small urban communities, the concentration of severe bicyclist crashes among areas with high poverty rates and majority POC residents are about six times higher than concentrations in areas with neither of these conditions present.
- **Motorist volumes:** Mid-range motorist traffic volumes (5,000 to 20,000 vehicles per day) were associated with more and more severe bicyclist crashes in urban areas. Low volume roads in rural areas and smaller communities also presented a significant problem for bicyclist safety.

SYSTEMIC CRASH ANALYSIS

Beyond the descriptive crash analysis, the systemic crash analysis identifies the types of locations where crashes are relatively more common or relatively more severe. Findings from this effort highlight:

- **Motorist Pre-Crash Movements:** Crashes involving a motor vehicle proceeding forward were more severe than other known movement types (left turn and right turn). Forward movement also represents the largest share of crashes and severe crashes.
- **Bicyclist Pre-Crash Movements:** Nearly half of all crashes and severe crashes occurred with the bicyclist crossing traffic/a roadway, followed by bicyclists traveling with traffic and cycling on the sidewalk.
- **Crash Types:** Most crashes and severe/fatal crashes involved the bicyclist cycling across traffic/a roadway while the motorist was moving forward, followed by the bicyclists cycling with traffic and the motorists moving forward.
- **Crash Tree – Group 1 (bicycling across traffic, motorist going forward):** The single biggest combination of factors for this crash type was location within the Minneapolis—St. Paul metropolitan region, partial stop-controlled intersections between an arterial or collector and a local or residential street, where shopping, dining, and entertainment destinations are not nearby. In small urban communities the combination of partial stop-controlled, arterial/collector and local intersection, and not near shopping, dining, or entertainment was also important for this crash type.
- **Crash Tree – Group 2 (bicycling with traffic, motorist going forward):** This crash type was a largely urban and large metropolitan area phenomenon, and particularly in areas with 30-mph speed limits (universal during the study period) and on arterials and collectors. The three most common profiles for this crash type included signalized intersections between arterial and/or collector streets, partial stop-controlled intersections between arterial/collector and local streets, and segment or midblock locations along arterial or collector streets, each with 30-mph speed limits. These crashes also happened in rural areas along arterial and/or collector segments with 50-mph or greater speed limits.

Additional data collection is needed to better understand conditions for people biking across the state.

Pedestrian Safety Analysis

This 2021 study laid the foundation for MnDOT's recent Bicyclist Safety Analysis and this VRUSA report. The descriptive and systemic crash analyses provide useful context on pedestrian and other vulnerable road user crashes from 2016—2019.

KEY FINDINGS

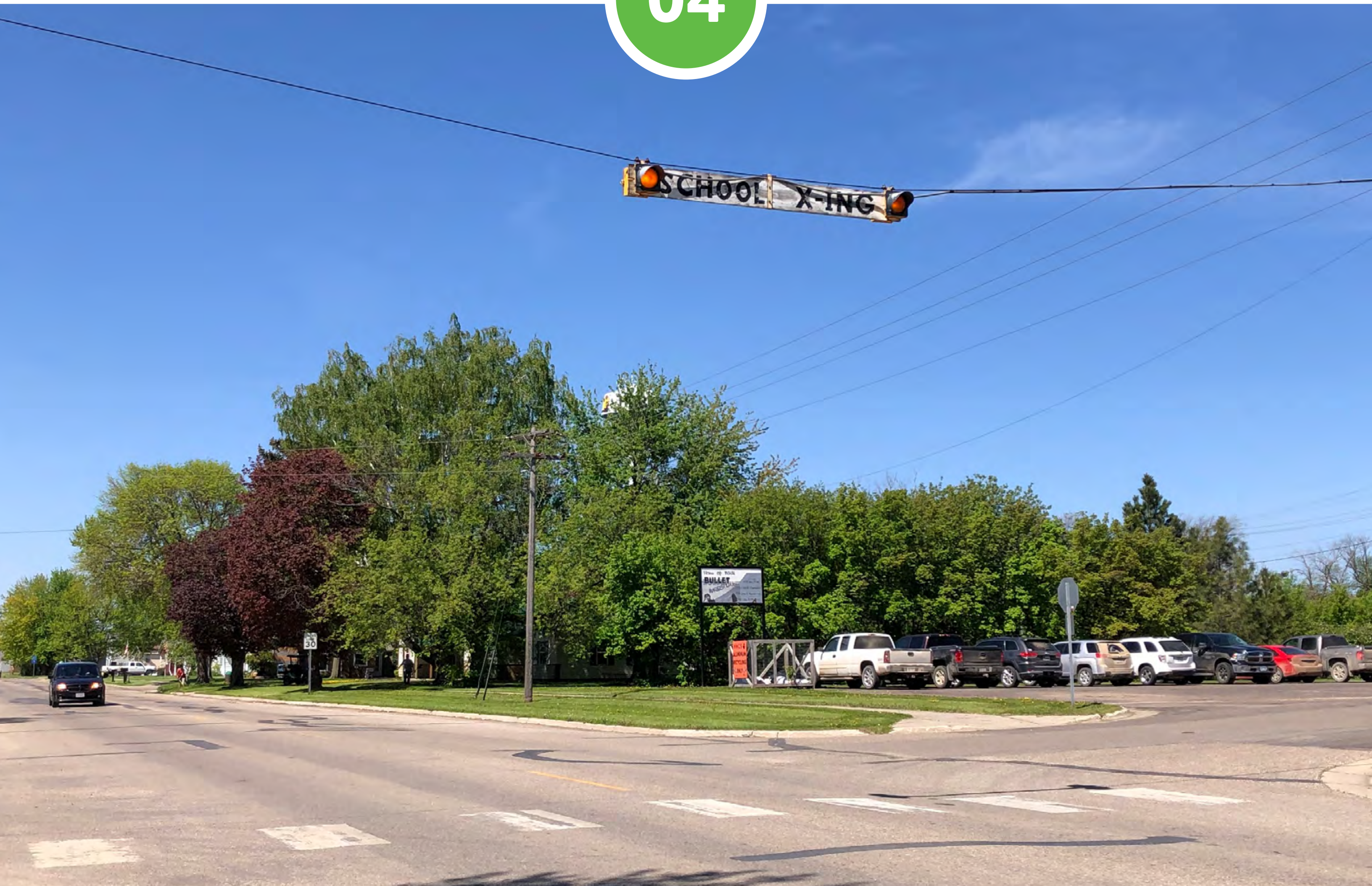
- The rate of pedestrian crashes with confirmed injuries —and pedestrian crashes overall—was **over twice as high on trunk highways** as non-trunk roadways.
- **Over half** of pedestrian crashes with confirmed injuries, and crashes overall, occurred on Minor Arterials, while **only seven percent** of Minnesota roads are estimated to be of this type.
- **Approximately three-fourths** of pedestrian crashes with confirmed injuries, and crashes overall, occurred in the Minneapolis—St. Paul Metropolitan Region.
- Areas with lower income and higher percentages of people of color have a **disproportionately higher** number of pedestrian crashes.
- **Approximately one-third** of pedestrian crashes occurred at intersections with signals. This is the highest percentage of any roadway location type.
- Pedestrian-oriented land uses, such as commercial land use and public transit stops were associated with a **higher number** of pedestrian crashes for most crash types.

SUMMARY OF RECOMMENDATIONS

- Collect Additional Key Pedestrian Safety Data
- Adjust Policies and Programs to Improve Pedestrian Safety
    - » Adopt and communicate about a speed management policy for MnDOT roads.
    - » Adjust the project delivery process to facilitate system-wide proactive pedestrian safety improvements, for example through routine resurfacing.
- Deploy Systemic Pedestrian Safety Countermeasures
    - » Install low-cost, rapid-implementation pedestrian safety countermeasures systemically at higher risk locations, for example: leading pedestrian intervals, high- visibility crosswalks, and pedestrian crossing islands.
- Identify Priority Locations for Longer-Term Improvements (e.g., roadway reallocation)
- Develop a Statewide Pedestrian Safety Action Plan to target statewide approaches for reducing or eliminating pedestrian deaths and serious injuries in the state
- Create District-Specific Systemic Pedestrian Safety Design and Implementation Guidebooks

SUMMARY OF CONSULTATION

04



4.1 Introduction

In addition to the data analysis undertaken for this Vulnerable Road User Safety Assessment, the project team reviewed Minnesota Department of Transportation (MnDOT) plans and policies to understand how the needs of VRUs across the state have been assessed in recent years. Specifically, the team looked at efforts to engage with the public and incorporate qualitative feedback into plans involving walking, biking, and rolling.

To supplement this effort, the team also held conversations with stakeholders across the state to better understand past engagement. The first half of this chapter summarizes the review of past plans and the second half describes these stakeholder conversations. Highlights will be carried forward into the program of projects and strategies in Chapter 5 for future safety investments.

Findings from these plans and policies were compiled and key themes were identified. Key themes were identified and used to build a greater understanding needs for VRUs.

4.2 Past MnDOT VRU Engagement Efforts

Over the last decade, MnDOT has intentionally worked to increase safety for VRUs across the state. MnDOT has expanded its family of plans to include a pedestrian plan and bicycle plan, while including these modes in other plan updates. These changes in planning and policy have led to substantial differences in how projects are delivered and whose needs are considered in the design of roadways.

To understand how the needs of the most vulnerable road users—including VRUs, such as with wheelchairs or mobility scooters—can continue to be prioritized in the future, the project team analyzed how the needs of these groups have been engaged in previous planning work. Table 1 shows each plan analyzed for this effort and the populations engaged for each plan.

The project team paid close attention to people walking and biking, and the six priority populations identified in the Minnesota Walks plan. Table 17 is based on information gathered during engagement and is not exhaustive. Boxes are checked if there was any evidence of engaging these populations. Lack of a checkmark on a plan does not necessarily mean that the group was not engaged, rather that the engagement team did not specifically report engagement to that group.

With each of these plan reviews, the project team identified the purpose of the plan, notable engagement and demographic information, and key themes and takeaways.

Table 17. *MnDOT and partner plans and policies reviewed for this assessment, with the priority populations involved in each*

PLAN	SMALL RURAL COMMUNITIES	CHILDREN & YOUTH	NATIVE AMERICAN POPULATIONS	PEOPLE WITH LOW INCOME LIVING IN URBAN COMMUNITIES	OLDER ADULTS	PEOPLE WITH DISABILITIES	PEOPLE WALKING	PEOPLE BIKING
Statewide Multimodal Transportation Plan	✓		✓				✓	✓
Minnesota State Highway Investment Plan	✓		✓		✓			
Strategic Highway Safety Plan					✓		✓	✓
Minnesota Walks	✓	✓	✓	✓	✓	✓	✓	
Statewide Pedestrian System Plan	✓	✓	✓	✓	✓	✓	✓	
Statewide Bicycle System Plan	✓			✓				✓
Minnesota Safe Routes to School Strategic Plan		✓					✓	✓

PLAN	SMALL RURAL COMMUNITIES	CHILDREN & YOUTH	NATIVE AMERICAN POPULATIONS	PEOPLE WITH LOW INCOME LIVING IN URBAN COMMUNITIES	OLDER ADULTS	PEOPLE WITH DISABILITIES	PEOPLE WALKING	PEOPLE BIKING
Pedestrian Crossings and Safety on Four Anishinaabe Reservations in Minnesota	✓		✓				✓	
Community Conversations Engagement Project	✓		✓	✓		✓		
Identifying and Implementing High Priority Pedestrian Safety Improvements							✓	
Active Transportation Scoping Assistance and Recommendations							✓	✓
Improving Transportation Equity by Centering the Needs of Underserved Communities	✓		✓				✓	✓
Metropolitan Council Transportation Needs in Daily Life Study		✓	✓	✓	✓	✓		

Statewide Multimodal Transportation Plan

Purpose

The Statewide Multimodal Transportation Plan is the highest policy transportation plan in the State of Minnesota, providing objectives, performance measures, strategies, and actions to move Minnesota's transportation system forward. The updated plan covers the years 2022 to 2041. The plan was developed by MnDOT but applies to all forms of transportation in the state. It is part of a "family of plans" including the Minnesota State Highway Investment Plan.

Timeline

There were four phases of engagement for this plan. Phase 1 engagement occurred between October 2020 and February 2021. Phase 2 took place between March and October 2021. Phase 3 took place between September and December 2021. Phase 4 was the public comment period, and the hearing for the draft plan took place from July to September 2022. See Appendix C for a graphic of the four phases and their goals.

Engagement

The project team created several committees representing a variety of audiences to guide the planning process, including a Policy Advisory Committee, a Technical Advisory Committee, and six work groups focusing on aging infrastructure, climate change, economy and employment, equity, safety, and transportation options. MnDOT also engaged with Tribal Nations through a government-to-government process. Boise Forte, Prairie Island Indian Community, and White Earth Nation participated in staff-to-staff coordination meetings.

Phases 1 through 3 engagement opportunities included surveys, online policy panel discussions, interactive online tools, virtual stakeholder forums, custom artwork, and in-person and virtual events. In-person events were limited due to the COVID-19 pandemic, but still included 14 events across the state. Posters, sidewalk stickers, social media posts and ads, newsletter content, and more were used to share information and engagement opportunities with Minnesotans as broadly as possible. A variety of virtual engagement opportunities were available during all phases of engagement to collect input, including an online tool for sharing comments, video-based survey, online trivia-themed events, an online discussion board, and virtual stakeholder forums.

Demographics

The project team committed to engaging with all of Minnesota. They cohosted outreach events with trusted community partner organizations to reach historically underrepresented communities. Demographic data was self-reported, so it was not always captured, and was only collected at a few events. Of what was captured, the team engaged with the following:

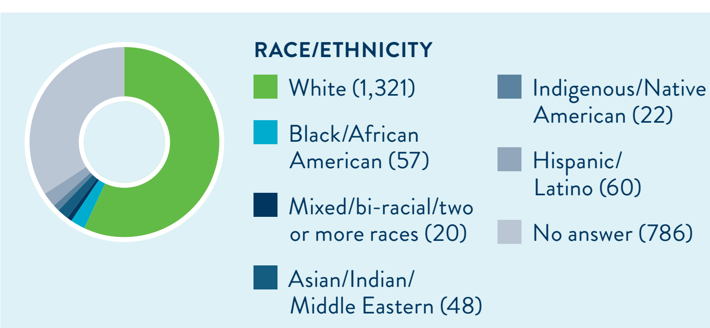
KEY THEMES AND TAKEAWAYS

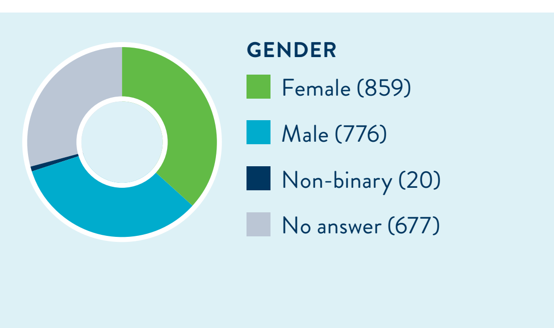
Phase 1

The first phase of engagement focused on connecting with the general public and transportation partners. This phase prioritized partnerships with community-based organizations and promoted input opportunities with communities and people who have been underserved by transportation decision-making. Activities built a broad understanding of Minnesotans' transportation challenges and priorities over the next 20 years. MnDOT asked participants to identify up to six focus areas for this plan update, of which participants chose:

- Aging infrastructure
- Climate change
- Economy and employment
- Equity
- Safety
- Transportation options

The most often-mentioned comments received during Phase 1 public engagement were about the condition of transportation infrastructure. Coming in a close second was the desire to have more options and better facilities for non-auto travel. Aging infrastructure was most commonly mentioned by transportation partners and industry stakeholders, whereas the desire for more transportation options was most frequently mentioned by more public audiences.





Phase 2

The second phase of engagement dove deep into each of six focus areas to understand impacts to the transportation system. People were asked to share ideas that evolved into draft strategies and actions for the six focus areas:

Aging Infrastructure

When asked about poor transportation conditions, responses overwhelmingly (76%) indicated that road conditions often created challenging circumstances for either themselves or their families. Responses received on this topic indicate a general feeling of frustration among Minnesotans related to aging infrastructure and road conditions. Most responses indicated that poor road conditions have created serious quality of life issues, including health and safety issues, vehicle damage, lost time due to commute, and so on. Further, many felt that these issues can be avoided with adequate funding, proactive maintenance, and future-oriented planning.

Climate Change

Responses on climate change seemed to be firmly divided between those who believed in climate change and are actively factoring this into their transportation decisions and those who reject climate change and think it should not be considered in long-range transportation planning. Respondents had a difficult time identifying a clear path toward a "cleaner transportation" future, although most responses focused on a need for diversified transportation options, including electric vehicles, improved public transportation, and identifying ways to incentivize carpooling or to get more vehicles off the roads.

Economy and Employment

Overall, the key takeaways from economy and employment indicate that Minnesotans realize there is a link between accessible, affordable transportation options and economic opportunity—both at an individual and a state, city, or county level. Responses suggest a need to prioritize expanded public transportation options, particularly in rural communities, to promote equity and provide access to equal economic opportunity to all Minnesotans.

Equity

Responses on the topic of equity focused on the need to better include Black, Indigenous, and People of Color (BIPOC) communities in long-range planning, as well as ensuring that multiple affordable transportation options are available in communities—particularly those that have historically been marginalized or underserved. It is worth noting that there were quite a few responses that expressed negative sentiments about equity, but those comments also often included additional, irrelevant political commentary. As the concept of equity—as opposed to equality—is fairly new to many people, it might be advisable to devote more effort to messaging and public education about what transportation equity means or could look like.

Safety

Nearly all responses indicated that—at some point—people felt unsafe while using transportation, regardless of whether driving, bicycling, or walking. The most cited reason for this was a perceived increase in unsafe driver behaviors, often linked to cell-phone usage and ignoring traffic laws. While participants often suggested increased law enforcement for making travel feel safer, it's important to note that increased law enforcement does not increase feelings of safety for all Minnesotans. The responses do indicate a need to strategize a way of decreasing distracted driving and driver awareness.

Transportation Options

While many participants indicated that their personal vehicles are their primary means of transportation, there was clearly a strong desire for improved public transportation options and an increased focus on alternative modes of transport (e.g., bicycling or walking). Those with personal vehicles often cited lack of accessible public transportation as the primary reason for not using those services more, particularly if the respondent was located outside of the Twin Cities metro area. Further, many responses suggested a need to provide not only improved local public transportation options, but also connection points throughout the state (Twin Cities to St. Cloud, Duluth, Rochester, and so on) via high-speed rail. There were several comments that suggested the need to focus only on personal vehicle transportation options, but these comments were in the minority.

Phase 3

Feedback obtained from stakeholders and participants during Phase 3 engagement activities informed the policy objectives of open decision-making, transportation safety, system stewardship, climate action, critical connections, and healthy equitable communities. Engagement also informed the performance measures, strategies, and actions supporting each objective.

Participants shared feedback on six policy areas that were the focus of the stakeholder forums: connected and automated vehicle readiness, climate change, vehicle miles traveled reduction, freight and economic competitiveness, Safe System approach to transportation safety, and transportation equity implementation.

Open Decision-Making

Open Decision-Making was not as frequently chosen by participants at the community events. Those that did suggested that transportation policy and planning would benefit if all or a wider variety of the public was included. In addition, people suggested the need to demystify the decision-making process or remove some of the bureaucracy so that the public better understands how and why decisions are made.

Transportation Safety

Transportation Safety was the most chosen objective in terms of priority at the community events. Comments focused on the need to address the increasing driver speed and distracted driving caused by cell-phone usage. Other comments focused on the need to improve signs, bicycle and pedestrian lanes, and road conditions.

System Stewardship

System Stewardship was the least chosen policy objective at the community events. Those that chose this objective as a priority pointed to the need to not only proactively repair infrastructure, but also design roadways to accommodate future traffic.

Climate Action

Climate Action was a frequently chosen policy objective at community events. Those that identified this objective as a priority often indicated that they were concerned about how climate change will impact future generations and the need to adopt policies and practices to mitigate any future harm. Another key theme in this category pointed to the fact that climate change is a time-sensitive issue that requires immediate attention and action if any progress or change is possible.

Critical Connections

Participants that chose Critical Connections as the highest priority focused on the need to improve transportation access for all, particularly rural, low-income, and historically underserved populations. Additionally, a key theme from this group suggested the need to make Minnesota's transportation system truly multimodal to improve access to economic opportunity, reduce climate impacts, and increase efficiency.

Healthy Equitable Communities

Healthy Equitable Communities was also a frequently chosen policy objective at community events. Those that identified this objective as a priority often noted the need for future transportation planning to place less emphasis on cars, not only for health and safety reasons but also economic ones (e.g., not everyone can afford a vehicle). Another key theme in this category focused on the need for a more equitable planning process that includes historically underserved and underrepresented voices and does not repeat the mistakes of the past (e.g., dividing communities to build a highway).

Attitudes – Transportation Modes and Options

There was strong agreement among the quantitative survey participants about the need to improve transportation modes and options in Greater Minnesota, with roughly three-quarters of respondents agreeing that Greater Minnesota could benefit from better transit options, support for teleworking, and improvements that would support the increased ease and comfort of walking and bicycling.

Attitudes – Community Engagement, Safety, and Equity

During quantitative survey, 54% of all respondents agreed that transportation agencies should change the design of the roads to slow traffic and improve safety. As this topic was discussed further during the qualitative discussion, most participants voiced support for increased safety measures even if it meant slowing traffic. Additionally, on average, participants felt that the responsibility for transportation safety was shared relatively equally between MnDOT, individuals, and law enforcement. Specifically, most individuals felt that MnDOT's responsibility lies in creating effective and safe infrastructure, but individuals need to do their part, along with law enforcement, to make it work.

Phase 4

Phase 4 was the public comment period and hearing for the draft Statewide Multimodal Transportation Plan. MnDOT held an eight-week public comment period from July 25 to September 18, 2022. An open house and public hearing occurred in St. Paul on September 7, 2022, from 4 to 6 p.m., and was connected to seven video conference locations throughout Minnesota. The public comment period, open house, and public hearing were announced in the State Register, in a press release, on social media, and through earned media. A total of 327 comments were received during the public comment period, including letters from 16 agencies.

Minnesota State Highway Investment Plan

Purpose

The Minnesota State Highway Investment Plan is a 20-year plan to direct capital investment for Minnesota's state highway system, and is part of a "family of plans" that connects vision and policy direction for transportation in Minnesota. This plan update was for 2023 to 2042.

Timeline

Phase 1 of engagement took place between July and September 2022. Phase 2 occurred between March and May 2023. The public comment period took place between September and November 2023.

Engagement

In-person engagement consisted of community events, stakeholder forums, partner and stakeholder briefings, and workplace-based outreach. Online engagement consisted of online surveys, a project website, social media, targeted Facebook ads and stakeholder email updates. Additionally, MnDOT provided specific outreach for traditionally underserved populations including Tribal outreach, targeted Facebook ads, and a partnership with Emergency, Community, Health, and Outreach (ECHO).

In total, over 600,000 people were reached, including:

- 2,448 responses
- 141 meetings attended
- 19 community events
- 4 community-based organizations

Demographics

Most respondents for Phase 1 of engagement were white (83%). The second largest group was Hispanic/Latinx/Latine (8%). There was an even male/female split, with about 2% of respondents identifying as nonbinary. The majority of respondents (56%) were ages 25 to 44. See Appendix C for a full demographic breakdown and map of responses.

KEY THEMES AND TAKEAWAYS

Survey respondents identified their preferred approach among six potential investment approaches: Improve Mobility for All Highway Users, Focus on Safe and Equitable Communities, Prioritize Pavements/ Current Approach, Adapt to Changing Technology and Climate, Prioritize Highway Capacity Expansion, Prioritize Bridges. The six approaches were described by vision statements highlighting the priorities of the approach.

Most respondents chose "improve mobility for all highway users" as their top priority in terms of preferred investment approaches (24%). The next highest priorities were "focus on safe and equitable communities" (21%) and "prioritize pavements/current approach" (20%).

Survey respondents' top five priorities out of 12 investment categories included, in order:

- **Pedestrian and Bicycle:** Maintain and expand pedestrian and bicycle infrastructure including making it accessible for all.
- **Local Partnerships:** Partner with cities and counties to address community priorities including quality of life and economic opportunity.
- **Pavement Condition:** Maintain smooth driving surface through more repair and reconstruction projects.
- **Climate Resilience:** Adapt infrastructure to resist damage from extreme weather events and improve resilience.
- **Bridge Condition:** Improve condition of bridges through more repair and replacement projects.

Strategic Highway Safety Plan

Purpose

The Minnesota Strategic Highway Safety Plan is Minnesota's plan to reduce fatal and serious injury crashes and, over time, to eliminate the loss of life on Minnesota roads. The plan is designed for all traffic safety partners at the state, county, and local government level as well as users of the roadway system. The plan includes 39 strategies and 168 tactics to foster coordination between traffic safety partners and improve transportation safety. The goal is to reach no more than 225 traffic deaths and 980 serious injuries by 2025, with an ultimate goal of zero.

Timeline

The plan update began in early 2019 under the direction of the Minnesota Toward Zero Deaths (TZD) Leadership Team.

Engagement

Engagement for the plan update consisted of an online survey distributed via existing public and stakeholder email lists and social media, garnering 2,636 responses. Stakeholders also gave input at regional TZD workshops, resulting in 546 responses with every TZD region represented. Live polling was conducted at the TZD 2019 annual meeting, resulting in 581 responses. There were additional one-on-one meetings with specific stakeholder groups.

KEY THEMES AND TAKEAWAYS

Focus areas for the plan were prioritized into four groups using stakeholder and steering committee input.

Core

The core focus areas have been given a high degree of emphasis in the traffic safety community and will continue to be strong areas of focus:

- Inattentive drivers
- Impaired roadway users
- Intersections
- Speed
- Lane departure
- Unbelted vehicle occupants

Strategic

The strategic focus areas are emerging priorities. They are rising in importance due to factors such as changes in prevalence, public and stakeholder perception, and demographics:

- Older drivers
- Pedestrians
- Younger drivers
- Work zones
- Commercial vehicles
- Motorcyclists

Connected

The connected focus areas represent a smaller portion of crashes compared to other focus areas, but most crashes are correlated with other focus areas:

- Unlicensed drivers
- Bicyclists
- Trains

Support Solutions

The support solutions focus areas are safety techniques and systems that enhance multiple strategies:

- Traffic safety education and awareness
- Emergency medical services and trauma systems
- Vehicle safety enhancements
- Data management
- Management systems

Minnesota Walks

Purpose

Minnesota Walks is a collaborative effort between MnDOT and the Minnesota Department of Health that provides a shared vision for how all Minnesotans can have safe, desirable, and convenient places to walk where they live, work, learn, and play.

Minnesota Walks includes guidance for planning, decision-making, and collaboration between agencies, advocacy organizations, policymakers, and public and private entities across the state. Minnesota Walks established an understanding of pedestrian needs and challenges in Minnesota rooted in engagement to help MnDOT and the Minnesota Department of Health better address needs for people walking.

Timeline

Summer and fall of 2015.

Engagement

The project team developed a community gathering engagement toolkit, which included a series of activities to collect input on walking destinations and characteristics that make walking safe, convenient, and desirable. The project team and partners used the toolkit to gather input at:

- 33 community gatherings (including the Minnesota State Fair with participation from more than 3,000 people)
- 2 online surveys reaching hundreds of people to supplement the in-person engagement and to better understand pedestrian comfort levels with different roadway treatments
- 14 focus groups with the goal of having a robust dialogue with people about walking
- 2 teen workshops conducted in Saint Paul to gather perspectives on walking issues from Minnesota teenagers
- 8 practitioner-oriented walking workshops to identify and prioritize walking issues and barriers in communities throughout the state from the perspective of professionals who regularly work on walking safety

Demographics

The engagement team focused on priority populations of small rural communities, children and youth, Native American populations, people with low incomes living in urban communities, older adults, and people with disabilities.

KEY THEMES AND TAKEAWAYS

The overarching theme that arose through engagement was to put pedestrians first. Participants expressed the general feeling that people walking with or without a mobility device do not receive enough priority in the planning and design of our streets and communities. Participants throughout the engagement process agreed with this position and conveyed a desire for walking to have a higher priority among transportation modes. This overarching theme was supported by community input, which was organized into nine supporting themes:

- **Universal Design:** Plan and design streets so that all people can safely and comfortably walk or roll to their desired destinations.
- **Roadway and Street Design:** Design roadways and streets to emphasize pedestrian safety and comfort. This includes all elements of roadway design and engineering—roadway geometry, urban design, landscaping, street furniture, crosswalks, wayfinding, signage, and more.
- **Land Use and the Built Environment:** Better coordinate multimodal transportation networks and land use decisions to improve characteristics of the built environment that impact walking, such as design and the location of destinations.
- **Maintenance:** Maintain year-round walking infrastructure by making necessary ongoing repairs and clearing snow and ice in a timely fashion.
- **Community Engagement:** Engage the people of Minnesota in future planning and roadway design projects, and throughout the next phase of developing the Minnesota Statewide Pedestrian System Plan.
- **Funding:** Allocate more funding for pedestrian-related projects and programs.
- **Partnerships and Coordination:** Leverage existing partnerships and create new ones to enhance coordination for developing and implementing programs, policies, and projects across the state.

- **Technical Resources:** Develop "how-to" resources for practitioners around the state to make it easier to implement walking programs, policies, and projects in their communities.
- **Integrated Planning:** Emphasize the importance of integrating pedestrian planning with other planning efforts such as comprehensive plans, corridor plans, neighborhood plans, transit plans, safe routes to school (SRTS), food access initiatives, and social services at the local, regional, and state levels.

Statewide Pedestrian System Plan

Purpose

The Statewide Pedestrian System Plan is a detailed path for MnDOT to maximize its role in making walking safe, convenient, and desirable for all. This plan draws on interviews with MnDOT staff and conversations with community members in each district, and builds on previous planning work. See Appendix C for a list of plan goals.

Timeline

Phase 1 of engagement occurred between May 2019 and October 2019. Phase 2 took place in the summer of 2020.

Engagement

Phase 1 included 42 in-person events, including 9 pop-up events, 22 tabling events, 8 listening sessions, and 3 on-street engagement sessions. The engagement team collected 884 surveys, several verbal or written comments, and 20 interactive posters. Online engagement for Phase 1 included a project website, social media, and project emails. This resulted in the collection of 1,219 additional surveys, totaling 2,103.

All engagement for Phase 2 was held online due to the COVID-19 pandemic. Engagement consisted of an additional online survey that gathered input on street designs. The online survey was available in Hmong, Spanish, Somali, and English and garnered 649 responses. Phase 2 of engagement also included project emails, social media, and signage and sidewalk decals.

Demographics

Around 20% of survey respondents for Phase 1 self-identified as a person of color. Nearly 20% identified as a senior, and nearly 20% identified as a person with a disability.

Because Phase 2 engagement was limited to online interactions during the COVID-19 pandemic, demographics shifted with only 10% of respondents self-identifying as a person of color, and just over 10% of respondents identifying as a senior, person with a disability, or person with a low income. See Appendix C for priority demographic information and a map of survey respondents by zip code for both phases.

KEY THEMES AND TAKEAWAYS

Minnesotans strongly support improved pedestrian crossings; more trees, benches, and other amenities; adequate space on sidewalks; separation for people walking from people bicycling; and buffer space from car and truck traffic.

- Nearly three out of four survey respondents answered that they "completely support improvements for walking."
- Public engagement revealed support for sidewalks or sidepaths in every land use context.
- "Sidewalks, or other walkways, where none currently exist" was the most frequently chosen answer on the survey in response to a question about which improvements could most improve walking along state roadways.
- "Street designs that encourage drivers to stop for people walking" was the most frequently chosen answer on the survey in response to a question about which improvements could most improve walking across state roadways (27%) followed by "a longer 'walk' signal to provide more time to cross the street" (21%), and "easier access for people with differing physical abilities (e.g., accessible corner curb ramps)" (20%).
- The consensus among members of the general public was that sidewalks and paths aren't maintained as well as roads in the winter. The most favored policy idea on the survey was "improved winter maintenance."
- There was also support for paved shoulders in natural areas and connections between rural towns.
- When asked what "pedestrian/walking safety" meant to survey respondents, the most common answer was "safe crossings/intersections" (22%).

Statewide Bicycle System Plan

Purpose

The Statewide Bicycle System Plan presents MnDOT's vision and goals for bicycle transportation, implementation strategies, and performance measures to evaluate progress toward achieving this vision.

Timeline

Phase 1 of engagement took place in spring 2014. Phase 2 occurred in winter 2015.

Engagement

Engagement consisted of two public open houses in each MnDOT district, a series of workshops in each district with MnDOT staff and agency partners, and online engagement opportunities. Activities included interactive mapping, visual preference surveys, and ranking and prioritization exercises. Over 4,500 people participated in public outreach activities, and MnDOT received tens of thousands of comments and data points.

Demographics

Almost 45% of survey respondents were ages 25 to 44. Almost 60% of respondents were male. Nearly 90% of respondents identified as Caucasian or European American. Over 70% of respondents had a total yearly income of $45,000 or greater, with over 46% with an income of $75,000 or greater.

More than 61% of all respondents lived in MnDOT's Metro District. Almost 9% of respondents lived in District 3, almost 8% of respondents lived in District 1, and 7% of respondents lived in District 6.

KEY THEMES AND TAKEAWAYS

- Over 61% of Phase 1 survey respondents identified "enhancing facility and network" as a desired improvement. See Appendix C for the full breakdown.
- The public values state bicycle routes, but people value opportunities for local and regional bicycle travel more.
- Routes to schools and parks were rated very highly by all participants and, for Greater Minnesota participants outside of the Twin Cities metro, were a top investment priority.
- State bicycle routes create opportunities for inter-community travel across the state and beyond.
- People prefer riding on facilities separated from motor vehicle traffic.
- Improving network connectivity was consistently identified as an effective tool for increasing bicycling.

Minnesota Safe Routes to School Strategic Plan

Purpose

The Minnesota Safe Routes to School Strategic Plan establishes a five-year action plan to improve walking and biking to school for youth in Minnesota. The latest update was in 2020, providing a refined vision and new goals, strategies, action steps, and performance measures to expand, strengthen, and monitor Minnesota's SRTS program.

Timeline

Fall 2019 to Spring 2020.

Engagement

Stakeholder engagement for the strategic plan included a SRTS Steering Committee workshop, Technical Advisory Group meetings, an online survey, activities during SRTS Network and Regional Development Organization Skill Share calls, stakeholder interviews, State Department listening sessions, and the SRTS Virtual Meet Up.

The SRTS team received 282 survey responses, conducted 38 follow-up phone interviews, and held three listening sessions with state agencies.

Demographics

Engagement was directed toward people who work on SRTS and related active transportation projects across Minnesota.

KEY THEMES AND TAKEAWAYS

- **Build Local Partners' Capacity to Implement SRTS:** Create an onboarding toolkit, materials for older students, additional training resources, and expanded grant opportunities.

- **Coordinate SRTS Implementation Statewide:** Pursue more attainable and flexible funding opportunities, dedicate SRTS staff to help districts with planning, connect SRTS to similar movements in the state, and make SRTS a requirement.
- **Increase Awareness of SRTS:** Improve name recognition, marketing materials, and storytelling.
- **Develop Process, Policy, and Design Guidance That Supports SRTS:** Provide model policy language and consider SRTS plans in scoping for infrastructure projects.
- **Measure Progress, Evaluate Impacts, and Continually Improve the Program:** Obtain better pedestrian and bicycle data, create a database of SRTS outcomes, and use more flexible surveys.
- **Innovate in Program Development and Implementation:** Create new programs to get families involved and additional engagement and communications resources.

Pedestrian Crossings and Safety on Four Anishinaabe Reservations in Minnesota

Purpose

MnDOT funded the first phase of this research project, Pedestrian Crossings and Safety on Four Anishinaabe Reservations in Minnesota, with the University of Minnesota to document pedestrian behavior on reservations and identify potential countermeasures to reduce risks to pedestrians. Minnesota Walks, Minnesota's policy framework for advancing safe, convenient walking, identifies Native American as one of six priority populations, with members that are more likely to walk in their everyday lives. Tribal transportation managers identify pedestrian safety as one or their top safety concerns on reservations.

The Advocacy Council on Tribal Transportation (ACTT) served as the Technical Advisory Panel. Transportation managers from the Bois Forte Band of Chippewa; Fond du Lac Band of Lake Superior Chippewa; Grand Portage Band of Ojibwe; and Mille Lacs Band of Ojibwe identified sites where Tribal elders and members were concerned about pedestrian safety. Red Lake Band of Chippewa, White Earth Band of Chippewa, and Leech Lake Band of Ojibwe joined Phase 2 of the project in 2020/21. University of Minnesota researchers conducted field studies and collaborated with MnDOT, Tribal transportation managers, and county engineers to identify potential countermeasures.

The research team studied 21 sites where pedestrians were crossing state or county highways mainly at unmarked crossings near destinations for employment, shopping, or other services such as casinos, trading posts, grocery stores, schools, or Tribal centers. The research team monitored these locations and collected more than 10 days of video data at most of the sites to identify potential countermeasures to address safety concerns at each crossing. Examples of countermeasures that were discussed include pedestrian actuated controls such as Rectangular Rapid Flashing Beacons, multiple types of roadway markings and signs, roadway or lane narrowing, improved nighttime lighting, education, and enforcement. See Appendix C for these potential countermeasures.

Timeline

Phase 1 of the study was initiated in 2016 and published in November 2020. Phase 2 was initiated in 2021 and will conclude in 2024 with the publication of another report.

Engagement

MnDOT's approach to the project was consultative and collaborative, working with four Anishinaabe Bands: Bois Forte Band of Chippewa, Fond du Lac Band of Lake Superior Chippewa, Grand Portage Band of Ojibwe, and Mille Lacs Band of Ojibwe. See Appendix C for a map of these reservations. MnDOT's Tribal liaison advised staff and researchers on project development and implementation. Following ACTT's agreement to participate in the project, MnDOT and the researchers:

- Consulted Tribal transportation managers who identified priority sites for monitoring

- Prepared monitoring plans and obtained approval from Tribes and agencies for monitoring
- Installed video equipment and analyzed videos
- Reviewed findings with Tribal representatives
- Identified potential countermeasures in consultation with Tribes and county engineers

Multiple representatives from each reservation and county engineers participated in meetings to identify potential countermeasures and review opportunities to integrate them into planned projects. MnDOT and researchers reviewed the literature and:

- Met with Tribal representatives to review results and brainstorm countermeasures
- Met with MnDOT safety and district engineers to refine possible countermeasures
- Met jointly with Tribal representatives, MnDOT district engineers, and county engineers to finalize short-lists of countermeasures and opportunities to integrate them into scheduled or planned projects. Results included:
    - Grand Portage: Addition of Safety Countermeasures in TH 61 Project (e.g.. marked crosswalks, advanced warning signs, ADA ramps, overhead lights, trail connections). Constructed in 2020 and 2021. Evaluated in 2022.
    - Mille Lacs: Awarded $300,000+ through MnDOT's TAP program for Sidewalk and HAWK system. Operational in December 2020. Evaluated in 2022.
    - Fond du Lac: Big Lake Trail (2019), Mission Rd improvements (2019), coordinating with County and MnDOT on upcoming projects. Evaluated in 2022.
    - Bois Forte: BIA funding and crossing data for Tribal Safety Transportation Study.
    - Leech Lake: video data incorporated into Hwy 2 redesign.
    - Red Lake: data used to improve many lighting, traffic control, and trail decisions. Led to partnership with UMN Capstone student projects.
    - White Earth: data used to inform traffic studies and discussion about crossing safety.

KEY THEMES AND TAKEAWAYS

Plans and Policies Matter

MnDOT's commitments to pedestrian safety and equity institutionalized in Minnesota Walks and other policies and programs provide a rationale for this project and increase likelihood of future implementation.

Evidence Is Essential

Rural and Tribal transportation managers often lack data about pedestrian activity. Evidence such as simple user counts can inform decision-making. Collaborative efforts can produce evidence that matters.

Risks Are Relative, but Real

Rural pedestrian crossing volumes are low relative to urban volumes, but the risks pedestrians face are real: drivers may not expect to see pedestrians on remote rural roadways. Low volumes are not a reason for no action to reduce risks.

Equity, as Well as Efficiency, Is Important

If efficiency (i.e., numbers of pedestrians) were the sole basis for investments, agencies would rarely fund countermeasures on reservations. Investments on reservations are needed to redress historical marginalization of Tribes and existing disparities in traffic safety.

Engage Collaborators Early-On

Tribes are sovereign governments with participatory decision-making processes. Pedestrian safety issues on reservations often are addressed in cooperation with county and state highway departments. Meetings to plan research, share and review findings, and discuss implications can increase likelihood of project funding and implementation.

Community Conversations Engagement Project

Purpose

The Community Conversations Engagement Project is a series of conversations between MnDOT staff and individuals and organizations who work with and represent underserved communities in Minnesota. The intent of these conversations is to learn directly from underserved communities about their unique experiences and challenges with transportation. MnDOT then documents these findings so they can be used to inform the agency's transportation funding, planning, and programming efforts.

Timeline

Conversations took place from 2018 to 2023 (ongoing).

Engagement

MnDOT typically conducts around 30 interviews in each district with nonprofit, government, transit, education, Tribal, and other partners to understand the transportation needs for underserved and underrepresented communities. A similar but separate process is expected for the Metro District.

Demographics

Key populations included: Tribal governments, racial and ethnic minorities, women, elderly and those aging in place, low-income, zero-vehicle households, people with disabilities, veterans, and disadvantaged business enterprises.

KEY THEMES AND TAKEAWAYS

Across districts, the following themes emerged:

People and Community Connections

People with Low Incomes

Owning a private vehicle is often out of reach for those with low incomes. Without a private vehicle, it is difficult to access jobs, grocery stores, pharmacies, medical appointments, and social and community activities. However, alternative options to owning a vehicle, such as public transit and ride-hailing services, are limited, especially in rural areas.

Rural Residents

Rural residents face difficulties in traveling due to the long distances between destinations and limited regional transit service. This impacts access to basic needs and services such as employment, health care, affordable housing, grocery stores, and recreational opportunities.

BIPOC

Engagement participants voiced concerns with transportation challenges and inequities for BIPOC folks. Language barriers are a challenge for those whose primary language is not English. BIPOC and immigrant communities also face additional barriers due to income, citizenship status, ability to get a license or own a car, and historical discriminatory practices leading to a lack of trust in government. Participants also noted the lack of diversity among transportation decision-makers and prejudiced treatment toward BIPOC folks by transportation providers.

People with Disabilities

Engagement participants mentioned a range of transportation challenges for people with disabilities, including lack of (or poor maintenance of) accessible pedestrian infrastructure and limited transportation options, especially regarding transit. Some also reported transportation providers being unwilling or unable to assist people who use wheelchairs.

Older Adults

Older adults face many of the same challenges as people with disabilities, with a lack of transportation options limiting access to health care, shopping, and social activities. Older adults often rely on friends and family, door-to-door mobility assistance, and transit.

Women and Girls

Women and girls may be less likely to walk or bicycle due to personal safety concerns. Lack of transportation options can leave women trapped in abusive or crisis situations. Some pregnant women in rural areas face challenges getting to hospitals and clinics with obstetric services.

Transportation and Infrastructure Barriers

Personal Vehicles

Personal vehicles are often the preferred or most critical mode of transportation. However, certain groups such as people with low incomes, immigrants, and refugees may not own a car or have a driver's license, which leads to reliance on friends, family, and other transportation options such as taxis.

Public Transit

Public transit is important for many communities, including older adults, low-income residents, immigrants, and people with disabilities. Across districts, people cited inadequate public transit options due to limited hours of operation, infrequent service, long wait times, and high fees.

