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INTRODUCTION

This memo summarizes the results of the risk factors analysis conducted for Red Wing, Minnesota's Comprehensive Road Safety Action Plan (CSAP). This memo provides a basis for understanding what risk factors may be present analyzing the High Injury Networks.

SUMMARY OF KEY FINDINGS

Analysis of the high injury networks shows certain risk factors related to increased fatal and injury crash likelihood. These risk factors are explained in greater detail in this report but are listed below.

For vehicle-only crashes:

- Stopping Sight Distance
  - Downgrades exceeding 3%
  - Horizontal curvature
- Intersection Sight Distance
  - Intersection skew
  - Obstacles in line of sight
  - Additional travel lanes
- Speed limits
- Average Daily Traffic (ADT) volumes
- Driveway and intersection quantity and spacing
- Intersection offset
- Lighting

For crashes involving vulnerable road users:

- Stopping Sight Distance
  - Downgrades exceeding 3%
  - Horizontal curvature
- Intersection Sight Distance
  - Intersection skew
  - Obstacles in line of sight
  - Additional travel lanes
- Speed limits
- Average Daily Traffic (ADT) volumes
- Lighting
- Areas with increased pedestrian and bicycle activity
  - Within public school non-busing area
  - Within 1/4 mile of a commercial area

- Within 1/4 mile of a park
- Incomplete Adjacent Sidewalk Network and/or Missing Crossings

RISK FACTORS ANALYSIS METHODOLOGY

The risk factors analysis methodology consisted of reviewing the High Injury Networks (vehicle-only and vulnerable road user) for different risk factors that may be associated with an increased likelihood of fatal and severe injury crashes. These potential risk factors include horizontal and vertical geometry, traffic control devices, environmental factors, exposure/conflict points, and transportation network features. These factors were analyzed based on experience with similar analyses in other communities as well as reviewing FHWA safety information.

HIGH INJURY NETWORK OVERVIEW

Analysis of risk factors is based upon analysis of the High Injury Networks (HINs) developed for the City of Red Wing's CSAP. The HINs were developed based on mapping of fatal and injury crashes from years 2014 to 2023 onto the roadway system within the City of Red Wing, inclusive of all jurisdictional systems (e.g., MnDOT, Goodhue County, City of Red Wing, private, etc.), functional classifications (e.g., arterials, collectors, local streets), and other roadway network features.

The vehicle-only HIN was developed looking only at crashes that did not involve vulnerable road users (pedestrians, bicyclists, and those using personal mobility devices). The vehicle-only HIN included all locations of fatal and serious injury crashes (those classified as "K" and "A" severities on the KABCO scale) and locations with multiple minor injury crashes (those classified as "B" severity on the KABCO scale). Single minor injury crash locations were generally not included when developing the vehicle-only HIN. Non-injury crashes and possible injury crashes were not considered in this analysis. The vehicle-only HIN was limited to approximately 20% of the total roadway system within the City of Red Wing.

The vulnerable road user (VRU) HIN was developed looking only at crashes that did involve vulnerable road users (pedestrians, bicyclists, and those using personal mobility devices). The VRU HIN included all locations of fatal, serious injury, and minor injury crashes (those classified as "K", "A", and "B" severities on the KABCO scale) Non-injury crashes and possible injury crashes were not considered in this analysis. The VRU HIN encompassed approximately 8% of the total roadway system within the City of Red Wing.

The vehicle-only HIN is shown in Figure 1, while the VRU HIN is shown in Figure 2. The combined HIN network is shown in Figure 3.