Walking and Bicycling

Many community members walk or bike in order to access basic needs and services, especially during the warmer months. Barriers to biking and walking include safety concerns, winter weather, and lack of infrastructure.

Other Transportation Modes

Community members use a range of additional transportation options—or might if they had the opportunity. These include taxis and other paid ride-hailing services, informal ridesharing and carpooling, volunteer driver programs, and medical transportation services.

Public Engagement Recommendations

- Expand in-person and virtual engagement efforts to reach underserved communities
- Include underserved communities in transit policy decisions
- Meet people where they are at (e.g., holding meetings where communities already gather)
- Offer information in accessible and centralized formats
- Make sure community members feel heard and acknowledged
- Continue to build relationships with agencies, governments, and organizations to coordinate processes and leverage existing resources
- Create district-specific public engagement plans
- Create a campaign to reach non-English speakers

Equity Impacts

- Explore ways to make transit more affordable
- Explore options for rides to essential services and delivery of essential services
- Measure equity impact efforts

Transit Improvements

- Work with local partners to expand access, availability, and safety of transit options
- Use designated bus lanes and signals to speed up public transit
- Increase connections between smaller and larger cities
- Plan transit routes to connect folks to day-to-day needs and popular destinations
- Improve transit service in rural areas in collaboration with Regional Transportation Coordinating Councils

Biking and Pedestrian Improvements

- Work with local partners to improve access, safety, and funding for bicycle and pedestrian infrastructure

Identifying and Implementing High Priority Pedestrian Safety Improvements (HiPPS)

Purpose

Identify pedestrian safety countermeasures in Tier 1 priority areas as defined by the Statewide Pedestrian System Plan. Improvements may be implemented through MnDOT's regular program of construction projects, demonstration projects, or grant programs such as the Highway Safety Improvement Program. This work will deliver a toolbox of pedestrian safety countermeasures that are tied to roadway typologies in Tier 1 areas, apply the toolbox to develop potential infrastructure treatments at three locations in each District, and recommend District-level and Central Office-led action steps to address the systemic barriers within MnDOT that prevent or delay pedestrian safety improvements.

Timeline

Winter 2022 to winter 2023.

Engagement

This project is internally focused, engaging with staff in every MnDOT district and Central Office staff.

KEY THEMES AND TAKEAWAYS

Initial engagement with district staff has started to identify barriers to pedestrian safety improvements:

- Improvements to pedestrian safety are driven by local governments, who can take ownership of projects and pay for construction and maintenance, pushing for change.
- Standalone improvements for people walking and biking are rare—standalone projects rely on discretionary dollars and grants, existing extra materials, and informal decision-making processes heavily influenced by levels of local support and perceptions of local support. Data-driven decision-making is not the starting point.
- Movement of permitted loads is important—heavy commercial traffic and seasonal traffic (e.g., agricultural vehicles and weekend visitors to cabins).
- Districts take some ownership of Americans with Disabilities Act (ADA) conditions on trunk highways; however, there is little ownership of conditions for people walking beyond ADA requirements.
- Corridor studies are the main tool outside of the CHIP that could lead to funding for pedestrian improvements, but it is not guaranteed.

District staff also identified barriers to installing demonstration projects, which are often focused on safety improvements for people walking and biking:

- There is a need for more community engagement around demonstration projects, but it requires additional staffing to do so (from the district, Office of Transit and Active Transportation, consultants, or the public health community).
- There is no defined process around selecting and funding demonstration projects; discretionary funding is often used.
- District staff need more support to lead demonstration projects, or need others to lead them.
- There is an overreliance on public feedback as the measure of success.

Active Transportation Scoping Assistance and Recommendations

Purpose

MnDOT's Office of Traffic Engineering has conducted active transportation (bicycle and pedestrian) scoping field walks for the Greater MN Districts to provide recommendations for inclusion of meaningful bicycle and pedestrian engineering solutions in MnDOT projects.

The long-term program goal is to better position bicycle and pedestrian recommendations within project development, particularly recommendations with additional costs, making recommendations early in the process so that walking and biking facilities can be included in the project scope. Recommendations promote walking and bicycling for Minnesotans as modes of transportation and include improvements such as safety countermeasures, safer crossings, network completion, and innovative treatments.

Timeline

These scoping walks began in 2018 and are ongoing.

Engagement

To select projects suitable for the Active Transportation Scoping Assistance and Recommendations, the team works with Districts to determine potential projects and then analyzes the projects with the SPACE tool. The Suitability of the Pedestrian and Cycling Environment (SPACE) tool is a GIS based spatial analysis tool that uses public data to highlight a latent demand for walking and biking.

The Active Transportation Scoping process includes feedback from local stakeholders identified by the Districts and structures virtual field walks as a listening session to hear about issues and concerns from the community.

KEY THEMES AND TAKEAWAYS

These field walks and other scoping assistance are offered to the Greater MN Districts. The walks are conducted separately and in addition to MnDOT ADA field walks. In addition to the active transportation field walks, MnDOT will continue conducting the ADA field walks, which focus primarily on compliance, constructability, and occasionally small network gaps up to one block. The pedestrian and bicycle scoping recommendations make suggestions for network connectivity, review needs for bicycling infrastructure, and plan for the future non-motorized transportation system. A bicycle and pedestrian scoping recommendation report is provided to the District team (PM, traffic engineer, and planner) to be considered during project scoping.

Improving Transportation Equity by Centering the Needs of Underserved Communities

Purpose

This study was funded by MnDOT and conducted by the University of Minnesota Humphrey School of Public Affairs.

Timeline

Research began in 2021, with a report published in 2023.

Engagement

The research team interviewed at least eight participants from each of 10 different communities. Outreach was primarily conducted through partner organizations, which helped connect the research team with 130 total participants. Some participants were included in multiple community groups. In addition to the interviews, participants took part in a smartphone-based travel behavior survey. Participants were compensated for their participation.

Demographics

- 20 participants from Fergus Falls
- 17 participants with a disability
- 16 first- and second-generation immigrants
- 16 participants who were HIV positive
- 14 African American transit riders
- 13 Hmong participants
- 11 Latinx participants
- 11 single mothers
- 8 Native American men from White Earth Nation
- 8 single fathers

See Appendix C for a full demographic breakdown and map.

KEY THEMES AND TAKEAWAYS

While each community shared unique transportation challenges, the common themes across communities were profound. In communities across Minnesota, the preferred method of transportation was a car, providing participants with a direct, timely, easy way around. However, cars also posed a significant challenge as purchasing and maintaining a car takes significant resources for anyone with a low or fixed income.

From Fergus Falls to the Twin Cities, public transportation served an important role and also was inadequate in meeting participants' needs. Inaccessibility, timeliness, and safety came up over and over in different forms as participants expressed frustrations with current systems and desires for service that better met their needs.

Ultimately, participants highlighted the many ways in which inadequate transportation kept them from flourishing (e.g., from good jobs or visits with family, doctor appointments, cultural events, or meaningful spiritual activities). Their experiences form a call for partnership with underserved communities to broaden the scope of public transportation and explore transformative innovations that address community needs.

Table 18. *Major themes on the transportation experience of underserved communities*

COMMUNITY	THEMES ON THE TRANSPORTATION EXPERIENCE	INADEQUATE PUBLIC TRANSIT	CAR-RELATED CHALLENGES	TRANSIT AFFECTING MAJOR LIFE OUTCOMES
Fergus Falls	• Barriers to essential employment, food, and healthcare needs • Dependency on rides from family and friends	✓	✓	✓
People with disabilities	• Metro Mobility - some independence but unreliable • The necessity of a support system • Reliance on door-to-door transportation	✓		✓
Immigrants	• Public transportation is inconvenient and inadequate • Transportation is important for culture and community connections • All modes of transportation are expensive	✓	✓	✓
People with HIV	• Transportation, nutrition, and health • Transportation, risks, and personal safety • Hidden affordability barriers	✓	✓	✓
African American	• Transportation and employment connection • Impact of transportation on social well-being • Safety concerns	✓		✓
Hmong	• Driving as caregiving • Hesitant about public transportation • Culturally relevant outreach	✓	✓	✓
Latinx	• Barriers to the use of public transportation • Preference for and dependency on cars • Inadequate public transportation for fulfilling essential activities	✓	✓	✓
Single mothers	• The necessity and unaffordability of automobile ownership • A desire for but lack of viable public transportation options • Community support for car ownership	✓	✓	✓
White Earth	• Deficiencies with transit systems and its impact on employment • Limited access to healthy food and spiritual activities • Re-prisoned: No driving license, no car, no job	✓	✓	✓
Single fathers	• Preference towards and conerns against public transportation use • Transportation limits employment and housing choices and medical and religious activities	✓		✓

Metropolitan Council Transportation Needs in Daily Life Study

Purpose

This study aims to understand how the current transportation system works - or does not work - for people's daily transportation needs. The study's goals are to (1) understand how people's values and needs influence their daily travel decisions, (2) incorporate people's lived experiences into regional policy documents and planning initiatives, and (3) ensure regional transportation resources support those who need them most.

Timeline

Ongoing in 2023.

Engagement

The study used an engagement- and equity-forward qualitative research approach to elicit in-depth feedback from members of the community. Through a series of 29 focus groups, the researchers spoke with 184 people about their travel experiences, identities, and their perspectives on transportation-related safety, security, cost, climate change, and government agencies.

Demographics

Focus groups were organized around key factors associated with identity and travel behavior: race/ ethnicity, gender, age, transit reliance, housing security, and ability. This structure aimed to ensure broad inclusion of historically underserved communities, and to foster familiar environments for participants to share their transportation experiences openly. The study was largely successful in reaching the target communities identified.

KEY THEMES AND TAKEAWAYS

Fear of traffic safety and environmental risk shape people's experiences while in transport. Fear of being struck while walking or biking stopped people from using these modes or allowing their children to walk or bike.

Weather-related risks also constrained people's options. Snowplows clear the roads for drivers while blocking corners for people walking, rolling, or trying to access the bus. Icy or unshoveled sidewalks increase the risk of falling. Extreme heat and cold alike created danger for people if their modes of travel left them exposed to the elements, especially for older adults.

Perceptions and fears for safety and security while traveling is communally shared and a defining feature of how people make travel choices. The presence of these fears appears to be nearly universal, though the extent and specific nature of those fears differ by population. The burden of fear is inequitably distributed throughout the region. Black and brown participants, women, LGBTQ+ participants, and participants experiencing housing insecurity expressed fears based on personal trauma or violence that had happened to them or people in their community (including police violence).

4.3 Summary of Stakeholder Conversations

Focus Groups

To build on the knowledge gained from their review of MnDOT's past engagement efforts, the project team held three focus groups in the summer of 2023 to better understand the strengths and weaknesses of prior engagement with people who walk, bike, and roll. Stakeholders included representatives from disability, public health, bike/walk advocacy, and other organizations across the state.

Each meeting included a similar structure, starting with an introduction to the project and relevant safety data from the project team, followed by a discussion of participant experiences. Specifically, stakeholders were asked:

- Where/when do you feel vulnerable as a road user? Generally (roads with no sidewalk) or specifically (the intersection of _____ and _____ because of _____).
- Do you feel that your group is adequately represented in the transportation planning process? What has been effective or what could have worked better?
- What future engagement would you like to see before transportation investments are made?
- What are your top priorities to improve safety for vulnerable road users? If there was one thing you could fix TODAY, what would you fix?

Notes from these conversations and the specific organizations involved in the focus groups are available in Appendix D.

KEY THEMES AND TAKEAWAYS

Overall, the project team gathered input on three categories:

- Priorities for improvements for VRUs (this category focused primarily on design improvements)
- Past engagement experience as someone interested in safety for walking, biking, and rolling, and recommendations for the future engagement
- Experiences walking, biking, or rolling in inclement weather conditions (this category focused primarily on maintenance improvements)

Design Improvements

People would like to see enhanced safety; improved infrastructure for VRUs; enforced traffic regulations; increased driver awareness; and accessible and reliable transit options. Much of the input received about design improvements coincides with findings in previous studies.

Key areas of concern mentioned across the groups include:

- High vehicle speeds on roads.
- Lack of adequate sidewalks and bike lanes as a barrier for VRUs.
- Intersections, especially unmarked crosswalks and locations where vehicles make right turns while there is a red light. There is a perception that drivers aren't looking for people walking.
- Drivers' ability to see people using wheelchairs.
- Limited transit and Metro Mobility options outside the Twin Cities.

Engagement

There was a mixed response to whether or not people thought their group was adequately represented in engagement. Advocacy groups, such as BikeMN, felt engagement with MnDOT was adequate. However, people with disabilities did not feel adequately represented in transportation work. There is a perception that disability advocacy in transportation decisions needs to be increased.

Input from the disability community also reflected some related findings in the Metropolitan Council Transportation Needs Study, that bike/walk engagement is often done with those that have choice in transportation options. The urgency for safe and reliable transportation options in all weather and at all times of day from those that do not drive is important for MnDOT to be aware of. A safe sidewalk and protected bike lane are not "nice to have" for these communities, they are a necessity. In the future, more focus on those that are dependent on transit, walking, biking, and rolling could bring important insight into transportation planning.

More experiential engagement is desired from the disability community so that planners and engineers better understand the challenges that this community faces. It is also important to acknowledge that the disability community still offers the best perspective on the barriers they face, and that experiential engagement should not replace their valuable input.

Finding common challenges between different groups can help engagement and strengthen improvement recommendations. For example: wheelchair users and children have similar issues being visible. Wheelchair users, young parents with strollers, and others who walk to fulfill daily needs such as grocery shopping may all deal with curbs or barriers in the walkway. Similarly, older adults, people with disabilities, and those with very young children may all need more time to cross the street.

Maintenance

When looking for solutions to increase safety for VRUs, maintenance is as important as design. People noted that snow clearing efforts are generally directed toward vehicles as opposed to VRUs, which is especially challenging for those with limited mobility. Trash along sidewalks and bikeways can also be an issue. While vehicles can drive over minor obstacles in the roadway, these items can force a walker or bicyclist off their path, and into dangerous conflict with other modes.

While not directly related to asset maintenance, behavior patterns on buses and trains affect people who walk and roll. Bus and train etiquette was an important theme among people with disabilities as non-disabled transit riders don't always give up priority accessible seating when needed. Better education or driver enforcement is desired so that transit works for everyone.

Consultation with the State's MPOs, RDCs, and Public Health Professionals

The project team met with the state's Metropolitan Planning Organizations (MPOs), Regional Development Commissions (RDCs), and public health professionals one time throughout the planning process. The MPO meeting was held on August 1, 2023 and was attended by MPO directors. The RDC meeting was held on May 23, 2023, and was a quarterly meeting of all the RDCs across the state. The public health professional meeting was held on May 11, 2023, and was part of a monthly technical assistance meeting on active living topics.

KEY THEMES AND TAKEAWAYS

The primary purpose of these meetings was to build a shared understanding of the VRUSA planning process and to understand how their work may interact with safety efforts. Each of these three groups has an interest in providing safe spaces for people to walk, bike, and roll in Minnesota. They also have roles that could help implement potential strategies for improving safety throughout the state.

The following are key takeaways from these conversations:

- Safety is a core part of the work of each of the organizations, and appears in different ways for different users.
- The data dashboard (showing the statewide HIN) will be useful to help prioritize safety efforts.
- Some guidance on how to use the HIN and other findings would be helpful for advancing safety work.

Coordination with the Advocacy Council for Tribal Transportation

The project team also met with the Advocacy Council for Tribal Transportation (ACTT) twice throughout the project (May 17, 2023, and August 30, 2023). These were relatively short and valuable meetings, leading to a site visit to the Red Lake Nation on September 11, 2023.

KEY THEMES AND TAKEAWAYS

In the initial conversation in May, participants shared how they feel safety factors into transportation work now, specifically for people walking, biking and rolling. Themes included:

- The data dashboard may assist planning efforts for walking, biking and rolling safety.
- Noted a need for more safety and planning research, including partnerships with the University of Minnesota.
- Could emphasize Tribal safety in updates to the MnDOT District Safety Plans.
- Incorporate safety into capital projects in close coordination with Tribal partners.

Site Visit to Red Lake Nation

The project team traveled to Red Lake Nation on September 11, 2023, and met with the Red Lake transportation and engineering team. As a part of the visit, the project team also conducted community engagement in front of the post office.

The trip to Red Lake was a positive step in broadening the relationship between MnDOT and Red Lake Nation. The project team worked closely with the Tribal Liaison office to identify the correct contacts, establish communication to set up meetings and plan the visit. Future engagement should continue to work with MnDOT's Tribal Liaison Office.

During the day-long trip, project team members and Red Lake representatives discussed two grant opportunities in addition to doing community engagement for this assessment. Covering multiple projects or topics in single trips can be cost effective for MnDOT as well as respect the time we ask of our Native transportation professionals. Better project coordination at MnDOT could improve overall engagement efforts with Tribal Nations and increase opportunities for input on projects.

Crash data on Tribal land was not available to be included in analyses that make up this assessment. Kade Ferris (Red Lake Nation Engineering and Tribal Roads) has developed a GIS database to populate crash data and is working on implementing it, though there are internal challenges in getting data from Tribal police. Anonymous data could better serve long-term improvements and collaboration moving forward. This is a topic that should continue to be addressed over time between MnDOT and Tribal Nations.

Internal Coordination with MnDOT Maintenance Staff

Based on feedback on the need to include maintenance issues as a part of this assessment, the project team held a conversation with maintenance staff at MnDOT on September 5, 2023.

Themes from the conversation include:

- MnDOT maintenance staff have been able to play an increased role in project scoping, which helps identify and set expectations around needs for walking and biking facility maintenance.
- Smaller winter maintenance vehicles and additional staff are needed for walking and biking facilities, which MnDOT staff often don't have access to or a place to store them; partnering with local road authorities is currently the best option for maintenance.
- With new federal guidance on the accessibility of pedestrian facilities in the public right-of-way (PROWAG), MnDOT maintenance leaders are thinking about how the agency's role will evolve.
- Despite recent progress in understanding District ADA needs through scoping, design and construction, staff turnover makes it challenging to hold onto ADA expertise.
- A sustainable funding source is needed to cover year-round maintenance of walking and biking infrastructure, as well as a better way to understand the full life cycle costs of these facilities.
- MnDOT maintenance leaders have identified opportunities to improve state funding for maintaining walking and biking infrastructure through partnership with local agencies and contractors. In the future, additional funding should be pursued.

4.4 Engagement and Consultation Findings

Over the last decade, MnDOT has intentionally worked to increase safety for VRUs across the state. Throughout these efforts, they have engaged with a wide variety of high-risk populations to gain knowledge and perspective on safety concerns and priorities for improvements. Specifically, engagement efforts have focused on people who walk, bike, and roll; children and youth; older adults; and people with disabilities, as well as Minnesotans that have historically been marginalized, especially in relation to infrastructure investments, including people in small rural communities, Native American populations, and people with low-income living in urban communities.

Chapter 4 discusses the detailed approach this project team undertook to gather engagement themes from prior engagement efforts, as well as new consultation conducted as a part of this planning process. The two-pronged approach of this assessment included a review of past MnDOT engagement and new, direct engagement with stakeholders to identify the following themes.

The review of previous MnDOT engagement in safety planning highlighted the need for:

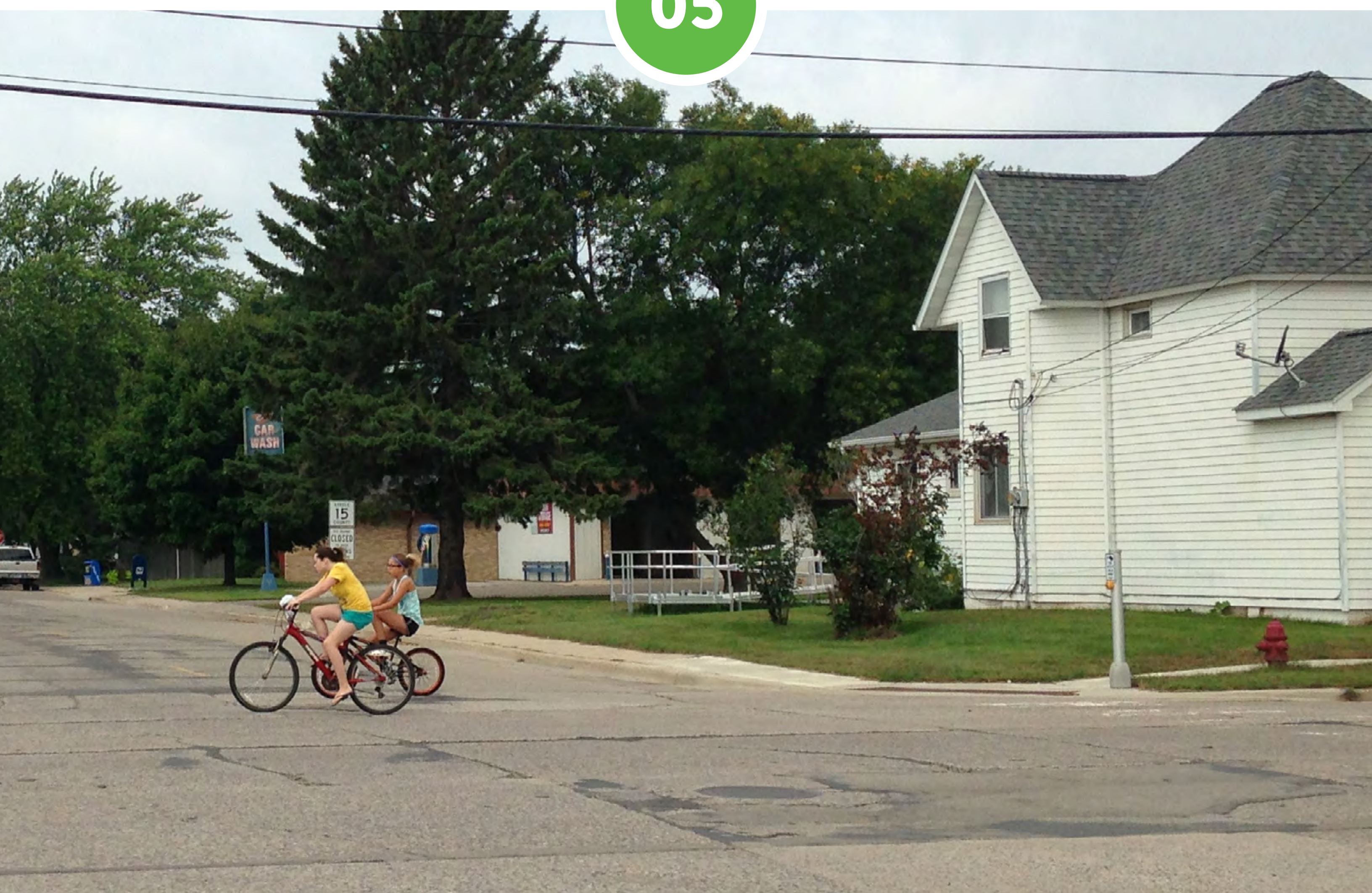
- More, better, and accessible bicycle and pedestrian infrastructure
- More and better sidewalks
- Better bike, pedestrian, and transit connections
- Safer crossings and intersections
- Improved winter maintenance
- Improved driver behavior
- Addressing aging infrastructure

Focus groups and discussions with agency stakeholders conducted as a part of this assessment's planning identified additional key takeaways for future safety investments around walking, biking, and rolling:

- **Design** improvements, such as:
  - Slowing vehicle speeds
  - Providing adequate facilities for people walking and biking
  - Improving visibility of people in wheelchairs and navigating intersections, especially unmarked crosswalks and locations where vehicles make right turns while there is a red light
- **Engagement** improvements, such as:
  - Targeting people who walk, bike, and roll in engagement efforts; especially older adults, children and youth, and people with disabilities
  - Engaging dependent transit riders and people who walk or bike out of necessity, rather than just choice or recreational users
  - Providing experiential engagement opportunities for staff with walking, biking, and rolling audits
  - Connecting challenges between different vulnerable communities to identify areas of greatest need
- **Maintenance** improvements, such as:
  - Maintenance can adversely affect VRUs more than larger vehicular traffic. For example, trash accumulation in the right-of-way poses a larger threat to someone biking who has to swerve into a lane of traffic, compared to a driver in a large vehicle.
  - Consider how some maintenance investments prioritize one mode over another, such as snow removal in the vehicle right-of-way but not on an adjacent sidewalk.

RECENT MNDOT VRU INITIATIVES

05



5.1 Introduction

The Minnesota Department of Transportation (MnDOT) has a strong history of planning for multimodal safety prior to this Vulnerable Road User Safety Assessment. The program of projects and strategies described in this chapter summarizes themes from prior safety work alongside new analysis from this assessment. Based on relevant themes, the program of projects and strategies will identify priority areas and strategies for future investments in safety for VRUs.

The takeaways from this section will guide MnDOT's Strategic Highway Safety Plan currently under development. Findings are also useful for agency and other partners across the state looking to understand the foundation of safety resources MnDOT has created for VRUs.

The VRUSA will provide data and insight that will inform both the current and 2025-2029 State of Minnesota Strategic Highway Safety Plan.

Content in this section is organized into three groups:

- Recent MnDOT Planning Work
- Data Analysis Findings
- Engagement and Consultation Findings

5.2 Recent MnDOT Planning Work

Statewide Multimodal Transportation Plan (2022)

The Statewide Multimodal Transportation Plan (SMTP) is Minnesota's highest-level policy plan for transportation. The plan includes objectives, performance measures, strategies, and actions. It is a 20-year plan, updated every five years, based on the Minnesota GO Vision for a transportation system that maximizes the health of people, the environment, and the economy.

The objectives, performance measures, strategies, and actions in the SMTP set policy direction for MnDOT's modal and system plans, including plans for bicycle, pedestrian, and transit. These plans are collectively known as the "Family of Plans." Together the Family of Plans directs investments, maintenance, operations, modal programs, and services for all types of transportation throughout the state. Other plans for safety, accessibility, operations, technology, and more can but are not required to follow the SMTP's policy direction.

Chapter 5 of the plan, Objectives, Performance Measures, Strategies, and Actions, includes a Transportation Safety objective: "Safeguard transportation users as well as the communities the system travels through. Apply proven strategies to reduce fatalities and serious injuries for all modes. Foster a culture of transportation safety in Minnesota."

The description of the objective highlights ongoing efforts to incorporate equity into transportation safety work, partnerships like Toward Zero Deaths (TZD) and the Safe System Approach.

There are 11 performance measures related to the Transportation Safety objective. Relevant considerations for people walking and biking are shown in Table 19.

Table 19. *SMTP performance measures related to the Transportation Safety objective and VRUs*

MEASURE	DESCRIPTION	CURRENT CONDITION	TARGET OR DESIRED DIRECTION	MNDOT'S ROLE	REPORTING
Pedestrian Fatalities and Serious Injuries	Annual fatalities and serious injuries of people walking on Minnesota roadways	55 pedestrians killed and 168 seriously injured (2021)	Decreasing to 0	Lead & Partner	Number and trend
Bicycle Fatalities and Serious Injuries	Annual fatalities and serious injuries of people bicycling on Minnesota roadways	9 bicyclists killed and 52 seriously injured (2021)	Decreasing to 0	Lead & Partner	Number and trend
Perception of Safe Walking and Bicycling	Percent of MnDOT Omnibus Survey respondents perceiving safe environments for walking, biking, and rolling	84% of respondents felt safe bicycling and 78% of respondents felt safe walking (2020)	≥ 80% overall and for all demographic segments	Partner	Percent and trend; report by different demographic segments

The plan identifies strategies and actions to advance the Transportation Safety objective, including the following for people walking and biking:

1. Coordinate with partners to ensure the health, safety, and security for people most vulnerable especially for those walking, rolling, bicycling, and taking transit.

- 1.1. Implement more forgiving road design to mitigate the severity of crashes and the resulting injuries.
- 1.2. Work with partners to create and implement shared values, actions, and behaviors that build a traffic safety culture for all modes.
- 1.3. Leverage partnerships to implement Toward Zero Deaths and Vision Zero strategies and road safety design initiatives.
- 1.4. Implement best practices for people to feel safe and secure walking, rolling, bicycling, and taking transit.
- 1.5. Develop effective engagement efforts to educate local agencies and the general public on engineering solutions that will improve safety.

2. Modify infrastructure to accommodate all modes of transportation using complete streets, context sensitive, and Safe System approaches.

- 2.1. Explore opportunities for lower cost solutions that can be deployed quickly.
- 2.2. Design roads for appropriate speeds based on land use context and user needs.
- 2.3. Design and maintain transportation infrastructure to support current and new technology with proven safety benefits for all users.

3. Emphasize equitable education and enforcement techniques with proven safety benefits for people and communities.

- 3.1. Support effective education and enforcement efforts focused on unsafe transportation behaviors such as speeding, not using seatbelts, distracted driving, driving under the influence, etc.
- 3.2. Engage communities in an ongoing dialogue on transportation safety needs for all people and modes.
- 3.4. Expand collecting and sharing of transportation safety data to include factors most important to underserved populations.

4. Prioritize safety for people and communities through the safe movement of goods.

- 4.3. Invest in safety improvements to roads, sidewalks, bicycle lanes, and trails that cross railroads and freight routes, including the installation of gates and warning signs.

6. Promote the development and deployment of connected and automated transportation technologies.

- 6.2. Use technology to improve transportation accessibility and safety for all Minnesotans and to reduce transportation disparities.
- 6.3. Improve school and work zone safety by leveraging connected and automated vehicle technologies and data.

The SMTP's work plan for Transportation Safety for the next five years includes the following items:

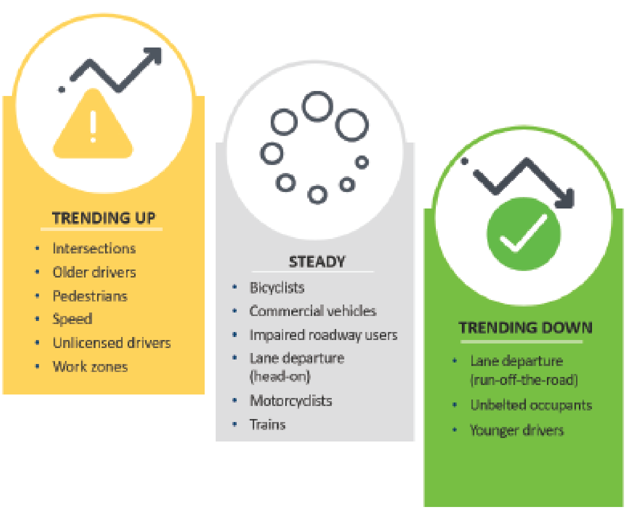
- Integrate Safe System approach in transportation safety processes and initiatives.
- Complete and implement district safety plans.
- Continue to strengthen and expand partnerships for Toward Zero Deaths, Vision Zero, Safe Routes to School, Active Transportation Program, Operation Lifesaver, and other partnerships.
- Expand efforts to ensure safe speeds.
- Collaborate with partners to evaluate speed enforcement options in school and work zones.

Strategic Highway Safety Plan (2020)

MnDOT's Strategic Highway Safety Plan (SHSP) provides strategies for reducing deaths and serious injuries on Minnesota roadways. The plan, updated every five years, uses a data-driven approach to identify key areas for focusing on traffic safety, and identifies actionable strategies for MnDOT and roadway partners around the state. The SHSP supports Minnesota's Highway Safety Improvement Program (HSIP) and Highway Safety Plan by setting priorities for safety investments and policies around the state.

The plan is divided into focus areas that represent common crash types or causes of crashes, with associated strategies and tactics for addressing each. Trends in each crash type are shown in Figure 13. While the plan focuses on all modes of transportation, there are key takeaways for people who walk and bike. Specifically, relevant focus areas include pedestrians, bicyclists, and more general categories that pose risks to people walking and biking such as intersections, speed, and inattentive drivers.

Figure 13. *Crash data trends by SHSP focus area (data collected 2014–2018)*



Strategies within the focus areas that support a Safe System Approach or have direct influence on conditions for people walking and biking include:

Inattentive Drivers

- Strategy 3: Support the advancement of technology improvements and road design to reduce the impact of inattentive driving

Intersections

- Strategy 1: Improve safety through intersection roadway design changes and alternative intersections
  - » Tactics include incorporating people who walk and bike into intersection design, and reducing conflict points/severity
- Strategy 2: Improve corridor and signalized intersection safety through intersection traffic design and signal timing
  - » Tactics include prioritizing people who walk and bike in design, improving visibility of people walking and biking, and providing leading pedestrian intervals and turning restrictions
- Strategy 3: Update planning policy
  - » Tactics include reducing over-building the roadway, improving coordination between roadway authorities, and linking high-crash intersections and corridors with design-related issues

Speeding

- Strategy 3: Improve road design and speed limit signing

Pedestrians

- Strategy 1: Increase education and awareness for drivers and pedestrians
- Strategy 2: Improve design and maintenance for pedestrian safety
  - » Tactics include prioritizing four-season maintenance for people walking, right-sizing roadways to improve crossing conditions, improving pedestrian lighting, and taking land use into consideration to prioritize crossing opportunities
- Strategy 3: Promote policy changes that impact pedestrian safety
  - » Tactics include increasing funding for safety campaigns and infrastructure, improving pedestrian data collection, and promoting pedestrian/complete street planning at regional and local levels

Overall, specific tactics that accompany these strategies focus on incorporating VRUs into overall facility design, limiting conflict with vehicles, and improving visibility of VRUs.

Minnesota Walks (2016)

Minnesota Walks is a statewide pedestrian planning framework, developed by MnDOT and the Minnesota Department of Health. The document provides a foundation for future actions and strategies to address walking needs throughout all parts of the state, with a focus on the priority populations identified in Minnesota Walks: Current & Future Steps Towards a Walkable Minnesota (2015). These priority populations include small rural communities, children and youth, Native American populations, people with low incomes living in urban communities, older adults, and people with disabilities.

Safety-related strategies in Minnesota Walks include:

Roadway and Street Design

- Design intersections, sidewalks, shared-use paths, and crossings to maximize accessibility, safety, and comfort for people who walk and roll.
- Establish specific design standards that go beyond Americans with Disabilities Act (ADA) compliance for consistency in signal timing, crosswalk design, wayfinding, signage, connectivity, and comfort.
- The standard for any future development should include sidewalks. Professionals involved in planning and design efforts should have to justify not including sidewalks, instead of the other way around.
- Establish a hierarchy of modal planning that prioritizes people walking.
- Increase and prioritize funding for roadway features such as sidewalk buffers, trees, lighting, benches, and other elements that enhance pedestrian safety and comfort.
- Re-evaluate road design to identify and accommodate lower speeds in areas where current and planned land use is conducive to walking.
- Prioritize pedestrian improvements in projects where priority populations are present.
- Review the implications of right on red turns and pork chops.
- Provide technical resources and training around the importance of meeting or surpassing ADA guidelines and provide case studies and visual examples.

> ***Minnesota Walks identifies people walking as the most vulnerable users of the transportation system.***

- Integrate best practices for walking infrastructure into established design manuals.
- Review whether road design standards are supportive of or conflicting with safety needs of people walking.
- Develop and adopt level of service ratings for pedestrian infrastructure that incorporate safety, mobility, demand, equity, and cost, among other things, into ratings.
- Continue to provide technical assistance to communities by offering local workshops for engineers, law enforcement, planners, public health practitioners, school administrators, elected officials, and advocates around planning and implementing walk friendly designs.
- Develop an understanding of how highways and county roads can be barriers for walking and strategies to address this issue.

Building a Culture of Walking

- Collaborate with driver education organizations and individuals to address driver behavior and pedestrian safety curriculum.
- Increase awareness, visibility, and effectiveness of "Toward Zero Deaths" with a stronger emphasis on people walking.
- Create consistent statewide pedestrian safety messages for communities and organizations, targeted at people who walk and people who drive.
- Encourage partnerships across agencies and organizations to create road safety education that has a broader reach in terms of content and audience.
- Explore differences between Minnesota's Toward Zero Deaths campaign and other states, regions, and cities with similar efforts, such as Vision Zero.

Statewide Pedestrian System Plan (2021)

MnDOT's Statewide Pedestrian System Plan, adopted in 2021, identifies action items to address pedestrian safety and network completion in Minnesota, along with identifying places in Minnesota where investments in walking are likely to have a significant impact through its PAWS (Priority Areas for Walking Study) analysis.

PAWS divided the state into half-mile wide hexagonal areas and categorized the hexagons into five tiers of need for investing in and improving walking, with Tier 1 hexagons showing the greatest need. While the Tier 1 hexagons contain only 7% of the trunk highway miles in the state, they account for nearly 48% of pedestrian crashes reported on all roadways statewide between 2016 and 2018.

Safety-related action items from the Statewide Pedestrian System Plan include:

- IP-1: In the next update of the Minnesota State Highway Investment Plan, expand the amount invested in "Accessible Pedestrian Infrastructure" to address walking improvements that go beyond ADA compliance projects.
- IP-5: Consider the use of HSIP, Local Partnership Program, and Local Road Improvement Program funding to address pedestrian safety-related issues.
- IP-6: Support opportunities to fund standalone walking improvements.
- IP-8: Coordinate with MnDOT partners who may be interested in using demonstration projects as a way to explore potential improvements for people walking, meet seasonal walking needs, and quickly respond to safety needs.
- IP-12: Seek opportunities to provide wide vegetated buffers between people walking and vehicle traffic.
- CP-2: Evaluate revising the existing cost participation policy to cover 100% of pedestrian-scale lighting.
- CP-5: Evaluate changes to the cost participation policy and supporting policies to allow MnDOT to pay for design elements that are context appropriate but may exceed current design standards.
- PS-15: When right-of-way space is limited, select a linear facility that enables safe and comfortable walking within the confines of the existing right-of-way, or work to acquire additional right-of-way for increased separation between people walking, people bicycling, and people driving.
- PS-16: Use the infrastructure expectations tables during project scoping.
  - » Note: these tables include treatments to reduce crash risks, like curb extensions and pedestrian refuge islands.

Statewide Bicycle System Plan (2016)

The Minnesota Statewide Bicycle System Plan (SBSP) provides a strategic framework for the development and enhancement of a comprehensive bicycle network throughout the state. The plan serves as a guiding document to promote active transportation, improve bicycle infrastructure, and enhance the overall bicycling experience in Minnesota.

MnDOT outlines key safety elements aimed at enhancing bicycle safety throughout the state. There is an emphasis on the importance of designing bicycle infrastructure that prioritizes safety. This includes the development of separated bicycle lanes, multi-use paths, and protected intersections, for example. By providing physical separation between people bicycling and motor vehicles, these design elements enhance safety and reduce the risk of crashes.

By prioritizing safety, the plan aims to create a connected and user-friendly bicycle network that encourages active transportation.

The safety elements outlined in the SBSP demonstrate a commitment to creating a safer and more accessible bicycle network through key practices such as:

- **Infrastructure Design:** By providing physical separation between bicycles and motor vehicles, these design elements enhance safety and reduce the risk of crashes.
- **Traffic Calming Measures:** Slowing down vehicle speeds in areas with high bicycle activity reduces the risk of accidents and promotes a safer coexistence between bicycles and motor vehicles.

- **Intersection Improvements:** Improvements such as dedicated bicycle signalization, clear signage, and advanced stop lines for bicycles. These enhancements improve visibility, reduce conflicts, and prioritize the safety of bicyclists.
- **Education:** Focus on sharing the road, understanding bicycle-specific laws, and promoting mutual respect between all road users.
- **Data Analysis:** Establishing comprehensive data systems to track bicycle crashes, near-misses, and infrastructure deficiencies. This information will guide decision-making and allow for targeted improvements where needed.
- **Collaborative Partnerships:** Engaging local communities, law enforcement agencies, advocacy groups, and transportation planners fosters a collective effort to prioritize bicycle safety. These partnerships facilitate the exchange of knowledge, resources, and expertise to implement effective safety measures.

Minnesota Safe Routes to School Strategic Plan (2020)

The Minnesota Safe Routes to School Strategic Plan establishes a five-year action plan to improve walking and biking to school for youth in Minnesota; providing an update to the previous Five-Year Strategic Plan, completed in 2015. The updated strategic plan provides a refined vision and new goals, strategies, action steps, and performance measures to expand, strengthen, and monitor Minnesota's Safe Routes to School (SRTS) program.

The strategic plan is a tool to guide state and regional SRTS practitioners and partners in building a stronger, more equitable SRTS program at the local, regional, and state levels. The ultimate goal is to make walking and biking to school and in daily life safe, comfortable, and convenient for youth in Minnesota.

The plan focuses especially on priority populations, including individuals, groups, and communities who are more likely to rely on walking, biking, or transit for transportation; are more vulnerable to unsafe traffic conditions; or have suffered historic disinvestment in safe, comfortable, walking, biking, and rolling infrastructure.

The plan's focus is on strategic, broad actions for the development, capacity building, and evaluation of the Minnesota SRTS program, and less on actions or performance measures specific to improving roadway safety for VRUs. However, the goals of the program and the strategic actions are in alignment with the aim to improve safety, as youth are vulnerable users of the transportation system and Minnesota SRTS supports activities and infrastructure changes that improve safety for youth walking and biking to school.

District Safety Plans (2016)

MnDOT updated the District Safety Plans in 2016 to identify urban and rural roadway facilities at high priority locations for safety investments. The plans identified safety projects that would give drivers a common set of roadway characteristics at similar locations across the state, identified for their sustained high crash rate or high crash risk.

The resulting plans, developed for each MnDOT district, provide a statewide and district-level overview of:

- Frequently occurring ("focus") crash types, with associated roadway and traffic characteristics
- Prioritized highway segments, curves, and intersections based on sustained high crashes or systemic risk assessment
- Prioritized list of safety strategies to reduce focus crash types
- Suggested safety projects and strategies at priority locations

Crashes involving people walking and biking were specifically identified in urban areas on trunk highways. MnDOT evaluated each intersection according to seven risk factors, prioritizing those with the highest number of risk factors present. These locations are a focus of the District Safety Plan recommendations due to the high opportunity for reducing severe crashes throughout the state highway system.

The effort identified two sets of locations: those known to have a sustained high number of crashes, and those with characteristics determined to be high risk for crashes. The 212 known intersections identified as high-crash locations account for only 3% of all intersections, and 10% of all severe crashes on the state highway system. Crashes outside the sustained high-crash locations are highly dispersed, yet not random. A more thorough systemic risk assessment was applied to the state roadway system to identify and prioritize high-risk locations based on roadway and traffic characteristics.

These plans identified characteristics associated with sustained high-crash intersections, as well as the safety countermeasures recommended to address these locations. Countermeasures include primarily upgrading signs, markings, and streetlights at rural two-lane intersections; reduced conflict intersections at expressway intersections; and addition of confirmation lights and countdown timers at urban signal-controlled intersections.

The plans also identified characteristics associated with high-risk locations. In urban areas where bicycle and pedestrian crashes were assessed, most projects included improved access management, confirmation lights at signalized intersections, and pedestrian facilities.

District Bicycle Plans (2019)

The district bicycle planning process built on the work of the SBSP, and included five major components:

- Identifying state bicycle route network priority corridors (completed in the SBSP)
- Identifying district regional priority corridors (completed in the SBSP)
- Analyzing bicycling suitability on all roadways across the state
- Identifying bicycle investment routes
- Developing a prioritization framework to help MnDOT prioritize bicycle investments

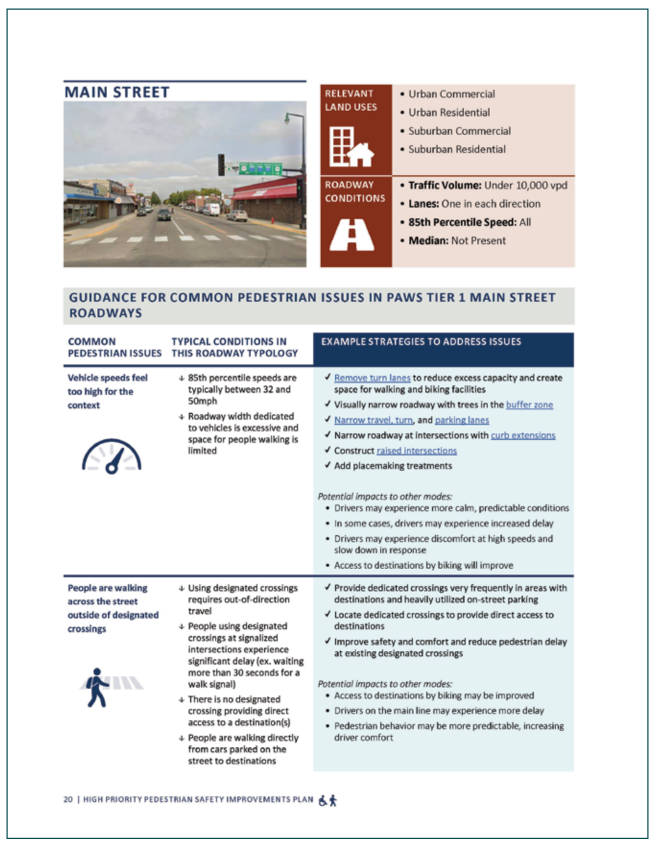
Each of MnDOT's eight districts completed a District Bicycle Plan that identifies roads and paths for future bicycle investment. Each district also created a scoring system based on policy from the SBSP to guide future improvements.

Bicycle investment routes in each district were prioritized based on a set of criteria weighted through rankings by each district's technical advisory committee. Thus, each district had a slightly different framework for prioritizing routes. Subcategories among prioritization criteria included projects that serve vulnerable road user populations, including children and youth, areas with significant poverty, workers with no vehicle access, Native American populations or Tribal Reservations, people with disabilities, older adults, and immigrant populations. Safety information, including whether a segment was identified in a MnDOT District Safety Plan or high-crash area, was also taken into consideration.

Identifying and Implementing High Priority Pedestrian Safety Improvements (2023)

The Identifying and Implementing High Priority Pedestrian Safety Improvements (HiPPS) project is part of the implementation of the Statewide Pedestrian System Plan. It is set for completion by the end of 2023.

Figure 14. *Example design typology from MnDOT's ongoing HiPPS effort*



MAIN STREET

RELEVANT LAND USES	• Urban Commercial • Urban Residential • Suburban Commercial • Suburban Residential
ROADWAY CONDITIONS	• **Traffic Volume:** Under 10,000 vpd • **Lanes:** One in each direction • **85th Percentile Speed:** All • **Median:** Not Present

GUIDANCE FOR COMMON PEDESTRIAN ISSUES IN PAWS TIER 1 MAIN STREET ROADWAYS

COMMON PEDESTRIAN ISSUES	TYPICAL CONDITIONS IN THIS ROADWAY TYPOLOGY	EXAMPLE STRATEGIES TO ADDRESS ISSUES
Vehicle speeds feel too high for the context	↓ 85th percentile speeds are typically between 32 and 50mph ↓ Roadway width dedicated to vehicles is excessive and space for people walking is limited	✓ Remove turn lanes to reduce excess capacity and create space for walking and biking facilities ✓ Visually narrow roadway with trees in the buffer zone ✓ Narrow travel, turn, and parking lanes ✓ Narrow roadway at intersections with curb extensions ✓ Construct raised intersections ✓ Add placemaking treatments *Potential impacts to other modes:* • Drivers may experience more calm, predictable conditions • In some cases, drivers may experience increased delay • Drivers may experience discomfort at high speeds and slow down in response • Access to destinations by biking will improve
People are walking across the street outside of designated crossings	↓ Using designated crossings requires out-of-direction travel ↓ People using designated crossings at signalized intersections experience significant delay (ex. waiting more than 30 seconds for a walk signal) ↓ There is no designated crossing providing direct access to a destination(s) ↓ People are walking directly from cars parked on the street to destinations	✓ Provide dedicated crossings very frequently in areas with destinations and heavily utilized on-street parking ✓ Locate dedicated crossings to provide direct access to destinations ✓ Improve safety and comfort and reduce pedestrian delay at existing designated crossings *Potential impacts to other modes:* • Access to destinations by biking may be improved • Drivers on the main line may experience more delay • Pedestrian behavior may be more predictable, increasing driver comfort

20 | HIGH PRIORITY PEDESTRIAN SAFETY IMPROVEMENTS PLAN

To date, the HiPPS project team has analyzed the contexts and conditions along trunk highways in each district's Tier 1 hexagons from the PAWS analysis, identifying six typologies that cover the most common types of roadways, as well as roadways of safety concern in all districts.

The HiPPS project team created a pedestrian safety improvement toolbox that includes the current universe of crossing and segment treatments available to address pedestrian infrastructure challenges. The team also connected that toolbox to commonly identified pedestrian safety comfort issues in the six typologies. The project team used the typologies and toolbox to analyze 24 locations with pedestrian safety concerns and produce cut sheets for each location recommending a path to mitigating safety concerns.

In the final stage of the project (fall 2023), HiPPS will convene district workshops to assess barriers to implementing pedestrian safety improvements and recommend action steps for each district as well as MnDOT as a whole.

Complete Streets

MNDOT COMPLETE STREETS POLICY (2022)

MnDOT's Complete Streets policy was updated in 2022 to provide policy and implementation guidance promoting the agency's vision of "a multimodal transportation system that maximizes the health of people, the environment, and our economy."

Minnesota Statute §174.75 defines "Complete Streets" as "the planning, scoping, design, implementation, operation, and maintenance of roads in order to reasonably address the safety and accessibility needs of people of all ages and abilities using the transportation system. Complete streets considers the needs of motorists, pedestrians, transit users and vehicles, bicyclists, and commercial and emergency vehicles moving along and across roads, intersections, and crossings in a manner that is sensitive to local context and recognizes that the needs vary in urban, suburban, and rural settings."

The policy defines "vulnerable users" as "road users who are most at risk for serious injury or death when involved in a motor-vehicle related collision, including but not limited to people bicycling and pedestrians of all ages, types, and abilities."

This policy is intended to minimize fatalities and injuries for transportation users, provide multimodal and intermodal transportation facilities and services, increase use of transit as a percentage of all trips, and promote and increase bicycling and walking as a percentage of all trips. The Complete Streets policy is intended to support related safety efforts, including TZD.

The policy update includes a requirement for project managers to fill out a Complete Streets Project Report during project scoping and 30% design. With a few exceptions, this is required on all projects.[1] Additional guidance is provided in the *Complete Streets Handbook*.

1. The policy states, "Some transportation projects, including some maintenance activities, landscaping, or roadside infrastructure projects that don't directly affect the layout or users, are exempt from the MnDOT Complete Streets Policy and reporting requirements."

MNDOT COMPLETE STREETS HANDBOOK (2022)

The Complete Streets Handbook provides guidance for implementing MnDOT's Complete Streets Policy. The handbook acknowledges the safety, mobility, and access needs of all transportation system users, with considerations for people walking and biking, using transit, driving, and freight (both trucks and rail).

The handbook notes that Complete Streets can be a tool to support VRUs, and that increasing the number of trips made by walking or bicycling is a state transportation goal. Meanwhile, the number of speed-related and total fatalities of people walking and biking is increasing. The handbook especially notes that older adults, people walking in low-income communities, and American Indian/ Alaskan Native, Black/African American, and Hispanic Minnesotans face the greatest risk of dying while walking.

Implementing Complete Streets with intentional design for all users increases the safety of vulnerable users. The handbook provides proactive guidance on understanding challenges facing all modes on Minnesota roadways, to improve predictability of movement and safety for all.

COMPLETE STREETS BASELINE PROJECT TRANSPORTATION HIERARCHY TOOL (2022)

The Hierarchy Tool provides a baseline modal hierarchy for projects in a range of context categories. The baseline considers the goal of preventing serious injury or death for the most vulnerable users, ease of travel, and expected volume of users for a given context category (land use and volume). The structure of the tool is shown in Figure 15.

The hierarchy provided for each context category is intended to shape planning, design, and operational elements to make sure each user group is appropriately accommodated. A higher transportation hierarchy rating means a higher level of service for that user group. A lower rating means a lower level of service than other user groups. Figure 16 and Figure 17 show the context categories and user group hierarchies.

Figure 15. *Transportation hierarchy framework process summary from MnDOT's Complete Streets Project Transportation Hierarchy Tool*

Figure 16. *Context categories from the MnDOT Complete Streets Handbook*

Context category	Walking	Bicycling	Transit	Autos	Trucks
Urban Core	High	High	High	Low	Medium
Urban Commercial	High	Medium	High	Low	Medium
Urban Residential	High	High	Medium	Low	Low
Suburban Commercial	High	High	Medium	Low	Low
Suburban Residential	High	High	Medium	Medium	Low
Industrial	Medium	Low	Low	High	High
Rural Crossroad	High	Medium	Low	High	Low
Rural	Medium	Low	Low	High	High
Natural	High	High	Low	Medium	High

Figure 17. *An example context category from the MnDOT Complete Streets Handbook*

The tool identifies people walking and people taking transit (since they often walk to transit stops) as the most vulnerable road users, and people biking as the second-most vulnerable road users. While the tool uses crash history, level of risk, user demand, and other factors as a first step in implementation, it notes that a lack of documented pedestrian and bicycle crashes does not necessarily mean conditions are currently safe for vulnerable users.

MNDOT COMPLETE STREETS CASE STUDIES

MnDOT is compiling case studies from across the state to illustrate a Complete Streets approach in different land use contexts (e.g., urban core, suburban commercial/residential, and rural) and on different project types (e.g. reconstruction, repaving, and bridge redecking). These case studies can be used by project managers and others to demonstrate examples of infrastructure that can provide safety benefits to VRUs; especially on trunk highway projects where there may be a perception of conflicting needs or priorities.

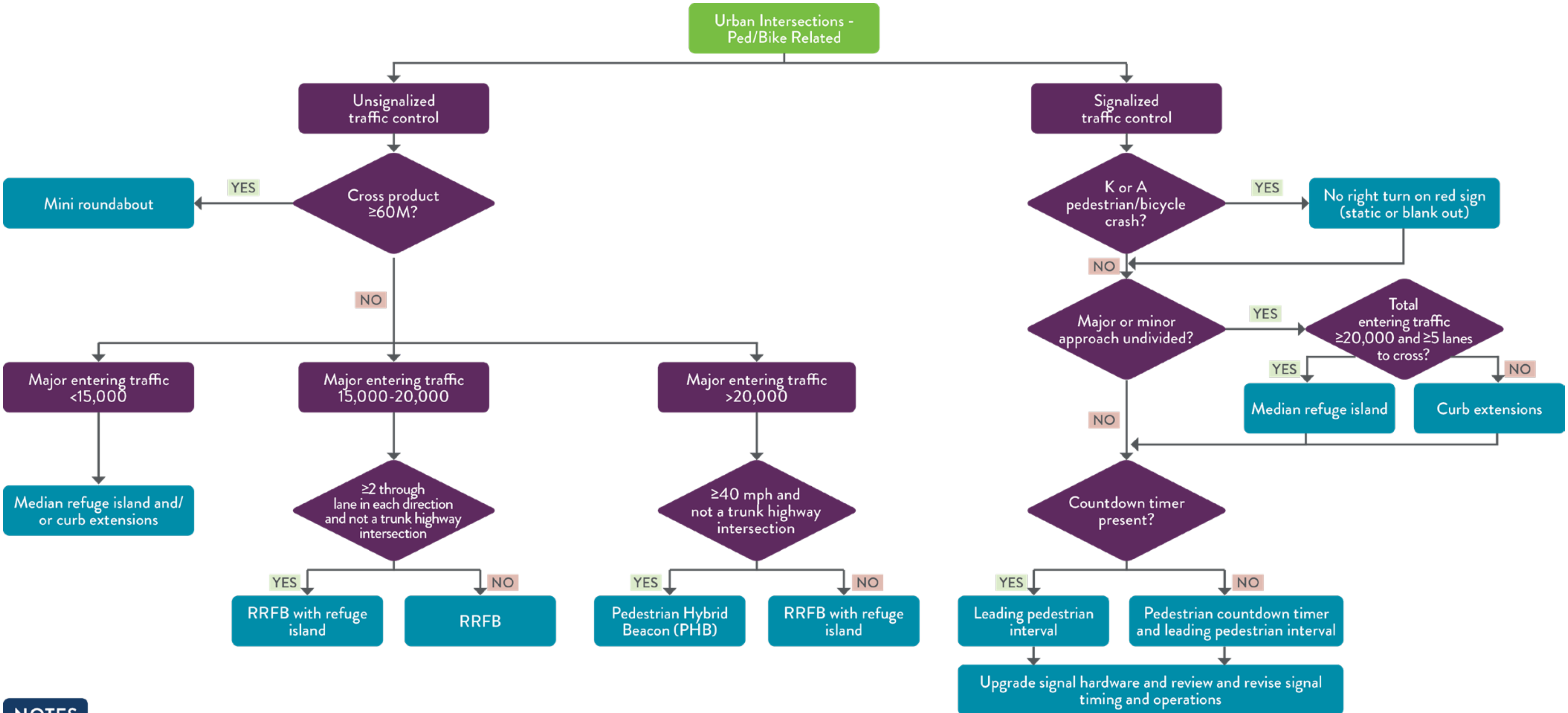
County Roadway Safety Plans

In 2010, MnDOT started developing County Roadway Safety Plans (CRSPs) for all 87 counties as well as each of the state's eight MnDOT districts. This showed a commitment to safety on all public roads and included dedicated HSIP funds for improvements on the local road system (in 2020, MnDOT targeted 50% of HSIP funding for local safety projects, and is now moved up to nearly 70% in some regions).

Each CRSP identifies safety concerns on county roads and suggests improvements that each county can implement. MnDOT in partnership with the FHWA and the Minnesota county engineers worked together to develop these plans. While not focused exclusively on VRUs, the goal of the CRSPs is to support the statewide TZD initiative through continued reduction of fatal and serious injury crashes on county roadways. The second round of CRSP and Metro counties have significant portions dedicated to pedestrian and bicycle safety.

The plans focus on systemic safety analysis and broad implementation of low-cost countermeasures at locations with high-risk characteristics for severe crashes; specifically linking projects to the causal factors associated with the most severe crashes (process shown in Figure 18 and Figure 19). After implementation of the CRSPs, the prioritized (mostly systemic) projects resulted in significant reduction in fatal and serious injury crashes on the county system.

Figure 18. *Decision trees with design recommendations for urban intersections from the CRSPs*



NOTES

Cross-Product: The product of the major entering traffic and minor entering traffic.

Entering Traffic:

- *Total Entering Traffic.* The sum of AADT on all approaches divided by 2.
- *Major or Minor Entering Traffic.* The sum of AADT for the Major or Minor approaches divided by 2. If a 5-leg intersection, the sum of three Major or Minor approaches is divided by 2.

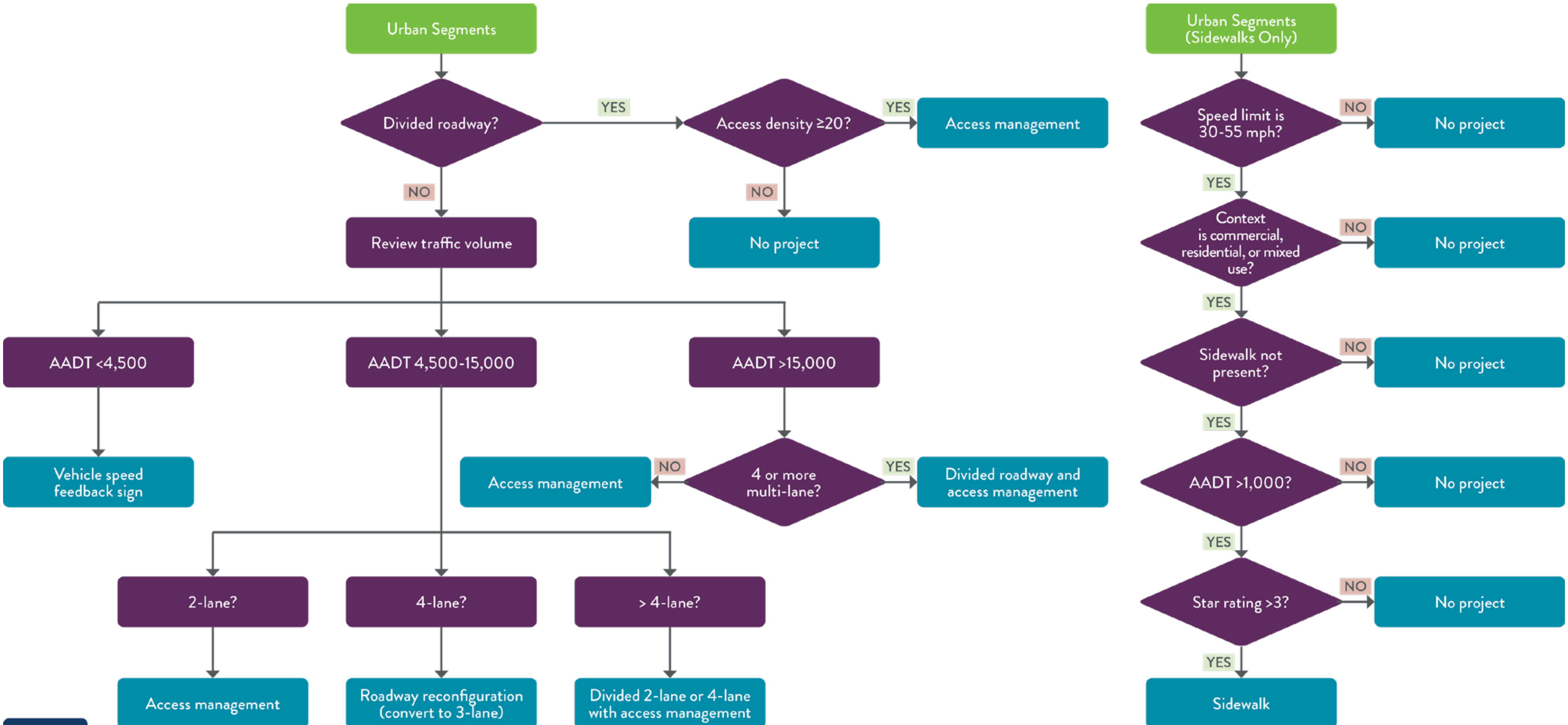
Manual Project Assignment: Locations that do not satisfy any case explicitly in the decision trees are not automatically assigned a project and are separately considered for manual project assignment.

RRFB: Rectangular Rapid Flashing Beacon

Review and Revise Signal Timing and Operations: Includes recommendations to slow the walk phase to 3 ft/sec, eliminate flashing yellow on pedestrian push-button activation, etc.

Upgrade Signal Hardware: Includes projects such as confirmation lights, pedestrian countdown timers, pedestrian push buttons, leading pedestrian intervals, backplates with retroreflective borders, flashing yellow arrows and emergency vehicle preemption related upgrades.

Figure 19. *Decision trees with design recommendations for urban segments from the CRSPs*



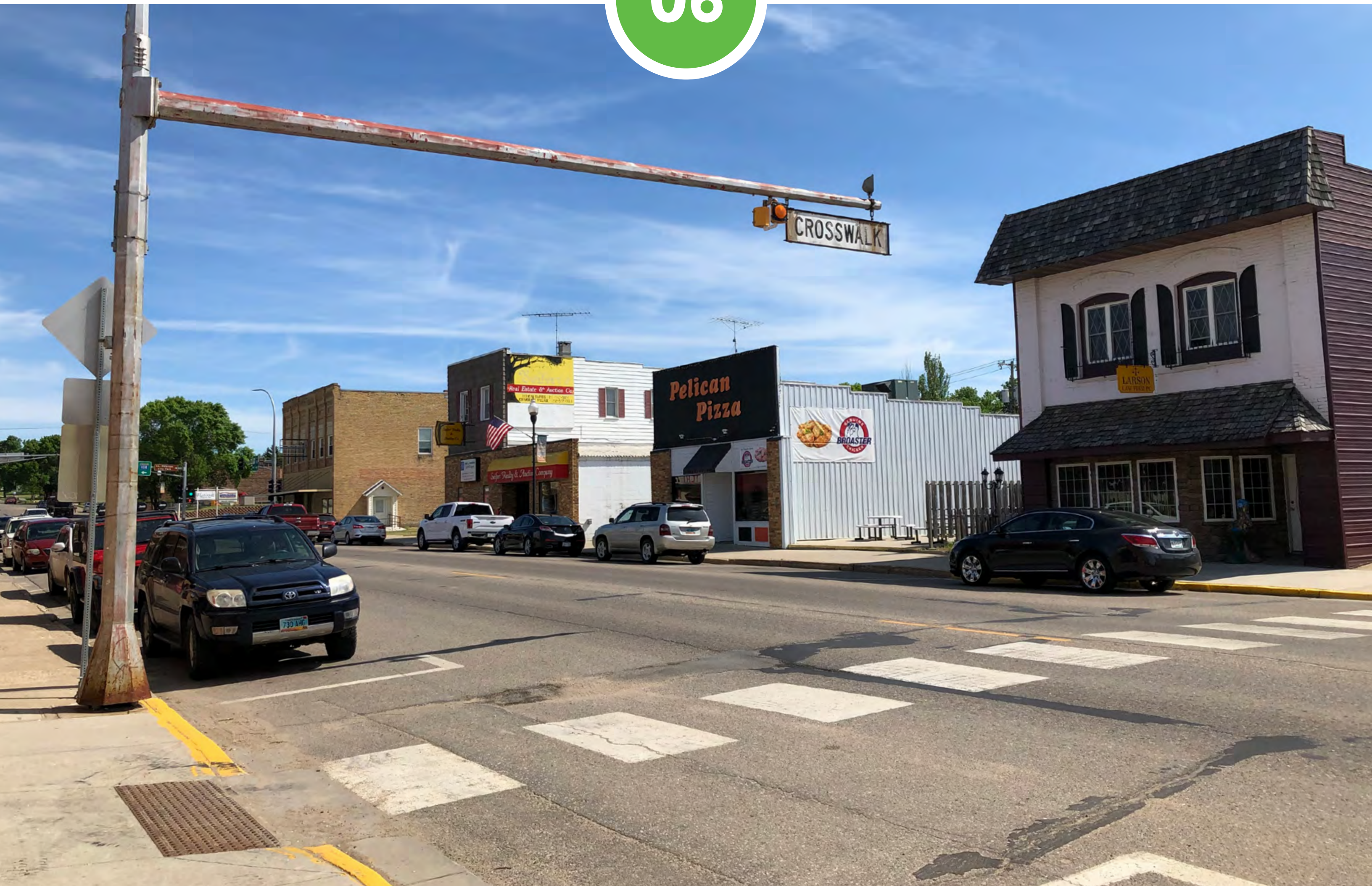
NOTES

Access Management: The planning, design, and implementation of land use and transportation strategies to maintain a safe flow of traffic while accommodating the access needs of adjacent development. Projects include limiting access points along the roadway and conflicts at driveways and intersections and increasing the distance between conflict points, so vehicles don't turn and cross in a chaotic way.

Manual Project Assignment: Locations that do not satisfy any case explicitly in the decision trees are not automatically assigned a project and are separately considered for manual project assignment.

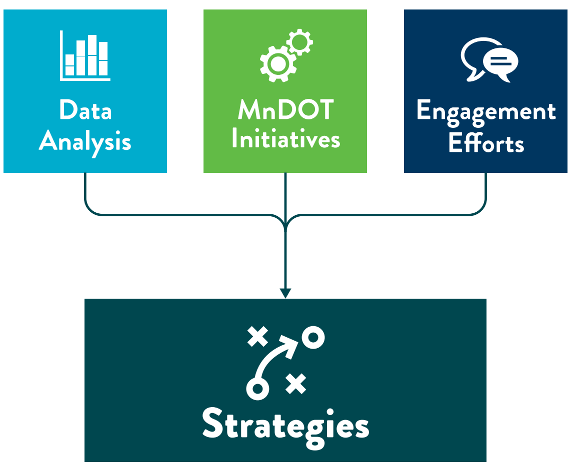
STRATEGIES

06



6.1 Overview

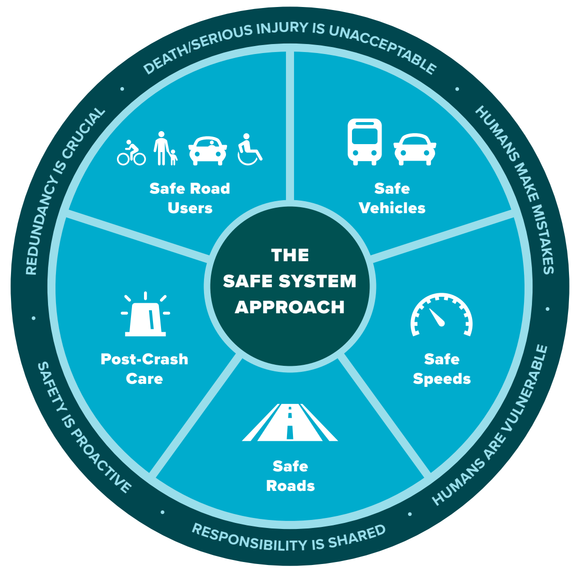
As MnDOT looks to the next iteration of the Strategic Highway Safety Planning process (currently underway) and future safety work, this assessment offers significant insight on safety priorities for the state's most vulnerable road users. The strategies were developed after identifying common themes from each of the key elements that make up this VRU document, including the existing and new safety analyses, consultation and engagement efforts, and recent MnDOT VRU initiatives. The strategies below were developed based on their connection to respective common themes.



Recommendations are rooted in a Safe System Approach—acknowledging that humans make mistakes and the transportation system should be designed to reduce the risk of fatalities and serious injuries when they do. The six core principles behind the Safe System Approach are reflected in the findings and strategies below, including the following: deaths and serious injuries are unacceptable, humans make mistakes, humans are vulnerable, responsibility is shared, safety is proactive, and redundancy is crucial.

Connecting with Tribal Nations to understand issues and opportunities for vulnerable roadway users on Tribal roadways was an important component of this project. The strategies outlined below include specific issues related to Tribal communities, such as data collection issues and the need for separated facilities for people of all ages and abilities. It's also important to note that all the strategies can apply to all public roads, including those through Tribal communities.

The Safe System Approach is a whole of transportation approach. The engineering profession can influence a minimum of two Safe System Elements: Safe Roads and Safe Speeds. To achieve safe roads and safe speeds, the strategies below are used.



Countermeasures rooted in the safe system approach princicples address safe roads, safe speeds, and safe road users by focusing on:

- **Separating users in space** (e.g., separated bike lanes, walkways, and pedestrian refuge islands)
- **Separating users in time** (e.g., leading pedestrian interval)
- Increasing **driver attentiveness and awareness** (e.g., crosswalk visibility enhancements, pedestrian hybrid beacons, and lighting)
- Implementing **physical features to slow traffic** (e.g., self-enforcing roads and road diets)
- Implementing **speed enforcing strategies** (e.g., speed safety cameras)

In addition to supporting these types of countermeasures, recommended strategies also support Minnesota's TZD goal (last set in 2019) of reducing traffic deaths to 225 or fewer and serious injuries to 980 or fewer by 2025.

6.2 Strategies

Action Area 1: Data Quality

FINDING 1.1

Data availability off the trunk highway system leaves gaps in MnDOT's understanding of statewide conditions.

Strategy 1.1.1 Expand data collection on roadway characteristics, pedestrian and bicycle facilities, and pedestrian and bicyclist traffic volumes. Invest in future efforts to collect and maintain accurate bicycle and pedestrian facility data with installation dates to help improve our understanding of crash risk in all parts of the state. Specific data collection recommended by the previous pedestrian safety study as well as this bicyclist safety assessment include:

- Motor vehicle operating speed—median and 85th percentile
- Non-MnDOT signals, PHBs, and RRFBs
- Statewide bikeways and off-street paths
- Crosswalk markings
- Crossing islands (pedestrian refuges)
- Non-MnDOT turn lanes (on cross streets approaching trunk highways, or full network)
- E-bike usage and an indicator for e-bike involvement in a crash

Strategy 1.1.2 Establish comprehensive data systems to track bicycle crashes, near-misses, and infrastructure deficiencies. This information will guide decision-making and allow for targeted improvements where needed.

Strategy 1.1.3 Revise crash data collection interface to eliminate ambiguous fields (e.g., pre-crash location, pre-crash action, sidewalk riding). Explore integration of relevant hospital data with Minnesota Department of Health to obtain potential unreported crashes and crash severities.

Strategy 1.1.4 Provide geolocation information from MnDOT back to the DPS MNCRASH system of record.

FINDING 1.2

Crashes are believed to be under-reported in Tribal areas, limiting MnDOT, State, and local officials ability to plan for safety improvements.

Strategy 1.2.1 Explore opportunities to coordinate with Tribal partners to address the gap in crash data on Tribal lands.

Action Area 2: Roadway Design

FINDING 2.1

The relative number of walking and biking crashes may be small; however, the severity and life-changing impact of these crashes warrants investment in risk reduction. HIN segments are concentrated where SPACE scores (a sign of latent demand) are medium and high. Engagement points to significant demand for more and better bicycle and pedestrian infrastructure.

Strategy 2.1.1 Enhance walking and biking infrastructure network to include destinations.

Strategy 2.1.2 Improve safety through intersection roadway design changes and alternative intersections. Tactics include incorporating people who walk and bike into intersection design, and reducing conflict points/severity.

Strategy 2.1.3 Improve corridor and signalized intersection safety through intersection traffic design and signal timing. Tactics include prioritizing people who walk and bike in design, improving visibility of people walking and biking, and providing leading pedestrian intervals and turning restrictions.

Strategy 2.1.4 Update planning policy. Tactics include reducing over-building the roadway, improving coordination between roadway authorities, and linking high-crash intersections and corridors with design-related issues.

Strategy 2.1.5 Strive to provide physical separation between bicycles and motor vehicles as those design elements enhance safety and reduce the risk of crashes.

FINDING 2.2

Engagement found that visibility of people walking and using wheelchairs is a primary safety concern.

Strategy 2.2.1 Provide pedestrian crossing improvements—particularly where sight lines may be obstructed—with a priority on bumpouts at intersections.

FINDING 2.3

Youth are overrepresented in bike crashes. Engagement found that routes to schools and parks are a top investment priority for Greater Minnesota residents.

Strategy 2.3.1 Designers should consider SRTS infrastructure improvements in locations near schools that have pedestrian and bicyclist safety needs and/or a desire for better biking and walking infrastructure.

FINDING 2.4

Where a trunk highway turns into a small-town main street, there is a significant concentration of vulnerable road user crashes.

Strategy 2.4.1 Design trunk highways in small urban areas for all modes and using Complete Streets policy.

Strategy 2.4.2 Utilize HiPPS typology for Main Street contexts.

Strategy 2.4.3 Design trunk highways in small urban areas to include speed management countermeasures or appropriate lane/roadway widths to help drivers maintain a context appropriate speed.

FINDING 2.5

Lighting conditions play a large role in the severity of crashes for people walking, biking and rolling. Motorist scale lighting may not adequately illuminate where people wait to cross the street.

Strategy 2.5.1 Prioritize pedestrian scale lighting where people are expected to cross the street walking, biking, or rolling.

Strategy 2.5.1 Evaluate light levels to ensure that sidewalks are sufficiently lit by existing light structures, and determine if lighting is appropriate for all roadway users.

FINDING 2.6

Where a trunk highway serves as the main arterial through a greater MN metro area, crashes with VRUs are disproportionately severe. More than half of all bicyclist crashes are on arterials; almost a third are at intersections between a minor arterial and residential street. Bicycle crashes were less severe if they occurred where a sidewalk or marked crosswalk facility was present. Engagement shows a preference for bicycle facilities separated from motor vehicle traffic.

Strategy 2.6.1 Provide bicyclist and pedestrian facilities along trunk highways and arterials with a priority on separated biking and walking infrastructure.

Strategy 2.6.2 Focus interventions on minor arterials, especially safe crossings along and across trunk highways and arterials.

Strategy 2.6.3 Integrate Safe System Approach in transportation safety processes and initiatives

FINDING 2.7

Maintenance of our transportation system is as important as design. Lack of maintenance can adversely affect VRUs more than vehicular traffic.

Strategy 2.7.1 Develop a plan that incorporates a hierarchy for maintenance activities on our transportation system (e.g. lighting, snow/ice, debris, etc).

Strategy 2.7.2 Throughout the project process, review the life-cycle costs of all facilities, including how projects may affect them.

Strategy 2.7.3 Resolve maintenance issues and challenges early in the project process. Coordinate with local partners to identify responsibility for maintenance activities.

Strategy 2.7.4 Right-size roadway facilities as rehabilitation and reconstruction opportunities arise and develop maintenance partnerships.

Strategy 2.7.5 Pursue additional funding and strategies to maintain walking and biking facilities for all relevant parties.

Strategy 2.7.6 Coordinate with local partners to determine an appropriate balance and source for construction and maintenance costs and activities. Resolve maintenance issues and challenges early in the project process.

Action Area 3: Implementing Infrastructure Improvements

FINDING 3.1

Pedestrian safety improvements are often challenging to implement outside of a larger project, with no clear path to implementation. Securing funding for pedestrian and bicyclist safety projects can also be a challenge, since they often don't score well with HSIP funding due to their relatively low frequency as compared to vehicle-only crashes.

Strategy 3.1.1 Use local or regional Safe System safety planning, in combination with high-risk areas identified in this VRUSA, to identify highest risk locations where available.

Strategy 3.1.2 Implement forthcoming HiPPS Action Plan recommendations for Central Office and district-level actions to overcome systemic barriers preventing action on pedestrian safety.

FINDING 3.2

The HIN is overrepresented in lower-income and majority POC neighborhoods.

Strategy 3.2.1 As a part of the data-driven approach referenced in Strategy 3.1.1, prioritize areas for investment that have significant populations of lower-income residents, POC, and Tribal communities.

FINDING 3.3

There is interest in using demonstration, quick build projects, and other interim improvements using more permanent materials to implement safety solutions for VRUs. Some MnDOT District staff identified barriers to installing demonstration projects and indicated an interest in more support (as a part of the HiPPS project).

Strategy 3.3.1 Continue to support implementation of demonstration projects, quick build projects, and other interim pedestrian and bicycle safety improvements. This could include existing programs, such as SRTS grants, or potential future funding/programs.

FINDING 3.4

While a significant percentage of crashes occur in the Twin Cities metropolitan area, contexts that pose higher risks for VRUs are found throughout the state. Key partners consulted as a part of the VRU process, such as the MPOs and RDCs, noted guidance on how to use the HIN in their work would be helpful.

Strategy 3.4.1 Share this assessment's HIN data with communities statewide to support local safety efforts and facilitate customized community analysis. Provide strategies to communicate how MnDOT and other agencies can use this information.

Strategy 3.4.2 Create a series of "how-to" resources for district and local staff connecting safety challenges with existing design guidance at multiple investment levels. Provide education to help locals understand the value of active transportation in their community.

FINDING 3.5

Dependent transit users and people who walk, bike, and roll out of necessity have different perspectives than choice users.

Strategy 3.5.1 As a part of capital project delivery, from scoping to preliminary design, engage people who are dependent on walking, biking, rolling, and transit—using creative, thoughtful, experiential methods.

FINDING 3.6

Engagement shows a clear desire for more accessible biking and walking infrastructure.

Strategy 3.6.1 Utilize the Minnesota Department of Health Inclusive Walk Audit Guide in project planning—being careful to not equate experiential use of disability simulators with the lived experience of having a disability.

CONCLUSION

07

Connecting the VRUSA to the SHSP via the Safe System Approach

This VRUSA was developed with an intentional focus on integrating the FHWA Safe System Approach at all levels of this project. The Statewide Multimodal Transportation Plan and the State Highway Safety Plan both articulate MnDOT's commitment to the Safe System Approach. The VRU data analysis accounts for where crashes are happening, who is involved, and what types of risks exist. Finally, the Strategies are also rooted in the Safe System Approach.

This VRUSA includes a significant amount of new analysis and previously completed studies and plans. New work includes a HIN and a new bicycle systemic analysis. Previously completed work includes a pedestrian systemic safety analysis and a summary of the District Safety Plans. Appendices contain a significant amount of additional detail that can further increase an understanding of crashes, including charts, etc.

Chapter 6 outlined various strategies based on key findings from the VRU analysis and engagement process. Due to the timeline provided by FHWA, the entire analysis (excluding the 2021 SPSA) and engagement process was completed in under nine months. The VRUSA does not specify priorities, timeframe, or specific implementation steps. The development of the 2025–2029 SHSP, which began shortly before this VRUSA was published, is an opportunity to dig deeper into the implementation priorities of strategies outlined in the VRUSA. The SHSP allows for more expansive engagement with stakeholders across the state and a longer timeline for developing and refining strategies. This will allow additional internal coordination within MnDOT.

The analysis in this first VRUSA centered around actionable findings and strategies related to three of the Safe System Approach elements: safe roads, safe speeds, and, to a lesser extent, safe road users. Strategies for safe roads included facility design recommendations (e.g., crossing enhancements or all ages and abilities bikeways). Safe speed strategies centered on the concentration of crashes at both moderate- and high-speed locations and using the design process to help manage speed. Safe road user strategies addressed nuance around the role of sidewalks for bicyclists and design elements that help increase driver attentiveness and awareness.

While redundancy within a safety system is central to the Safe System Approach, these elements are not equally actionable for state and local transportation agencies. Recent research from public health disciplines has confirmed that energy transfer in crashes is the primary cause of injury, and roadway and speed strategies that reduce energy transfer are more effective than attempting to secure collective changes in behavior from millions of individuals simultaneously or increasing the quality of post-crash care once energy transfer has already occurred (Ederer et al 2023). Strategies requiring the most individual effort, like personal protective equipment, are also the least effective at the population scale (Ederer et al 2023).

Using safe road users as an example, this VRUSA's findings about the role of lighting and darkness for pedestrian crashes might prompt an agency to set goals around encouraging the use of retroreflective gear. However, research has not shown this to be effective. While there may be safety benefits to individuals who choose to wear retroreflective gear, relying on pedestrians to wear special clothing is inherently inequitable as it puts the burden of visibility on the pedestrian, who may lack access to these materials and is more likely to experience harm in a crash. (Balasubramanian and Bhardwaj 2018). It is possible that if drivers are conditioned to expect pedestrians to wear retroreflective gear, they may be even less likely to look for pedestrians in regular clothing (Tijerina 2016). Education campaigns to persuade pedestrians to dress differently have been found ineffective, and efforts toward these detract from efforts to make more meaningful and effective changes (e.g., road design, speeds, vehicle design). (Kwan and Mapstone 2006). Focusing on safe road users through this lens of compliance and personal protection, therefore, may divert limited resources away from more effective population-scale and infrastructure-scale strategies and would not be consistent with the principles of a truly Safe System Approach.

Given the body of research and evidence around how various Safe System Approach elements can be used and to what effect, this first VRUSA focused primarily on elements through which state and local agencies have the most influence, and from which state and local actions have the greatest likelihood of success. Nonetheless, future VRUSAs and the next iteration of the SHSP may wish to continue to explore other ways to target safe road users, safe vehicles, and post-crash care. For example, due to the catastrophic effect of increasing vehicle size on vulnerable road users, a future SHSP or VRUSA might evaluate the feasibility and potential effectiveness of a tax on oversize consumer vehicles registered in the State of Minnesota. Collaboration between transportation and public health agencies might identify opportunities to strengthen the post-crash care network in areas experiencing the most severe crash outcomes, as well.

This VRUSA also revealed a specific need for more safety and usage data, specifically in partnership with Tribal Transportation. MnDOT and the University of Minnesota currently partner with Tribal Nations on a variety of research efforts. This work should continue, and in the context of the VRUSA, could focus on safety data gaps so that future VRUSA and SHSP strategies could better reflect the needs and priorities of Tribal governments.

Finally, there is an opportunity to promote the use of the HIN associated with the VRUSA to help local agencies implement a Safe System approach. There will be a publicly available data dashboard following the completion of this assessment. It will have significant value for partners across the state. The dashboard could be helpful in applying for funding to make safety improvements.

Ederer, David J., Rachael Thompson Panik, Nisha Botchwey, and Kari Watkins. "The Safe Systems Pyramid: a new framework for traffic safety." Transportation research interdisciplinary perspectives 21 (2023): 100905.

Balasubramanian, V., & Bhardwaj, R. (2018). Pedestrians' perception and response towards vehicles during road-crossing at nighttime. Accident Analysis & Prevention, Volume 110, Issue 0, pp 128-135.

Tijerina, L. (2016). Information Processing, Attention, and Driver Workload. In A. Smiley (Ed.), Human Factors in Traffic Safety (pp. 37-56). Lawyers & Judges Publishing Company, Inc.

Kwan, I., Mapstone, J. (2006). Interventions for increasing pedestrian and cyclist visibility for the prevention of death and injuries. Cochrane Database Syst. Rev. (4), CD003438.

MEMO

TO: Matthew Dyrdahl, AICP, CTP, LCI & Team, Alta Planning + Design
FROM: Jessica Schoner, PhD; Brian Almdale, MUPP; Rachel Thompson Panik; Rebecca Sanders, PhD RSP2B,
DATE: 2023-10-02
RE: Appendix A High Injury Network Analysis Report
PROJECT: P018 MnDOT Vulnerable Road User Safety Assessment

Executive Summary

High injury networks (HIN) are a simple and effective tool for identifying concentrations of severe crashes to prioritize. They strike a balance between a reactive and proactive approach by identifying not only high-crash hotspots, but also clusters of single or small numbers of crashes that occur in close proximity to one another and often share risk factors. The clustering approach provides a better understanding of the role of particular roadways and roadway risk factors that lead to a more systemic understanding of safety.

MnDOT's Office of Traffic Engineering (OTE) developed a statewide High Injury Network as part of its Vulnerable Road User Safety Assessment (VRUSA). The HIN, alongside other systemic safety resources included in the VRUSA, can help MnDOT prioritize safety improvements and can provide technical assistance to communities looking to improve vulnerable road user (VRU) safety on their local networks.

The HIN was built using standard methods on a dataset containing VRU crashes from 2017—2021. The HIN only represents fatal and injury crashes, and fatal and serious injury crashes are weighted more heavily than minor injury crashes. In larger urban metro areas, where sample sizes allow, separate pedestrian and bicyclist networks were developed and then combined, to better represent the distinct needs of different types of VRUs. In small urban communities and rural areas, all VRU types are combined into a single network since sample sizes are usually smaller.

After several rounds of discussion with MnDOT staff and technical advisory group, the resulting HIN uses a threshold of 5 (combined VRU score) in small urban areas and rural areas, thresholds of 5 (bicyclists) and 7 (pedestrians) in greater MN urban metro areas and the Twin Cities metro outside of Minneapolis and St. Paul, and 7 (bicyclists) and 12 (pedestrians) within the cities of Minneapolis and St. Paul. This yields about 352 miles of HIN statewide, or about 0.2% of the state's overall road mileage.

The HIN captures about 30% of the state's total VRU crashes. This amount varies by year, mode, and severity. A smaller share of crashes during pandemic years (2020 and 2021) are on the HIN.

Nearly 33% of pedestrian and other VRU crashes are on the HIN, compared with only 26% of bicyclist crashes. Over 35% of serious injury crashes are on the HIN.

The HIN within Minneapolis and St. Paul captures nearly 50% of VRU crashes, but only about 2% of rural VRU crashes are on the HIN. Variations by geography reflect the general urban character of VRU crashes in general – about 75% of all VRU crashes happen in the Twin Cities metro region.

VRU crashes at signal-controlled intersections are best captured by the HIN, with 49% of all severities and 59% of severe crashes on the HIN. Other location types (unsignalized intersection, midblock) have lower concentrations on the HIN.

The HIN's spatial distribution reflects the underlying inequities in traffic crashes. VRU crashes are overrepresented in lower income and majority POC neighborhoods, and the HIN follows this pattern with greater concentrations of HIN in these areas.