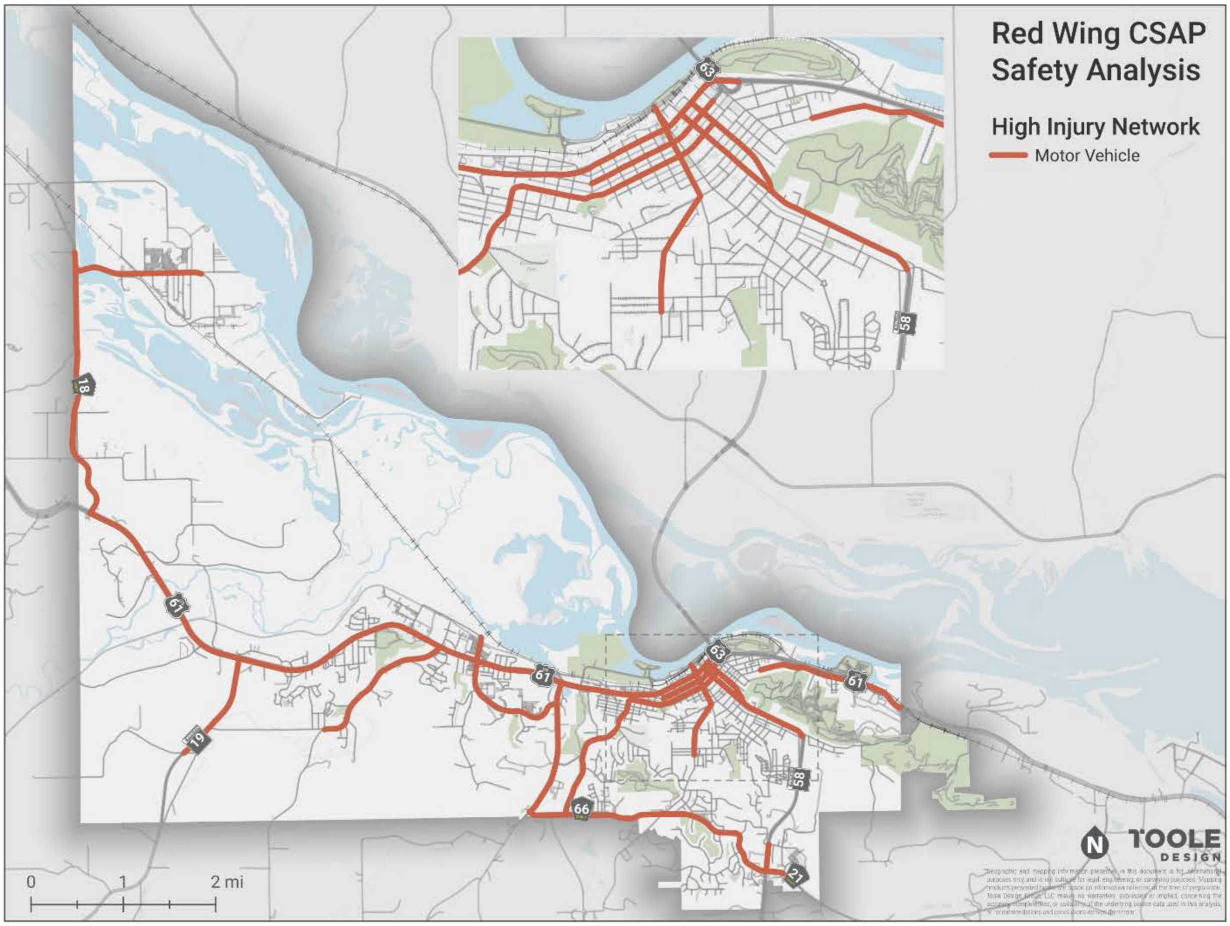

Figure 1: Vehicle-Only High Injury Network

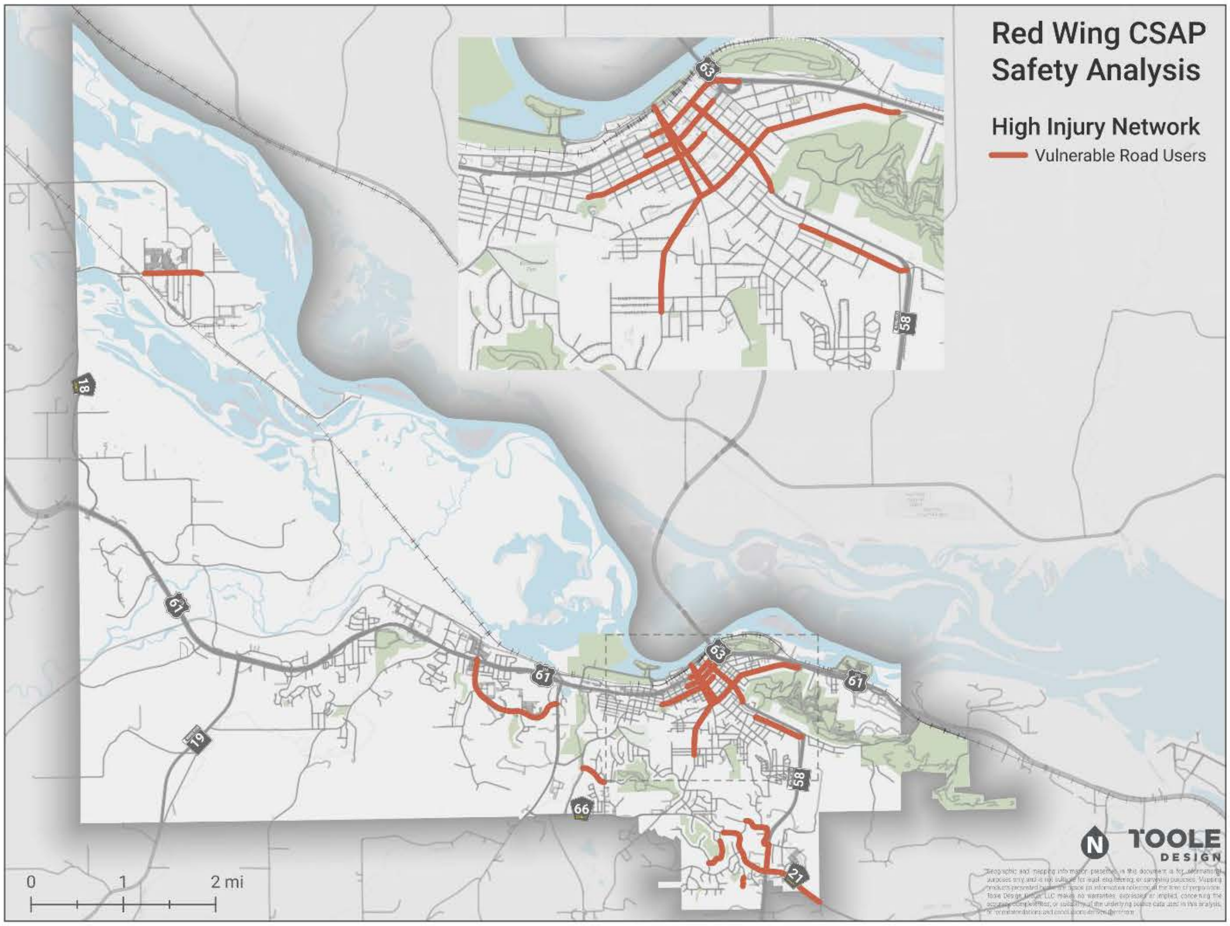

Figure 2: Vulnerable Road User High Injury Network

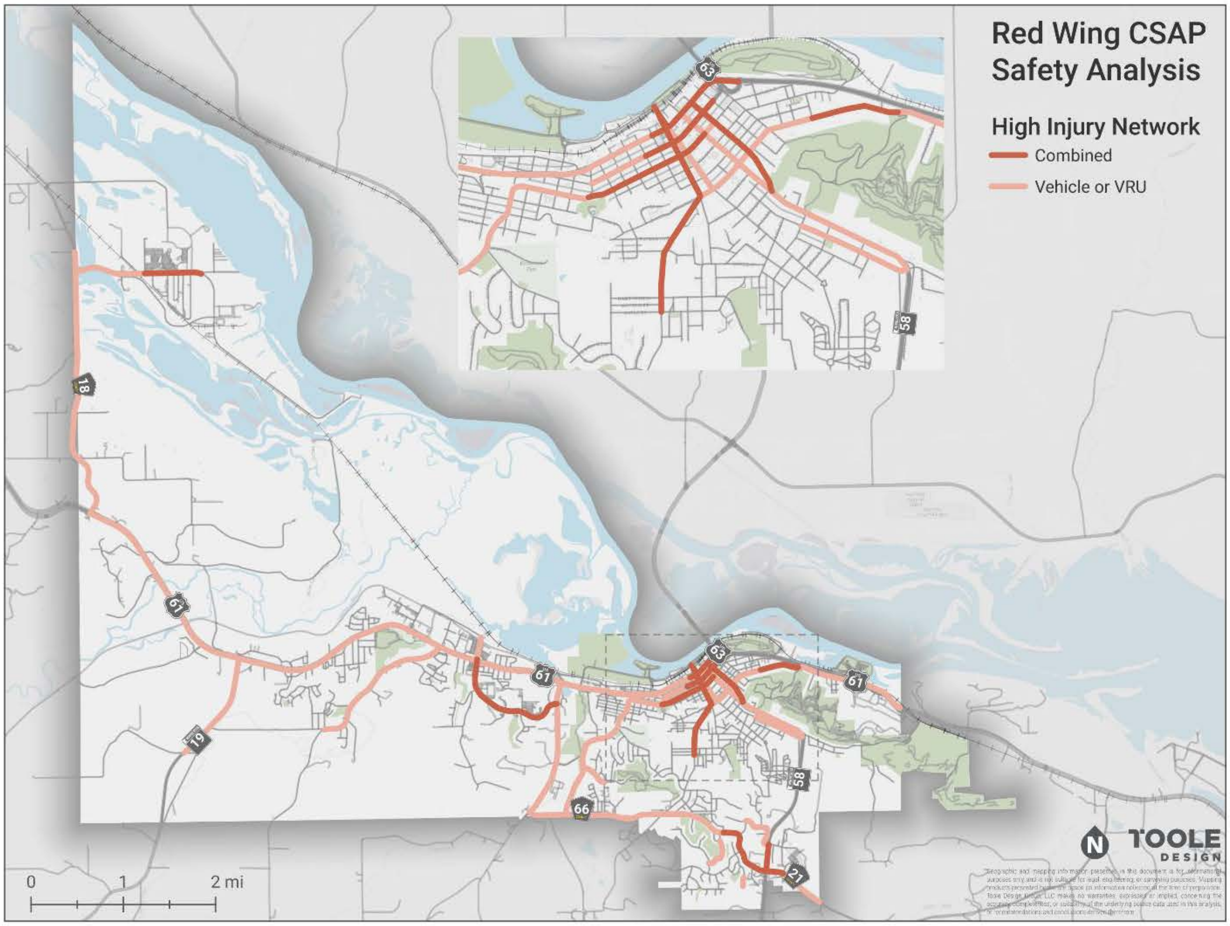

Figure 3: Combined High Injury Networks

STUDY LIMITATIONS

LIMITED FEATURE DATA

The City of Red Wing does not have a robust set of roadway feature data for use in this analysis. For the purposes of this analysis, Google Earth and Google Streetview data was measured and analyzed to provide approximate data for use in this analysis with confirmation of general accuracy by City staff and field visits. Further safety analysis should include collection of additional roadway feature data.

Some risk factors being analyzed in this report are based on qualitative rather than quantitative analysis due to lack of quantitative data.

RISK FACTORS ANALYSIS

SIGHT DISTANCE

Sight distance is defined by the American Association of State Highway and Transportation Officials (AASHTO) as the length of roadway that a driver can see clearly. For the purposes of this analysis, that definition is expanded from "driver" to include all transportation system users, including people walking, biking, and using personal mobility devices (sometimes referred to as "rolling"). There are various types of sight distance; this analysis focuses on the two types of sight distance most commonly applicable to urban environments: stopping sight distance and intersection sight distance.

STOPPING SIGHT DISTANCE (VEHICLE-ONLY AND VULNERABLE ROAD USER)

The Federal Highway Administration (FHWA) defines stopping sight distance as the distance needed for drivers to see an object on the roadway ahead and bring their vehicles to a safe stop before colliding with the object. Stopping sight distance includes two separate components: perception-reaction and deceleration. Both components of stopping sight distance are directly affected by vehicle operating speed.

Table 1 shows the stopping sight distance necessary for various vehicle speeds for level and dry conditions.

Table 1: Necessary Stopping Sight Distances for Level and Dry Conditions

Vehicle Speed (mph)	Stopping Sight Distance (SSD) (ft) - Level/Dry
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730

Most of the City-owned transportation network has 30 mph speed limits and vehicles are assumed to operate at approximately 30 mph, equating to a necessary 200 feet of stopping sight distance. This amount of stopping sight distance is approximately 2/3 of a typical City block. When vehicle operating speeds increase, the amount of needed stopping sight distance increases. At 40 mph operating speeds, the required stopping sight distance approaches an entire typical City block. It is very important, especially in complex urban environments, to keep vehicle operating speeds low to minimize required stopping sight distance to fit within the context of the community.

In some cases, stopping sight distance is either increased from the amounts shown in Table 1 or conditions do not allow for adequate sight distance. These conditions are explained below.

<u>Downgrades Exceeding 3%</u>

In locations where running grades exceed 3%, additional stopping sight distance is needed to provide adequate space for perception-reaction and deceleration. Due to Red Wing's topography, many locations on the City's transportation network exceed 3% roadway grade.

<u>Horizontal Curvature</u>

In some locations along the High Injury Network, roadways contain horizontal curves within or approaching intersections. This can lead to the amount of available sight distance being less than the necessary stopping sight distance, particularly when vehicle operating speeds are relatively high. This is of particular concern for roadway approaches on the "inside" of a horizontal curve. Exhibit 1 shows an example of horizontal curvature within an intersection at the intersection of Trunk Highway (TH) 58 and South Park Street. Vehicles on TH 58 approaching from the north generally do not have adequate stopping sight distance to react to obstacles within the approaching intersection.

Exhibit 1: TH 58 & South Park Street Intersection (Looking North/West) – Google Streetview Imagery

INTERSECTION SIGHT DISTANCE (VEHICLE-ONLY AND VULNERABLE ROAD USER)

Intersection sight distance is defined by FHWA as the distance a motorist can see approaching vehicles before their line of sight is blocked by an obstruction near the intersection. The minimum amount of intersection sight distance needed allows vehicles (and other users) on a minor leg of the intersection to adequately judge gaps in traffic to cross a non-stop controlled street.

Exhibit 2 shows an example of the line of sight quantified by intersection sight distance.

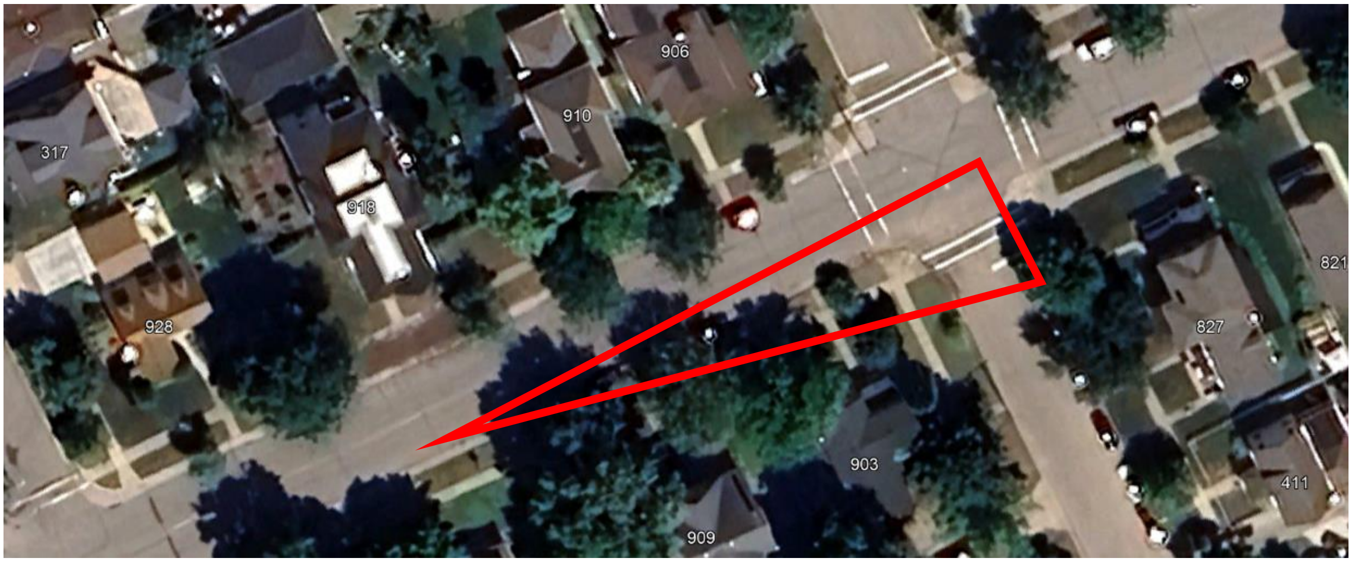

Exhibit 2: Intersection Sight Distance Sight Triangle Example – Google Earth Aerial