The HIN is one of many tools to assist MnDOT and local agencies with planning and engineering for VRU safety. The HIN itself can help communities identify segments with the greatest concentration of crashes needing further investigation and safety improvements. Communities may also access the underlying sliding windows data, if they wish to identify their own threshold and local HIN. Systemic and predictive analyses can also be used to screen both the HIN and other streets for risk factors.

Acronyms

AADT	Annual Average Daily Traffic
AADT	Annual Average Daily Traffic
ADA	Americans with Disabilities Act
BIL	Bipartisan Infrastructure Law
DPS	Department of Public Safety
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GIS	Geographic Information System
HIN	High Injury Network
HIN	High Injury Network
KA	Killed of severely injured
LRS	Linear Referencing System
MMUCC	Model Minimum Uniform Crash Criteria
MN	Minnesota
MnDOT	Minnesota Department of Transportation
MSI	Most severely injured
MSP	Minneapolis—St. Paul
MV	Motor Vehicle
OTE	Office of Traffic Engineering
Ped	Pedestrian
SPACE	Suitability of Pedestrian and Cyclist Environment
SSA	Safe System Approach
TAMS	Transportation Asset Management System
TCMA	Twin Cities (Minneapolis—St. Paul) Metropolitan Area
USDOT	US Department of Transportation
VPD	Vehicles per day
VRU	Vulnerable road user
VRUSA	Vulnerable Road User Safety Assessment

Table of Contents

Introduction & Purpose

The Bipartisan Infrastructure Law (BIL), passed in 2021, created a new requirement for state departments of transportation to conduct a Vulnerable Road User Safety Assessment (VRUSA) every five years. Anchored in the Safe System Approach (SSA), this assessment must use a data-driven process to identify high risk areas and incorporate equity and demographics into the analysis. Official guidance[1] around this new Vulnerable Road User Safety Assessment recommends the use of High Injury Network, predictive, and/or systemic analysis to identify high risk areas.

There are many established ways to examine crashes to better understand traffic safety patterns. Hotspot analyses have long been used to address high crash locations by retrospectively identifying the greatest concentration of reported crashes over a determined period of time. Hotspot analysis is a valuable method to visualize locations with historic crash issues, but it is less effective at identifying locations with higher crash risk. For example, a wide arterial with a 45-mph posted speed limit, high traffic volumes, no bike facility, and few trip-attracting land uses may not have any reported bike crashes. However, the roadway and operational characteristics of that arterial are associated with higher bicycle crash risk. The absence of crashes is therefore not a reflection of low crash risk, but a reflection of lack of exposure that hotspot analyses cannot adequately convey. Additionally, hotspots may be less effective for analyzing bicyclist safety if crash frequencies are low due to geographic sparsity, which can exacerbate issues related to regression to the mean.

High injury networks strike a balance between entirely retrospective and entirely proactive/predictive methods. Using spatial patterns of crash history, a High Injury Network identifies areas on the road network where crashes have been concentrated in sequence. A stretch of arterial roadway with crashes occurring every other intersection might not show up on a traditional hotspot analysis because no one location has multiple crashes happening in the same place. However, the pattern of crashes all along the corridor suggests a larger safety issue. Further, the entire corridor likely shares similar characteristics that could be addressed systemically – even the intersections along the corridor that have not yet had crashes.

To improve the safety of vulnerable road users in the state of Minnesota and partially satisfy the new VRUSA requirements, the Minnesota Department of Transportation's (MnDOT) Office of Traffic Engineering (OTE) commissioned a Vulnerable Road User Safety Assessment, including development of a High Injury Network for the state, among other analyses. While bicyclists and pedestrians are different roadway users, use different infrastructure in many places, and have

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[1] FHWA Memorandum, "Vulnerable Road User Safety Assessment Guidance". https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-10/VRU%20Safety%20Assessment%20Guidance%20FINAL_508.pdf

different safety concerns, both bicyclists and pedestrians are vulnerable roadway users that are disproportionately likely to be killed or severely injured in the transportation system.

This report describes the process by which a statewide High Injury Network was built, and the results of that High Injury Network analysis. The High Injury Network was built from a standard sliding windows analysis, which measures severity-weighted crash density by mode along segments on the network. This section of the analysis spans all vulnerable road users, including bicyclists, pedestrians, and other personal conveyances.

The rest of the report is structured as follows: First, an overview of the crash data is presented, followed by basic descriptive summaries of the crash data. Next, we describe methodological trade-offs and decisions for High Injury Network analysis, including the decisions that guided the development of this HIN. Finally, we present the resulting High Injury Network for the state of Minnesota, along with accompanying descriptive analysis of the HIN.

Data Overview

Crash Data

Crash, party, and vehicle data were provided to the consultant team includes reported crashes from 2016 through 2021 for crashes for all modes (pedestrians, bicyclists, and motorists). The statewide High Injury Network (HIN) analyzed the five most recent years of crash data available at the time the project began: 2017-2021, Other VRUSA analyses used different time periods within this dataset; these are documented elsewhere.

All crash data were processed by Safe Streets Research & Consulting ("Safe Streets") and loaded into a Postgres database for additional analysis. The crash, party or vehicle, and person or victim tables have a relational structure, which is common for storing crash data. For every reported crash, there is one record in the crash table. The party/vehicle and person/victim tables contain information for all the primary "actors" and their respective "vehicle" involved in the crash and has a many-to-one relationship – i.e., all relevant party records are matched via a case identification number to the one crash record. The party and victim tables contain information for each primary person and their "vehicle" (if applicable) such as age, sex, pre-crash action, injury severity, and vehicle characteristics. Figure 1 illustrates this relational structure. Parties are classified by the mode of travel or type of vehicle being used. Three of the eight categories are applicable to the VRUSA: mode 5 (pedestrian), mode 6 (bicyclist), and mode 8 (other personal conveyance).

The database we received included all reported crashes for the specified years (2016—2021). However, the scope and methodology of this study necessitated filtering this dataset. Our exclusion criteria were defined by mode(s) involved in the crash and location-based characteristics.

Motorist-only (non-VRU) crashes

For the purpose of the VRUSA, FHWA defines VRU as a nonmotorist with a person code attribute in the Fatality Analysis Reporting System (FARS) equivalent to pedestrian, bicyclist, other cyclist, or other personal conveyance. FHWA further clarifies that VRUs include highway workers on foot in a work zone and exclude motorcyclists.[2] Therefore, we removed crashes that only involved motorists (i.e., did not include person type 5, 6, or 8). We did not attempt to remove highway worker or unintended pedestrian crashes (e.g., crashes involving a driver who has exited their vehicle after breaking down on the highway).

Crashes in which a person was using a scooter or other mobility device (e.g., shared e-scooter or ADA assistive device) are classified within the data as “Other personal conveyance”. Many of these crashes – especially those involving someone using a wheelchair or other assistive scooter or device – are more accurately described as “pedestrian” crashes, for the purposes of this analysis. However, this category of “other personal conveyance” crashes includes a broad range of user types that the reporting officer is otherwise unable to categorize, some of which are considered vulnerable road users (people using e-scooters or assistive devices), and some of which are not (e.g., tractors). Indeed, the consultant team read one crash report in which the officer categorized the party as “other personal conveyance” and explained in the narrative that the involved vehicle was actually an airplane.

[2] FHWA Memorandum, “Vulnerable Road User Safety Assessment Guidance”. https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-10/VRU%20Safety%20Assessment%20Guidance%20FINAL_508.pdf

Crash Record

ACCN	ACCDAY	LIGHT
161720219	Wednesday	Daylight
160040017	Sunday	Dark (Street Lights On)

ACCN 1:N

Vehicle/Unit Record

ACCN	RVN	VEHTYPE
161720219	1	Pickup
161720219	2	Pedestrian
160040017	1	Passenger Car
160040017	2	Bike

ACCN RVN 1:N

Person Record

ACCN	RVN	RVP	PTYPE	UNITPER	INJSEV
161720219	1	1	Driver	Motor Vehicle in Transport	No Apparent Injury
161720219	1	2	Passenger	Motor Vehicle in Transport	No Apparent Injury
161720219	2	3	Non-Motorist	Pedestrian	Suspected Serious Injury
160040017	1	1	Driver	Motor Vehicle in Transport	No Apparent Injury
160040017	2	2	Non-Motorist	Bicycle	Suspected Minor Injury

Note: ACCN and RVN uniquely identify vehicles in the database.

Figure 1. Crash Database Schema

We made a targeted effort to categorize “other personal conveyance” crashes based on their likelihood of having been a VRU.

- Other personal conveyance crashes in which the narrative mentions various permutations of the words “walk”, “cycle”, “wheelchair”, “scooter”, and other VRU-related keywords were kept as likely VRU crashes.
- Crashes in which the narrative mentions farm or other road equipment, such as “tractor”, “horse”, or “combine”, were excluded as likely not VRU for the purpose of this study.
- The remainder that could not readily be classified were also kept in the study as “other personal conveyance” crashes.

As stated in the 2019 Pedestrian Safety Analysis, a long-term solution to facilitate routine analysis of scooter involvement in crashes in Minnesota would be to update the crash form with a field to indicate the type of scooter involvement (e.g., e-scooter, kick-scooter, ADA assistive device, moped scooter) and retrain officers to utilize the new field to record accurate and detailed information for more streamlined analysis.

Inapplicable or missing geo-locations

As this study relied heavily on geospatial processing and analysis, crashes with missing geo-location data were excluded – with some exceptions. A small number of pedestrian crashes were missing geo-location data in MnDOT’s main crash database, but had previously been assigned corrected location data as part of MnDOT’s Statewide Pedestrian Crash Analysis study. We migrated this corrected geo-location data to the current project dataset. This affected fatal and serious injury pedestrian crashes from 2016—2019 which had previously been assigned corrected geo-location information. Pedestrian crashes from 2020—2021 and all bicyclist crashes with missing geo-location information were excluded from the analysis.

Crashes that were reported to have occurred in a parking lot were excluded since this study focused on roadways.

Crashes that occurred more than 300 feet from any street were excluded, as were crashes that occurred along private roadways.

Injury Severity Assignment

Crashes in the dataset were assigned a global severity variable that represented the most seriously injured (MSI) party. Usually, the most seriously injured party is also the most vulnerable road user; however, there are rare exceptions. We identified the most seriously injured VRU within each crash and assigned a VRU-specific crash severity to each crash. Since this study focuses exclusively on VRUs, using the victim-level severity helps improve accuracy of summarizing injury severities as they relate to VRU safety and risk factors. It should be noted that the San Francisco Department of Public Health has conducted extensive research and has documented reporting errors related to mis-coded injury severities, particularly for severe injuries[3], suggesting a need for some fluidity when discussing minor and serious injuries. This analysis does not have access to hospital records to verified injury severities stored in the crash data, so the results in this document reflect the best available data at the time.

For reference, the injury severities recorded in the crash data and summarized in this analysis are defined as followed:

- **K - Fatal:** A fatal injury is any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred. If the person did not die at the scene but died within 30 days of the motor vehicle crash in which the injury occurred, the injury classification should be changed from the injury previously assigned to "Fatal Injury"
- **A – Suspected Serious Injury:** An incapacitating injury is any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury occurred. This category includes:
    - severe lacerations
    - broken or distorted limbs
    - skull or chest injuries
    - abdominal injuries
    - unconsciousness at or when taken from the accident scene
    - unable to leave the accident scene without assistance
- **B – Suspected Minor Injury:** A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include:
    - lump on the head
    - abrasions, bruises
    - minor lacerations (cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle)
- **C – Possible Injury**: A possible injury is any injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Possible injuries are those which are reported by the person or are indicated by their behavior, but no wounds or injuries are readily evident. Examples include:
    - momentary loss of consciousness
    - claim of injury
    - limping, or complaint of pain or nausea.
- **O – Property Damage Only**: Crash where only property is damaged. No injuries resulted from the crash.

There are known variations within MnDOT's crash data over time as they relate to injury severity definitions. DPS's reporting forms were updated for compliance with the Model Minimum Uniform Crash Criteria (MMUCC) and for electronic reporting capabilities, with the new system going live at the beginning of 2016. This shift updated the description of crash severities from "Serious Injury" and "Minor Injury" to "*Suspected* Serious Injury" and

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[3] https://www.visionzerosf.org/wp-content/uploads/2021/11/Severe-Injury-Trends 2011-2020 final report.pdf

"*Suspected* Minor Injury" (emphasis added). The crash data in 2016 showed an initial surge in injuries classified as serious injuries that would have been classified as minor injuries in 2015 or earlier. Over time, severity rates stabilized as officers received more training and had more experience with the new system. Year-to-year severity comparisons from about 2015 to 2017 may be affected by this shift. Because the High Injury Network pools data *across years*, rather than comparing *between years*, this analysis should be largely unaffected by the change.

Roadway and Contextual Data

High Injury Network analysis primarily relies on spatially processing crash history along a road network. Therefore, minimal – if any – roadway attributes are needed for this type of analysis. We joined High Injury Network analysis results to MnDOT's Trunk Highway network to be able to identify which segments of the HIN are on state-owned roadways. We also joined the HIN to MnDOT's Suitability of the Pedestrian and Cycling Environment (SPACE) dataset to be able to evaluate the HIN through this lens. Crash and HIN segment data were joined to these layers spatially.

Crash Data Summary

This section briefly summarizes crashes by mode, year, and severity for VRU crashes that are included in the sliding windows analysis.

Crash Mode

Table 1 shows the distribution of VRU crashes by mode and severity that were considered for the HIN analysis. Among the VRU crashes considered for High Injury Network analysis, 55% were pedestrian crashes, 39% bicyclist crashes, and the remainder were other personal conveyance (including those flagged as likely VRU, and excluding those flagged as farm equipment). As discussed in the next section, only fatal, serious injury, and minor injury crashes were ultimately included in the final High Injury Network, so the subtotal of included crashes is also shown in the table.

Table 1. Number of crashes by mode and severity, 2017—2021.

Mode	Fatal and Serious Injury	Minor Injury	Possible Injury and PDO (excluded)	Total Crashes	Total Included (KAB only)	Percentage of All Crashes*	Percentage Included* (KAB only)
Bicyclist	302	1,431	1,133	2,866	1,733	39%	38%
Pedestrian	981	1,675	1,395	4,051	2,656	55%	59%
Other - Personal Conveyance	29	89	272	390	118	5%	3%
Total	**1,312**	**3,195**	**2,800**	**7,307**	**4,507**	**100%**	**100%**

**Percentages may not sum to 100% due to rounding error*

Injury Severity

Table 2 shows the crash distribution by injury severity for all VRUs. Pedestrians have the largest share of fatal crashes at 5%, followed by other VRU crashes. Most bicyclist crashes are minor injury and possible injury crashes, although 9% are severe injury crashes. Other personal conveyance crashes are much more likely to be property damage only crashes than our other VRU-identified crashes – that may reflect the composition of modes within this "catch all" category that has neither been confirmed VRU nor confirmed non-VRU/farm equipment.

Table 2: All Study Crashes by Severity, 2017 – 2021

Mode		Fatal (K)	Severe Injury (A)	Minor Injury (B)	Possible Injury (C)	Property Damage Only (O)	*Total*
Bicyclist	Count	41	261	1,431	919	214	2,866
	Percentage	1.4%	9.1%	49.9%	32.1%	7.5%	100.0%
Pedestrian	Count	221	760	1,674	1,238	158	4,051
	Percentage	5.5%	18.8%	41.3%	30.6%	3.9%	100.0%
Other - VRU	Count	5	15	58	51	32	161
	Percentage	3.1%	9.3%	36.0%	31.7%	19.9%	100.0%
Other – Personal Conveyance	Count	0	9	31	20	169	229
	Percentage	0.0%	3.9%	13.5%	8.7%	73.8%	100.0%
Total	**Count**	**267**	**1,045**	**3,195**	**2,228**	**572**	**7,307**
	Percentage	**3.7%**	**14.3%**	**43.7%**	**30.5%**	**7.8%**	**100.0%**

Year

Table 3 describes the distribution of VRU crashes by year, including the number of Fatal and Serious Injury crashes (KA), and the shares of total crashes and KA among each VRU mode per year. Table 3 shows several trends. First, pedestrian crashes make up the largest share of all VRU crashes each year and the largest share of KA crashes each year. Each year, pedestrian crashes are more likely than other VRU modes to result in death or serious injury ("% KA within Mode and Year"). Both of these trends indicate that pedestrians are overburdened for severe and fatal injuries in the Minnesota statewide transportation system.

Another trend is that, while the modal composition from year to year remains fairly stable, the severity across all VRU modes has increased in recent years. Bicyclist crashes have comprised about 36% to 42% of all yearly VRU crashes, and pedestrian crashes represent about 53% to 59%. The severity rate for bicyclist crashes peaked in 2020, with just over 14% of bicyclist crashes resulting in a severe outcome. Pedestrian crashes appeared to be decreasing in severity prior to the 2020 COVID-19 pandemic, but the severity rate increased in 2020 and again in 2021. The pandemic-affected years show lower totals of crashes overall, but the decreases appear to be the result of reductions in non-severe crashes. These severity patterns mimic national trends, where empty, over-capacity roads encouraged unsafe speeds and an increase in high motorist speed crashes for all road users.

It is possible that these pandemic-related severity patterns could correlate with pandemic-related geospatial differences. Travel behavior shifted as more people worked from home or stayed home for leisure activities. However, the number of crashes in 2020 and 2021 is too small to perform a separate High Injury Network analysis to verify the potential effects of the pandemic on the final HIN. We recommend further analysis once additional years of data are available to understand whether and how the pandemic has shifted spatial patterns for vulnerable road users.

Table 3: All Crashes, By Year and Mode, 2017 – 2021

Year and Mode	# Crashes	# KA Crashes	% Yearly Crashes	% Yearly KA Crashes	% KA within Mode and Year
2017	1,724	305	100.0%	100.0%	17.7%
Bicyclist	720	61	41.8%	20.0%	8.5%
Pedestrian	943	239	54.7%	78.4%	25.3%
Other - VRU	20	3	1.2%	1.0%	15.0%
Other – Personal Conveyance	41	2	2.4%	0.7%	4.9%
2018	1,593	262	100.0%	100%	16.4%
Bicyclist	576	56	36.2%	21.4%	9.7%
Pedestrian	931	203	58.4%	77.5%	21.8%
Other - VRU	30	2	1.9%	0.8%	6.7%
Other – Personal Conveyance	56	1	3.5%	0.4%	1.8%
2019	1,654	246	100.0%	100%	14.9%
Bicyclist	642	65	38.8%	26.4%	10.1%
Pedestrian	906	175	54.8%	71.1%	19.3%
Other - VRU	44	4	2.7%	1.6%	9.1%
Other – Personal Conveyance	62	2	3.7%	0.8%	3.2%
2020	1,114	236	100.0%	100%	21.2%
Bicyclist	433	61	38.9%	25.8%	14.1%
Pedestrian	617	170	55.4%	72.0%	27.6%
Other - VRU	26	3	2.3%	1.3%	11.5%
Other – Personal Conveyance	38	2	3.4%	0.8%	5.3%
2021	1,222	263	100.0%	100%	21.5%
Bicyclist	495	59	40.5%	22.4%	11.9%
Pedestrian	654	194	53.5%	73.8%	29.7%
Other - VRU	41	8	3.4%	3.0%	19.5%
Other – Personal Conveyance	32	2	2.6%	0.8%	6.2%
Total	**7,307**	**1,312**			

High Injury Network Methodology

High Injury Networks are typically built using a process called sliding windows analysis, which helps detect patterns of crashes happening in sequence. A sliding windows analysis calculates linear crash densities (often weighted by injury severity) for each mode separately. The sliding windows analysis consists of a virtual window of a predetermined length that is moved along the street network at predetermined step lengths and aggregates crashes that are within each window (see Figure 2).

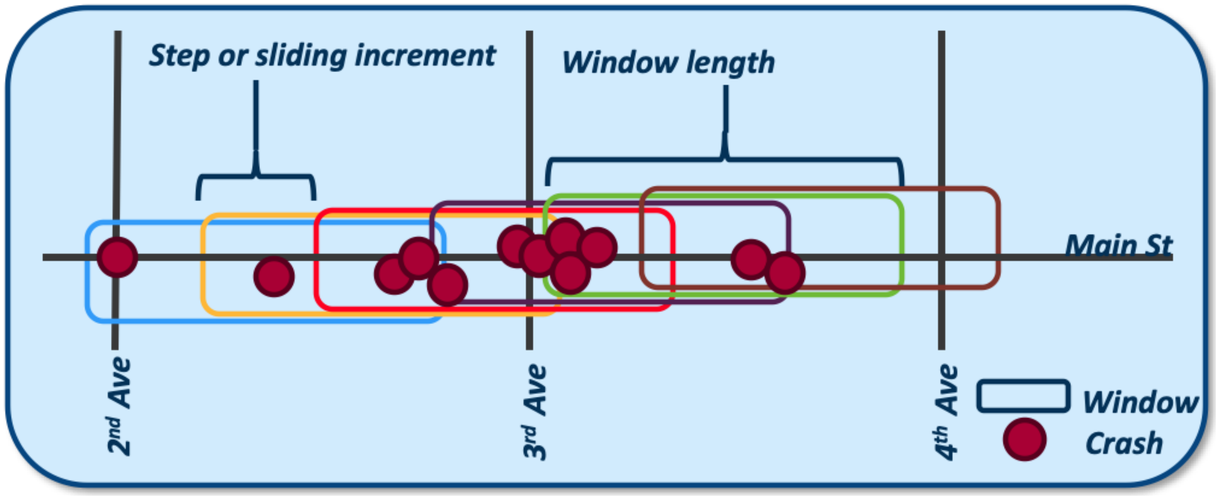

Figure 2. Sliding windows process to measure crash density along a network.

Two different window lengths were used based on the SPACE urban/rural designations as a means to account for different crash densities, roadway characteristics, and land use across the urban—rural gradient. Large metropolitan urban areas (e.g., Minneapolis—St. Paul, Rochester, Duluth, St. Cloud, Fargo-Moorehead, Mankato), one-mile window lengths and 1/10th-mile step increments were used in this analysis. For smaller urban communities (e.g., Bemidji, Brainerd, Alexandria, Willmar, Redwing, etc.) as well as rural areas, two-mile window lengths and ¼-mile step increments were used.

Additionally, only fatal (K), severe injury (A), and minor injury (B) crashes were included in the sliding window analysis and HIN development process. This decision was made to prioritize locations that have a history and high concentration of crashes that resulted in death or injury. The Safe System Approach pushes us to prioritize fatal and serious injury crashes. We additionally included minor injury crashes for several reasons, including:

1) The geographic sparsity of vulnerable road user crashes, especially in smaller urban communities and urban areas, leads to sparse or patchy results in a High Injury Network.
2) Misclassification between serious injury and minor injury crashes in police reports is common.
3) Individual characteristics like age and frailty can influence how severe an injury outcome is.

To maintain an appropriate emphasis on life-altering crashes, we weighted fatal and serious injury crashes more heavily in the analysis (3:1 weighting).

Threshold Determination

HINs are a blend of art and science, needing to be large enough to be meaningful, but not so large as to be meaningless. This balance is even more pronounced for larger HINs, e.g., at the regional or statewide level, that cover vastly different land use patterns and geography types. To strike this balance, each mode-specific HIN is produced by an initial determination of a minimum threshold for the weighted crash value of segments to be included in the HIN, followed by review of the distribution of crashes for each mode along the relevant HIN and the percentage of the network that is along that HIN. If necessary, the threshold is adjusted to achieve the sought-after balance described above.

- Using a **high threshold** will make a high injury network smaller (fewer miles), focusing only on the places that have had many fatal and injury crashes.
- Using a **low threshold** will make a high injury network larger (more miles), including places that may have only had one or two fatal and injury crashes.
- Using **too low of a threshold** produces networks that are not meaningfully targeted at fatal and injury crashes.

Generally speaking, with fatal and serious injury crashes weighted at 3 and minor injury crashes weighted at 1, the lowest possible threshold that may still reflect spatial patterns is 5. With a score of 5, a segment will have had at least 2-3 crashes within the window size (1-2 miles) over the previous 5 years, with at least 1-2 of them resulting in death or serious injury.

In addition to being tailored to each mode, thresholds may vary by geography. Denser, larger urbanized areas have more VRU crashes in general and have higher scores on average. Smaller urban areas and rural areas have fewer VRU crashes and lower scores on average. Choosing a single threshold to use across all geography types ("severe injury density" approach) results in a HIN that is heavily concentrated in denser, larger urbanized areas. It aggressively targets the highest concentrations of fatal and injury crashes. Choosing variable thresholds based on geography type ("geographic balance" approach) results in a HIN that has broad coverage across many contexts, though coverage may not be proportionate to the severity of safety problems.

HIN Considerations and Use

There are benefits and drawbacks to each approach, and the best approach depends heavily on the intended purpose or uses of the HIN. For a city with a dedicated pot of safety funding, the severe injury density approach may lead them to make more efficient investments by targeting the highest concentrations of severe crashes first. In the State DOT context, where there is no single dedicated funding source and the HIN must serve many purposes, the geographic balance approach helps ensure the ability to make progress on safety across the state and with many local partner agencies. These benefits and trade-offs are described in greater detail in Table 4.

Table 4. How should the HIN's intended use inform its definition?

Potential Uses for HIN	Threshold Recommendation	Relationship between HIN and predictive or systemic analysis	Pros/Cons of Geographic Balance Strategy	Pros/Cons of Severe Injury Density Strategy	Conclusions
Prioritization on agency's own roads	• A higher threshold helps the agency identify and target the highest priority areas.	• Use HIN to identify highest priorities based on crash history as the "backbone" of the safety plan. These are sites that have known, repeated VRU safety problems. • Predictive or systemic results could in theory be used to screen for additional priorities within or beyond the HIN, as roadway data attributes allow.	• PRO: Recognizes the reality that the agency must invest and improve safety across the whole state, not just in one area. • PRO: Provides opportunities for all districts to work on VRU safety. • CON: Areas with greater numbers of fatalities and severe injuries may receive proportionally less funding, which may impact the speed at which problems are ultimately addressed.	• PRO: More directly works toward the goal of zero deaths and serious injuries by prioritizing areas with the highest raw numbers. • CON: Areas with smaller, sparser populations, even with high-risk roads, may be systematically disadvantaged because they cannot compete with larger, denser areas. • CON: Concentrating priorities in a single district may be politically infeasible	• HIN plays a larger role for this use than other uses, and pred/sys results play a smaller role • Choose a higher threshold (small HIN) to focus on the highest priorities on state roads • Some amount of geographic balancing is likely necessary
Project scoping on agency's own roads	• A lower threshold allows the agency to identify VRU safety needs in places where other, non-safety projects are scheduled	• Predictive or systemic analyses can play a significant role in scoping, since projects are evaluated on a case-by-case basis. Co-location with the HIN may be one of many factors to identify VRU safety needs.	• PRO: Provides opportunities for VRU safety needs to be added to projects statewide, including in lower density areas • CON: May dilute the power of being on the HIN if low-scoring areas are included	• PRO: Helps ensure that safety needs are identified in the highest priority areas. • CON: Areas with smaller, sparser populations, even with high-risk roads, may be systematically disadvantaged because they cannot compete with larger, denser areas. • CON: Concentrating priorities in a single district may be politically infeasible	• HIN relatively less important, and pred/sys can play a larger role. • Higher HIN threshold can be appropriate for this use with or without geo balancing, given complementary use of pred/sys results.
Funding allocation for other agencies' roads	• A lower threshold may be appropriate to evaluate safety projects statewide by other agencies. • A higher threshold helps direct limited funds to the highest safety priorities.	• Predictive or systemic analyses can play a significant role in scoping, since projects are evaluated on a case-by-case basis. Co-location with the HIN may be one of many factors to identify VRU safety needs. • All of this assumes that HIN status is NOT a requirement for state funding applications.	• PRO: Provides opportunities for jurisdictions throughout the state to apply for funding based on statewide analysis • CON: Areas with greater numbers of severe injuries may receive proportionally less funding, which may impact the speed at which problems are ultimately addressed	• PRO: More directly works toward the goal of zero deaths and serious injuries by targeting funding to the areas with the highest raw numbers • CON: Areas with smaller, sparser populations, even with high-risk roads, may be systematically disadvantaged because they cannot compete with larger, denser areas. • CON: Concentrating investment opportunities in just one area may be politically infeasible	• HIN relatively less important and pred/sys can play a larger role • It may be impossible to choose a threshold and a strategy that are agreeable to all stakeholders, since these choices influence who would receive funding
Technical support for other agencies	• A lower threshold helps maximize the number of agencies that have HIN on their local networks. • Providing underlying scoring data can help agencies refine a local HIN if desired.	• In theory, predictive and systemic results as well as underlying scoring data can be useful resources for local agencies. • However, if local agencies are pursuing funding that requires projects be on the HIN, then the role for the other analysis methods is diminished.	• PRO: Helps ensure no one agency is overwhelmed with too many priorities. • PRO: Helps ensure more agencies have at least 1-2 priority segments they can focus on. • PRO: The agencies most likely to benefit from a geo balance strategy are the least likely to already have their own HIN. • CON: May dilute the power of being on the HIN if low-scoring areas are included.	• PRO: For all agencies outside of MSP, inclusion on the statewide HIN may communicate a very high VRU safety need. • CON: Areas with smaller, sparser populations, even with high-risk roads, may be systematically disadvantaged because they cannot compete with larger, denser areas and may not have any HIN within their boundaries. • CON: The areas with the most HIN mileage already have their own HINs.	• While pred/sys and underlying scoring data are valuable, HIN status may be a requirement for some funding types (e.g., SS4A) • A "big tent" geographically balanced network provides the most opportunities for local agencies to focus on VRU safety – even if it includes lower or moderate-scoring areas

MnDOT intends for this HIN to provide technical support to local partner agencies, and recognizes that the HIN is one of many tools and resources available for prioritizing investment, scoping projects, and allocating funds. After discussion with MnDOT and stakeholders, and testing and receiving feedback from MnDOT on various thresholds, the project team developed this High Injury Network using the geographic balance approach.

HINs can make for a useful communication tool because the data are reduced to a simple binary: streets on and off the high injury network. At the same time, this data reduction masks variation, so the underlying granular sliding windows data may be more useful for internal prioritization procedures or for providing technical assistance. Unlike intersection hotspot analysis, sliding windows analysis and HINs can identify entire corridors that have experienced patterns of crashes, leading to the possibility of systemic treatments. The High Injury Network will be analyzed and described further in this memo, and the granular underlying data will be made available for future work or for providing technical support to local agencies.

Sliding windows results

Note that all roadway mileage estimates are just that – estimates. Our dataset included dual centerlines for divided roadways. Total mileage may not match published statewide totals. But the approximate distribution should be similar, as should the order of magnitude.

Table 5 shows the distribution of network mileage by sliding windows score. The distribution is shown for five geographic groupings across the state, derived from MnDOT's SPACE dataset's "urban" variable and the city boundaries of Minneapolis and St. Paul.

- Cities of Minneapolis and St. Paul
- Remainder of Twin Cities metropolitan area
- Other metropolitan and large urban areas in the state (e.g., Duluth and surrounding metro area)
- Small urban areas (e.g., Alexandria, Bemidji)
- Rural areas

This score represents all vulnerable road user types (ped, bike, and other) and spans data from 2017–2021. Crashes are weighted by severity, with fatal and serious injury crashes scoring 3 points, minor injury crashes scoring 1 point, and lower severity crashes excluded from the High Injury Network analysis.

Table 5: Approximate network mileage of combined VRU scores by geography (dual carriageways are double-counted so mileage totals may not match centerline miles)

Score	TCMA - Minneapolis and St. Paul		TCMA - Other cities		Greater MN metro areas		Small urban communities		Rural areas	
	N	%	N	%	N	%	N	%	N	%
0	1,079	53.3%	10,244	84.3%	1,844	83.3%	11,898	92.6%	118,669	99.4%
1-2	386	19.0%	1,067	8.8%	203	9.2%	541	4.2%	270	0.2%
3-5	258	12.7%	679	5.6%	123	5.6%	336	2.6%	403	0.3%
6-8	112	5.5%	116	1.0%	26	1.2%	57	0.4%	17	<0.1%
9-11	46	2.3%	26	0.2%	16	0.7%	13	0.1%	2	<0.1%
12-14	47	2.3%	13	0.1%	0	<0.1%	0	0.0%	0	0.0%
15-17	37	1.8%	4	<0.1%	0	<0.1%	0	0.0%	0	0.0%
18-20	31	1.5%	2	<0.1%	1	<0.1%	0	0.0%	0	0.0%
21-29	21	1.0%	3	<0.1%	0	0.0%	0	0.0%	0	0.0%
30+	9	0.5%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	*2,026*	*100.0%*	*12,154*	*100.0%*	*2,213*	*100.0%*	*12,845*	*100.0%*	*119,361*	*100.0%*

From this table we see further evidence of patterns already identified in the previous chapter. Vulnerable road user crashes have the greatest concentration within the most densely, heavily urbanized areas of the state. Nearly half of Minneapolis and St. Paul's road network has a score of 1 or greater, indicating at least one minor injury (or worse) crash over the previous 5 years. In the rest of the Twin Cities metro and in other metro and large urban areas around the state, this figure is just over 15%. In smaller urban areas, less than 10% of road miles have seen one or more fatal or injury crashes in the past 5 years. And in rural areas, which represent over 80% of the state's network, segments with a vulnerable road user fatal or injury crash history comprise just over one half of one percent (0.6%). This table underscores why we recommended a methodology that sets distinct thresholds for different geography types – to ensure that the HIN is not exclusively or primarily clustered in just one area, and that cities, counties, and districts across the state can identify opportunities to work toward reducing and eliminating vulnerable road user traffic deaths.

The next two tables show this same distribution separated by mode – first, for pedestrians and other vulnerable road users, then for bicyclists. The modal distributions are largely similar, with greater concentrations of fatal and injury crashes within denser, more urbanized areas. Pedestrian and other vulnerable road user crashes are more numerous and widespread than bicyclist crashes. With both Table 6 and Table 7, the distribution of scores for smaller urban areas is between that for larger urban areas (excluding Minneapolis and St. Paul) and rural areas. For bicyclist crashes, however, the distribution for small urban areas is very similar to that of rural areas, with over 96% of the network in small urban communities having had zero bicyclist fatal or injury crashes over the previous 5 years. Note that High Injury Networks do not control for bicyclist or pedestrian volumes; an area with 0 crashes is not necessarily safe for VRUs.

Table 6: Pedestrian and other VRU scores by geography

Score	TCMA – Minneapolis and St. Paul		TCMA – Other cities		Greater MN metro areas		Small urban communities		Rural areas	
	N	%	N	%	N	%	N	%	N	%
0	1,254	62.0%	11,006	90.5%	1,963	88.6%	12,228	95.2%	118,938	99.6%
1-2	308	15.2%	612	5.0%	138	6.2%	297	2.3%	134	0.1%
3-5	243	12.0%	436	3.6%	88	4.0%	283	2.2%	280	0.2%
6-8	78	3.8%	76	0.6%	19	0.9%	35	0.3%	8	<0.1%
9-11	52	2.5%	17	0.1%	5	0.2%	2	<0.1%	0	<0.1%
12-14	39	1.9%	3	<0.1%	0	<0.1%	0	0.0%	0	0.0%
15-17	21	1.0%	2	<0.1%	1	<0.1%	0	0.0%	0	0.0%
18-20	16	0.8%	1	<0.1%	0	0.0%	0	0.0%	0	0.0%
21-29	7	0.4%	3	<0.1%	0	0.0%	0	0.0%	0	0.0%
30+	7	0.3%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	*2,025*	*100.0%*	*12,156*	*100.0%*	*2,214*	*100.0%*	*12,845*	*100.0%*	*119,360*	*100.0%*

Table 7: Bicyclist scores by geography

Score	TCMA – Minneapolis and St. Paul		TCMA – Other cities		Greater MN metro areas		Small urban communities		Rural areas	
	N	%	N	%	N	%	N	%	N	%
0	1,425	70.4%	10,957	90.1%	1,987	89.8%	12,349	96.1%	119,064	99.8%
1-2	355	17.6%	873	7.2%	158	7.2%	397	3.1%	151	0.1%
3-5	185	9.2%	307	2.5%	68	3.1%	89	0.7%	145	0.1%
6-8	43	2.1%	15	0.1%	0	0.0%	10	0.1%	1	<0.1%
9-11	10	0.5%	3	<0.1%	0	0.0%	0	0.0%	0	0.0%
12-14	4	0.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
15-17	0	<0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
18-20	2	0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Total	*2,024*	*100.0%*	*12,155*	*100.0%*	*2,213*	*100.0%*	*12,845*	*100.0%*	*119,361*	*100.0%*

HIN Thresholds and Results

Based on the distribution of scores by geography, conversations with MnDOT and stakeholders, review of draft HINs using various thresholds, and MnDOT's goals for the HIN, our team ultimately recommended the following thresholds:

Table 8: HIN threshold by mode and geography group

Geography group	Window Length	Pedestrian/Other VRU Threshold	Bicyclist Threshold	All VRU Threshold
TCMA - Minneapolis and St. Paul	1 mile	12	7	N/A
TCMA - Other cities	1 mile	7	5	N/A
Greater MN metro areas	1 mile	7	5	N/A
Small urban communities	2 miles	N/A	N/A	5
Rural areas	2 miles	N/A	N/A	5

These thresholds yield the following miles of HIN:

Table 9: Miles of HIN by geography group

HIN	TCMA - Minneapolis and St. Paul		TCMA - Other cities		Greater MN metro areas		Small urban communities		Rural areas		Statewide	
	N	%	N	%	N	%	N	%	N	%	N	%
HIN for all VRU	19	0.9%	7	0.1%	0	0.0%	95	0.7%	20	<0.1%	140	0.1%
HIN for Bike only	23	1.1%	30	0.2%	10	0.4%	0	0.0%	0	0.0%	62	<0.1%
HIN for Ped/ Other only	72	3.5%	64	0.5%	15	0.7%	0	0.0%	0	0.0%	150	0.1%
Any HIN Subtotal	***113***	***5.6%***	***100***	***0.8%***	***24***	***1.1%***	***95***	***0.7%***	***20***	***<0.1%***	***352***	***0.2%***
Non-HIN	1911	94.4%	12,055	99.2%	2,190	98.9%	12,751	99.3%	119,341	>99.9%	148,247	99.8%
Total	2,024	100.0%	12,155	100.0%	2,214	100.0%	12,845	100.0%	119,361	100.0%	148,600	100.0%

Since the purpose of a High Injury Network is to identify clusters or patterns of crashes, it is important to choose a threshold that is high enough to represent a true pattern. We recommend five as the lowest possible threshold for defining a High Injury Network because it implies a minimum of 2-3 fatal and injury crashes to meet or exceed it. In order to reach this minimum threshold in small urban areas and rural areas, we used a longer window length and also combined all VRU crashes into a single HIN category.

We see over 200 miles of HIN within the Twin Cities metro area alone, plus 25 in other large metro urban areas, 95 in smaller urban areas, and 20 in rural areas. Note that crash data on

Tribal lands are typically incomplete in MnDOT's dataset, so the rural HIN may underestimate crash concentrations in rural areas absent this data.

In the Twin Cities, there is a small amount of overlap between pedestrian/other VRU HIN and bicyclist HIN, whereas in other large metro urban areas around the state, we do not see any overlap. The fact that we see different spatial patterns here reinforces the decision to analyze pedestrian and bicyclist crashes separately where data allow.

Descriptive Analysis of Crashes On and Off the HIN

We joined HIN status and sliding window scores back to individual crashes for further analysis.

High Injury Network Patterns Over Time

Table 10 shows how many crashes are on any HIN-identified segments for any mode. Table 11 shows this filtered on fatal and serious injury (K+A) crashes. On average, about 29% of all VRU crashes and 31% of severe VRU crashes are on the HIN, though this varies year to year.

The HIN was defined using 2017–2021 data, so 2016's crashes are an "out-of-sample" test of how well the HIN correlates with crashes in other years; 26% of 2016's VRU crashes and only 20% of 2016's severe VRU crashes are on the HIN. For the pre-pandemic HIN years 2017–2019, roughly 31-33% of VRU crashes and 35 to almost 38% of severe VRU crashes are on the HIN. During the pandemic years (2020–2021), the HIN covers a smaller share of crashes (26% of all severity and 29-31% of severe), indicating that crashes were more dispersed and less clustered than VRU crashes in earlier years.

As previously noted with Table 3, the sample size is too small to compare a pandemic-only version of the HIN to a non-pandemic version, but continuing to monitor these trends as more post-pandemic years of crash data become available will help MnDOT understand the latest evolving patterns.

Table 10: N and % of VRU crashes on and off any HIN by year (note that HIN was developed on 2017--2021 crashes, so 2016 crashes are "out of sample")

Year	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
2016	1,277	73.9%	452	26.1%
2017	1,184	68.7%	540	31.3%
2018	1,082	67.9%	511	32.1%
2019	1,114	67.4%	540	32.6%
2020	823	73.9%	291	26.1%
2021	900	73.6%	322	26.4%
Total	***6,380***	***70.6%***	***2,656***	***29.4%***

Table 11: N and % of severe (K+A) VRU crashes on and off any HIN by year (note that HIN was developed on 2017--2021 crashes, so 2016 crashes are "out of sample")

Year	KA Crashes off the HIN		KA Crashes on the HIN	
	N	%	N	%
2016	269	80.1%	67	19.9%
2017	197	64.6%	108	35.4%
2018	170	64.9%	92	35.1%
2019	153	62.2%	93	37.8%
2020	168	71.2%	68	28.8%
2021	181	68.8%	82	31.2%
Total	***1,138***	***69.1%***	***510***	***30.9%***

The previous two HIN summary tables included 2016 because 2016 provides an "out-of-sample" check on the HIN. All remaining analyses in this section include only 2017–2021 crashes, since those are the ones used to define the HIN.

HIN Status by Crash Mode and Severity

The HIN is defined by fatal, serious injury, and minor injury crashes, using weights to more heavily emphasize fatal and serious injury crashes. We see varying percentages of crashes on and off the HIN by crash severity, though the pattern is not very intuitive or meaningful. Serious injury crashes have the greatest representation on the HIN, with over 35% of them falling on the HIN (Table 12).

Table 12: N and % of VRU crashes on and off any HIN by crash severity

Injury Severity	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
Fatal (K)	194	72.7%	73	27.3%
Serious injury (A)	675	64.6%	370	35.4%
Minor injury (B)	2,295	71.8%	900	28.2%
Possible injury (C)	1,509	67.8%	719	32.3%
Property damage only (O)	430	75.2%	142	24.8%
Total	***5,103***	***69.8%***	***2,204***	***30.2%***

Pedestrian and other VRU crashes were more tightly clustered on the network, with nearly 33% of them being on the HIN compared to only 26% of bicyclist crashes (Table 13). Note that this is the entire HIN, not limited by mode (e.g., bicyclist crashes on the bicycle HIN).

Table 13: N and % of VRU crashes on and off any HIN by crash mode

Mode	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
Bicyclist	2,118	73.9%	748	26.1%
Pedestrian/VRU	2,985	67.2%	1,456	32.8%
Total	***5,103***	***69.8%***	***2,204***	***30.2%***

Among bicyclist crashes in metro, large urban areas, the bicycle HIN best represents the location of serious injury crashes (almost 30% on the network) but overall captures just under 17% of all urban bicyclist crashes (Table 14).

HIN Status by Geography

Table 14: Urban bike crashes on and off the urban bike HIN, by severity

Injury Severity	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
Fatal (K)	21	84.0%	4	16.0%
Serious injury (A)	138	70.1%	59	29.9%
Minor injury (B)	984	84.4%	182	15.6%
Possible injury (C)	701	85.7%	117	14.3%
Property damage only (O)	152	80.4%	37	19.6%
Total	**1,996**	**83.3%**	**399**	**16.7%**

The pedestrian/other VRU HIN in urban areas does a better job of capturing urban pedestrian/other VRU crashes, with 33% of all severities on the network and nearly 39% of serious injury crashes on the HIN (Table 15).

Table 15: Urban ped and other VRU crashes on and off the urban ped and other VRU HIN, by severity

Injury Severity	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
Fatal (K)	101	69.2%	45	30.8%
Serious injury (A)	370	61.4%	233	38.6%
Minor injury (B)	1,030	68.6%	472	31.4%
Possible injury (C)	744	64.2%	414	35.8%
Property damage only (O)	193	78.1%	54	21.9%
Total	**2,438**	**66.7%**	**1,218**	**33.3%**

Only about 15% of small urban community and rural area crashes are on the small urban community and rural HINs, though the small urban and rural HIN does a better job of capturing fatal and serious injury crashes in these areas (23% and 20% respectively; Table 16).

Table 16: Small urban community and rural VRU crashes on and off the small urban and rural HIN, by severity

Injury Severity	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
Fatal (K)	74	77.1%	22	22.9%
Serious injury (A)	196	80.0%	49	20.0%
Minor injury (B)	447	84.8%	80	15.2%
Possible injury (C)	225	89.3%	27	10.7%
Property damage only (O)	128	94.1%	8	5.9%
Total	**1,070**	**85.2%**	**186**	**14.8%**

Across all VRU modes, the Minneapolis and St. Paul HIN captures the greatest share of crashes. Table 17 shows nearly 50% of them falling on the network (which, as Table 9 showed, comprises only 5% of the network mileage). In the rest of the Twin Cities metro, other large metro urban areas, and small urban communities, 16-20% of VRU crashes are on the HIN. Only 2% of rural area crashes are on the rural HIN.

Table 17: N and % of VRU crashes on and off any HIN by geography group

Geography group	Crashes off the HIN		Crashes on the HIN	
	N	%	N	%
TCMA - Minneapolis and St. Paul	1,560	50.2%	1,550	49.8%
TCMA - Other cities	1,963	84.4%	362	15.6%
Greater MN metro areas	510	82.8%	106	17.2%
Small urban communities	732	80.4%	179	19.6%
Rural areas	338	98.0%	7	2.0%
Total	**5,103**	**69.8%**	**2,204**	**30.2%**

Among severe crashes, our HIN does a better job in all geography groups (Table 18).

Table 18: N and % of severe (K+A) VRU crashes on and off any HIN by geography group

Geography group	KA Crashes off the HIN		KA Crashes on the HIN	
	N	%	N	%
TCMA - Minneapolis and St. Paul	193	44.5%	241	55.5%
TCMA - Other cities	337	76.9%	101	23.1%
Greater MN metro areas	69	69.7%	30	30.3%
Small urban communities	139	68.5%	64	31.5%
Rural areas	131	94.9%	7	5.1%
Total	**869**	**66.2%**	**443**	**33.8%**

HIN Status by Location Type

The HIN does a much better job of capturing signalized intersection VRU crashes than crashes at other location types, with 49% of all VRU crashes at signalized intersections and 59% of severe crashes at signalized intersections falling on the HIN (Table 19 and Table 20). These other location types (e.g., midblock or segment locations, with 16%, and unsignalized/stop-controlled intersections, with 22%) are vastly more numerous around the state than signalized intersections; without exposure data, we can't normalize crashes per location or per VRU walking, biking, or rolling there.

Table 19: N and % of VRU crashes on and off any HIN by location type

Crash Location	Crashes off the HIN		Crashes on the HIN		Total	
	N	%	N	%	N	%
Intersection - Signal controlled	1,285	50.8%	1,246	49.2%	2,531	100.0%
Intersection - Partial or all-way stop controlled	1,883	78.1%	528	21.9%	2,411	100.0%
Segment or midblock	1,651	83.6%	325	16.4%	1,976	100.0%
Other or unknown location	284	73.0%	105	27.0%	389	100.0%
Total	**5,103**	**69.8%**	**2,204**	**30.2%**	**7,307**	**100%**

Table 20: N and % of severe (K+A) VRU crashes on and off any HIN by location type

Crash Location	KA Crashes off the HIN		KA Crashes on the HIN		Total	
	N	%	N	%	N	%
Intersection - Signal controlled	141	41.4%	203	58.6%	348	100.0%
Intersection - Partial or all-way stop controlled	296	72.0%	114	28.0%	414	100.0%
Segment or midblock	388	78.9%	105	21.1%	498	100.0%
Other or unknown location	44	67.7%	21	32.3%	65	100.0%
Total	**869**	**66.2%**	**443**	**33.8%**	**1,312**	**100%**

HIN Status by Location Type and Pre-Crash Movement / Action

The following tables (Table 21 and Table 22) show what percentage of all and severe VRU crashes fall on the HIN by crash type, focusing on crash types that have at least 40 fatal and serious injury crashes. The rows are sorted by the total number of fatal and serious injury crashes for each type (not shown in the tables). All crash types with fewer than 40 fatal and serious injury crashes are combined into "Other bicyclist crash type" and "Other pedestrian/VRU crash type."

Among bicyclist crash types, the "Signal - MV Forward - Bike Walk/Cycle Across Traffic/Roadway" crash type has the best representation on the HIN. Thirty five percent of all severity crashes and 48% of severe crashes of this type are on the HIN.

Table 21: N and % of Bicyclist crashes by crash type and location status (among crash types with >=40 K+A bicyclist crashes)

Crash Type	Crashes off the HIN		Crashes on the HIN		Total	
	N	%	N	%	N	%
Stop - MV Forward - Bike Walk/Cycle Across Traffic/Roadway	347	86.1%	56	13.9%	403	100.0%
Signal - MV Forward - Bike Walk/Cycle Across Traffic/Roadway	191	65.2%	102	34.8%	293	100.0%
Other bicyclist crash type	1,580	72.8%	590	27.2%	2,170	100.0%
Total	**2,118**	**73.9%**	**748**	**26.1%**	**2,866**	**100.0%**

Table 22: N and % of severe (K+A) Bicyclist crashes by crash type and location status. (Crash types with >=40 K+A bike crashes are shown separately, and the rest are combined in the final row)

Crash Type	KA Crashes off the HIN		KA Crashes on the HIN		Total	
	N	%	N	%	N	%
Stop - MV Forward - Bike Walk/Cycle Across Traffic/Roadway	36	81.8%	8	18.2%	44	100.0%
Signal - MV Forward - Bike Walk/Cycle Across Traffic/Roadway	22	52.4%	20	47.6%	42	100.0%
Other bicyclist crash type	150	69.4%	66	30.6%	216	100.0%
Total	**208**	**68.9%**	**94**	**31.1%**	**302**	**100.0%**

Like bicyclist crash types, pedestrian and other VRU crash types that occur at signalized intersections have the greatest representation on the network (Table 23 and Table 24). Segment/midblock and stop-controlled intersection crash types are less likely to happen on the HIN. The higher inclusion of signalized intersection crashes may reflect higher volumes and higher VRU activity at signalized intersections, as well as the general spatial clustering of signalized intersections in denser, urbanized areas. Among bicyclist crashes, crashes involving a driver going forward and the bicyclist crossing the roadway were much better captured by the HIN than crashes in which the driver was turning or the bicyclist was riding with or against traffic. The HIN best captures pedestrian signalized intersection crashes in which the driver was going forward or turning left. This finding has important implications for how the HIN is used, since we know the HIN captures signalized intersection crashes better than other crash types. Systemic network screening or other tools should be used in tandem with the HIN to help agencies target crash types that are poorly represented on the HIN.

Table 23: N and % of Pedestrian/VRU crashes by crash type and location status. (Crash types with >=40 K+A ped/VRU crashes are shown separately, and the rest are combined in the final row)

Crash Type	Crashes off the HIN		Crashes on the HIN		Total	
	N	%	N	%	N	%
Stop - MV Forward - Ped at intersection	572	73.5%	206	26.5%	778	100.0%
Segment - MV Forward - Ped Crossing	321	76.6%	98	23.4%	419	100.0%
Signal - MV Forward - Ped at intersection	232	43.2%	305	56.8%	537	100.0%
Segment - MV Forward - Ped Not Crossing	251	86.3%	40	13.7%	291	100.0%
Signal - MV Left - Ped at intersection	259	44.7%	320	55.3%	579	100.0%
Segment - MV Left/Right/Other/unknown	216	85.4%	37	14.6%	253	100.0%
Segment - MV Forward - Ped In Roadway - Other (working playing etc.)	84	84.8%	15	15.2%	99	100.0%
Other pedestrian/VRU crash type	1,050	70.7%	435	29.3%	1,485	100.0%
Total	**2,985**	**67.2%**	**1,456**	**32.8%**	**4,441**	**100.0%**

Table 24: N and % of severe (K+A) Pedestrian/VRU crashes by crash type and location status. (Crash types with >=40 K+A ped/VRU crashes are shown separately, and the rest are combined in the final row)

Crash Type	KA Crashes off the HIN		KA Crashes on the HIN		Total	
	N	%	N	%	N	%
Stop - MV Forward - Ped at intersection	148	66.4%	75	33.6%	223	100.0%
Segment - MV Forward - Ped Crossing	92	65.7%	48	34.3%	140	100.0%
Signal - MV Forward - Ped at intersection	48	35.8%	86	64.2%	134	100.0%
Segment - MV Forward - Ped Not Crossing	73	83.9%	14	16.1%	87	100.0%
Signal - MV Left - Ped at intersection	33	44.6%	41	55.4%	74	100.0%
Segment - MV Left/Right/Other/unknown	54	84.4%	10	15.6%	64	100.0%
Segment - MV Forward - Ped In Roadway - Other (working playing etc.)	47	87.0%	7	13.0%	54	100.0%
Other pedestrian/VRU crash type	166	70.9%	68	29.1%	234	100.0%
Total	**661**	**65.4%**	**349**	**34.6%**	**1,010**	**100.0%**

HIN Status by SPACE Score and Variables

We joined the High Injury Network to the SPACE dataset by flagging any hexagon that intersects with any HIN segment. Overall, there were 868 hexagons out of 522,263 that contained any of the HIN, or about 0.2% of the state (Table 25). The HIN is concentrated in hexagons with medium and high SPACE suitability scores, with the greatest concentration in the 70-74 and 75-79 score range (34% and 39% respectively).

Table 25. Presence of HIN by SPACE score

SPACE Suitability Score	Hexagons with 1+ HIN segments	Hexagons with no HIN segments	Percentage of hexagons with 1+ HIN segments
0-39	49	302,093	0%
40-44	57	110,965	0.1%
45-44	152	62,227	0.2%
50-54	144	32,213	0.4%
55-59	135	10,404	1.3%
60-64	104	2,672	3.7%
65-69	108	601	15.2%
70-74	68	130	34.3%
75-79	40	63	38.8%
80-100	11	27	28.9%
Total	**868**	**521,395**	**0.2%**

The HIN is over-represented among hexagons where 50% or more of residents are People of Color. Just under 1% of hexagons where 50% or more of residents are POC and 40% or more are low income contain HIN segments. Where residents are majority POC and less than 40% low income, about 2.5% of hexagons contain HIN. These represent a 4-fold and 15-fold over-representation, respectively, relative to the state at large.

Table 26. Presence of HIN by SPACE equity variables – areas of concentrated poverty and areas where 50% or more of residents are People of Color

SPACE Equity Variables (income and race/ethnicity)	Hexagons with 1+ HIN segments	Hexagons with no HIN segments	Percentage of hexagons with 1+ HIN segments
At least 40% low income - At least 50% POC	71	10,087	0.7%
Less than 40% low income - At least 50% POC	4	157	2.5%
At least 40% low income - Less than 50% POC	63	35,631	0.2%
Less than 40% low income - Less than 50% POC	730	475,520	0.2%
Total	**868**	**521,395**	**0.2%**

Conclusions and Next Steps

This analysis produced a statewide HIN that captures about 30% of Minnesota's total VRU crashes. There is considerable variation by geography, year, mode, and severity regarding which crashes are well represented on the HIN and which are more dispersed. The HIN best captures signalized intersection crashes in major urban areas, though smaller urban areas are also represented. Reflecting underlying inequities in who bears the burden of VRU crashes, the HIN is relatively more concentrated in majority-POC neighborhoods.

The HIN is one of many tools to assist MnDOT and local agencies with planning and engineering for VRU safety. The HIN itself can help communities identify segments with the greatest concentration of crashes needing further investigation and safety improvements. Communities may also access the underlying sliding windows data, if they wish to identify their own threshold and local HIN. Systemic and predictive analyses can also be used to screen both the HIN and other streets for risk factors.

The project team is working to assemble a data dashboard visualizing the High Injury Network alongside other crash trends and patterns. Our next steps are to finalize the systemic analysis and bring together findings and recommendations.

Future updates to the VRUSA should explore patterns over time around the COVID-19 pandemic, once more years of post-pandemic crash data are available.

MEMO

TO: Matthew Dyrdahl, AICP, CTP, LCI & Team, Alta Planning + Design
FROM: Jessica Schoner, PhD; Brian Almdale, MUPP; Rachel Thompson Panik; Rebecca Sanders, PhD RSP_{2B},
DATE: 2023-11-13
RE: Appendix B Bicycle Safety Analysis Report
PROJECT: P018 MnDOT Vulnerable Road User Safety Assessment

Executive Summary

To address vulnerable road user safety, including bicyclist safety, the Minnesota Department of Transportation (MnDOT) Office of Traffic Engineering (OTE) conducted a statewide, data-driven, systemic safety study to identify conditions that contribute to a higher risk of bicyclist death or serious injury. Using the findings from this analysis, proactive identification and application of bicyclist safety engineering countermeasures is recommended.

This report provides detailed information regarding the analysis methodology (closely resembles the 2019 Pedestrian Statewide Safety Analysis methodology), a descriptive bicyclist crash analysis, a predictive crash analysis using crash trees, and recommended next steps. This was a data-driven approach used to better understand bicyclist crashes and the conditions that may contribute to bicyclist fatalities and serious injuries (KA). The findings from this report can be used to systematically address bicyclist safety through the application of engineering countermeasures.

Identified conditions include not only existing roadway design features but also surrounding contextual features, such as existing non-motorized trip-attracting land uses or the presence of public transit facilities.

This report is organized into five chapters:

Summary of Key Findings

Data Assessment:

- While the crash data provided notable insights, there were several characteristics or trends in crashes that were not discernable from the data. To supplement the data, the study team scanned crash narratives from police reports of bicycle crashes. These provided clearer details in some cases, especially related to the pre-crash positioning of bicyclists and vehicles, as well as sidewalk bicycling. While officer narratives are not always the most reliable source of information for pedestrian and bicyclist crash factors, keyword searching on their narratives proved useful to add nuance where roadway data are limited or coded crash report variables are ambiguous.

Descriptive Crash Analysis:

- **Injury Severity:** There were 2,643 reported bicycle crashes between 2016 and 2019. Roughly 10% of those crashes were reported to be fatal or result in a serious injury.
- **Area Land Development Intensity:** Most crashes (41%) occurred within Minneapolis and St. Paul, followed by other cities in the TCMA (35%). Small urban communities (defined as *rural downtown* in SPACE) had the third largest share of crashes (13%) and KA crashes (13%). While bicycle riding is less frequent (lower levels of exposure) in small urban areas relative to denser metro areas, this may be an indication of high crash risk in these areas of the state. Interestingly, while crashes in rural areas were the least frequent, more than one-third of crashes resulted in a fatality or serious injury.
- **Month:** In general, there were more bicycle crashes during warmer months (May through September). This finding aligns with our understanding of bicyclist volume seasonality: bicyclist volumes are highest during warmer months and lowest during colder and snowier months.
- **Lighting Condition:** Most of the crashes happened in well-lit conditions, although KA crashes are slightly overrepresented in dark and low-light conditions. Both dark conditions with no street lighting and sunrise/sunset hours appear to be especially severe for people riding bicycles, with 23% and 16-17%, respectively, of all crashes resulting in a serious injury or fatality.
- **Age:** When comparing the distribution of victims by age to the state's population, younger bicyclists are much more likely to be involved in a crash and a KA crash compared to older populations. Bicyclists aged 10-19 were the most overrepresented in crashes and bicyclists aged 15-19 were the most overrepresented in KA crashes.
- **Crash Location Type:** Overall crashes and KA crashes occurred most frequently at stop-controlled intersections (40% of all crashes; 39% of KA crashes). Other findings in this study confirm that these are likely partial stop-controlled intersections, and not all-way stop-controlled intersections. This may be a systemic issue across the state, with bicyclists riding along lower-intensity streets (often residential streets) needing to cross major streets at

partial stop-controlled intersections. This combination of lower-stress streets without crossing accommodations likely contributes to bicyclists attempting to cross a major street and being struck by a motorist who does not have a traffic control device. The crash data support this theory: 47% of all bicyclist crashes and 55% of bicyclist KA crashes at stop-controlled intersections report the cyclist as crossing the traffic/roadway. Furthermore, nearly all of those crashes are at an intersection with the lowest functional classification being a residential street.

- **MnDOT Trunk Highways:** Crashes along trunk highways appear to be more severe in both urban and rural areas than crashes off the trunk highway system, but the patterns may be especially significant for rural areas. A large share of crashes occurs on four-lane trunk highways, and they carry this safety burden even when they have low AADT. Even if cyclists are not traveling along these locations, they may need to cross them, as these highways cut through urban areas and become main streets in smaller towns.
- **Trunk Highways - AADT:** Crashes on many higher-volume (AADT > 15,000) sections of the trunk network result in a KA roughly 15% of the time. The severity outcomes could be due to several possible factors, including trunk highways with lower AADT acting as main streets in rural towns, the potential usage of these lower-volume roads as bike routes, and a lack of protected bicycle facilities in general along these roadways.
- **Trunk Highways – Location Type:** Of the 343 crashes that occurred along the trunk highway, more than three-quarters of them occurred at some kind of intersection; 52% occurred at signalized intersections and 24% were at all-way or partial stop-controlled intersections. A larger share of crashes occurred at stop-controlled intersections off the trunk highway network (42%) compared to stop-controlled intersections along the trunk highway network (24%).
- **Trunk Highways – Through Lanes:** For both on and off trunk highways, overall crashes and severe crashes occurred most frequently along or at streets with two through lanes followed by four through lanes. Interestingly, most of the crashes that occurred along two-lane roads occurred along a 30 mph street for both on and off the trunk highway system and in both urban and rural areas. This may reflect both the overall network having a large share of two-lane streets and bicyclists' route preference (selecting lower-stress streets rather than higher-stress).
- **Trunk Highways – Urban/Rural:** Most bicycle crashes happened off of the trunk highway system within Minneapolis and St. Paul, which makes sense, as there are likely more cyclists in Minneapolis and St. Paul than in other locations in the state, and there are proportionally fewer trunk highways and more locally owned roadways in these cities. Interestingly, most KA crashes both on and off the trunk highway network within the TCMA metro occurred in the surrounding suburban communities. For crashes that did occur along the trunk highway system, they most frequently occurred within small urban communities.
- **Trunk Highways – Sidewalk:** Most severe crashes occurred along trunk highways that lacked a sidewalk and where there was no indication that the bicyclist was riding along the

sidewalk (50% of KA crashes) – many of these crashes would likely have been prevented if the cyclist had been separated from vehicular traffic.

- **Sidewalks**: Often cyclists may be using sidewalk infrastructure to avoid bicycling on high speed or uncomfortable facilities, especially for younger cyclists and especially on trunk highways. While sidewalk riding is believed to pose a safety risk for bicyclists at intersections, bicycling on sidewalks may be the best choice people have to mitigate their overall risk in the absence of dedicated bicycle facilities. Sidewalk riding appears to be more common on high-risk facilities where there are large shares of serious injury and fatal crashes, so prohibiting sidewalk riding or enforcing sidewalk riding bans could potentially *increase* crashes and injury severity outcomes. Sidewalk bicycle riding points to the need for more infrastructure that facilitates safe and comfortable riding for people with different levels of bicycling confidence.

- Bicyclist crashes that occurred along trunk highways most frequently occurred if the bicyclist was using the sidewalk rather than riding within the road (40%). This is not surprising given that most trunk highways lack low-stress on-street bicycle facilities designed to encourage bicyclists of all ages and abilities to ride within the road rather than on the sidewalk. Furthermore, the need for these low-stress facilities is not just preference-based: most trunk highway severe crashes occurred along trunk highways that lacked a sidewalk and where there was no indication that the bicyclist was riding along the sidewalk (50% of KA crashes) – many of these crashes would likely have been prevented if the cyclist had been separated from vehicular traffic.

- **Hit and Run:** Most bicycle crashes (84%) and KA crashes (82%) were not hit and run. The distribution of hit-and-run crashes was similar between most urban and rural areas in terms of the percentage of crashes and severe crashes that were hit-and-run. However, TCMA Minneapolis and St. Paul had the largest relative share of hit-and-run responses for all crashes (20%) and KA crashes (11%).

- **Functional Classification:** More than half of all crashes and 46% of severe crashes occurred on minor arterials. Since minor arterials comprise much less of the state’s roadway mileage, this indicates a serious safety issue with these roadways. Local roadways and major collectors had the next two largest shares of crashes and KA crashes.

- **Functional Classification Intersections:** Most crashes (29%) and KA crashes (24%) occurred at intersections between minor arterials and local streets followed by major collectors and local streets (14% of all intersection crashes). Nearly half of all crashes (48%) and more than half of KA crashes (56%) indicate the bicyclist was cycling across traffic/roadway. Looking only at crashes at these locations with this crossing pre-crash action, 60% of crashes and 68% of KA crashes were at an intersection with some type of stop control (most likely two-way stop signs with the major street uncontrolled). This indicates an important safety issue at locations in which bicyclists are attempting to cross a major street but do not have a traffic control or crossing enhancement to facilitate a safe crossing.

- **Number of Through Lanes:** Most crashes occur on two- and four-lane roadways, and these roadways had the most severe crashes as a share of all KA bicycle crashes.
- **Speed limit:** Most crashes (58%) and KA crashes (52%) occurred in places where there are 30mph speed limits. This could be due to several possible reasons, such as the prevalence of roadways where the posted speed limit is 30mph or a perception by cyclists that roadways with 30 mph speed limits are "low enough" stress for riding. However, there are notably fewer crashes and KA crashes on roadways signed at 25 mph or lower. Note that the crash data used in this analysis predates the legislative action in 2020 that allowed communities to lower speed limits on many locally-owned roads, so relatively few roads in the state had speed limits lower than 30 mph for crashes in this study.
- **Traffic Volume:** The relationship between bicyclist safety and motorist volumes is complex and nonlinear. Areas with the highest motorist volumes have relatively fewer bicyclist crashes. Mid-range AADT areas (5k-15k) appear to have the greatest concentrations of bike crashes. Low-volume trunk highways have a relatively higher severity rate than other AADT ranges, possibly due to overbuilt roadways encouraging excess speed.
- **HERE – Entertainment, Retail, and Restaurants:** Destinations such as entertainment establishments, retail, and restaurants appear to have some correlation with crashes, as 42% of all crashes were within 100 meters of one of the target destinations; however, only 34% of KA crashes were within this buffer.
- **Presence of Transit near Intersection Crashes:** There were no bicycle crashes in proximity to transit in the rural context. In larger urbanized areas, crashes in Minneapolis and St. Paul and severe crashes oftentimes occurred near transit stops or stations.
- **SPACE Score:** Most crashes occurred in areas with mid-range SPACE scores. There appears to be an inverse correlation between the percentage of severe crashes and the SPACE score. This possible inverse correlation may be due to lower motor vehicle speeds in locations with higher SPACE scores (for example, due to congestion, existing roadway design, or lower posted speed limits) or greater motorist expectations of bicyclist presence.
- **Equity:** While the majority of bicyclist crashes happen outside of low-income and majority communities of color areas, areas where 40% or more of households are low-income and/or 50% or more of residents are POC have a greater concentration of bicyclist crashes and severe bicyclist crashes. While this pattern is strongest in Minneapolis and St. Paul, there is evidence of disparities across all geography groups – including small urban areas. Residents in low-income areas and communities of color are exposed to greater risk of bicyclist crashes.

Predictive Analysis - Crash Trees:

- **Motorist Pre-Crash Movements:** Crashes involving a motor vehicle proceeding forward were more severe than other known movement types (left turn and right turn), with 12 percent of crashes resulting in a KA. Forward movement also represents the largest share of crashes (57 percent) and KA crashes (70 percent).

- **Bicyclist Pre-Crash Movements**: Nearly half of all crashes (47%) and KA crashes (47%) occurred with the bicyclist crossing traffic, followed by bicyclists traveling with traffic (24% all crashes; 28% of KA crashes) and cycling on the sidewalk (13% all crashes; 6% of KA crashes).
- **Crash Types:** Most crashes involved the bicyclist cycling across traffic/roadway while the motorist was moving forward for both overall crashes (30%) and KA crashes (35%), followed by the bicyclists cycling with traffic and the motorists moving forward (11% of all crashes; 17% of KA crashes).
- **Crash Tree - Branch 1 (bicycling across traffic, motorist going forward):** The single biggest combination of factors for this crash type was intersections within the Minneapolis—St. Paul metropolitan region with partial stop control between an arterial or collector and a local or residential street, where shopping, dining, and entertainment destinations are not nearby. The combination of a partial stop-controlled intersection between an arterial/collector and local street, not near shopping, dining, or entertainment was also important for this crash type in small urban communities.
- **Crash Tree - Branch 2 (bicycling with traffic, motorist going forward):** This crash type was a largely urban and large metropolitan area phenomenon, particularly in areas with 30mph speed limits (as were ubiquitous during the study period) and on arterials and collectors. The three most common profiles for this crash type included signalized intersections between arterial and/or collector streets, partial stop-controlled intersections between arterial/collector and local streets, and segment or midblock locations along arterial or collector streets, each with 30mph speed limits. These crashes also happened in rural areas along arterial and/or collector segments with 50+ mph speed limits.

Acronyms

AADT	Annual Average Daily Traffic
ADA	Americans with Disabilities Act
BIL	Bipartisan Infrastructure Law
DPS	Department of Public Safety
FHWA	Federal Highway Administration
GIS	Geographic Information System
HIN	High Injury Network
HIN	High Injury Network
KA	Killed or seriously injured (also called severe crashes)
LRS	Linear Referencing System
MN	Minnesota
MnDOT	Minnesota Department of Transportation
MSI	Most severely injured
MSP	Minneapolis—St. Paul
MV	Motor Vehicle
OTE	Office of Traffic Engineering
Ped	Pedestrian
POC	People of Color
SPACE	Suitability of Pedestrian and Cyclist Environment
SSA	Safe System Approach
TAMS	Transportation Asset Management System
TCMA	Twin Cities (Minneapolis—St. Paul) Metropolitan Area
USDOT	US Department of Transportation
VPD	Vehicles per day
VRU	Vulnerable road user
VRUSA	Vulnerable Road User Safety Assessment

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Introduction & Purpose

The Bipartisan Infrastructure Law (BIL), passed in 2021, created a new requirement for state departments of transportation to conduct a Vulnerable Road User Safety Assessment (VRUSA) every five years. Anchored in the Safe System Approach (SSA), this assessment must use a data-driven process to identify high-risk areas and incorporate equity and demographics into the analysis. Official guidance around this new Vulnerable Road User Safety Assessment recommends the use of a High Injury Network, predictive, and/or systemic analysis to identify high-risk areas[1].

To improve the safety of vulnerable road users in the state of Minnesota and partially satisfy the new VRUSA requirements, the Minnesota Department of Transportation's (MnDOT) Office of Traffic Engineering (OTE) commissioned a Vulnerable Road User Safety Assessment, including the development of a High Injury Network for the state and a study of bicycling crashes in urban and rural areas within the state. This report captures trends of bicycle crashes across the state, documenting risk factors to direct infrastructure improvements and safety countermeasures, especially those that reduce crashes that result in cyclists' serious injury or death. This report presents three major approaches to bicycle safety analysis: (1) a descriptive analysis and (2) a "predictive" analysis, which were conducted on four years of crash data (2016-2019), totaling 2,643 bicycle crashes; and (3) a Statewide High Injury Network, which was built on 7,307 bicyclist, pedestrian, and other vulnerable road user crashes from 2017-2021.

The content of this report focuses on bicycle crashes, and it parallels the 2021 Minnesota Statewide Pedestrian Safety Analysis[2], which captured pedestrian safety trends and risk factors based on 5,472 crashes between 2016-2019. While bicyclists and pedestrians are different roadway users, use different infrastructure in many places, and have different safety concerns, both bicyclists and pedestrians are vulnerable roadway users who are disproportionately likely to be killed or seriously injured in the transportation system. Often bicycle and pedestrian countermeasures are planned and implemented in tandem, so it is necessary to have safety analyses of bicycle and pedestrian crash trends to inform these processes. Collectively, the 2021 Minnesota Statewide Pedestrian Safety Analysis, this analysis of bicyclist crashes, and the development of a High Injury Network for vulnerable road users constitute a robust, data-driven process for identifying higher-risk areas in the transportation system.

This report and the Minnesota Statewide Pedestrian Safety Report follow similar methodologies. For the descriptive and systemic analyses, bicycle crashes from 2016-2019 are conflated with roadway and environmental characteristics to create a dataset for analysis,

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[1] https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-10/VRU%20Safety%20Assessment%20Guidance%20FINAL_508.pdf

[2] https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=26158751

including variables about injury severity, lighting, functional classification of the roadways, development intensity, Suitability of Pedestrian and Cyclist Environment (SPACE) scores and related factors, and bicycle infrastructure. Given some data limitations, some of the detailed analysis focuses on MnDOT's trunk highway network.

This report also presents a statewide High Injury Network, which was built from which uses a standard sliding window analysis to measure severity-weighted crash density by mode. This section of the analysis spans all vulnerable road users, including bicyclists, pedestrians, and other personal conveyances. Sliding windows analysis and High Injury Network were not included in the Minnesota Statewide Pedestrian Safety Report.

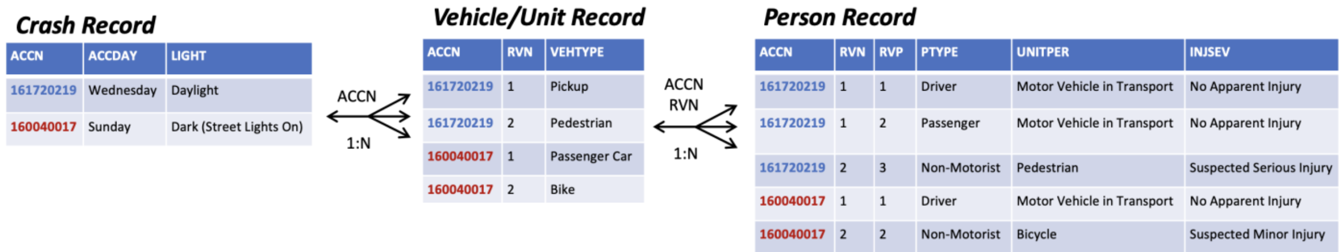
The rest of the report is structured as follows: First, an overview of the crash data is presented, followed by descriptive and predictive analyses. The descriptive analyses present trends among crash and temporal variables. The systemic analyses present the High Injury Network and crash trees that identify the highest-risk locations in the network and the most salient risk factors, respectively. Finally, a crash typology is presented, which defines categories of crashes based on person and roadway characteristics.

Data Overview

Crash Data

Crash, party, and vehicle data that were provided to the consultant team includes reported crashes from 2016 through 2021 for crashes for all modes (pedestrians, bicyclists, and motorists). There are two different study periods used in the safety analyses documented in this report. The descriptive and predictive crash analyses analyzed crashes that occurred between 2016-2019 to be consistent with the 2019 MnDOT Statewide Pedestrian Safety Analysis. The statewide High Injury Network (HIN) analyzed more recent crash data that include VRU crashes that occurred between 2017-2021.

All crash data was processed by Safe Streets Research & Consulting ("Safe Streets") and loaded into a Postgres database for additional analysis. The crash, party, and vehicle tables have a relational structure, which is common for storing crash data. For every reported crash, there is one crash record. The party and vehicle tables contain information for all the primary "actors" and their respective "vehicles" involved in the crash and have a many-to-one relationship – i.e., all relevant party records are matched via a case identification number to the one crash record. The party and vehicle tables contain information for each primary person and their "vehicle" such as age, sex, pre-crash action, injury severity, and vehicle characteristics. This structure is shown in Figure 1.



Note: ACCN and RVN uniquely identify vehicles in the database.

Figure 1. Crash Database Schema

The crash data used in this analysis was processed by Safe Streets to restructure the data. New variables were calculated and assigned and the quality of the data was assessed through a robust quality control process. All reported crashes were processed (not just bicyclist crashes), but only crashes that involved at least one bicyclist are included in this analysis. These bicyclist crashes include any crash involving a bicyclist and motorist or pedestrian.

These contextual datasets can provide a better understanding of the systemic risk factors for severe bicyclist outcomes. Missing spatial data is a common issue in crash analysis. There were 276 crashes that involved at least one bicyclist that did not have coordinates. Of those 276 crashes, 23 involved a bicyclist who was fatally or severely injured. Because this study relies on relating crashes to the associated roadway and land use context where the event occurred, crashes with missing location data were removed from the study dataset.

Crashes involving a person using a scooter (e.g., shared e-scooter or ADA assistive device) are defined in the State of Minnesota as pedestrian crashes. However, they are coded in MnDOT's crash database as the unit type "Other – Personal Conveyance" rather than as "Pedestrian". The "Other – Personal Conveyance" category also includes many modes that are not pedestrians, such as farm equipment (tractor, combine), all-terrain vehicles, snowmobiles, horse and buggy, and the like. There is no single coded field in the crash database that differentiates between pedestrians using personal conveyance devices and these other modes. A targeted effort was conducted to classify these crashes based on a keyword scan of officer narratives. While we could reliably differentiate these crashes from farm equipment based on this procedure, we could not consistently differentiate between mobility scooters and other devices used by people with mobility disabilities and other types of scooters or pedestrian devices. As stated in the 2019 Pedestrian Safety Analysis, a long-term solution to facilitate routine analysis of these modes in Minnesota would be to update the crash form with a field to indicate the type of scooter or device involvement (e.g., e-scooter, kick-scooter, ADA assistive device, moped scooter) and retrain officers to utilize the new field to record accurate and detailed information for more streamlined analysis.

Crashes that met one or more of the following criteria were removed from the study dataset during the data consolidation process (see Table 1 for the number of crashes that met each criterion; crashes can meet more than one criterion). The following criteria were used to filter crashes out of the study data used for the descriptive analysis and predictive analysis:

- **Motorist-only (non-VRU)** – The research team received all crashes that included crashes that involved a pedestrian, bicyclist, motorist, airplane, etc. The scope of this project is to only analyze vulnerable road users. As such, if the units involved in the crash do not include a bicyclist, pedestrian, or someone potentially using a personal conveyance device.
- **Missing coordinates** - Crash location GPS coordinates were not available.
- **Farm Equipment** – If the "unit type" is coded as "Other – Personal Conveyance" and the officer narrative includes the words "tractor", "horse", or "trailer"
- **Too far away from the street or along a private street** - The geospatial location of the crash is greater than 300 feet from any street or the street was a private roadway.
- **The crash occurred in a parking lot** –If the location type recorded in the crash data is noted as having occurred within a parking lot, those crashes have been removed from the study dataset.

Table 1: Crash records removed from study dataset

Crash Data Assessment	# of Instances	% of Excluded Crashes	% of All Crashes*
Crash is Missing coordinates	666	78%	19%
Non-Motorist considered Farm-equipment	146	17%	4%
Crash was Too far away from street or Private Street	287	34%	8%
Crash occurred in parking lot - officer reported	1	<1%	<1%
Total # of excluded pedestrian or bicycle crashes	***855***	***100%***	
Total # of bicyclist crashes used in analysis	***2,643***		***24%***

** Excluded crashes + study crashes*

Injury Severity Assignment

The officer-reported injury severity levels used in this analysis are specific to the most severely injured (MSI) road user involved in the crash. This injury severity is different than the reported MSI assigned to each crash record. In most cases, VRUs are the most severely injured victim involved in the crash. Using the victim-level severity helps improve accuracy of summarizing injury severities. It should be noted that the San Francisco Department of Public Health has conducted extensive research and has documented reporting errors related to mis-coded injury severities, particularly for serious injuries[3], suggesting a need for some fluidity when discussing minor and serious injuries. This analysis does not have access to hospital records to verified injury severities stored in the crash data, so the results in this document reflect the best available data at the time. For reference, the injury severities recorded in the crash data and summarized in this analysis are defined as followed:

- **K - Fatal:** A fatal injury is any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred. If the person did not die at the scene but died

[3] https://www.visionzerosf.org/wp-content/uploads/2021/11/Severe-Injury-Trends 2011-2020 final report.pdf

within 30 days of the motor vehicle crash in which the injury occurred, the injury classification should be changed from the injury previously assigned to “Fatal Injury”

- **A – Suspected Serious Injury:** An incapacitating injury is any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury occurred. Also called “Serious Injury” or “Injury A”. This category includes:
    - severe lacerations
    - broken or distorted limbs
    - skull or chest injuries
    - abdominal injuries
    - unconsciousness at or when taken from the accident scene
    - unable to leave the accident scene without assistance
- **B – Suspected Minor Injury:** A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Also called “Minor Injury” or “Injury B”. Examples include:
    - lump on the head
    - abrasions, bruises
    - minor lacerations (cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle)
- **C – Possible Injury**: A possible injury is any injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Possible injuries are those that are reported by the person or are indicated by their behavior, but no wounds or injuries are readily evident. Examples include:
    - momentary loss of consciousness
    - claim of injury
    - limping, or complaint of pain or nausea.
- **O – Property Damage Only**: Crash where only property is damaged. No injuries resulted from the crash.

Roadway and Contextual Data

The crash dataset includes many useful variables for analyzing VRU safety; however, detailed information about roadway conditions and nearby land uses is also necessary to provide a more complete understanding of the context in which crashes occurred and support future countermeasure selection. A robust data collection and consolidation process was conducted as part of the 2021 MnDOT Statewide Pedestrian Safety Analysis. Data from that effort was provided to the study team for use in this VRU assessment. Data collected during the Statewide Pedestrian Safety Analysis was re-processed using the same methods documented in the data collection section of the Pedestrian Safety Analysis. Please refer to the Statewide Pedestrian Crash Analysis[4] for a detailed summary regarding data usage and limitations.

[4] https://edocs-public.dot.state.mn.us/edocs_public/DMResultSet/download?docId=26158751

Descriptive Crash Analysis

The descriptive crash analysis consists of tabulations on key variables of interest to identify attributes that are linked to crashes and crash severity. The consulting team used frequency tables to identify variables for further analysis through the development of crash trees. The descriptive analysis reviewed factors including the following:

- Injury severity
- Lighting condition
- Functional classification (of the road on which the crash occurred)
- Location type (segment vs. intersection; intersection signalization)
- Area land development intensity
- Suitability of Pedestrian and Cyclist Environment (SPACE) scores and their contributing factors tabulated to the SPACE score hexagons, including demographics and intersection star ratings
- Variables from the SPACE tool related to environmental justice such as the racial and income demographics of areas surrounding crash locations.
- Location types stratified by the crash's occurrence on a trunk highway or off the trunk highway network
- Bicycle facility type (2007 data)

All Vulnerable Road User Crashes (2016-2019)

Injury Severity – All VRU

The data used in this study contained all vulnerable road user (VRU) crashes that occurred in Minnesota during 2016-2019, representing four years of crash data. Several modes are considered in the VRU category, including bicyclists, pedestrians, other personal conveyance, and other VRUs. The following tables show trends in the data for all VRU modes contained in the data.

Table 2 shows the crash distribution by injury severity for all VRUs. Pedestrians have the largest share of fatal crashes at 5%, followed by other VRU crashes. Most bicyclist crashes are minor injury and possible injury crashes, although 9% are serious injury crashes.

Table 2: All Study Crashes by Severity, 2016-2019

Mode		Fatal (K)	Serious Injury (A)	Minor Injury (B)	Possible Injury (C)	Property Damage Only (O)	*Total*
Bicyclist	Count	30	231	1,362	848	172	**2,643**
	Percentage	1%	9%	52%	32%	7%	**100%**
Pedestrian	Count	188	679	1,596	1,139	126	**3,728**
	Percentage	5%	18%	43%	31%	3%	**100%**
Other - Personal Conveyance	Count	0	8	22	18	165	**213**
	Percentage	0%	4%	10%	8%	77%	**100%**
Other - VRU	Count	3	10	36	35	32	**116**
	Percentage	3%	9%	31%	30%	28%	**100%**
Total	**Count**	**221**	**928**	**3,016**	**2,040**	**495**	**6,700**
	Percentage	**3%**	**14%**	**45%**	**30%**	**7%**	**100%**

Year – All VRU

Table 3 describes the distribution of VRU crashes by year, including the number of Fatal and Serious Injury crashes (KA), and the shares of total crashes and KA among each VRU mode per year. Table 3 shows several trends. First, pedestrian crashes make up the largest share of all VRU crashes each year and the largest share of KA crashes each year. Each year, pedestrian KA crash shares are larger than shares of all pedestrian crashes. Both of these trends indicate that pedestrians are overburdened for serious and fatal injuries in the Minnesota statewide transportation system.

Another trend is that bicycle crashes make up a similar share of VRU crashes each year. While the overall number of bicycle crashes (and all VRU crashes) generally decreased each year, bicyclists represented 36-42% of all crashes and 20-27% of all KA crashes each year. While the system is getting safer overall, the safety benefits do not seem to accrue to cyclists specifically during the study period.

Table 3: All Crashes, By Year and Mode, 2016-2019

Year and Mode	# Crashes	# KA Crashes	% Yearly Crashes	% Yearly KA Crashes
2016	**1,729**	**338**	**100%**	**100%**
Pedestrian	948	250	55%	74%
Bicyclist	705	79	41%	23%
Other - Personal Conveyance	54	5	3%	1%
Other - VRU	22	4	1%	1%
2017	**1,724**	**308**	**100%**	**100%**
Pedestrian	943	241	55%	78%
Bicyclist	720	61	42%	20%
Other - Personal Conveyance	41	3	2%	1%
Other - VRU	20	3	1%	1%
2018	**1,593**	**265**	**100%**	**100%**
Pedestrian	931	205	58%	77%
Bicyclist	576	56	36%	21%
Other - Personal Conveyance	56	2	4%	1%
Other - VRU	30	2	2%	1%
2019	**1,654**	**250**	**100%**	**100%**
Pedestrian	906	176	55%	70%
Bicyclist	642	65	39%	26%
Other - Personal Conveyance	62	4	4%	2%
Other - VRU	44	5	3%	2%
Total	**6,700**	**1,161**		

Table 4 below shows the distribution of bicycle crashes during the 4 years captured in the study period. Of all the bike crashes in the study period (n = 2,643), earlier years in the study period have the highest share of crashes, which may indicate improved safety during later years or changes in crash reporting. Additionally, 2016 accounted for the largest share of KA crashes (30%) and 2018 had the lowest share (21%). In general, the proportion of crashes that resulted in a KA outcome was mostly consistent across years between 10-11%, though 2017 had the lowest proportion with 8% of crashes resulting in a KA outcome.