Intersection sight distance is directly related to the speed of the approaching vehicle on the non-stop controlled street and the time gap needed for the stopped user to clear the intersection. The needed time gap varies based on the size of the vehicle and the maneuver being performed. Left turns require the greatest amount of time gap (7.5 seconds for a passenger vehicle), while right turns require the least amount of time gap (6.5 seconds for a passenger vehicle). Larger vehicles require greater amounts of time gap due to slower vehicle acceleration.

Table 2 shows the necessary intersection sight distance needed for left turns for different types of vehicles for varying major street vehicle operating speeds per AASHTO design guidance.

Table 2: Necessary Intersection Sight Distances for Passenger Vehicles, Single Unit Trucks, and Combination Trucks

Vehicle Speed (mph)	Intersection Sight Distance (ISD) (ft) - Left Turn, Passenger Vehicle	Intersection Sight Distance (ISD) (ft) - Left Turn, Single Unit Truck	Intersection Sight Distance (ISD) (ft) - Left Turn, Combination Truck
15	170	210	255
20	225	280	340
25	280	350	425
30	335	420	510
35	390	490	595
40	445	560	680
45	500	630	765
50	555	700	850
55	610	770	930
60	665	840	1015
65	720	910	1100
70	775	980	1185

Most of the City-owned transportation network has 30 mph speed limits and vehicles are assumed to operate at approximately 30 mph, equating to a necessary 335 feet of intersection sight distance for passenger vehicles, 420 feet for single unit trucks (such as garbage trucks or school buses), and 510 feet for combination trucks (such as semi-trucks with trailers). This amount of stopping sight distance is about a full typical City block for passenger vehicles and approaching two city blocks for combination trucks. When vehicle operating speeds increase, the amount of needed intersection sight distance increases. At 40 mph operating speeds, the required intersection sight distance approaches 1 1/2 typical City blocks for passenger vehicles and over two City blocks for combination trucks. It is very important, especially in complex urban environments, to keep vehicle operating speeds low to minimize required intersection sight distance to fit within the context of the community.

In some cases, intersection sight distance is either increased from the amounts shown in Table 2 or conditions do not allow for adequate sight distance. These conditions are explained below.

INTERSECTION SKEW

Intersection skew is defined as two roadways meeting at angles less than 90 degrees. Intersection skew presents problems for roadway users on the side street to adequately see the users on the major street, particularly as skews exceed 60 degrees. Users with limited neck mobility are particularly susceptible to problems at skewed intersections as their limited range of mobility does not allow for them to see the entire necessary sight distance triangle. Exhibit 3 shows an example of a skewed intersection.

Exhibit 3: Skewed Intersection Example (Spring Creek Road at Mill Road) – Google Earth Aerial

Skewed intersections also increase exposure to other vehicles due to the increased time it takes to navigate the intersection. Some State Departments of Transportation quantify this by adding 0.5 seconds to the time gap used in the intersection sight distance calculation.

OBSTACLES IN THE LINE OF SIGHT

Where obstacles are present in the line of sight, roadway users may take risks when trying to cross or turn onto a major street. Examples of obstacles that may be in the line of sight are parked cars, utility poles and boxes, boulevard trees, light poles, retaining walls, signs, and tall landscaping items (bushes, other features). Exhibit 4 shows an example of a line of sight obstructed by many of these examples that does not allow for the side street user to see a vehicle (or on-street bike rider) approaching.

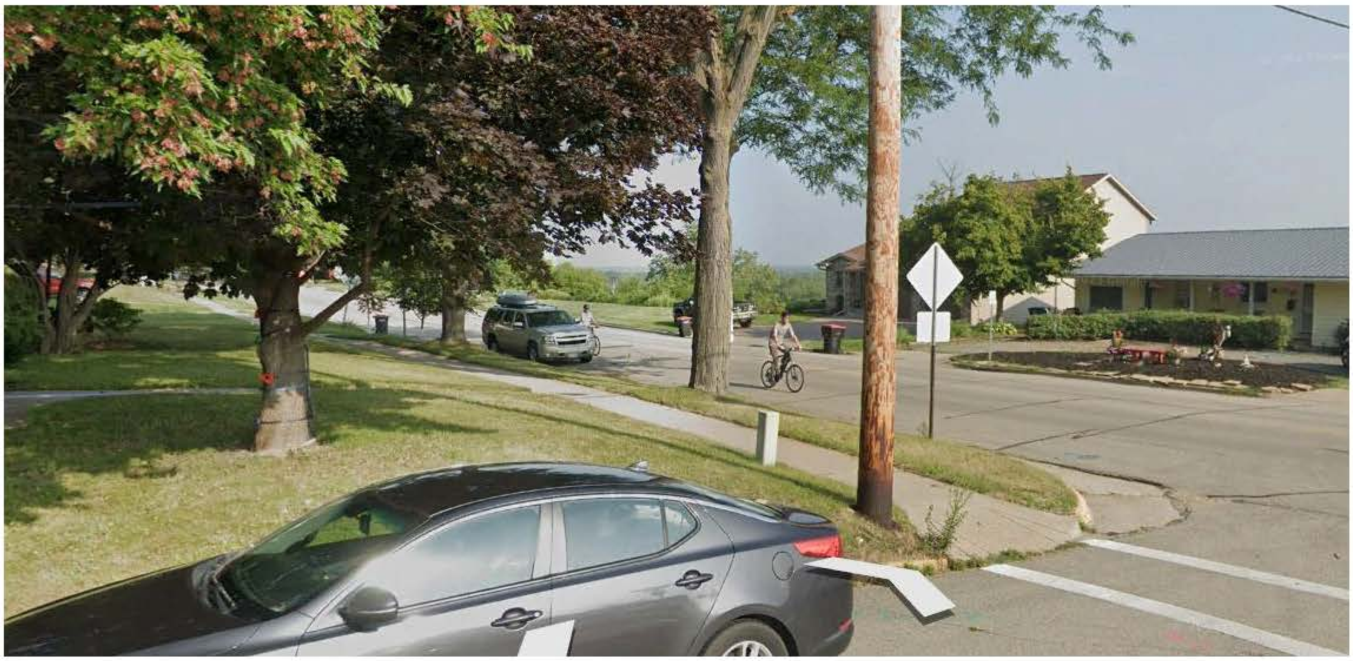

Exhibit 4: Example of Obstructions in the Line of Sight (W 4th Street at Jefferson Street) – Google Streetview Image

ADDITIONAL TRAVEL LANES

The time gaps in Table 2 assume a two-lane roadway is being crossed by the stopped vehicle. When roadways include additional lanes, additional time gap is needed and thus the necessary intersection sight distance is increased. Some State Departments of Transportation quantify this additional time gap as 0.5 seconds per additional lane for passenger vehicles and more for larger vehicles.

SPEED LIMITS

SPEED LIMITS (VEHICLE-ONLY AND VULNERABLE ROAD USER)

Until recently, roadway speed limits in Minnesota for local roadways were set by commissioner's orders based on the 85th-percentile speed found in a traffic study, except where statutory speed limits of 30 mph in urban areas were utilized. In the past few years, cities have been given additional flexibility in setting speed limits by allowing reduction of speed limits to 20 or 25 mph citywide if a city chooses to adopt an ordinance to do so. County and state highways currently are not allowed to reduce speed limits to less than 30 mph except in limited circumstances.

Roadways in Red Wing with speed limits exceeding 30 mph are overrepresented on the Vehicle-Only and VRU high injury networks as shown in Figures 4 and 5. Speed limits are generally (but not always) correlated to vehicle operating speeds and to design speeds of the roadways.

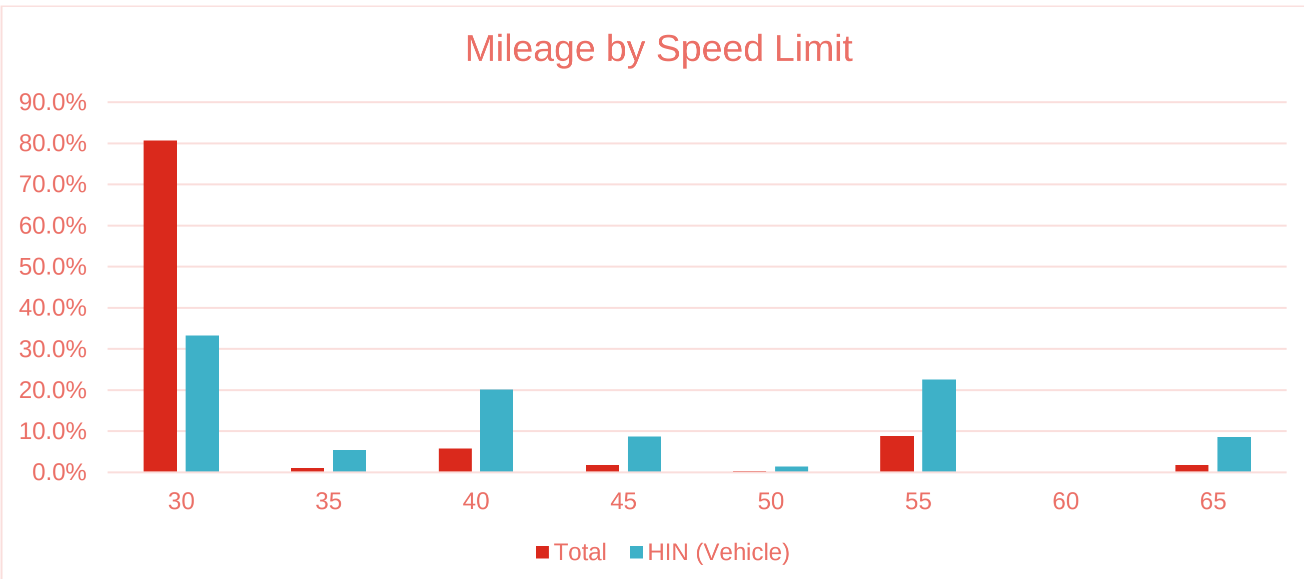

Figure 4: Total Roadway Network vs. Vehicle-Only High Injury Network by Speed Limit