Table 4: Bicyclist Crashes by Year, 2016-2019

Year	# Crashes	% of Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
2016	705	27%	79	30%	11%
2017	720	27%	61	23%	8%
2018	576	22%	56	21%	10%
2019	642	24%	65	25%	10%
Total	**2,643**	**100%**	**261**	**100%**	**10%**

MnDOT SHSP Focus Areas

MnDOT has designated several focus areas related to safety as a part of its Strategic Highway Safety Plan, such as impairment, speeding, inattention, and other areas. Several of these focus areas as they relate to VRU crashes are reported below. The project team reviewed all VRU crashes for impairment, speeding, inattention, work zones, and unlicensed drivers, as shown in Table 5 through Table 9. Only the findings related to impairment were meaningful, although it's important to note that several focus areas may not be the most effective indicators of crash risk for VRUs, particularly inattention and speeding. Inattention can be difficult for a responding officer to prove, leading to a large share of underreported inattention-related crashes. While speed is an important safety component related to crash risk and injury severity, the difference between a motorist speeding along a 25mph street compared to speeding along a 50mph street may result in substantially different injury potential due to higher levels of kinetic energy. Additionally, while speeding as a violation may not show up as a risk factor in the VRU data, design speed is a known risk factor. Therefore, the posted speed limit or ideally observed vehicle speed is a more effective indicator of crash risk.

Table 5 shows VRU crashes by mode and impairment. Most VRU crashes do not involve impairment, although a disproportionate share of KA pedestrian crashes did involve impairment (89% of all VRU crashes; 77% of all KA VRU crashes). Pedestrians had the largest share of crashes that involved impairment for all crashes (15%) and KA crashes (27%). For each VRU, KA crashes accounted for a larger share of crashes when impairment was reported.

Table 5: All VRU Crashes by Impairment, 2016-2019

Crash Mode	Impairment	# Crashes	% Crashes	# KA Crashes	% KA Crashes
Bicyclist	Unknown	2	0%	0	0%
	No	2,516	95%	228	87%
	Yes	125	5%	33	13%
Bicyclist Total		**2,643**	**39%**	**261**	**22%**
Other - Personal Conveyance	No	304	92%	23	82%
	Yes	25	8%	5	18%
Other - Personal Conveyance Total		**329**	**5%**	**28**	**2%**
Pedestrian	Unknown	2	0%	0	0%
	No	3,152	85%	640	73%
	Yes	574	15%	232	27%
Pedestrian Total		**3,728**	**56%**	**872**	**75%**
All VRU	Unknown	4	0%	0	0%
	No	5,972	89%	891	77%
	Yes	724	11%	270	23%
All VRU		**6,700**	**100%**	**1161**	**100%**

Table 6: All VRU Crashes by Speeding, 2016-2019

Crash Mode	Speeding	# Crashes	% Crashes	# KA	% KA
Bicyclist	Unknown	2	0%	0	0%
	No	2,622	99%	253	97%
	Yes	19	1%	8	3%
Bicyclist Total		**2,643**	**39%**	**261**	**22%**
Other - Personal Conveyance	No	322	98%	26	93%
	Yes	7	2%	2	7%
Other - Personal Conveyance Total		**329**	**5%**	**28**	**2%**
Pedestrian	Unknown	2	0%	0	0%
	No	3,631	97%	827	95%
	Yes	95	3%	45	5%
Pedestrian Total		**3,728**	**56%**	**872**	**75%**
All VRU	Unknown	4	0%	0	0%
	No	6,575	98%	1,106	95%
	Yes	121	2%	55	5%
All VRU		**6,700**	**100%**	**1,161**	**100%**

Table 7: All VRU Crashes by Inattention, 2016-2019

Crash Mode	Inattention	# Crashes	% Crashes	# KA	% KA
Bicyclist	Unknown	2	0%	0	0%
	No	2,527	96%	248	95%
	Yes	114	4%	13	5%
Bicyclist Total		**2,643**	**39%**	**261**	**22%**
Other - Personal Conveyance	No	302	92%	25	89%
	Yes	27	8%	3	11%
Other - Personal Conveyance Total		**329**	**5%**	**28**	**2%**
Pedestrian	Unknown	2	0%	0	0%
	No	3,515	94%	807	93%
	Yes	211	6%	65	7%
Pedestrian Total		**3,728**	**56%**	**872**	**75%**
All VRU	Unknown	4	0%	0	0%
	No	6,344	95%	1,080	93%
	Yes	352	5%	81	7%
All VRU Total		**6,700**	**100%**	**1,161**	**100%**

Table 8: All VRU Crashes by Work Zone, 2016-2019

Crash Mode	Work Zone	# Crashes	% Crashes	# KA	% KA
Bicyclist	Unknown	2	0%	0	0%
	No	2,603	98%	256	98%
	Yes	38	1%	5	2%
Bicyclist Total		**2,643**	**39%**	**261**	22%
Other - Personal Conveyance	No	311	95%	26	93%
	Yes	18	5%	2	7%
Other - Personal Conveyance Total		**329**	**5%**	**28**	**2%**
Pedestrian	Unknown	2	0%	0	0%
	No	3,657	98%	848	97%
	Yes	69	2%	24	3%
Pedestrian Total		**3,728**	**56%**	**872**	**75%**
All VRU	Unknown	4	0%	0	0%
	No	6,571	98%	1,130	97%
	Yes	125	2%	31	3%
VRU Total		**6,700**	**100%**	**1,161**	**100%**

Table 9: All VRU Crashes by Unlicensed Driver, 2016-2019

Crash Mode	Unlicensed Driver	# Crashes	% Crashes	# KA	% KA
Bicyclist	Unknown	2	0%	0	0%
	No	2,525	96%	251	96%
	Yes	116	4%	10	4%
Bicyclist Total		**2,643**	**39%**	**261**	**22%**
Other - Personal Conveyance	No	308	94%	26	93%
	Yes	21	6%	2	7%
Other - Personal Conveyance Total		**329**	**5%**	**28**	**2%**
Pedestrian	Unknown	2	0%	0	0%
	No	3,462	93%	780	89%
	Yes	264	7%	92	11%
Pedestrian Total		**3,728**	**56%**	**872**	**75%**
All VRU	Unknown	4	0%	0	0%
	No	6,295	94%	1,057	91%
	Yes	401	6%	104	9%
All VRU Total		**6,700**	**100%**	**1,161**	**100%**

Descriptive Analysis of Bicycle Crashes

The project team created frequency tables to identify common attributes that are associated with crashes. The focus of this section is bicycle crashes that occurred between 2016 and 2019 (consistent with the 2019 Pedestrian Safety Analysis). Through a review of these frequency tables, we identify the key variables that can be used for further analysis through crash trees.

Injury Severity

Table 10 shows the distribution of all bike-related crashes by injury severity. Most of the reported bike crashes resulted in a possible or confirmed injury, an expected result due to the overall vulnerability of bicyclists traveling within space shared with motorists. Property damage only crashes accounted for only seven percent of crashes, which may reflect underreporting[5] of these types of crashes or these crashes do not meet the minimum cost threshold ($1.000).

Injury severities in Table 6 other than fatal also likely include some degree of both underreporting and misclassification -- previous research found crash reporting levels in police crash data range from 7-46%[6] and the San Francisco Department of Public Health found

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[5] Stutts, J., & Hunter, W. (1998). Police reporting of pedestrians and bicyclists treated in hospital emergency rooms. Transportation Research Record: Journal of the Transportation Research Board, (1635), 88-92.

[6] https://safetrec.berkeley.edu/publications/evaluating-research-data-linkage-assess-underreporting-pedestrian-and-bicyclist-injury

miscoding between a non-trivial percentage of serious and minor injuries[7]. Future efforts to link police crash data with hospital or other public health data may help provide a more accurate assessment of bicyclist crash severity across the state. In total, there were 2,643 reported bicycle crashes during 2016 – 2019. Roughly 10% of those crashes were reported to be fatal or result in a serious injury.

Table 10: All Bicycle Crashes by Severity, 2016-2019

Crash Severity	# Crashes	% Crashes
Fatal (K)	30	1%
Serious Injury (A)	231	9%
Minor Injury (B)	1,370	52%
Possible Injury (C)	847	32%
Property Damage Only (O)	165	6%
Total	**2,643**	**100%**

Area Land Development Intensity

Table 11 shows the distribution of bicycle crashes by the land development intensity recorded in MnDOT SPACE data surrounding the facility where the crash occurred. Twin Cities Metropolitan Areas (TCMA) have been subdivided to analyze crashes that occurred within Minneapolis and St. Paul separate from other cities within the metro area.

Most crashes (41%) occurred within the TCMA -Minneapolis and St. Paul areas and most KA crashes occurred within other cities in the TCMA (36%). When looking at crashes that occurred within both subdivisions of the TCMA, most crashes (75%) and most KA crashes (68%) occurred in the TCMA, which is likely confounded with the number of people riding bikes; more bicyclists are expected to ride in urban areas, so it follows that there would be more crashes.

Small urban communities (defined as *rural downtown* in SPACE) had the third largest share of crashes (13%) and KA crashes (13%). While bicycle riding is less frequent (lower levels of exposure) in small urban areas relative to denser metro areas, this may be an indication of high crash risk in these areas of the state. Future efforts to collect bicyclist exposure data and to correct bike facility data with installation dates will help improve our understanding of crash risk in small urban areas.

Only 3% of all crashes occurred in rural areas, but 10% of KA crashes occurred in rural areas, and more than a third of all crashes that occurred in rural areas resulted in a KA crash. This finding may indicate potential underreporting of non-KA bicyclist crashes in rural areas and/or

[7] San Francisco Department of Public Health-Program on Health, Equity and Sustainability. 2017. Vision Zero High Injury Network: 2017 Update – A Methodology for San Francisco, California. San Francisco, CA. Available at: https://www.sfdph.org/dph/files/EHSdocs/PHES/VisionZero/Vision_Zero_High_Injury_Network_Update.pdf

more severe outcomes for crashes that occurred in rural areas relative to more urban areas. Furthermore, this is also an indication of higher posted speed limits in rural areas with 80% of rural crashes and 72% of rural KA crashes having occurred along streets with a posted speed limit of at least 50 mph.

Table 11: Bicycle Crashes by Land Development (SPACE), 2016-2019

Area Land Development Intensity	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA	Crashes per Hex	KA Crashes per Hex	% Square Mileage
TCMA - Minneapolis and St. Paul	1,079	41%	84	32%	8%	137.6	10.7	0%
TCMA - Other cities	916	35%	94	36%	10%	11.4	1.2	2%
Small urban communities	339	13%	35	13%	10%	3.7	0.4	2%
Greater MN metro	238	9%	23	9%	10%	17.5	1.7	0%
Rural	71	3%	25	10%	35%	0.0	0.0	96%
Total	***2,643***	***100%***	***261***	***100%***	***10%***	***0.5***	***0.0***	100%

Month

Table 12 reviews the distribution of crashes by month of the year. In general, there were more bike crashes during warmer months (May through September). This finding aligns with our understanding of bicyclist volume seasonality: bicyclist volumes are highest during warmer months and lowest during colder and snowier months. As such, we can expect months with higher bicyclist volumes (exposure) to have the highest bicyclist crash frequencies.

The share of KA crashes follows the same trend - there are more KA crashes in warmer months than in colder months. March had the largest share of crashes that resulted in a KA outcome (14%) which may indicate environmental risks from ice or snow posed to road users (narrower roadways, reduced traction, longer braking distances, etc.), darker lighting conditions, and/or visibility challenges related to snowfall during this season.

Table 12: Bicycle Crashes by Month, 2016-2019

Month	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
January	42	2%	4	2%	10%
February	36	1%	4	2%	11%
March	71	3%	10	4%	14%
April	131	5%	13	5%	10%
May	306	12%	31	12%	10%
June	394	15%	41	16%	10%
July	428	16%	48	18%	11%
August	472	18%	49	19%	10%
September	355	13%	25	10%	7%
October	236	9%	21	8%	9%
November	131	5%	13	5%	10%
December	41	2%	2	1%	5%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Lighting Condition

Table 13 shows how bicycle crashes and crash severity vary by lighting condition. Compared to dark and low-light conditions, most of the crashes happened in well-lit conditions, although fatal and serious injury crashes are slightly overrepresented in dark and low-light conditions relative to non-severe crashes. Both findings align with expectations, as there are more people biking during daylight hours, but low lighting impairs the visibility of people biking.

Out of all crashes that occurred in darkness where there were no streetlights, 23% of the crashes resulted in a serious injury or fatality. Similarly, 14% of all crashes that occurred in dark hours at locations where streetlights were turned off resulted in serious injuries or fatalities. Crashes occurring in dark, unlit conditions and during sunrise and sunset are more likely to be severe than crashes at other times, with 23% and 16-17%, respectively, of these crashes resulting in a fatality or serious injury.

Table 13: Bicycle Crashes by Lighting Condition, 2016-2019

Lighting Condition	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Daylight	2,034	77%	189	72%	9%
Dark (Street Lights On)	391	15%	39	15%	10%
Sunset	105	4%	17	7%	16%
Sunrise	46	2%	8	3%	17%
Dark (No Street Lights)	26	1%	6	2%	23%
Dark (Unknown Lighting)	18	1%	1	0%	6%
Unknown	15	1%	0	0%	0%
Dark (Street Lights Off)	7	0%	1	0%	14%
Other	1	0%	0	0%	0%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

These trends are further investigated in Table 14, which separates crashes by lighting and urban or rural context. Most bike crashes occurred in urban areas (84%). Within urban areas, most crashes occurred during daylight hours (76%), as did most KA crashes (72%). Dark conditions without streetlights appear to be the riskiest: 19% of crashes that occurred in these conditions resulted in a KA outcome, compared to 12% for sunrise/sunset and 11% for dark conditions with streetlights.

Of the crashes that occurred in rural areas, 82% occurred during daylight hours, as did most KA crashes (75%). In contrast to urban areas, however, sunrise/sunset times appear to be a much more prevalent risk factor, with 42% of those crashes resulting in a KA outcome. In contrast, just 3% of the crashes that occurred in darkness with streetlights resulted in a KA outcome, which may reflect where those crashes occurred (e.g., downtown main streets or in neighborhoods) as much as the impact of street lighting on crash severity.

Table 14: All Bicycle Crashes by Lighting, Rural vs. Urban Context, 2016-2019

Urban/ Rural (SPACE)	Lighting	# Crashes	% Crashes	% Crashes (within urban/rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% KA of All Crashes
Urban	Daylight	1,697	64%	76%	144	55%	72%	9%
	Dark (Street Lights On)	356	13%	16%	38	15%	19%	11%
	Sunrise/Sunset	127	5%	6%	15	6%	7%	12%
	Dark (Unknown Lighting)	18	1%	1%	1	0%	0%	6%
	Dark (No Street Lights)	16	1%	1%	3	1%	1%	19%
	Other/Unknown	14	1%	1%	0	0%	0%	0%
	Dark (Street Lights Off)	5	0%	0%	0	0%	0%	0%
Urban Total		***2,233***	***84%***	***100%***	***201***	***77%***	***100%***	***9%***
Rural	Daylight	337	13%	82%	45	17%	75%	13%
	Dark (Street Lights On)	35	1%	9%	1	0%	2%	3%
	Sunrise/Sunset	24	1%	6%	10	4%	17%	42%
	Dark (No Street Lights)	10	0%	2%	3	1%	5%	30%
	Other/Unknown	2	0%	0%	0	0%	0%	0%
	Dark (Street Lights Off)	2	0%	0%	1	0%	2%	50%
Rural Total		***410***	***16%***	***100%***	***60***	***23%***	***100%***	***15%***
Total		***2,643***	***100%***		***261***	***100%***		***10%***

Table 15 shows crashes grouped by both lighting status and intersection versus segment location types. Within each lighting status category, we calculated a ratio of intersection to segment location crashes. For example, in daylight conditions, there are 1,601 intersection crashes and 433 segment crashes, for a ratio of 3.7 intersection crashes per segment crash. This shows us whether certain lighting types are relatively more common at intersection or segment locations. Lighting type for crashes occurring in darkness appears to correlate with location type in predictable ways. Crashes with streetlights on are relatively more common at intersections than segment locations. Among crashes with no streetlights present, segment crashes are overrepresented. These patterns reflect road design and the propensity for street lighting to be installed at intersection locations while midblock and segment locations remain unlit. Additional patterns related to crash location type are explored more fully in the next few sections.

Table 15: Bicycle Crashes by Lighting Condition and Crash Location, 2016-2019

Lighting	Crash Location	# Crashes	% Crashes	Crashes – Ratio of Intersection to Segment	# KA	% KA	KA – Ratio of intersection to segment crashes	% KA of All Crashes
Daylight	Segment	433	16%	3.7 : 1	54	21%	2.5 : 1	12%
	Intersection	1,601	61%		135	52%		8%
Dark (Street Lights On)	Segment	63	2%	5.2 : 1	3	1%	12.0 : 1	5%
	Intersection	328	12%		36	14%		11%
Sunset	Segment	23	1%	3.6 : 1	5	2%	2.4 : 1	22%
	Intersection	82	3%		12	5%		15%
Sunrise	Segment	9	<1%	4.1 : 1	4	2%	1 : 1	44%
	Intersection	37	1%		4	2%		11%
Dark (No Street Lights)	Segment	16	1%	0.6 : 1	5	2%	0.2 : 1	31%
	Intersection	10	<1%		1	<1%		10%
Dark (Unknown Lighting)	Segment	3	<1%	5.0 : 1	0	0%	N/A	0%
	Intersection	15	1%		1	<1%		7%
Unknown	Segment	2	<1%	6.5 : 1	0	0%	N/A	0%
	Intersection	13	<1%		0	0%		0%
Dark (Street Lights Off)	Segment	2	<1%	2.5 : 1	1	<1%	N/A	50%
	Intersection	5	<1%		0	0%		0%
Other	Segment	1	<1%	N/A	0	0%	N/A	0%
Total		***2,643***	***100%***	***3.8 : 1***	***261***	***100%***	***2.6 : 1***	***10%***

Lighting status also correlates with victim age. Youth-involved bicyclist crashes are relatively more common during daylight hours. While 77% of all bicyclist crashes happen in daylight, a full 84% of youth bicyclist crashes happen in daylight. Youth crashes comprise 21% of all bicyclist crashes and 25% of daylight bicyclist crashes. This likely reflects typical travel patterns of youth bicyclists; they are less likely to ride at night or in dark conditions. Additional patterns related to age are explored in the next section.

Table 16: Bicycle Crashes and Youth Bicyclist Crashes by Lighting Condition, 2016-2019

Lighting	% All Crashes	% All KA	# Youth Crashes	% Youth Crashes	# KA Youth Crashes	% KA Youth Crashes	% All Crashes that Involved Youth	% All KA Crashes that Involved Youth
Daylight	77%	72%	599	84%	47	84%	29%	25%
Dark (Street Lights On)	15%	15%	71	10%	4	7%	18%	10%
Sunset	4%	7%	21	3%	2	4%	20%	12%
Sunrise	2%	3%	9	1%	2	4%	20%	25%
Dark (No Street Lights)	1%	2%	5	1%	1	2%	19%	17%
Dark (Unknown Lighting)	1%	0%	4	1%	0	0%	22%	0%
Unknown	1%	0%	3	0%	0	0%	20%	0%
Dark (Street Lights Off)	0%	0%	1	0%	0	0%	14%	0%
Other	0%	0%	1	0%	0	0%	100%	0%
Total	**100%**	**100%**	**714**	**100%**	**56**	**100%**	**27%**	**21%**

Age

This section reports on the number of victims/parties involved in crashes throughout the state, focusing on the main road users/vehicles involved in the crash, such as drivers, pedestrians, bicyclists, and parked vehicles. There will be more than one party for every crash record summarized in this memo except for solo-bicyclist crashes or hit-and run-crashes.

Analyzing the victim data provides additional insight into these crashes and potential crash dynamics. This analysis compared the distribution of parties involved in crashes to the population distribution of the state. Values greater than one suggest that a certain segment of the population is overrepresented on a per capita basis, while values less than one suggest that that segment of the population is underrepresented on the same basis.

It is important to note that this comparison is imperfect in two ways. First, if more or fewer people from a segment of the population bicycle or drive, we would expect that to be reflected in crash rates, all else equal – and this proportion of people who bicycle or drive may not reflect their per capita proportion. We likely see this, for example, in trends related to age and sex. In the absence of more nuanced exposure data, however, a per capita understanding is still valuable to help us understand how crashes are distributed among various segments of the population.

Second, the home zip code is not readily available for all parties involved in the crash, so we cannot rule out that some people riding a bicycle or driving a motor vehicle live outside of the state and their inclusion will therefore marginally affect the accuracy of the victim-to-population ratio. This effect is more likely to apply to drivers than to bicyclists.

Table 17 summarizes the distribution of bicyclist victims (not crashes) and drivers by age and injury severity. This table shows that most crashes and the most severe bicycle crashes involved younger cyclists. People riding bikes aged between 10-14 accounted for the largest share of victims (13-14%) and bicyclists aged between 15-19 accounted for the largest share of KA victims (15%). The distribution of driver ages was slightly more dispersed than that for bicyclist ages, though drivers aged 20-34 were most frequently involved in a crash with a bicyclist. Drivers aged 20-29, 35-39, and 55-59 were most frequently involved in KA crashes with a bicyclist.

When comparing the distribution of victims by age to the state's population by age, younger bicyclists are much more likely to be involved in a crash and a KA crash compared to older populations. Bicyclists aged 10-19 were the most overrepresented in crashes and bicyclists aged 15-19 were the most overrepresented in KA crashes. This highlights the vulnerability of bicyclists, especially for Minnesota's youth. Driver representation relative to the state's population was less skewed than bicyclist representation, however, younger drivers were more overrepresented.

Table 17: Bicyclists and Drivers by Age, 2016-2019

Age	Bicyclists				Drivers				% Population	Party to Population Ratio			
	#	%	# KA	% KA	#	%	# KA	% KA		Bike	KA Bike	Driver	KA Driver
Under 5	13	0%	0	0%					6.2%	0.1	0.0		
5 to 9	90	3%	6	4%					6.4%	0.5	0.6		
10 to 14	359	13%	11	7%					6.6%	2.0	1.1		
15 to 19	367	14%	22	15%	150	6.4%	11	8.5%	6.4%	2.1	2.3	1.0	1.3
20 to 24	262	10%	17	11%	240	10.2%	13	10.1%	6.1%	1.6	1.8	1.7	1.6
25 to 29	269	10%	14	9%	245	10.4%	16	12.4%	6.8%	1.5	1.4	1.5	1.8
30 to 34	228	9%	12	8%	223	9.5%	11	8.5%	6.8%	1.2	1.2	1.4	1.3
35 to 39	149	6%	8	5%	205	8.7%	13	10.1%	6.8%	0.8	0.8	1.3	1.5
40 to 44	125	5%	7	5%	184	7.8%	9	7.0%	6.1%	0.8	0.8	1.3	1.1
45 to 49	132	5%	8	5%	174	7.4%	11	8.5%	5.8%	0.8	0.9	1.3	1.5
50 to 54	169	6%	10	7%	185	7.9%	8	6.2%	6.1%	1.0	1.1	1.3	1.0
55 to 59	152	6%	12	8%	207	8.8%	14	10.9%	6.9%	0.8	1.2	1.3	1.6
60 to 64	116	4%	9	6%	176	7.5%	9	7.0%	6.6%	0.7	0.9	1.1	1.1
65 to 69	67	3%	5	3%	138	5.9%	6	4.7%	5.4%	0.5	0.6	1.1	0.9
70 to 74	43	2%	1	1%	90	3.8%	4	3.1%	4.1%	0.4	0.2	0.9	0.8
75 to 79	18	1%	3	2%	59	2.5%	1	0.8%	2.9%	0.2	0.7	0.9	0.3
80 to 84	8	0%	1	1%	38	1.6%	2	1.6%	2.0%	0.1	0.3	0.8	0.8
85+	5	0%	0	0%	31	1.3%	1	0.8%	2.0%	0.1	0.0	0.7	0.4
Unknow	104	4%	5	3%	1	0.0%	-	0.0%					
Total	***2,676***	***100***	***151***	***100***	***2,34***	***100%***	***129***	***100%***	***100%***	***1.0***	***1.0***	***1.0***	***1.0***

Crash Location Type

Table 18 summarizes bicyclist crashes by crash location type. The table shows that nearly three-quarters of crashes occurred at an intersection. Following the MnDOT Statewide Pedestrian Safety Analysis methodology, crashes were considered intersection-related if the crash occurred within 100 feet of the center of an intersection. Other crashes not flagged as intersection-related were coded as segment crashes.

Overall crashes and KA crashes occurred most frequently at stop-controlled intersections (40% of all crashes; 39% of KA crashes). Detailed information related to the type of stop control (all-way or two-way) is not available for all crashes and intersections. There may be several factors that contribute to stop-controlled intersections accounting for the largest share of all crashes and KA crashes. These types of intersection and control type likely account for the largest share of intersections across the state, resulting in a higher percentage of crashes occurring at these locations.

A factor that may be a systemic issue across the state for bicyclists may relate to bicyclists riding along lower-intensity streets (often residential streets) who need to cross major streets that are often controlled with a two-way stop sign. This combination of lower-stress streets without crossing accommodations likely contributes to bicyclists attempting to cross a major street and being struck by a motorist who does not have a traffic control device.

The crash data support this theory: 47% of all bicyclist crashes and 55% of bicyclist KA crashes at stop-controlled intersections report the cyclist as crossing traffic/roadway. Furthermore, nearly all of those crashes are at an intersection where the lowest functional classification was a residential street.

Signalized intersections accounted for the largest share of overall crashes (34%) and the second largest share of KA crashes (28%). However, these crashes tended to be slightly less severe than other location types, with 8% of crashes resulting in a KSI outcome compared to 10% at stop-controlled intersections and 13% at segment locations.

Table 18: Bicycle Crashes by Location, 2016-2019

Crash Location	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Intersection with Stop Sign	1,048	40%	103	39%	10%
Intersection with Signal	910	34%	72	28%	8%
Segment	552	21%	72	28%	13%
Intersection with Other/unknown Control	133	5%	14	5%	11%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Table 19 summarizes bicyclist crashes by location type and urban/rural context. Examining crashes by context provides insight into how safety issues differ between urban and rural areas across Minnesota. For example, urban areas tend to have more signalized intersections than rural areas; correspondingly, only 3% of signalized intersection crashes occurred in rural areas.

Additionally, rural areas often have more lane miles of higher-speed roads as a proportion of the total area, which may help explain why 29% of rural segment crashes result in a KA outcome, compared to just 9% of segment locations in urban areas. Crashes that occurred at stop-controlled intersections were also more likely to be severe in rural areas than in urban areas.

Table 19: Bicycle Crashes by Location in Urban and Rural Contexts, 2016-2019

Urban/Rural	Crash Location	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Rural (including small urban communities and rural areas)	Stop	208	8%	25	10%	12%
	Segment	108	4%	31	12%	29%
	Signal	77	3%	4	2%	5%
	Other/unknown	17	1%	0	0%	0%
Rural Total		**410**	**16%**	**60**	**23%**	**15%**
Urban (including large urban metropolitan areas)	Stop	840	32%	78	30%	9%
	Signal	833	32%	68	26%	8%
	Segment	444	17%	41	16%	9%
	Other/unknown	116	4%	14	5%	12%
Urban Total		**2,233**	**84%**	**201**	**77%**	**9%**
Total		***2,643***	***100%***	***261***	***100%***	***10%***

MnDOT Trunk Highways

In addition to functional classification, the project team also reviewed crash distribution by the network of trunk highways within the state, as shown in Table 20. Trunk highways are state-operated roadways that range from freeways and interstates down to urban arterials and small-town main streets. Most crashes and most severe crashes occur off the trunk network, likely because these are the most attractive roadways for cyclists and thus have higher levels of ridership (exposure) than the trunk network. This points to the need for further VRU analyses to focus on non-trunk roadways, although the crash types along the trunk highway should be investigated for possible countermeasures, especially considering that the trunk highway data has the most roadway characteristic information of all the data analyzed in this study.

Table 20 shows bicycle crash trends on the trunk highway. Most bicyclist crashes occurred at non-trunk highway locations (87%, n=2,300). This is noteworthy because trunk highway mileage represents a relatively small percentage of all roadway network mileage, and therefore there are comparatively fewer locations where deployment of safety countermeasures would be under MnDOT's purview. MnDOT also has a direct influence on the design of trunk highways, so it is important to consider these safety trends.

Table 20: Trunk vs Non-Trunk Crashes, 2016-2019

Trunk Highway	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Non-Trunk Highway	2,300	87%	223	85%	10%
Trunk Highway	343	13%	38	15%	11%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Table 21 shows bicycle crash trends on the trunk highway network in urban and rural contexts. A larger share of crashes occurs on the trunk network in small urban communities (33%) compared to TCMA and greater MN metro areas (9-13%), and more of these crashes were severe (17-24% in rural areas compared to 11% in TCMA locations). Most of the trunk highway network by mileage is in rural areas (80%), whereas only 11 percent of the network is within small urban communities, seven percent in the TCMA, and one percent in the greater MN metro.

Crashes are still concentrated in more urban areas along the trunk highway network with the TMCA Minneapolis & St. Paul location having 28 crashes per 1,000 miles followed by Greater MN Metros (10 crashes per 1,000 miles), and TCMA Other Cities (6 crashes per 1,000 miles). Crashes along the trunk network in rural and small urban communities could be in places where the trunk network becomes a central roadway within smaller urban areas or rural towns. In urban areas, crashes that occurred on the trunk highway network were more likely to be severe, pointing to the injury burden carried by these facilities.

Table 21: Trunk vs Non-Trunk Crashes and urban/rural context, 2016-2019

Urban/Rural (SPACE)	Trunk Highway	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA	Crashes per 1,000 Miles (trunk only)	KA Crashes per 1,000 Miles (trunk only)
TCMA - Minneapolis & St. Paul	Non-Trunk	958	36%	91%	74	28%	89%	8%		
	Trunk	93	4%	9%	9	3%	11%	10%	276	27
TCMA - Minneapolis & St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**		
TCMA - Other cities	Non-Trunk	854	32%	90%	85	33%	89%	10%		
	Trunk	90	3%	10%	10	4%	11%	11%	57	6
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**		
Greater MN metro	Non-Trunk	207	8%	87%	16	6%	70%	8%		
	Trunk	31	1%	13%	7	3%	30%	23%	102	23
Greater MN metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**		
Small urban communities	Non-Trunk	227	9%	67%	29	11%	83%	13%		
	Trunk	112	4%	33%	6	2%	17%	5%	40	2
Small urban communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**		
Rural	Non-Trunk	54	2%	76%	19	7%	76%	35%		
	Trunk	17	1%	24%	6	2%	24%	35%	< 1	< 1
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**		
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***		

Table 22: Trunk Highway Mileage by Urban/Rural Context

Urban/Rural (SPACE)	Mileage	% Mileage
Rural	20,740	80.4%
Small urban communities	2,819	10.9%
TCMA - Other cities	1,581	6.1%
Greater MN metro	305	1.2%
TCMA - Minneapolis and St. Paul	337	1.3%

Trunk Highways - AADT

Crashes along the trunk highway vary by vehicle AADT, as shown in Table 23. Off of the trunk network, nearly 20% of crashes occur on roadways with less than 5,000 AADT, 24% occur on roadways with 5,000-9,999 AADT, and 33% occur where there is 10,000 - 19,999 AADT; only 8% of crashes occur on roadways with 20,000 AADT or greater, which likely reflects the relatively low number of non-trunk roadways that carry these volumes. The severity of crashes off the network follows the same trend, although crashes on the lowest-volume roads are more severe on average (13% of crashes on roadways with less than 5,000 AADT resulted in a KA outcome, compared to 8% of crashes on roadways with 5,000-19,999 AADT and 10% on roadways with 20,000 AADT or higher).

On the trunk network, 19% of crashes occurred where there are 5,000 - 9,999 AADT, but 40% of crashes occurred with AADT of 10,000-19,999 and 26% occurred on roadways with 20,000 AADT or greater. Crash severity follows the same pattern as on the non-trunk roads, but is higher overall. In particular, 23% of crashes on sections of the trunk network with the lowest AADT (less than 3,000) resulted in a KA outcome, far higher than any other volume category (although the sample size is relatively small). Crashes on several higher-volume sections of the trunk network result in a KA 15% of the time. The severity outcomes could be due to several possible factors, including, trunk highways with lower AADT acting as main streets in rural towns, the potential usage of these lower-volume roads as bike routes, and a lack of protected bicycle facilities in general along these roadways.

Table 23: Bicycle Crashes by Vehicle AADT by Trunk Highway, 2016-2019

Trunk Highway	Vehicle AADT	# Crashes	% Crashes	% Crashes (on/off network)	# KA Crashes	% KA Crashes	% KA (on/off network)	% Crashes Resulting in KA
Non-Trunk Highway	0-2,999	223	8%	10%	30	11%	13%	14%
	3,000-4,999	187	7%	8%	22	8%	10%	12%
	5,000-9,999	552	21%	24%	52	20%	23%	9%
	10,000-14,999	452	17%	20%	36	14%	16%	8%
	15,000-19,999	310	12%	13%	24	9%	11%	8%
	20,000-24,999	111	4%	5%	13	5%	6%	12%
	25,000-29,999	27	1%	1%	2	1%	1%	7%
	30,000-34,999	23	1%	1%	3	1%	1%	13%
	35,000+	14	1%	1%	1	0%	0%	7%
	Unknown	401	15%	17%	40	15%	18%	10%
Non-Trunk Highway Total		**2,300**	**87%**	**87%**	**223**	**85%**	**85%**	**10%**
Trunk Highway	0-2,999	22	1%	6%	5	2%	13%	23%
	3,000-4,999	17	1%	5%	1	0%	3%	6%
	5,000-9,999	65	2%	19%	6	2%	16%	9%
	10,000-14,999	86	3%	25%	6	2%	16%	7%
	15,000-19,999	50	2%	15%	7	3%	18%	14%
	20,000-24,999	26	1%	8%	4	2%	11%	15%
	25,000-29,999	15	1%	4%	1	0%	3%	7%
	30,000-34,999	26	1%	8%	4	2%	11%	15%
	35,000+	20	1%	6%	3	1%	8%	15%
	Unknown	16	1%	5%	1	0%	3%	6%
Trunk Highway Total		**343**	**13%**	**13%**	**38**	**15%**	**15%**	**11%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Trunk Highways – Location Type

Of the 343 crashes that occurred along the trunk highway, more than three-quarters of crashes occurred at some kind of intersection; 52% occurred at signals and 24% were at partial or all-way stop-controlled locations, as shown in Table 24. A Larger share of crashes occurred at stop-controlled intersections off the trunk highway network (42%) compared to stop-controlled intersections along the trunk highway network (24%). This may be an indication that there is a lower share of intersections along the trunk highway network that are stop-controlled compared to all non-trunk highway intersections. Furthermore, a greater share of KA crashes were at stop-controlled intersections off the trunk highway network (44% v. 13%).

Table 24: Bicycle Crashes by Location by Trunk Highway, 2016-2019

Trunk Location	Crash Location	# Crashes	% Crashes	% of subtotal crashes	# KA Crashes	% KA Crashes	% of subtotal KA crashes	% Crashes Resulting in KA
Non-Trunk Highway	Stop	967	37%	42%	98	38%	44%	10%
	Signal	730	28%	32%	51	20%	23%	7%
	Segment	481	18%	21%	62	24%	28%	13%
	Other/unknown	122	5%	5%	12	5%	5%	10%
Non-Trunk Highway Total		**2,300**	**87%**	**100%**	**223**	**85%**	**100%**	**10%**
Trunk Highway	Stop	81	3%	24%	5	2%	13%	6%
	Signal	180	7%	52%	21	8%	55%	12%
	Segment	71	3%	21%	10	4%	26%	14%
	Other/unknown	11	0%	3%	2	1%	5%	18%
Trunk Highway Total		**343**	**13%**	**100%**	**38**	**15%**	**100%**	**11%**
Total		***2,643***	***100%***			***100%***		

Trunk Highways – Through Lanes

Table 25 summarizes bicyclist crashes by the number of through lanes and trunk highway status. For both on and off the trunk highway network, overall crashes and KA crashes occurred most frequently along or at streets with two through lanes followed by four through lanes. Interestingly, most of the crashes that occurred along two-lane roads occurred along 30 mph streets for both on and off the trunk highway system and in urban and rural areas (not shown in the table). This may reflect both the overall network having a large share of two-lane streets and bicyclists' route preference (selecting lower-stress streets rather than higher-stress). Statewide bicyclist exposure is not available at the time of this analysis to better estimate bicyclist crash risk. State law during this time period (2016—2019) made reducing speed limits below 30 miles per hour challenging in most cases; therefore, few streets had speed limits lower than 30, which further led to the clustering of bicyclist crashes on 2-lane 30mph roads. Speed limits are explored more fully in a subsequent section.

Table 25: Bicycle Crashes by Location by Number of Through Lanes Trunk Highway, 2016-2019

Trunk Location	Number of Through Lanes	# Crashes	% Crashes	% of subtotal crashes	# KA Crashes	% KA Crashes	% of subtotal KA crashes	% Crashes Resulting in KA
Non-Trunk Highway	1	20	1%	1%	1	0%	0%	5%
	2	1,271	48%	55%	134	51%	60%	11%
	3	174	7%	8%	12	5%	5%	7%
	4	680	26%	30%	57	22%	26%	8%
	5+	152	6%	7%	16	6%	7%	11%
	Unknown	3	0%	0%	3	1%	1%	100%
Non-Trunk Highway Total		**2,300**	**87%**	**87%**	**223**	**85%**	**85%**	**10%**
Trunk Highway	1	2	0%	1%	0	0%	0%	0%
	2	150	6%	44%	20	8%	53%	13%
	3	20	1%	6%	2	1%	5%	10%
	4	133	5%	39%	11	4%	29%	8%
	5+	38	1%	11%	5	2%	13%	13%
Trunk Highway Total		**343**	**13%**	**13%**	**38**	**15%**	**15%**	**11%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Trunk Highways – Urban/Rural

Table 26 summarizes bicyclist crashes by urban/rural context and trunk highway status. Five contexts are considered: TCMA Minneapolis and St. Paul, TCMA Other Cities; Metro – Greater MN, which includes the entire metropolitan region; Small urban communities (called "Rural downtown" in SPACE), which contain rural towns and small urban locations' built-up areas; and Rural. Most bicycle crashes were off the trunk network in the TCMA Minneapolis and St. Paul category, which makes sense, as there are likely more cyclists in Minneapolis and St. Paul than in other locations in the state, and there are proportionally fewer trunk highways and more local roadways in these cities. Interestingly, most KA crashes both on and off the trunk highway network occurred in the TCMA Other Cities category. Notably, there are fewer crashes (as respective proportions) in small urban communities off the trunk highway than on the network. This may be additional evidence of safety issues along the trunk highway network where it interacts with rural towns, perhaps becoming central streets in these more walkable and bikeable areas.

Table 26: Bicycle Crashes by Location by urban/rural context and Trunk Highway, 2016-2019

Trunk Location	Urban/Rural (SPACE)	# Crashes	% Crashes	% of subtotal crashes	# KA Crashes	% KA Crashes	% of subtotal KA crashes	% Crashes Resulting in KA
Non-Trunk Highway	TCMA - Minneapolis and St. Paul	958	36%	42%	74	28%	33%	8%
	TCMA - Other Cities	854	32%	37%	85	33%	38%	10%
	Greater MN Metro	207	8%	9%	16	6%	7%	8%
	Small Urban Communities	227	9%	10%	29	11%	13%	13%
	Rural	54	2%	2%	19	7%	9%	35%
Non-Trunk Highway Total		**2,300**	**87%**	**100%**	**223**	**85%**	**100%**	**10%**
Trunk Highway	TCMA - Minneapolis and St. Paul	93	4%	27%	9	3%	24%	10%
	TCMA - Other Cities	90	3%	26%	10	4%	26%	11%
	Greater MN Metro	31	1%	9%	7	3%	18%	23%
	Small Urban Communities	112	4%	33%	6	2%	16%	5%
	Rural	17	1%	5%	6	2%	16%	35%
Trunk Highway Total		**343**	**13%**	**100%**	**38**	**15%**	**100%**	**11%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Trunk Highways – Sidewalk

Sidewalk data are only available for locations along MnDOT trunk highways or overpasses that cross trunk highways. Table 27 summarizes crashes that occurred at or along trunk highways by the presence of a sidewalk. Most bicyclist crashes occurred along trunk highways where a sidewalk was present. However, trunk highways that lack a sidewalk had more than twice the percentage of crashes resulting in a KA outcome (18%) compared to trunk highways with a sidewalk (8%).

Table 27: Bicyclist crashes at/along trunk highways by presence of sidewalk (excludes crashes off trunk highways), 2016-2019

Presence of sidewalk (trunk highways only)	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
No Sidewalk	103	30%	19	50%	18%
Sidewalk	240	70%	19	50%	8%
Total	***343***	***100%***	***38***	***100%***	***11%***

The *nmloctn* (non-motorized roadway user location) and the *nmaction* (non-motorized roadway user action) variables include information that can provide additional insight into the bicyclists' relationship to sidewalks at the time of the crash. However, both of these attributes do not consistently or accurately convey if the bicyclist was riding their bike along a sidewalk before the crash occurred. The *nmloctn* attribute records where the bicyclist was located at the time of the crash. Of the 343 crashes along trunk highways, only 9 crashes were coded as the bicyclist at/along a sidewalk. The *nmaction* attribute reflects how the bicyclist was traveling leading up to the crash. This attribute better captures if the bicyclist was riding along a sidewalk or within the street, but it still does not entirely catch all crashes in which the bicyclist was using the sidewalk rather than the street, particularly when the bicyclist was crossing the street at an intersection. Note that the *nmloctn* field also allows officers to report a bicyclist's pre-crash location as a shared use path, bicycle lane, or shoulder/roadside, so our findings from this field should represent true sidewalk locations, not merely any sidewalk-level VRU facility. The *nmaction* field, however, does not have options to classify non-sidewalk dedicated facilities (e.g., sidepath, shared use path, cycle track, etc.). These two fields are limited in that they require an officer to choose one response for each, even if multiple responses are accurate. For example, it is possible for a driver to hit a bicyclist while the bicyclist is on the sidewalk at a driveway access ramp, but a reporting officer must choose *either* sidewalk or driveway access as the pre-crash location – not both.

To increase the chance of capturing sidewalk crashes along trunk highways, all crash narratives were systematically scanned for the word "sidewalk" (or some other spelling of sidewalk). The following criteria were used to code crashes as the bicyclist possibly using the sidewalk:

- Narrative suggests the bicyclist used the sidewalk prior to the crash
- Narrative suggests the bicyclist was using the crosswalk AND the crash occurred along a trunk sidewalk WITH a sidewalk
- *nmloctn* = 'sidewalk'
- *nmaction* = 'Walk/cycle on Sidewalk'

Table 28 shows bicyclist crashes along/at trunk highways using the flag that indicates if the bicyclist possibly used the sidewalk or a sidewalk-level facility before the crash. Interestingly, bicyclist crashes that occurred along trunk highways most frequently occurred if the bicyclist was using the sidewalk or a crosswalk connected to a sidewalk (40%) rather than riding within the road for overall crashes. This is not surprising given that most trunk highways lack low-stress on-street bicycle facilities designed to encourage bicyclists of all ages and abilities to ride within the road or in dedicated facilities rather than on the sidewalk.

Furthermore, the need for these low-stress facilities is not just preference-based: most KA crashes occurred along trunk highways that lacked a sidewalk and where there was no indication that the bicyclist was riding along the sidewalk (50% of KA crashes) – many of these crashes would likely have been prevented if the cyclist had been separated from vehicular traffic.