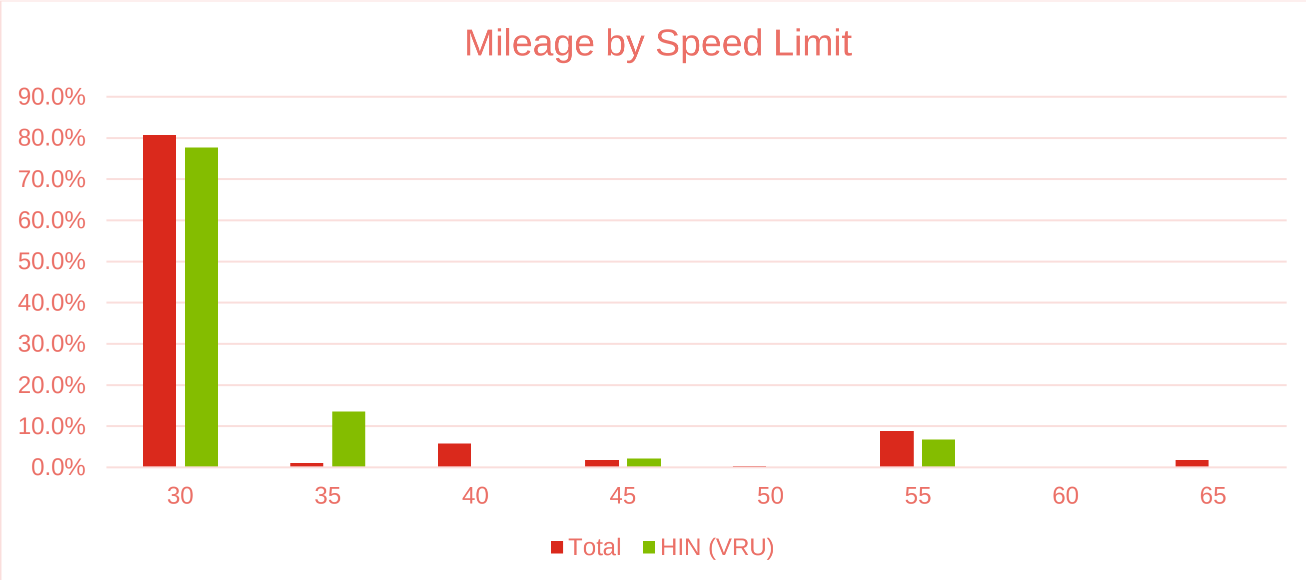

Figure 5: Total Roadway Network vs. Vulnerable Road User High Injury Network by Speed Limit

Adjusting speed limits on roadways without corresponding changes to roadway design and/or surrounding land use context has been shown to have limited effectiveness in significantly reducing vehicle speed.

EXPOSURE

AVERAGE DAILY TRAFFIC VOLUMES (VEHICLE-ONLY AND VRU)

Roadways with greater traffic volumes provide increased opportunities for crashes to occur. Roadways with average daily traffic volumes of over 1,000 vehicles per day were overrepresented in the high injury networks, with greater volumes (particularly those with other 5,000 vehicles per day or greater) increasingly overrepresented on the high injury networks as shown in Figures 6 and 7.