Table 28: Bicyclist crashes at/along Trunk Highways by presence of sidewalk and if the bicyclists possibly used the sidewalk before the crash (excludes crashes off trunk highways), 2016-2019

Presence of sidewalks (trunk highways only)	Possible sidewalk usage flag	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
No Sidewalk	No	94	27%	19	50%	20%
	Yes	9	3%	0	0%	0%
Sidewalk	No	104	30%	14	37%	13%
	Yes	136	40%	5	13%	4%
Total		***343***	***100%***	***38***	***100%***	***11%***

Table 29 summarizes all crashes (statewide) that were flagged as possibly being related to a sidewalk using the method described above. There were 766 crashes (29% of all crashes) and 46 KA crashes (18% all KA crashes). This table illustrates the need for an attribute to be added to the crash report that is specific to whether the bicyclist was riding along the sidewalk before/during the crash. Currently, the crash report only includes the location of the crash and the reported action, which do not consistently capture sidewalk riding. In fact, only 47% of crashes and 37% of KA crashes that were flagged using the above screening process reported the crash as having occurred at a sidewalk or the bicyclist as cycling on the sidewalk. Our understanding of bicyclist riding on the sidewalk versus on the street and the associate crash risk is limited without specific and reliable data to analyze. We strongly recommend including a sidewalk riding attribute in future crash report revisions.

Table 29: Possibly Sidewalk Related Bicyclist Crashes by Reported Location and Action, 2016-2019

	Police Reported Location	Police Reported Action	# Crashes	% Crashes	# KA Crashes	% KA Crashes
Crashes flagged by the research team as the bicyclist possibly using the sidewalk at before or at the time of the crash	**Sidewalk**	**Cycle on Sidewalk**	**87**	**11%**	**2**	**4%**
		Other	11	1%	0	0%
		Adjacent to Roadway	5	1%	0	0%
		Cycle Across Traffic/Roadway	5	1%	0	0%
		Cycle Against Traffic	4	1%	0	0%
		Cycle With Traffic	2	0%	0	0%
		In Roadway - Other	1	0%	0	0%
	NULL	Other	5	1%	0	0%
	Bicycle Lane	Cycle With Traffic	2	0%	0	0%
		Cycle on Sidewalk	**1**	**0%**	**0**	**0%**
	Driveway Access	**Cycle on Sidewalk**	**38**	**5%**	**3**	**7%**
		Other	4	1%	0	0%
		Cycle Across Traffic/Roadway	4	1%	0	0%
	Intersection – Marked Crosswalk	Cycle Across Traffic/Roadway	206	27%	10	22%
		Cycle on Sidewalk	**119**	**16%**	**8**	**17%**
		Cycle With Traffic	16	2%	0	0%
		Cycle Against Traffic	9	1%	0	0%
		Other	8	1%	1	2%
		In Roadway - Other	7	1%	1	2%
		Adjacent to Roadway	1	0%	0	0%
		Cycle Across Traffic/Roadway	18	2%	1	2%

	Police Reported Location	Police Reported Action	# Crashes	% Crashes	# KA Crashes	% KA Crashes
	Intersection – Other	**Cycle on Sidewalk**	**15**	**2%**	**0**	**0%**
		Cycle With Traffic	5	1%	1	2%
		Cycle Against Traffic	3	0%	1	2%
		Other	1	0%	0	0%
	Intersection – Unmarked Crosswalk	Cycle Across Traffic/Roadway	65	8%	6	13%
		Cycle on Sidewalk	**62**	**8%**	**4**	**9%**
		Other	5	1%	0	0%
		Cycle With Traffic	5	1%	2	4%
		Cycle Against Traffic	4	1%	0	0%
		In Roadway - Other	3	0%	2	4%
	Midblock – Marked Crosswalk	Cycle Across Traffic/Roadway	4	1%	1	2%
		Cycle Against Traffic	1	0%	0	0%
		Cycle on Sidewalk	**1**	**0%**	**0**	**0%**
	Other	Cycle Across Traffic/Roadway	3	0%	0	0%
		Cycle on Sidewalk	**2**	**0%**	**0**	**0%**
		Other	1	0%	0	0%
	Shared-Use Path or Trail	Cycle on Sidewalk	1	0%	0	0%
	Shoulder/Roadside	**Cycle on Sidewalk**	**4**	**1%**	**0**	**0%**
		Cycle Against Traffic	3	0%	0	0%
		In Roadway - Other	2	0%	0	0%
		Cycle With Traffic	2	0%	1	2%
		Adjacent to Roadway	1	0%	1	2%
		Other	1	0%	0	0%
		Cycle Across Traffic/Roadway	1	0%	0	0%
	Travel Lane – Other Location	Cycle Across Traffic/Roadway	5	1%	0	0%
		Cycle With Traffic	4	1%	0	0%
		In Roadway - Other	3	0%	1	2%
		Cycle on Sidewalk	**2**	**0%**	**0**	**0%**
		Other	1	0%	0	0%
	Unknown	Other	2	0%	0	0%
		Cycle Across Traffic/Roadway	1	0%	0	0%
	Total		**766**	**100%**	**46**	**100%**
	Reported Location: *Sidewalk* Total		**115**	**15%**	**2**	**4%**
	Reported Action: *Cycle on Sidewalk* Total		**244**	**32%**	**15**	**33%**
	Any Reported Action or Location Related to Sidewalk Any sidewalk		**359**	**47%**	**17**	**37%**

Hit and Run

The project team also reviewed the frequency of hit and run bicycle crashes, shown in Table 30. Most of bicycle crashes (84%) and KA crashes (17%) were not hit and run. Hit and run crashes were not typically more or less severe than non-hit and run crashes, with both responses having roughly one in ten crashes resulting in a KA outcome.

Table 30: Bicycle Hit and Run crashes, Statewide, 2016-2019

Crash Response	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Hit and Run	419	16%	45	17%	11%
Not Hit and Run	2,224	84%	216	83%	10%
Total	**2,643**	**100%**	**261**	**100%**	**10%**

Table 31 summarizes bicyclist hit and run crashes by urban/rural context. The distribution of hit and run crashes was similar between most urban and rural areas in terms of the percentage of crashes (all and KA) that were hit and run, however TCMA Minneapolis and St. Paul had the largest relative share of hit and run responses for all crashes (20%) and KA crashes (11%). In all cases, rural crashes were more likely to be severe.

Table 31: Bicycle Hit and Run Crashes by Urban/Rural Context, 2016-2019

Urban/Rural	Crash Response	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KSI (within urban/ rural)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	Hit and Run	206	8%	20%	9	3%	11%	4%
	Not Hit and Run	845	32%	80%	74	28%	89%	9%
TCMA - Minneapolis and St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other Cities	Hit and Run	65	2%	7%	0	0%	0%	0%
	Not Hit and Run	879	33%	93%	95	36%	100%	11%
TCMA - Other Cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN Metro	Hit and Run	19	1%	8%	2	1%	9%	11%
	Not Hit and Run	219	8%	92%	21	8%	91%	10%
Greater MN Metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small Urban Communities	Hit and Run	20	1%	6%	1	0%	3%	5%
	Not Hit and Run	319	12%	94%	34	13%	97%	11%
Small Urban Communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural	Hit and Run	6	0%	8%	5	2%	20%	83%
	Not Hit and Run	65	2%	92%	20	8%	80%	31%
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Functional Classification

More than half of all crashes and 46% of KA crashes occurred on minor arterials. This indicates a serious safety issue with these roadways. Local roadways and major collectors had the next two largest shares of crashes and KA crashes. When looking at crashes on a per mile basis, minor arterials rise to the top for all crashes (10.8 crashes per 100 miles) and KA crashes (0.9 KA crashes per mile), followed by principal arterials (4.8 crashes per 100 miles; 0.5 KA crashes per 100 miles). When looking at the percentage of crashes that resulted in a KA outcome, minor collectors, local, and principal arterials had the largest share of crashes that resulted in a KSI outcome. Interestingly, local streets had the second largest share of crashes that resulted in a KA outcome (12%), which may indicate systemic safety issues at these locations.

Table 32: All Bicycle Crashes by Functional Classification, 2016-2019

Functional Class	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA	% Roadway Mileage	Crashes per 100 Miles	KA per 100 Miles
Minor Arterial	1,383	52%	121	46%	9%	9%	10.8	0.9
Major Collector	495	19%	44	17%	9%	12%	2.8	0.2
Local	437	17%	53	20%	12%	69%	0.4	0.1
Principal Arterial	272	10%	30	11%	11%	4%	4.8	0.5
Minor Collector	55	2%	12	5%	22%	6%	0.6	0.1
Unknown	1	0%	1	0%	100%			
Total	**2,643**	**100%**	**261**	**100%**	**10%**		**1.79**	**0.18**

Table 33 summarizes bicyclist crashes by functional classification and urban/rural context. These findings stratified by urban/rural context are similar to statewide trends – crashes are concentrated along minor arterials.

Table 33: All Bike Crashes by Functional Classification, Rural vs. Urban Context, 2016-2019

Urban/Rural	Functional Class	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	Principal Arterial	38	1%	4%	9	3%	11%	24%
	Minor Arterial	631	24%	60%	46	18%	55%	7%
	Major Collector	211	8%	20%	9	3%	11%	4%
	Local	171	6%	16%	19	7%	23%	11%
TCMA - Minneapolis and St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other cities	Principal Arterial	124	5%	13%	8	3%	8%	7%
	Minor Arterial	505	19%	53%	49	19%	52%	10%
	Major Collector	153	6%	16%	19	7%	20%	12%
	Minor Collector	10	0%	1%	2	1%	2%	20%
	Local	152	6%	16%	17	7%	18%	11%
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN metro	Principal Arterial	28	1%	12%	5	2%	22%	18%
	Minor Arterial	117	4%	49%	8	3%	35%	7%
	Major Collector	45	2%	19%	5	2%	22%	11%
	Minor Collector	15	1%	6%	2	1%	9%	13%
	Local	32	1%	13%	2	1%	9%	6%
	Unknown	1	0%	0%	1	0%	4%	100%
Greater MN metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small urban communities	Principal Arterial	76	3%	22%	6	2%	17%	8%
	Minor Arterial	105	4%	31%	9	3%	26%	9%
	Major Collector	66	2%	19%	5	2%	14%	8%
	Minor Collector	22	1%	6%	4	2%	11%	18%
	Local	70	3%	21%	11	4%	31%	16%
Small urban communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural	Principal Arterial	6	0%	8%	2	1%	8%	33%
	Minor Arterial	25	1%	35%	9	3%	36%	36%
	Major Collector	20	1%	28%	6	2%	24%	30%
	Minor Collector	8	0%	11%	4	2%	16%	50%
	Local	12	0%	17%	4	2%	16%	33%
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Table 34 summarizes intersection bicyclists crashes by the highest and lowest functional classification at the intersection. Most crashes (29%) and KA crashes (24%) occurred at intersections between minor arterials and local streets followed by major collectors and local streets (14% of all intersection crashes). Exploring the pre-crash action of the bicyclist at both locations, nearly half of all crashes (48%) and more than half of KA crashes (56%) indicate the bicyclists was cycling across traffic/roadway. Looking only at crashes at these locations with this crossing pre-crash action, 60% of crashes and 68% of KA crashes were at an intersection with some type of stop control (most likely two-way stop signs). This indicates serious safety issues at locations in which bicyclists are attempting to cross a major street but do not have a traffic control or crossing enhancement to facilitate a safe crossing.

Our data also suggest safety concerns at larger intersections – where a minor arterial meets another minor arterial or major collector. These combinations contribute 25% of all bicyclist crashes and 23% of severe bicyclist crashes. Even at signalized intersections, careful attention to design is needed to ensure safe passage for bicyclists.

Table 34: Intersection Bicycle Crashes by Highest and Lowest Functional Classification at the Intersection, 2016-2019

Highest Functional Class	Lowest Functional Class	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
Principal Arterial	Principal Arterial	29	1%	4	2%	14%
	Minor Arterial	59	3%	4	2%	7%
	Major Collector	40	2%	6	3%	15%
	Minor Collector	11	1%	0	0%	0%
	Local	114	5%	10	5%	9%
Minor Arterial	Minor Arterial	277	13%	23	12%	8%
	Major Collector	253	12%	21	11%	8%
	Minor Collector	21	1%	2	1%	10%
	Local	615	29%	46	24%	8%
Major Collector	Major Collector	92	4%	7	4%	8%
	Local	289	14%	25	13%	9%
Minor Collector	Minor Collector	6	0%	0	0%	0%
	Local	33	2%	8	4%	24%
Local	Local	252	12%	33	17%	13%
Total		***2,091***	***100%***	***189***	***100%***	***9%***

Number of Through Lanes

Table 35 shows the distribution of crashes and crash severity for the study data. Several trends emerge. First, most crashes occur on two- and four-lane roadways, and these roadways had the most severe crashes as a share of all KA bicycle crashes. This could be because there are safety issues associated with many of these roadways, or it could be because two- and four-lane roadways comprise the larger shares of the network.

The data to needed to parse this difference was not available to the project team at the time of the analysis, such as centerline mileage by number of through lanes and statewide roadway characteristics to better understand the configuration of the street along these two- and four-lane roads.

Table 35: Bicycles Crashes at Intersections by Number of Lanes, 2016-2019

# Through Lanes	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% KA of All Intersection Crashes
1	22	1%	1	0%	5%
2	1,421	54%	154	59%	11%
3	194	7%	14	5%	7%
4	813	31%	68	26%	8%
5+	190	7%	21	8%	11%
Unknown	3	0%	3	1%	100%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Similar trends emerge when separating by urban and rural context, albeit with some nuance, as shown Table 36. In general, more crashes occurred on roadways with two or four lanes, and in rural areas, crashes were concentrated on two-lane roads and were more likely to be severe than those on other roadways. In TCMA other cities and greater MN metro, in contrast, crashes on roadways with five or more lanes tended to be the most severe. These patterns likely reflect the interaction of roadway design, vehicle speed, and countermeasure presence in each area.

Table 36: Bicycle Crashes by the Number of Through Lanes and Urban/Rural Context, 2016-2019

Urban/ Rural	# Through Lanes	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	1	12	0%	1%	1	0%	1%	8%
	2	486	18%	46%	38	15%	46%	8%
	3	105	4%	10%	9	3%	11%	9%
	4	358	14%	34%	27	10%	33%	8%
	5+	90	3%	9%	8	3%	10%	9%
TCMA - Minneapolis and St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other cities	1	7	0%	1%	0	0%	0%	0%
	2	512	19%	54%	56	21%	59%	11%
	3	69	3%	7%	4	2%	4%	6%
	4	277	10%	29%	25	10%	26%	9%
	5+	79	3%	8%	10	4%	11%	13%
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN metro	1	1	0%	0%	0	0%	0%	0%
	2	123	5%	52%	12	5%	52%	10%
	3	10	0%	4%	0	0%	0%	0%
	4	89	3%	37%	6	2%	26%	7%
	5+	13	0%	5%	3	1%	13%	23%
	Unknown	2	0%	1%	2	1%	9%	100%
Greater MN metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small urban communities	1	2	0%	1%	0	0%	0%	0%
	2	242	9%	71%	25	10%	71%	10%
	3	8	0%	2%	1	0%	3%	13%
	4	79	3%	23%	8	3%	23%	10%
	5+	7	0%	2%	0	0%	0%	0%
	Unknown	1	0%	0%	1	0%	3%	100%
Small urban communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural	2	58	2%	82%	23	9%	92%	40%
	3	2	0%	3%	0	0%	0%	0%
	4	10	0%	14%	2	1%	8%	20%
	5+	1	0%	1%	0	0%	0%	0%
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Speed limit

Vehicle speed is a common risk factor for bicycle crashes and crash severity. Table 37 shows crashes segmented by posted speed limit. While posted speed limit is not always indicative of prevailing vehicle speed, it is used as a proxy in this analysis. Most crashes (58%) and KA crashes (52%) occurred in places where there are 30mph speed limits. This could be because there are many roadways where the posted speed limit is 30mph, because roadways where vehicle speeds are 30 mph are perceived by cyclists as "low enough" stress roadways, or other reasons; however, there are notably fewer crashes and KA crashes on roadways signed at 25mph or lower.

Crashes were more likely to be severe on higher speed roadways, with the likelihood of a severe crash increasing as posted speed increased. For example, 7% of crashes were severe at 35mph, compared to 11% at 40mph and 16% at 50mph or more. While this finding is expected, as higher speed crashes release more energy during the crash, resulting in more serious injuries – it also underscores the safety benefits of lower speeds.

Table 37: Bicycle Crashes by Speed Limit, 2016-2019

Posted Speed Limit (mph)	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
<25	34	1%	0	0%	0%
25	45	2%	3	1%	7%
30	1,545	58%	137	52%	9%
35	287	11%	19	7%	7%
40	228	9%	24	9%	11%
45	144	5%	22	8%	15%
50+	295	11%	48	18%	16%
Unknown	65	2%	8	3%	12%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

In general, the same trends are present across the urban—rural spectrum, as shown in Table 38, with some differences. First, compared to TCMA, more of the crashes that occur on high-speed segments in rural areas are likely to result in a serious injury or death. This differential should be further investigated to understand its cause. For example, many non-highway (non-trunk) rural roads have speed limits above 50 miles per hour but are very narrow with no shoulders, affording no space for safe or comfortable passing when bicycling with traffic on these roads. If people are more likely to drive above the posted speed limit in rural areas due to lack of enforcement or environmental cues to slow down, such that a crash in a 50-mph zone actually occurs at 60 mph, this crash would be more likely to be severe. There may also be connections with post-crash care that result in a higher likelihood of a serious injury or fatality given the time that it takes for the injured person to be brought to or reached by adequate emergency care. These and other factors need to be investigated and understood in order to be addressed by the state.

Table 38:Bicycle Crashes by Speed Limit and Urban/Rural Context, 2016-2019

Urban/ Rural (SPACE)	Posted Speed Limit	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	<25	14	1%	1%	0	0%	0%	0%
	25	38	1%	4%	3	1%	4%	8%
	30	877	33%	83%	65	25%	78%	7%
	35	47	2%	4%	2	1%	2%	4%
	40	24	1%	2%	7	3%	8%	29%
	45	5	0%	0%	0	0%	0%	0%
	50+	22	1%	2%	3	1%	4%	14%
	Unknow	24	1%	2%	3	1%	4%	13%
TCMA - Minneapolis and St. Paul		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other cities	<25	10	0%	1%	0	0%	0%	0%
	25	4	0%	0%	0	0%	0%	0%
	30	274	10%	29%	30	11%	32%	11%
	35	192	7%	20%	14	5%	15%	7%
	40	153	6%	16%	13	5%	14%	8%
	45	105	4%	11%	15	6%	16%	14%
	50+	188	7%	20%	22	8%	23%	12%
	Unknow	18	1%	2%	1	0%	1%	6%
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN Metro	<25	6	0%	3%	0	0%	0%	0%
	25	1	0%	0%	0	0%	0%	0%
	30	158	6%	66%	12	5%	52%	8%
	35	20	1%	8%	0	0%	0%	0%
	40	28	1%	12%	3	1%	13%	11%
	45	13	0%	5%	2	1%	9%	15%
	50+	8	0%	3%	4	2%	17%	50%
	Unknow	4	0%	2%	2	1%	9%	50%
Greater MN Metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small urban communities	<25	4	0%	1%	0	0%	0%	0%
	25	1	0%	0%	0	0%	0%	0%
	30	232	9%	68%	28	11%	80%	12%
	35	27	1%	8%	2	1%	6%	7%
	40	22	1%	6%	1	0%	3%	5%
	45	16	1%	5%	2	1%	6%	13%
	50+	20	1%	6%	1	0%	3%	5%
	Unknow	17	1%	5%	1	0%	3%	6%
Small urban communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural	25	1	0%	1%	0	0%	0%	0%
	30	4	0%	6%	2	1%	8%	50%
	35	1	0%	1%	1	0%	4%	100%
	40	1	0%	1%	0	0%	0%	0%
	45	5	0%	7%	3	1%	12%	60%
	50+	57	2%	80%	18	7%	72%	32%
	Unknow	2	0%	3%	1	0%	4%	50%
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Traffic Volume

Table 39 summarizes bicyclist crashes by vehicle annual average daily traffic (AADT). AADT is not available for all streets across the state; as such, 16% of all bicycle crashes and KA crashes occurred along streets that lack documented AADT. The vast majority of the street network with available AADT is comprised of streets with an AADT less than 3,000 vehicles per day (VPD), accounting for 84% of the network mileage but only 9% of crashes. Even if we assume all crashes that do not have available AADT occurred along streets with less than 3,000 VPD, that will still result in a low crash per mile rate (6.5 crashes per 100 miles) and KA crashes per mile (0.8 KA crashes per 100 miles) than most other AADT categories.

However, the AADT findings also appear to corroborate the findings about functional classification above -- crashes that occurred along street with an AADT less than 3,000 were equally likely to result in a KA outcome (14%) as crashes that occurred along streets with an AADT between 30,000-34,999. This finding suggests safety issues along what is commonly considered lower-stress streets (lower volume and lower speed) that should be further investigated.

Furthermore, lower-volume streets had a larger share of bicyclist crashes that involved a bicyclist who was less than 18 years of age. One in three crashes that occurred along a street with less than 5,000 VPD involved a youth bicyclist, compared to 20% for streets with an AADT greater than 15,000. When looking at these lower volume streets (less than 5,000 AADT), more than half of all crashes in small urban communities involved a youth bicyclist, followed by Metro Greater MN (36%), Metro (26%), and rural (14%).

Most crashes occurred along streets with an AADT between 5,000-9,999 VPD (23%) and 10,000-14,999 VPD (20%), although these categories had among the lowest rates of severe crashes on a per-crash basis.

Table 39: Bicycle Crashes by Vehicle AADT, 2016-2019

Vehicle AADT	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA	Crashes per 100 Mile*	KA Crashes per 100 Mile*	% Street Mileage (where AADT is available)
0-2,999	245	9%	35	13%	14%	0.5	0.1	84%
3,000-4,999	204	8%	23	9%	11%	6.0	0.7	6%
5,000-9,999	617	23%	58	22%	9%	19.3	1.8	5%
10,000-14,999	538	20%	42	16%	8%	44.7	3.5	2%
15,000-19,999	360	14%	31	12%	9%	51.1	4.4	1%
20,000-24,999	137	5%	17	7%	12%	38.8	4.8	1%
25,000-29,999	42	2%	3	1%	7%	23.4	1.7	<1%
30,000-34,999	49	2%	7	3%	14%	35.8	5.1	<1%
35,000+	34	1%	4	2%	12%	6.0	0.7	1%
Unknown	417	16%	41	16%	10%	--	--	--
Total	***2,643***	***100%***	***261***	***100%***	***10%***	--	--	**100%**

*Mileage is only for streets where AADT is available. AADT is not available statewide.

Table 40 summarizes bicyclist crashes by vehicle AADT and urban/rural context. This table highlights differences between urban and rural roadway operations as they relate to bicyclist crashes. In urban areas, all crashes (61% of urban crashes) and KA crashes (57% of urban KA crashes) were concentrated along streets with an AADT between 5,000-20,000 VPD. However, these crashes were less likely to result in a KSI outcome, which may indicate that these streets have larger bicyclist volumes and therefore greater separation between motorists and bicyclists, greater awareness for bicyclists, or slower vehicle speeds.

Table 41 explores this by summarizing KA bicyclist crashes by vehicle AADT and posted speed limit by urban/rural context. These tables show that the urban crashes along streets with an AADT between 5-20k resulting in a lower percentage of KA outcomes are mostly concentrated along lower-speed streets (30 mph or lower).

Conversely, most crashes in rural areas (60% of all crashes; 70% of KA crashes) occurred along streets with less than 10,000 VPD and, in keeping with the findings from Table 40, the crashes on the lowest volume roads were disproportionately severe. Looking at the posted speed limits of those streets provides insight into why: nearly half of the rural bicyclist KSI crashes on low-volume roads occurred at posted speed limits of 50 mph or higher, underscoring the criticality of speed to injury severity and the importance of understanding the nature of these crashes.

Table 40: Bicycle Crashes by Vehicle AADT and Urban/Rural Context, 2016-2019

Urban/ Rural (SPACE)	Vehicle AADT	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA
TCMA and Greater MN Metro	<3,000	152	6%	7%	10	4%	5%	7%
	3,000-4,999	152	6%	7%	17	7%	8%	11%
	5,000-9,999	516	20%	23%	47	18%	23%	9%
	10,000-14,999	493	19%	22%	36	14%	18%	7%
	15,000-19,999	342	13%	15%	31	12%	15%	9%
	20,000-24,999	122	5%	5%	15	6%	7%	12%
	25,000-29,999	41	2%	2%	3	1%	1%	7%
	30,000-34,999	46	2%	2%	7	3%	3%	15%
	35,000+	32	1%	1%	4	2%	2%	13%
	Unknown	337	13%	15%	31	12%	15%	9%
Urban Total		**2,233**	**84%**	**100%**	**201**	**77%**	**100%**	**9%**
Rural and Small Urban Communities	<3,000	93	4%	23%	25	10%	42%	27%
	3,000-4,999	52	2%	13%	6	2%	10%	12%
	5,000-9,999	101	4%	25%	11	4%	18%	11%
	10,000-14,999	45	2%	11%	6	2%	10%	13%
	15,000-19,999	18	1%	4%	0	0%	0%	0%
	20,000-24,999	15	1%	4%	2	1%	3%	13%
	25,000-29,999	1	0%	0%	0	0%	0%	0%
	30,000-34,999	3	0%	1%	0	0%	0%	0%
	35,000+	2	0%	0%	0	0%	0%	0%
	Unknown	80	3%	20%	10	4%	17%	13%
Rural Total		**410**	**16%**	**100%**	**60**	**23%**	**100%**	**15%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Table 41: KA Bicycle Crashes by Vehicle AADT, posted speed limit, and Urban/Rural Context, 2016-2019

Urban/ Rural (SPACE)	Vehicle AADT	Posted Speed Limit								*Total*
		<25	25	30	35	40	45	50+	Unknown	
TCMA and Greater MN Metro	0-2,999	0	0	8	0	0	1	1	0	*10*
	3,000-4,999	0	0	7	2	1	2	2	3	*17*
	5,000-9,999	0	1	24	6	4	4	6	2	*47*
	10,000-14,999	0	0	23	3	2	5	3	0	*36*
	15,000-19,999	0	0	16	3	7	2	3	0	*31*
	20,000-24,999	0	0	4	1	4	1	5	0	*15*
	25,000-29,999	0	0	2	0	1	0	0	0	*3*
	30,000-34,999	0	0	2	0	1	1	3	0	*7*
	35,000+	0	0	0	0	2	0	2	0	*4*
	Unknown	0	2	21	1	1	1	4	1	*31*
Urban Total		**0**	**3**	**107**	**16**	**23**	**17**	**29**	**6**	***201***
Rural and Small Urban Communities	0-2,999	0	0	9	1	0	3	11	1	*25*
	3,000-4,999	0	0	2	1	1	0	2	0	*6*
	5,000-9,999	0	0	5	1	0	1	4	0	*11*
	10,000-14,999	0	0	5	0	0	0	1	0	*6*
	15,000-19,999	0	0	0	0	0	0	0	0	*0*
	20,000-24,999	0	0	0	0	0	1	1	0	*2*
	25,000-29,999	0	0	0	0	0	0	0	0	*0*
	30,000-34,999	0	0	0	0	0	0	0	0	*0*
	35,000+	0	0	0	0	0	0	0	0	*0*
	Unknown	0	0	9	0	0	0	0	1	*10*
Rural Total		**0**	**0**	**30**	**3**	**1**	**5**	**19**	**2**	***60***
Total		***0***	***3***	***137***	***19***	***24***	***22***	***48***	***8***	***261***

HERE – Entertainment, Retail, and Restaurants

The 2019 Pedestrian Safety Analysis crash tree analysis found pedestrian crashes were highly associated with pedestrian trip attracting destinations such as entertainment establishment, retail, and restaurants. Table 42 summarizes bicyclist crashes that are within 100 meters[8] of any of those destinations. Indeed, destinations appear to have some correlation with crashes, as 42% of all crashes were within 100 meters of one of the target destinations; however, only 34% of KA crashes were within this buffer.

[8] 100 meters is the same distance threshold used in the 2019 Pedestrian Safety Analysis.

Table 42: Bicycle Crashes Within 100 Meters of an Entertainment, Retail, or Restaurant Establishment, 2016-2019

Within 100m of entertainment, retail, or restaurant	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
No	1,542	58%	172	66%	11%
Yes	1,101	42%	89	34%	8%
Total	*2,643*	*100%*	*261*	*100%*	*10%*

Table 43 summarizes crashes by entertainment, retail, and restraint locations by urban/rural context. As is expected given land use patterns, crashes that occurred in more urban areas had a higher percentage of crashes and KA crashes near these target destinations compared to rural areas crashes (38%) and KA crashes (18%).

Table 43: Bicycle Crashes by Within 100 Meters of an Entertainment, Retail, or Restaurant Establishment and Urban/Rural Context, 2016-2019

Urban/ Rural	Within 100m of entertainment, retail, or restaurant	# Crashes	% Crashes	% Crashes (within geo)	# KA Crashes	% KA Crashes	% KA (within geo)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	No	529	20%	50%	47	18%	57%	9%
	Yes	522	20%	50%	36	14%	43%	7%
TCMA - Minneapolis and St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other cities	No	624	24%	66%	61	23%	64%	10%
	Yes	320	12%	34%	34	13%	36%	11%
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN metro	No	136	5%	57%	15	6%	65%	11%
	Yes	102	4%	43%	8	3%	35%	8%
Greater MN metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small urban communities	No	185	7%	55%	24	9%	69%	13%
	Yes	154	6%	45%	11	4%	31%	7%
Small urban communities Total		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural	No	68	3%	96%	25	10%	100%	37%
	Yes	3	0%	4%	0	0%	0%	0%
Rural Total		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		*2,643*	*100%*	*100%*	*261*	*100%*	*100%*	*10%*

Presence of Transit – Intersection Crashes

Transit serving intersections may create additional conflict points for cyclists, so the project team reviewed bicycle crashes by the presence of nearby transit stops, shown in Table 44. There were no bicycle crashes in proximity to transit in the rural context, as shown in Table 45, so Table 44 only applies to bicycle crashes in TCMA and Greater MN Metro locations. Most crashes and severe crashes are not near transit stops. While this is encouraging given the important role of both bicycling and transit in a healthy transportation system, still 78 KA crashes occurred in proximity to transit. However, when looking crashes split by urban/rural context, crashes within the TCMA Minneapolis and St. Paul crashes occurred most often near transit stop. Further crash trees can investigate the scenarios of these crashes to ensure safety for bicyclists in multimodal areas.

Table 44: Bicycle Crashes by Proximity to Transit, 2016-2019

Proximity to Transit Stop	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA
No	1,606	61%	183	70%	11%
Yes	1,037	39%	78	30%	8%
Total	**2,643**	**100%**	**261**	**100%**	**10%**

Table 45: Bicycle Crashes by Proximity to Transit and urban/rural context, 2016-2019

Urban/Rural (SPACE)	Proximity to Transit Stop	# Crashes	% Crashes	% Crashes (within urban/ rural)	# KA Crashes	% KA Crashes	% KA (within urban/ rural)	% Crashes Resulting in KA
TCMA - Minneapolis and St. Paul	No	399	15%	38%	38	15%	46%	10%
	Yes	652	25%	62%	45	17%	54%	7%
TCMA - Minneapolis and St. Paul Total		**1,051**	**40%**	**100%**	**83**	**32%**	**100%**	**8%**
TCMA - Other cities	No	560	21%	59%	62	24%	65%	11%
	Yes	384	15%	41%	33	13%	35%	9%
TCMA - Other cities Total		**944**	**36%**	**100%**	**95**	**36%**	**100%**	**10%**
Greater MN metro	No	237	9%	100%	23	9%	100%	10%
	Yes	1	0%	0%	0	0%	0%	0%
Greater MN metro Total		**238**	**9%**	**100%**	**23**	**9%**	**100%**	**10%**
Small urban communities		**339**	**13%**	**100%**	**35**	**13%**	**100%**	**10%**
Rural		**71**	**3%**	**100%**	**25**	**10%**	**100%**	**35%**
Total		***2,643***	***100%***	***100%***	***261***	***100%***	***100%***	***10%***

Bike Facilities

Bike facility data were reviewed to help us understand the relationship between bicyclist crashes and bike facilities, with the understanding that statewide exposure data is not available to account for bicyclist volumes. The research team decided to omit this analysis as the bike facility appears to be incomplete and outdated. According to the Minnesota Geospatial Commons, the data was last updated in 4/6/2007 and does not include all existing facilities throughout the state.

For example, any facilities such as protected or separated bike lanes, neighborhood greenways, intersection crossing enhancements, and many other safety countermeasures and bike facility designs that have been improved and installed in 2007 are not represented in this data. Additionally, these data are missing marked shared lanes, which often have moderate bicyclist volumes and higher crash risk than other facilities that provide more separation between moving traffic and people riding bicycles.

Furthermore, statewide bicyclist volumes are not available throughout the state to help us better estimate risk. Lower-stress facilities, such as protected bike lanes, often have higher volumes of bicyclists which may translate to higher frequencies of crashes despite a lower crash risk. Therefore, higher crash frequencies do not necessarily reflect higher crash risk, and, conversely, the absence of reported crashes does not necessarily reflect the absence of crash risk.

Future data collection efforts should work towards creating a more recent and detailed statewide network or existing bicycle facility both on and off trunk highways.

SPACE Score

Figure 2 Displays the distribution of bicyclist crashes by severity and SPACE score. MnDOT developed the Pedestrian and Cycling Environment (SPACE) methodology. This method and corresponding output dataset score half-mile hexagons across the entire state based on 19 variables describing demographic, economic, and transportation characteristics. The full method is documented in an internal memo titled "Statewide Bicycle/Pedestrian Suitability Analysis.[9]"

The research team examined the distribution of crashes by SPACE score and found that higher numbers of crashes occurred in areas with mid-range SPACE scores (

Figure 2). The percentage of high-severity crashes did not follow this pattern, and there appears to be an inverse correlation between the percentage of severe crashes and SPACE score. This possible inverse correlation may be due to lower motor vehicle speeds in locations with higher SPACE scores (for example, due to congestion, existing roadway design, or lower posted speed limits) or greater motorist expectation of bicyclist presence. Further research would be needed to understand the relationship between SPACE score and bicyclist safety in greater detail.

9 Eric Devoe, Statewide Bicycle/Pedestrian Suitability Analysis, 2019-06-25.

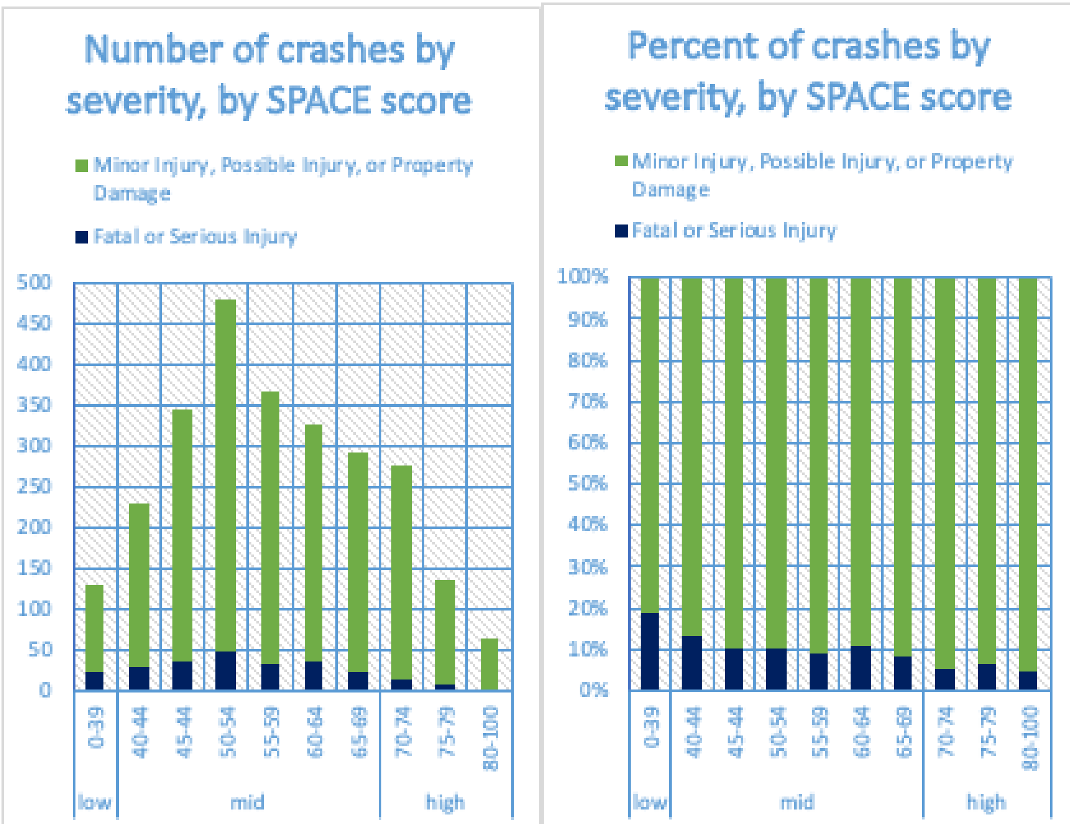


Figure 2: Distribution of Bicyclist Crashes by Severity and SPACE Score, 2016-2019

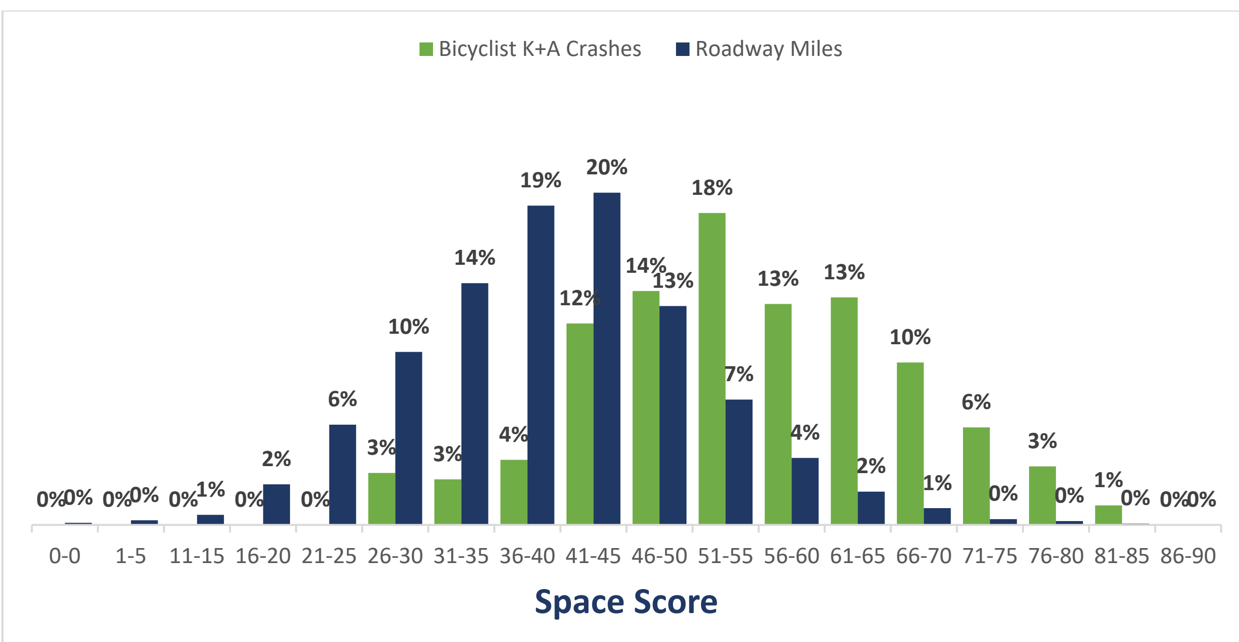


Figure 3: Distribution of KA Bicyclist Crashes and Roadway Mileage by SPACE Score, 2016-2019

MnDOT's Office of Traffic Engineering created a star rating system in 2016 to screen urban intersections for risk factors. These ratings were aggregated into the SPACE tool by MnDOT. SPACE hexagons with three- or four-star ratings, indicating greater presence of bicyclist roadway and contextual risk factors from that study, had the highest number of fatal or serious injury and bicyclist crashes overall. Locations with similar star ratings may be useful to prioritize for improvements. Note that the screening was done for individual signalized intersections on Trunk highways in urban areas, and then aggregated to the SPACE hexagon surface. Therefore, this analysis represents crashes happening within hexagons that contain one or more higher risk urban signalized intersection.

As described in the 2019 Pedestrian Safety Analysis, while the SPACE tool covers the whole state, the previous study that produced star ratings calculated them for trunk highway intersections in urbanized areas only. Only 994 of over 500,000 hexagons across the state contain a valid "dsp_risk" score. Therefore, the underlying data in Table 46 represent the subset of 398 crashes occurring within these 994 hexagons. This represents 15% of the state's 2,643 bicyclist crashes during the study period. For serious injury or fatal bicyclist crashes, 34 of 261 such crashes, or 13%, occurred in a location with a valid star rating, and among these, most occurred in hexagons with 4 or more stars.

Table 46: Bicyclist Crashes by DSP STAR Rating (only crashes with valid STAR Rating), 2016-2019

DSP STAR Rating	# Crashes	% Crashes	# KA Crashes	% KA Crashes	% Crashes Resulting in KA	Crashes per hex	KA per Hex
0	5	1%	0	0%	0%	10.4	0.0
1	7	2%	0	0%	0%	6.9	0.0
2	59	15%	8	24%	14%	28.5	3.9
3	146	37%	9	26%	6%	48.8	3.0
4	99	25%	10	29%	10%	54.1	5.5
5	60	15%	4	12%	7%	60.6	4.0
6	22	6%	3	9%	14%	40.0	5.5
7	0	0%	0	0%	0%	0.0	0.0
Total	***398***	***100%***	***34***	***100%***	***9%***	***40.0***	***3.4***

Equity

The distribution of fatal and serious injury crashes was explored across geography types as well as demographic variables from the SPACE tool related to environmental justice[10]. Figure 4 shows the distribution of KA crashes by the five urban development intensity categories and concentrations of low-income populations and communities of color. Equity was explored using the same process used in the 2019 Pedestrian Safety Analysis using the definitions of low-

[10] For more information on environmental justice at MnDOT, see: http://www.dot.state.mn.us/environmentaljustice/

income populations and communities of color identified in the SPACE tool using the Minnesota Pollution Control Agency (MNPCA)[11].

The majority of bicyclist crashes in Minnesota happen in areas where less than 40% of households are considered “low income” and less than 50% of residents are people of color (POC) (Figure 4). However, this does not mean there are no inequities in bicyclist crashes. Within Minneapolis and St. Paul, a sizeable percentage of severe bicyclist crashes happen in these equity-identified communities (40%+ low income and/or majority people of color). Further, the concentration of bicyclist crashes in these areas relative to the state at large is much higher.

Figure 5 shows the concentration of severe bicyclist crashes per hexagon in the SPACE data. In most geography groups, the concentrations of bicyclist crashes are higher in hexagons with at least one of these risk factors present (blue, green, or gray bars) relative to hexagons with neither risk factor present (orange bars). In small urban communities, the concentration of severe bicyclist crashes among areas with high poverty rates and majority POC residents are about 6 times higher than concentrations in areas with neither risk factor present. Figure 6 shows the same calculations done for bicyclist crashes of all severities. From this plot, both the dominance of Minneapolis and St. Paul in the data as well as the racial and socioeconomic disparities within these cities are evident.

Put another way, even though smaller numbers of severe bicyclist crashes are happening in these areas, people who live in these areas – who, by definition, are more likely to be low-income or people of color – are exposed to greater risk of bicyclist crashes.

[11] Low income is defined as incomes less than 185% of the federal poverty level, and hexagons are identified as low income if at least 40% of people meet this criterion. People of color are defined using Census data as anyone who is not white, non-Hispanic, and hexagons are identified for having at least 50% of people meeting this criterion.

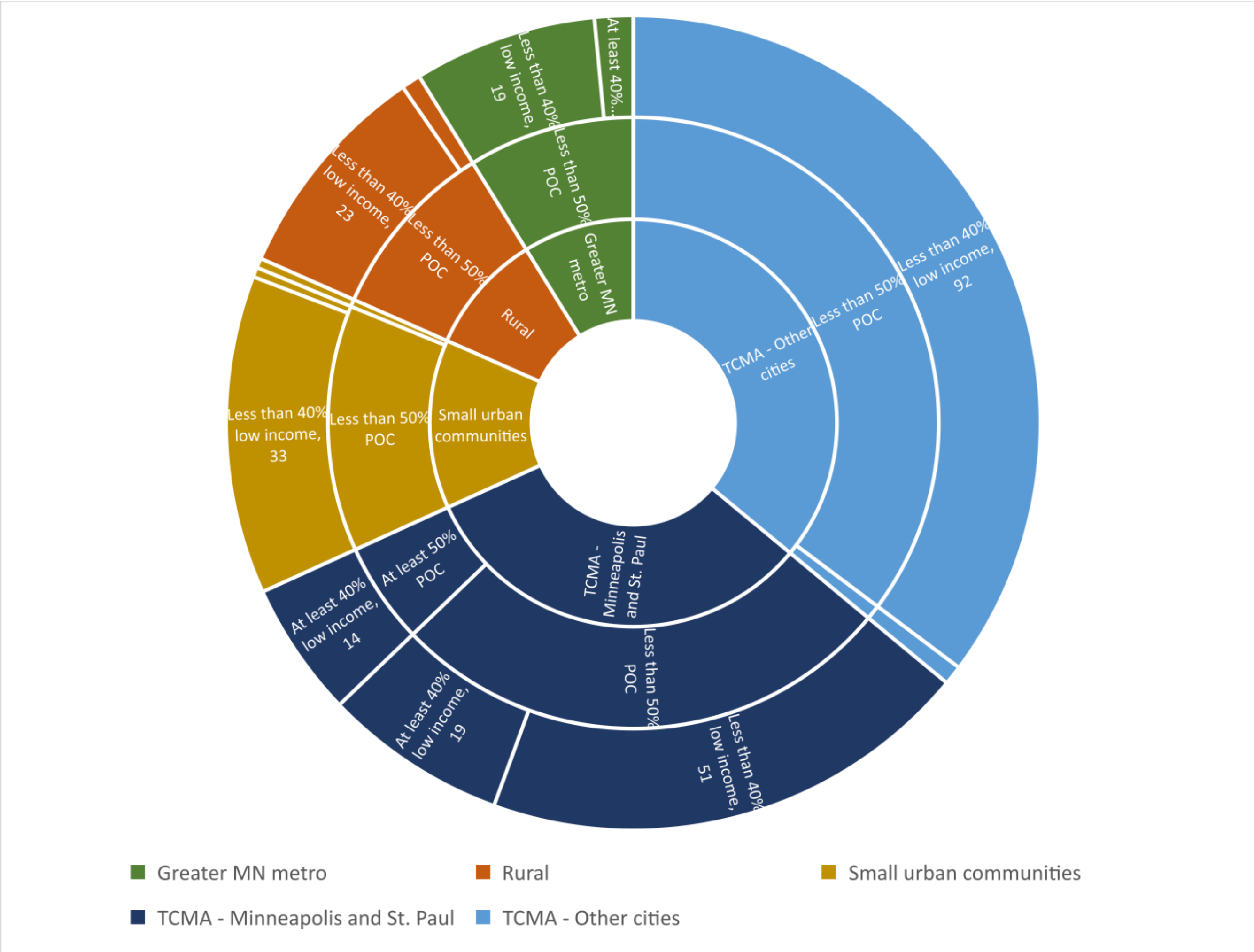
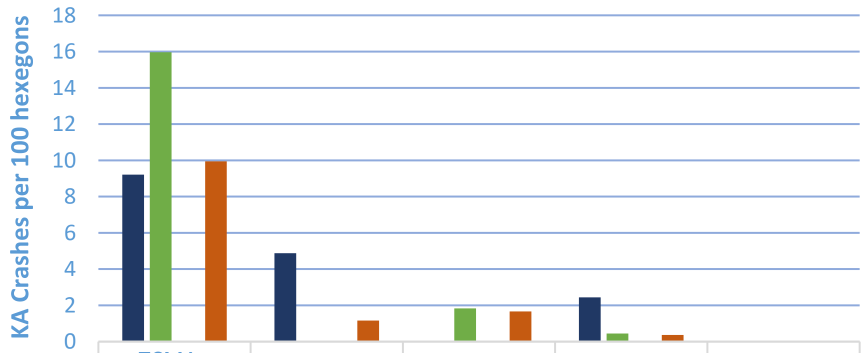
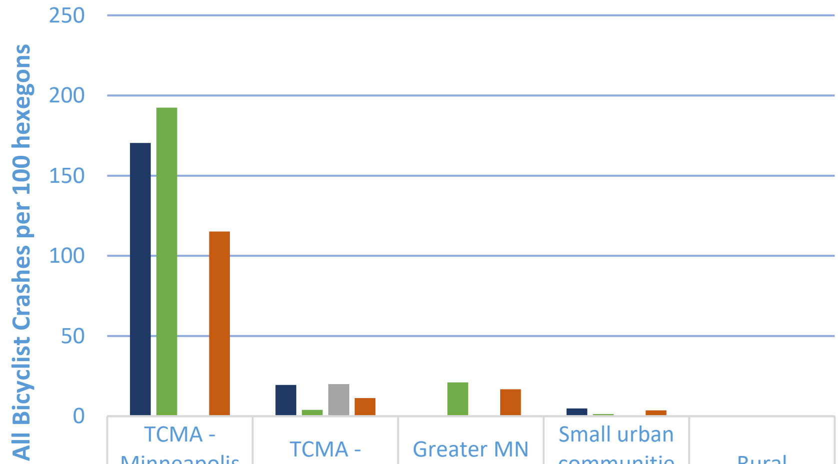


Figure 4: Number of KA Crashes by Geography and Environmental Justice Factors



	TCMA - Minneapolis and St. Paul	TCMA - Other cities	Greater MN metro	Small urban communities	Rural
At least 40% low income - At least 50% POC	9.2	4.9	0.0	2.4	0.0
At least 40% low income - Less than 50% POC	16.0	0.0	1.8	0.4	0.0
Less than 40% low income - At least 50% POC	0.0	0.0	0.0	0.0	0.0
Less than 40% low income - Less than 50% POC	9.9	1.2	1.7	0.4	0.0

Figure 5: Rate of KA crashes per hexagon area by urban/rural geography and EJ demographics in the SPACE tool



	TCMA - Minneapolis and St. Paul	TCMA - Other cities	Greater MN metro	Small urban communitie s	Rural
At least 40% low income - At least 50% POC	170.4	19.5	0.0	4.9	0.0
At least 40% low income - Less than 50% POC	192.4	4.0	21.1	1.3	0.0
Less than 40% low income - At least 50% POC	0.0	20.0	0.0	0.0	0.0
Less than 40% low income - Less than 50% POC	115.2	11.3	16.8	3.7	0.0

Figure 6: Rate of crashes per hexagon area by urban/rural geography and EJ demographics in the SPACE tool

Predictive Analysis - Crash Trees

Crash tree diagrams are a type of multivariate descriptive or frequency analysis that divides crashes into separate levels (urban vs. rural, intersection vs. mid-block, etc.,) that are progressively more detailed categories. The priority crash types (likely crash types with the largest frequency of fatal and serious injuries) for each mode will be included in the crash tree diagram as separate branches. Crash tree diagrams are used to help identify potential combinations of roadway, land use, and operational characteristics that are associated with high crash histories. The crash trees presented in this report are informed both by the data stored within the MnDOT crash database and by available statewide contextual data. By combining datasets, crash trees can help practitioners and researchers better understand how combinations of variables relate to crash outcomes.

This type of analysis is considered “systemic” or “predictive” because it helps to identify the types of locations where crashes are relatively more common or relatively more severe so that proactive safety countermeasures can be considered in these types of locations.

For this analysis and the 2021 Pedestrian Safety Analysis, crash types were used as the foundation of the crash trees to help identify similar crash circumstances that could be addressed using related safety countermeasures. The research team constructed the bicyclist crash types using the bicyclist and motorist pre-crash movement.

Crash Tree Methodology

Crash trees are developed iteratively. The research team explored different combinations of roadway and contextual variables, informed by the key findings from the descriptive analysis, for each crash type. As crash tees were developed, the process tabulates crash frequencies, KA crash frequencies, and the percentage of crashes that resulted in a KA for each node/leaf in the crash tree. As they are finalized, different visualization approaches can be used that draw attention to the most impactful conclusions. Both this analysis and the 2019 Pedestrian Safety Analysis used branching tree diagrams (see
Figure 7) that depict cascading subsets of data, focusing on combinations of attributes where crashes are clustered or disproportionately severe.

Through this process, the findings from the crash tree analysis will help identify specific combinations of contextual and infrastructure variables that are associated high each target crash type. Using these finding, targeted countermeasures can be recommended in the future to mitigate systemic safety problems throughout the state.

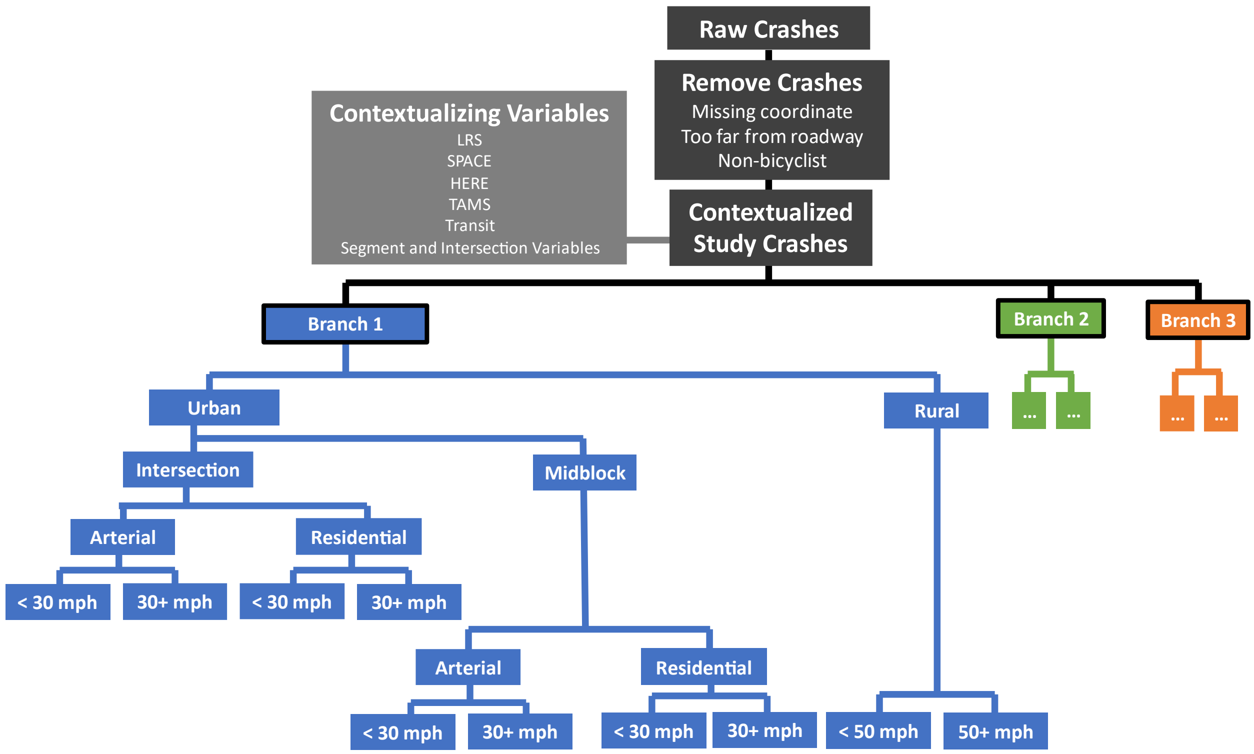


Figure 7: Generalized Example of the Crash Tree Process and Structure

The general crash tree development process is illustrated in
Figure 7 and the steps leading up to the crash tree analysis are similar to those used in the 2019 Pedestrian Safety Analysis.

After the raw crashes have been filtered and contextualized using roadway, land use, and demographic variables, and crash types have been developed, branches are developed and explored by segmenting the entire study dataset of crashes based on contextual variables that can be used to guide countermeasure selection. The process can be summarized as follows:

1. Collected and process crash data to be analyzed.
2. Assess crash data quality and identify crashes to be removed from the study dataset.
3. Contextualize crash data with variables that are not included in the crash data.
4. If there are gaps due to missing data in the contextual data (i.e., intersection signalization, posted speed limit, etc.), fill those gaps with attributes recorded in the crash data.
5. Conduct a descriptive crash analysis to identify patterns and potential risk factors.
6. Create crash types for use in countermeasure identification and to serve as the first node (start of the branch) crash tree analysis.
7. Create branches starting by examining different combinations of variables informed by the crash analysis.
8. Evaluate the number and percentage of KA and all crashes captured for each variable combination.
9. Identify crash “profiles” that have a high frequency and high number or KA/crash ratio.

10. Iterate based on review between the research team and MnDOT.

As applied to the Statewide Pedestrian Safety Analysis and shown in Figure 7, the research team began by filtering the pedestrian crash dataset to only those that were useful for crash tree analysis and future countermeasure identification (those that did not meet any of the criteria outlined in Table 1). A key difference between the Pedestrian Safety Analysis and this Bicyclist Safety Analysis is the sample size. The pedestrian study included 4,143 crashes whereas the bicyclist study used 2,643 crashes. The bicyclist study having a smaller sample size constrains some of the exploration that is possible relative to what can be explored with a larger dataset.

Crash location types, intersection traffic control types, and bicyclist and motorist pe-crash movement were initially used to develop the crash types. However, given the smaller sample sizes, the crash types were constructed using the bicyclist and motorist pre-crash movements. These crash types are the first branch (node) of the crash tree constructed. Additional variables were then explored individually by adding and reclassifying (grouping/binning variables as needed) roadway and land use characteristics. The following variables are some examples of the variables explored as part of the crash tree analysis:

- Intersection v. midblock
- Intersection control type
- number of travel lanes
- posted speed limit
- presence of a median
- land use (land use types and urban/rural designations)
- Destination types (retail, restaurant, etc.)
- SPACE score
- Transit
- Trunk highway
- Presence of shoulder

The research team selected two crash types (Branches 1 & 2) for further exploration by considering roadway and land use characteristics related to the number of KA crashes. Table 52 summarizes bicyclist crash frequencies and severities by crash type.

Crash Typology

As described above, crash typing defines sub-sets of crashes based on the actors and actions that contributed to the crash event. For this analysis, unit types and their pre-crash movement were used to develop the bicyclist crash types, which was largely informed by sample sizes. The purpose of using these two variables in the development of these crash types is to group characteristics that likely have similar conditions and possible countermeasures. Further exploration in the crash tree analysis helps refine these possible countermeasures.

Unit Types Involved

The first step in the crash typing process consisted of grouping unit types that were involved in the crash and counted. Unit types in the raw crash dataset provided to the research team included:

- Pedestrian
- Bicycle
- Motor Vehicle in Transport
- Parked/Stalled Motor Vehicle
- Hit-And-Run Vehicle or Unknown Driver
- Working Vehicle / Equipment
- Other Personal Conveyance[12] (Wheelchair, Horse, Buggy, Skates, Skateboard, Segway, etc.)

Crashes were assigned a "mode" at the start of this analysis, and this section reiterates the process described earlier in this report. Crashes were assigned the mode of the most vulnerable road user involved in the crashes with pedestrians considered the most vulnerable followed by bicyclists. All crashes that did not involve a bicyclist were excluded from the crash tree analysis.

Crash Location

The research team used spatial proximity to categorize crashes that occurred at intersections and stratify by traffic controls (using TAMS and crash records). Traffic control device data was not available statewide at the time this analysis was conducted (noted in 2019 Pedestrian Safety Analysis). The Transportation Asset Management System (TAMS) sign and signal inventory data was used as the primary source for coding intersection control (only along trunk highways). Where TAMS data was not present, the officer-reported traffic control device was used, if available, or the control type was listed as other/unknown. Table 47 summarizes the criteria used to assign location types to crashes.

Table 47: Crash Location Categorization

Location Type	Within 100' from Intersection	Traffic Control Type
Signalized Intersection	Yes	Traffic Signal (TAMS GIS data and officer reported).
Stop-Controlled Intersection	Yes	Stop (TAMS GIS data and officer reported. Stop control type – e.g., two- vs. four-way stop locations – is not differentiated in the crash report and are only reported as "stop sign").
Stop-Controlled Intersection	Yes	No controls (officer reported). Upon reviewing numerous locations, many crashes were located at a two-way stop- controlled intersection.
Other/unknown	Yes	Officer reported as 'Not found', 'Flashing Overhead Traffic Control Signal', 'Rural Intersection Conflict Warning System.'
Segment	No	Blank (none/NA).

[12] Includes scooter users

Pre-Crash Movements

The pre-crash movement from the motorist involved in the bicyclist crash was selected as a key attribute to be used in crash typing. This variable can help us better understand what events occurred leading up to the crash giving us a better picture of the crash dynamics and factors that contributed to the crash.

Similar motorist pre-crash movements were consolidated into four movement types and are outlined summarized in Table 48. The purpose of consolidating these movement types is largely to combine movement types that have similar crash dynamics, possible applicable countermeasures, and to increase the sample sizes for each branch being developed in the crash tree. We applied the consolidation process used in the 2019 Pedestrian Safety Analysis to this analysis.

Table 48: Pre-Crash Vehicle Movement Consolidation

Consolidated Motor Vehicle Movement Type	Reported Motor Vehicle Movement Type
Forward	• Moving Forward • Slowing • Swerved or Attempt to Avoid Object in Roadway (Due to Wind, Slippery • Surface, Motor Vehicle, Object, Non-Motorist in Roadway, etc.) • Overtaking/Passing • Negotiating a Curve • Changing Lanes • Wrong Way into Opposing Traffic • Vehicle Stopped or Stalled in Roadway
Left	• Turning Left • Making a U-Turn
Right	• Turning Right
Other/unknown	• Backing • Parked • Entering or Leaving a Parked Position • Unknown • Not found • Other • Leaving Traffic Lane • Entering Traffic Lane

Table 49 summarizes motor vehicle movements for all crashes and KA crashes by motor vehicle type. Crashes involving a motor vehicle proceeding forward were more severe than other known movement types (left turn and right turn), with 12 percent of crashes resulting in a KA. Forward movement also represents the largest share of crashes (57 percent) and KA crashes (70 percent). This is consistent both with crash trends we see in other locations as well as known risk factors; forward-moving drivers are usually traveling at a higher speed than turning motorists.

Table 49: Motorist Pre-Crash Action, 2016-2019

Motorist Pre-Crash Action	# Crashes	% Crashes	# KA	% KA	% Crashes Resulting in KA
Forward	1,495	57%	183	70%	12%
Right	564	21%	23	9%	4%
Left	411	16%	39	15%	9%
Other/unknown	132	5%	12	5%	9%
Parked/Entering or Leaving a Parked Position	41	2%	4	2%	10%
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Similar reported non-motorized action types have been consolidated into seven pre-crash movements and are summarized in Table 50. The purpose of consolidating the bicyclist pre-crash movements is the same as consolidating the motorist pre-crash movements.

Table 50: Pre-Crash Bicyclist Movement Consolidation

Consolidated Bicyclist Movement Type	Reported Bicyclist Movement Type
Cycle Across Traffic/Roadway	• Cycle Across Traffic/Roadway
Cycle With Traffic	• Cycle With Traffic
Cycle on Sidewalk	• Cycle on Sidewalk
Cycle Against Traffic	• Cycle Against Traffic
In Roadway - Other (working playing etc.)	• In Roadway - Other (working playing etc.)
Adjacent to Roadway (shoulder median etc.)	• Adjacent to Roadway (shoulder median etc.)
Other/Unknown	• Going to or From School (K-12) • Going to or From Public Transit • Standing/Stopped • Other • Unknown • NULL values

Table 51 shows the distribution of bicycle crashes by the pre-crash action of the bicyclist recorded in the crash reports. Nearly half of all crashes (47%) and KA crashes (47%) occurred with the bicyclist crossing traffic/roadway, followed by bicyclists traveling with traffic (24% all crashes; 28% of KA crashes) and cycling on the sidewalk (13% all crashes; 6% of KA crashes).

Table 51: Bicyclists Pre-Crash Action

Bicyclist Pre-Crash Action	# Crashes	% Crashes	# KA	% KA	% Crashes Resulting in KA
Cycle Across Traffic/Roadway	1,235	47%	122	47%	10%
Cycle With Traffic	638	24%	72	28%	11%
Cycle on Sidewalk	332	13%	17	7%	5%
Other	161	6%	15	6%	9%
Cycle Against Traffic	139	5%	13	5%	9%
In Roadway - Other (working playing etc.)	103	4%	19	7%	18%
Adjacent to Roadway (shoulder median etc.)	35	1%	3	1%	9%
Total	**2,643**	**100%**	**261**	**100%**	**10%**

Crash Types

Table 52 shows the distribution of bicycle crashes by the pre-crash action of the bicyclist and motorist recorded in the crash reports. The research team typically employs the Location Movement Classification Method for understanding the dynamic events leading up to every crash.[13]

In a larger sample, this method would consist of creating crash types that include the two primary parties involved in the crash, each party's pre-crash movement (e.g., proceeding straight, turning left, and turning right for motorists and crossing traffic, cycling with traffic, etc. for bicyclists), and their relative direction (perpendicular, opposite direction, etc.). These more detailed crash types help us better understand the contributing factors which can lead to a more targeted and effective countermeasure selection process.

However, due to the low sample size of bicyclist crashes once the sample has been stratified by pre-crash movement, as well as missing bicyclist pre-crash direction of travel and movement types, the crash types developed in this analysis consist only of the bicyclists' pre-crash action and the motorists' pre-crash movement. Location attributes will be explored as the crash tree is built out.

Most crashes involved the bicyclist cycling across traffic/roadway while the motorist was moving forward for both overall crashes (30%) and KA crashes (35%), followed by the bicyclists cycling with traffic and the motorists moving forward (11% of all crashes; 17% of KA crashes).

These top two crash type have been selected for additional analysis through the crash tree analysis. It's notable that the primary motorist movement type involved the motor vehicle proceeding forward rather than turning movement. The other crash types were not selected for further exploration due to the low number of KA crashes for each. To ensure the sample size is

[13] R. J. Schneider & J. Stefanich. 2016. Application of the Location—Movement Classification Method for Pedestrian and Bicycle Crash Typing. *Transportation Research Record:* 2601 (1). https://doi.org/10.3141/2601-09

large enough for a more robust crash tree analysis, we produced individual branches for the top two crash types.

Table 52: Top 10 Bicyclist and Motorist Pre-Crash Action

Crash Types	# Crashes	% Crashes	# KA	% KA	% Crashes Resulting in KA
Bike Cycle Across Traffic/Roadway, MV Forward	**791**	**30%**	**91**	**35%**	**12%**
Bike Cycle With Traffic, MV Forward	**285**	**11%**	**45**	**17%**	**16%**
Bike Cycle Across Traffic/Roadway, MV Right	257	10%	12	5%	5%
Bike Cycle With Traffic, MV Left	171	6%	14	5%	8%
Bike Cycle Across Traffic/Roadway, MV Left	158	6%	18	7%	11%
Bike Cycle on Sidewalk, MV Forward	156	6%	7	3%	5%
Bike Cycle on Sidewalk, MV Right	117	4%	5	2%	4%
Bike Cycle With Traffic, MV Right	101	4%	4	2%	4%
Bike Other, MV Forward	98	4%	11	4%	11%
Bike Cycle Against Traffic, MV Forward	74	3%	10	4%	14%
Not Top 10	*435*	*16%*	*44*	*17%*	*10%*
Total	***2,643***	***100%***	***261***	***100%***	***10%***

Branch 1: Bike Cycle Across Traffic/Roadway, MV Forward

Crashes involving a bicyclist cycling across traffic/roadway and the motorist proceeding forward accounted for the largest share of bicyclist crashes (30%, n=791) and KA crashes (35%, n=91). Roughly 12% of crashes in the crash type resulted in a KA crash, which is marginally more severe than the overall average of 10% for all bicyclist crashes.

Figure 8. Variables included in Branch 1 Crash Tree.

The majority of crashes in this branch occurred in urban areas (Minneapolis—St. Paul Metro or Metro Greater MN), accounting for 81% of crashes and 76% of KA crashes while 17% of crashes occurred in small urban communities and 2% in rural areas. This is expected due to substantially higher exposure rates in urban areas compared to rural geographies, while there are low-moderate levels of bicyclist activity in small urban communities.

Location type and intersection control proved to be an impartment factor for this crash type. There were 84% of crashes within this crash type that occurred at an intersection while the remaining occurred at midblock/segment locations. Crashes were more concentrated at intersection locations for urban and small urban communities, which can be expected as there was a higher density of intersections in these geography types compared to urban areas.

Looking at crashes in urban areas, most crashes occurred at stop-controlled intersections (34.9% of all crashes; 31% KA crashes) followed by signalized intersections (30% of all crashes; 31% KA crashes). For both rural and small urban communities, most crashes and KA crashes occurred at stop-controlled intersections, which may reflect the smaller share of intersections in these geographies that have a traffic signal.

Functional classification plays a large roll in where crashes have occurred in this branch for all geography types. To increase the sample sizes for each step of the crash tree process, all collector and arterials were grouped into "Major" while all residential streets were assigned "Local." This grouping process was used for both the highest and lowest functional classification for crashes that occurred at intersections, while the highest and lowest functional classification for segment crashes will be the same.

Across all geography types, crashes were concentrated along or at intersections with major streets. Most crashes (29%) and KA crashes (30%) occurred at signalized intersections at a major intersection within urban areas. These are likely locations that have higher bicyclist volumes and perhaps are locations that may be easier for bicyclists to cross than other major intersections, but may have risk factors that contribute to a higher share of crashes and fatal/serious injury crashes.

When looking at the highest and lowest functional classification groupings at urbanized intersections, crashes are closely split between major-major and major-locations sections, though major-major signalized intersections had a larger share of crashes and twice the number of KA crashes (18 compared to 9).

Stop-controlled intersections at major streets within urban areas had the second largest share of crashes (25%) and KA crashes (22%). Unlike at signalized intersection, most of these crashes (83%) occurred between a major and a local street. This is likely due to where and how stop signs are used to control traffic at locations involving local functional classifications. Signals are less likely to be used than stop signs where local roads intersect with higher functional class roads. However, some bicyclists (less confident or younger) may choose to ride along slower street streets (often lower speed and lower volume) but may be required to cross major streets that do not have traffic signals or crossing enhancements to facilitate a safe crossing.

Unlike many of the pedestrian key findings, bicyclist crashes were relatively less concentrated near trip attracting land uses including entertainment, restaurants, and shopping locations.

Table 53: Branch 1 of Bicyclist Crash Trees

Urban / Rural	Geography Type	Crash Location	Highest FC	Lowest FC	Entertainment / restaurant / shopping	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Urban	METRO	Other/ unknown	Local	Local	yes	2	0%	1	1%	50%
Urban	METRO	Other/ unknown	Art / Coll	Local	no	16	2%	3	3%	19%
Urban	METRO	Other/ unknown	Art / Coll	Local	yes	3	0%	0	0%	0%
Urban	METRO	Other/ unknown	Art / Coll	Art / Coll	no	4	1%	0	0%	0%
Urban	METRO	Other/ unknown	Art / Coll	Art / Coll	yes	5	1%	0	0%	0%
Urban	METRO	Segment	Local	Local	no	35	4%	3	3%	9%
Urban	METRO	Segment	Local	Local	yes	11	1%	1	1%	9%
Urban	METRO	Segment	Art / Coll	Art / Coll	no	21	3%	1	1%	5%
Urban	METRO	Segment	Art / Coll	Art / Coll	yes	21	3%	3	3%	14%
Urban	METRO	Signal	Local	Local	no	3	0%	1	1%	33%
Urban	METRO	Signal	Local	Local	yes	1	0%	0	0%	0%
Urban	**METRO**	**Signal**	**Art / Coll**	**Local**	**no**	**44**	**6%**	**2**	**2%**	**5%**
Urban	**METRO**	**Signal**	**Art / Coll**	**Local**	**yes**	**50**	**6%**	**7**	**8%**	**14%**
Urban	**METRO**	**Signal**	**Art / Coll**	**Art / Coll**	**no**	**52**	**7%**	**8**	**9%**	**15%**
Urban	**METRO**	**Signal**	**Art / Coll**	**Art / Coll**	**yes**	**56**	**7%**	**5**	**5%**	**9%**
Urban	**METRO**	**Stop**	**Local**	**Local**	**no**	**59**	**7%**	**7**	**8%**	**12%**
Urban	METRO	Stop	Local	Local	yes	8	1%	1	1%	13%
Urban	**METRO**	**Stop**	**Art / Coll**	**Local**	**no**	**107**	**14%**	**13**	**14%**	**12%**
Urban	METRO	Stop	Art / Coll	Local	yes	31	4%	1	1%	3%
Urban	METRO	Stop	Art / Coll	Art / Coll	no	20	3%	2	2%	10%
Urban	METRO	Stop	Art / Coll	Art / Coll	yes	10	1%	2	2%	20%
Urban	METRO - GREATER MN	Other/ unknown	Local	Local	no	1	0%	0	0%	0%
Urban	METRO - GREATER MN	Other/ unknown	Art / Coll	Local	no	1	0%	0	0%	0%
Urban	METRO - GREATER MN	Other/ unknown	Art / Coll	Local	yes	1	0%	0	0%	0%

Urban / Rural	Geography Type	Crash Location	Highest FC	Lowest FC	Entertainment / restaurant / shopping	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Urban	METRO - GREATER MN	Other/ unknown	Art / Coll	Art / Coll	no	1	0%	0	0%	0%
Urban	METRO - GREATER MN	Segment	Local	Local	no	5	1%	0	0%	0%
Urban	METRO - GREATER MN	Segment	Art / Coll	Art / Coll	no	4	1%	1	1%	25%
Urban	METRO - GREATER MN	Segment	Art / Coll	Art / Coll	yes	4	1%	0	0%	0%
Urban	METRO - GREATER MN	Signal	Art / Coll	Local	no	3	0%	0	0%	0%
Urban	METRO - GREATER MN	Signal	Art / Coll	Local	yes	6	1%	0	0%	0%
Urban	METRO - GREATER MN	Signal	Art / Coll	Art / Coll	no	13	2%	3	3%	23%
Urban	METRO - GREATER MN	Signal	Art / Coll	Art / Coll	yes	6	1%	2	2%	33%
Urban	METRO - GREATER MN	Stop	Local	Local	no	2	0%	0	0%	0%
Urban	METRO - GREATER MN	Stop	Local	Local	yes	2	0%	0	0%	0%
Urban	METRO - GREATER MN	Stop	Art / Coll	Local	no	18	2%	2	2%	11%
Urban	METRO - GREATER MN	Stop	Art / Coll	Local	yes	8	1%	0	0%	0%
Urban	METRO - GREATER MN	Stop	Art / Coll	Art / Coll	no	2	0%	0	0%	0%
Urban	METRO - GREATER MN	Stop	Art / Coll	Art / Coll	yes	1	0%	0	0%	0%
Rural	RURAL	Segment	Local	Local	no	1	0%	0	0%	0%
Rural	RURAL	Segment	Art / Coll	Art / Coll	no	3	0%	0	0%	0%
Rural	RURAL	Stop	Local	Local	no	1	0%	1	1%	100%
Rural	RURAL	Stop	Local	Local	yes	1	0%	0	0%	0%
Rural	RURAL	Stop	Art / Coll	Local	no	7	1%	2	2%	29%
Rural	RURAL	Stop	Art / Coll	Art / Coll	no	4	1%	1	1%	25%
Rural	RURAL DOWNTOWN	Other/ unknown	Local	Local	no	1	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Other/ unknown	Art / Coll	Local	no	1	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Other/ unknown	Art / Coll	Local	yes	3	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Other/ unknown	Art / Coll	Art / Coll	no	1	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Segment	Local	Local	no	9	1%	2	2%	22%

Urban / Rural	Geography Type	Crash Location	Highest FC	Lowest FC	Entertainment / restaurant / shopping	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Rural	RURAL DOWNTOWN	Segment	Art / Coll	Art / Coll	no	8	1%	3	3%	38%
Rural	RURAL DOWNTOWN	Segment	Art / Coll	Art / Coll	yes	6	1%	1	1%	17%
Rural	RURAL DOWNTOWN	Signal	Art / Coll	Local	no	2	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Signal	Art / Coll	Local	yes	8	1%	1	1%	13%
Rural	RURAL DOWNTOWN	Signal	Art / Coll	Art / Coll	no	2	0%	0	0%	0%
Rural	RURAL DOWNTOWN	Signal	Art / Coll	Art / Coll	yes	13	2%	0	0%	0%
Rural	RURAL DOWNTOWN	Stop	Local	Local	no	14	2%	4	4%	29%
Rural	RURAL DOWNTOWN	Stop	Local	Local	yes	6	1%	0	0%	0%
Rural	**RURAL DOWNTOWN**	**Stop**	**Art / Coll**	**Local**	**no**	**32**	**4%**	**5**	**5%**	**16%**
Rural	RURAL DOWNTOWN	Stop	Art / Coll	Local	yes	13	2%	0	0%	0%
Rural	RURAL DOWNTOWN	Stop	Art / Coll	Art / Coll	no	12	2%	2	2%	17%
Rural	RURAL DOWNTOWN	Stop	Art / Coll	Art / Coll	yes	6	1%	0	0%	0%

Branch 2: Bicycle With Traffic, MV Forward

Crashes involving a bicyclist cycling with traffic and the motorist proceeding forward accounted for the second largest share of bicyclist crashes (11%, n=285) and KA crashes (17%, n=45). Roughly 16% of crashes in the crash type resulted in a KA crash, which is marginally more severe than the overall average of 10% for all bicyclist crashes.

Figure 9. Variables included in Branch 2 Crash Tree.

Like the first branch, most crashes occurred within urban areas (86%) with two-thirds of KA crashes. Rural geography types (excludes small urban communities) accounted for the second largest share of crashes (8%) and KA crashes (22%).

Crashes were concentrated at intersection locations in urban areas with nearly two-thirds of all crashes (61%) and nearly half of all KA crashes (47%) in this branch. When looking at the marginal share of crashes within urban areas by location type, crashes occurred most often at intersections (72%).

Crashes in rural and small urban communities were not concentrated at intersection like crashes in urban areas with 79% of crashes in rural areas having occurred at segment locations and 53% of crashes in small urban communities having occurred at intersections. This may reflect there being fewer intersections within these geography types or the lack of facilities that provide adequate separation between moving traffic and bicyclists in these areas.

When diving deeper and looking at location type and traffic control, crashes were concentrated at urban stop-controlled intersections (32%) followed by urban signalized intersections (23%), and urban segment locations (24%). As previously mentioned, most rural crashes occurred at segment locations (7%). Crashes in small urban communities occurred most frequently at signalized intersections (3%) followed by stop-controlled intersections (2%).

Posted speed limit illustrates the statutory speed limits throughout the state (50 mph in rural areas and 30 mph in urban areas). Crashes in urban areas occurred most often at locations with a 30 mph speed limit and crashes in rural areas occurred at locations with a posted speed limit of 50 mph. Interestingly, most crashes within small urban communities occurred at stop controlled intersections at 30 mph street, though the sample size in only six crashes.

Looking at functional classification groupings (collector/arterial v. residential), urban crashes occurred most frequently at signalized intersections between major streets (13%) followed by stop-controlled intersections between major-local streets (12%), both at locations with a 30 mph speed limit. The third most frequent location was at urban segment locations along major streets with a posted speed limit of 30 mph (11%).

Table 54: Branch 2 of Bicyclist Crash Trees

Urban/ Rural	Geography Type	Intersection v. Segment	Crash Location	Speed Limit	Highest FC	Lowest FC	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Urban	Urban	segment	Segment	<25	Local	Local	1	0%	0	0%	0%
Urban	Urban	segment	Segment	25	Local	Local	1	0%	0	0%	0%
Urban	Urban	segment	Segment	30	Local	Local	12	4%	0	0%	0%
Urban	**Urban**	**segment**	**Segment**	**30**	**Major**	**Major**	**31**	**11%**	**2**	**4%**	**6%**
Urban	Urban	segment	Segment	30	(blank)	(blank)	1	0%	1	2%	100%
Urban	Urban	segment	Segment	35	Major	Major	6	2%	2	4%	33%
Urban	Urban	segment	Segment	40	Major	Major	6	2%	0	0%	0%
Urban	Urban	segment	Segment	45	Local	Local	1	0%	1	2%	100%
Urban	Urban	segment	Segment	45	Major	Major	5	2%	2	4%	40%
Urban	Urban	segment	Segment	50+	Major	Major	1	0%	1	2%	100%
Urban	Urban	segment	Segment	Unknown	Local	Local	2	1%	0	0%	0%
Urban	Urban	segment	Segment	Unknown	Major	Major	2	1%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	25	Major	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	30	Local	Local	4	1%	1	2%	25%
Urban	Urban	intersection	Other/ unknown	30	Major	Local	6	2%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	30	Major	Major	2	1%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	35	Local	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	35	Major	Major	1	0%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	35	Major	Local	1	0%	0	0%	0%

Urban/ Rural	Geography Type	Intersection v. Segment	Crash Location	Speed Limit	Highest FC	Lowest FC	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Urban	Urban	intersection	Other/ unknown	40	Major	Major	1	0%	0	0%	0%
Urban	Urban	intersection	Other/ unknown	50+	Local	Local	1	0%	1	2%	100%
Urban	Urban	intersection	Other/ unknown	50+	Major	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Signal	30	Local	Local	1	0%	0	0%	0%
Urban	**Urban**	**intersection**	**Signal**	**30**	**Major**	**Major**	**38**	**13%**	**4**	**9%**	11%
Urban	Urban	intersection	Signal	30	Major	Local	18	6%	2	4%	11%
Urban	Urban	intersection	Signal	35	Major	Local	2	1%	0	0%	0%
Urban	Urban	intersection	Signal	35	Major	Major	1	0%	1	2%	100%
Urban	Urban	intersection	Signal	40	Major	Local	3	1%	0	0%	0%
Urban	Urban	intersection	Signal	50+	Major	Major	3	1%	1	2%	33%
Urban	Urban	intersection	Stop	25	Local	Local	2	1%	1	2%	50%
Urban	Urban	intersection	Stop	25	Major	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Stop	30	Local	Local	27	9%	4	9%	15%
Urban	**Urban**	**intersection**	**Stop**	**30**	**Major**	**Local**	**34**	**12%**	**1**	**2%**	**3%**
Urban	Urban	intersection	Stop	30	Major	Major	7	2%	1	2%	14%
Urban	Urban	intersection	Stop	35	Local	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Stop	35	Major	Local	4	1%	0	0%	0%
Urban	Urban	intersection	Stop	35	Major	Major	2	1%	0	0%	0%
Urban	Urban	intersection	Stop	40	Local	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Stop	40	Major	Major	1	0%	0	0%	0%
Urban	Urban	intersection	Stop	40	Major	Local	1	0%	0	0%	0%
Urban	Urban	intersection	Stop	50+	Major	Local	6	2%	3	7%	50%
Urban	Urban	intersection	Stop	Unknown	Local	Local	1	0%	0	0%	0%

Urban/ Rural	Geography Type	Intersection v. Segment	Crash Location	Speed Limit	Highest FC	Lowest FC	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Urban	Urban	intersection	Stop	Unknown	Major	Major	1	0%	1	2%	100%
Urban	Urban	intersection	Stop	Unknown	Major	Local	1	0%	0	0%	0%
Rural	Rural	segment	Segment	30	Local	Local	1	0%	0	0%	0%
Rural	Rural	segment	Segment	35	Local	Local	1	0%	1	2%	100%
Rural	**Rural**	**segment**	**Segment**	**50+**	**Major**	**Major**	**17**	**6%**	**8**	**18%**	**47%**
Rural	Rural	intersection	Signal	50+	Major	Local	1	0%	0	0%	0%
Rural	Rural	intersection	Stop	45	Major	Local	1	0%	0	0%	0%
Rural	Rural	intersection	Stop	50+	Local	Local	1	0%	0	0%	0%
Rural	Rural	intersection	Stop	50+	Major	Major	1	0%	1	2%	100%
Rural	Rural	intersection	Stop	50+	Major	Local	1	0%	0	0%	0%
Rural	Small urban communities	segment	Segment	30	Local	Local	3	1%	2	4%	67%
Rural	Small urban communities	segment	Segment	30	Major	Major	1	0%	0	0%	0%
Rural	Small urban communities	segment	Segment	35	Major	Major	1	0%	1	2%	100%
Rural	Small urban communities	segment	Segment	40	Local	Local	1	0%	0	0%	0%
Rural	Small urban communities	segment	Segment	40	Major	Major	1	0%	0	0%	0%
Rural	Small urban communities	segment	Segment	50+	Major	Major	1	0%	0	0%	0%
Rural	Small urban communities	intersection	Other/ unknown	Unknown	Major	Major	1	0%	0	0%	0%
Rural	Small urban communities	intersection	Signal	30	Major	Major	2	1%	0	0%	0%
Rural	Small urban communities	intersection	Stop	30	Local	Local	2	1%	1	2%	50%

Urban/ Rural	Geography Type	Intersection v. Segment	Crash Location	Speed Limit	Highest FC	Lowest FC	# Crashes	% Crashes	# KA	% KA	% KA of All Crashes
Rural	Small urban communities	intersection	Stop	30	Major	Local	3	1%	1	2%	33%
Rural	Small urban communities	intersection	Stop	30	Major	Major	1	0%	0	0%	0%

Conclusion and Next Steps

The project team is working to assemble a data dashboard visualizing the High Injury Network alongside other crash trends and patterns. Our next steps are to bring together findings and recommendations based on both the HIN and systemic analysis. Future updates to the VRUSA should explore patterns over time around the COVID-19 pandemic, once more years of post-pandemic crash data are available. Additionally, to better understand bicyclist safety throughout the state, collecting additional existing conditions data are recommended. Many of these data are also recommended in the 2019 Pedestrian Safety Analysis:

- Operating Speed – Median and 85th percentile
- Non-MnDOT Sidewalks
- Non-MnDOT Signals, PHBs, and RRFBs
- Statewide bikeways and off-street paths
- Crosswalk markings
- Crossing Islands (Pedestrian Refuges)
- Non-MnDOT Turn Lanes (on cross streets approaching Trunk highways, or full network)
- Statewide bicyclist volumes/exposure estimates

Analyses where we were able to normalize by area, population, mileage, or another metric provided some of the most interesting insights in this analysis. For example, equity concerns might have been obscured by raw numbers, but being able to assess not only the total number but the concentration within the SPACE hexagon surface helped us tease out patterns.

Certain types of data structures make this type of normalization easier or harder; for example, evaluating roadway mileage can be problematic when datasets depict a mix of centerline miles, lane miles, and directional miles. Nonetheless, identifying other opportunities to normalize crash data by one of these denominators can help the state identify conditions under which bicyclist crashes are disproportionately concentrated – even if raw numbers do not appear clustered.

Finally, findings from this report have been summarized into a program of projects and strategies to help MnDOT deploy this information to improve safety conditions for vulnerable road users. For example, findings about the overrepresentation of youth among bicyclist crashes lend evidence for MnDOT to prioritize investment in all ages and abilities facilities rather than high stress facilities aimed at athletic adults.

Our results about sidewalk riding – both the large numbers of crashes happening under possible sidewalk riding conditions as well as the relatively lower severity rate of these possible sidewalk riding crashes – can inform decisions about education and enforcement as well as engineering. With data suggesting that sidewalk riding may be less dangerous than riding in a street that lacks adequate bicyclist facilities, greater emphasis must be placed on adding appropriate facilities. Enforcement and education against bicyclists for riding on the sidewalk are likely counterproductive.

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