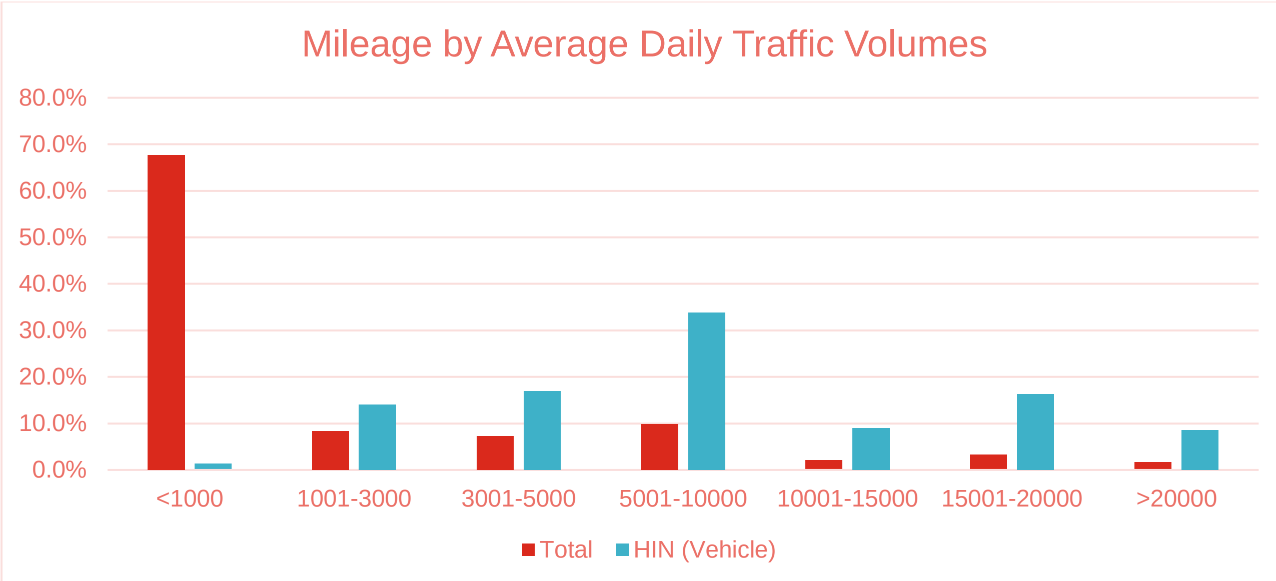

Figure 6: Total Roadway Network vs. Vehicle-Only High Injury Network by Average Daily Traffic Volumes

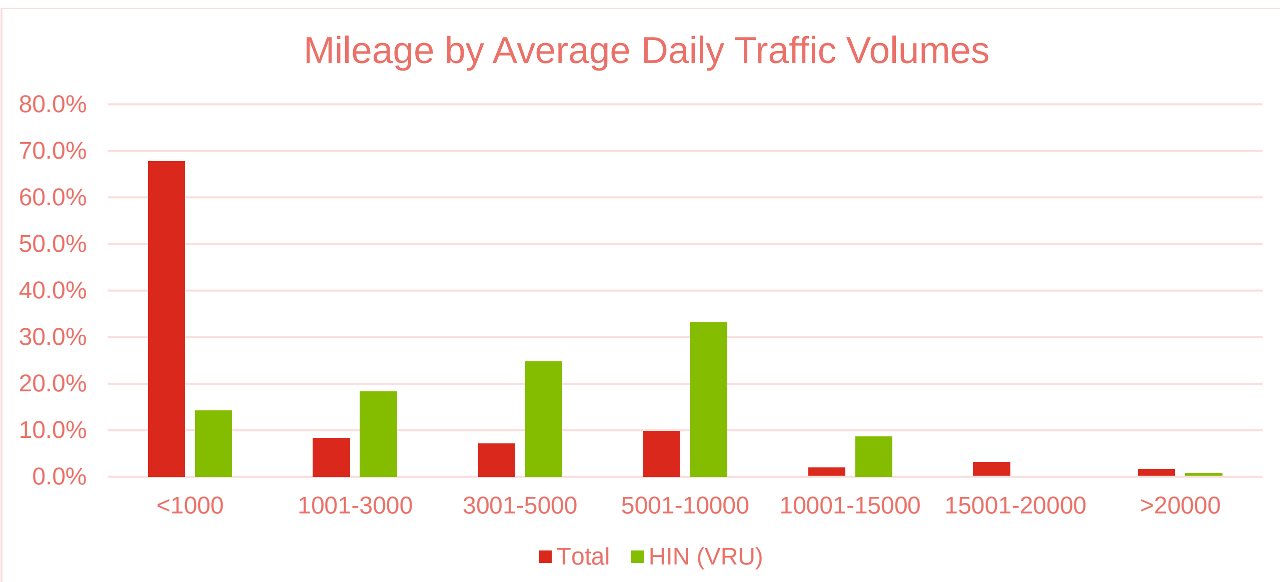

Figure 7: Total Roadway Network vs. VRU High Injury Network by Average Daily Traffic Volumes

STREET WIDTH/CROSSING DISTANCE (VEHICLE-ONLY AND VULNERABLE ROAD USER)

Increased street widths lead to a number of issues related to exposure and vehicle operating speed.

Between intersections, streets with underutilized parking lead to effective lane widths being increased, tending to lead to vehicle operating speed increasing. As described in the sight distance section of this report, vehicle operating speeds need to be relatively low in complex urban environments.

At intersections, increased street widths (in particular, increased amounts of travel lanes) lead to increased conflict points when crossing or accessing a major street from a minor street or taking a left turn from a major street to a minor street.

Pedestrian crossing distance is also used to quantify exposure risk for those crossing a street outside of a vehicle. Pedestrian crossing distances include not only the width of the travel lanes being crossed but also increased distance caused by intersection corner radii needed to accommodate turns for larger vehicles. Analysis of the VRU HIN showed that crossing distances between 33 and 60 feet were most common on the VRU HIN. Crossing distances over 33 feet generally correlate to more than two travel lanes being crossed (or two travel lanes plus on-street parking lanes that can be used for turning vehicles or to pass vehicles stopped in-lane to make a left turn). Pedestrians may find that crossing distances greater than 60 feet are generally undesirable unless absolutely necessary.

DRIVEWAY AND INTERSECTION QUANTITY AND SPACING (VEHICLE-ONLY)

Greater amounts of driveways leading onto roadways with greater traffic volumes increase not only the overall complexity of the transportation system but also the potential for exposure by creating additional conflict points. As vehicle quantity and speed increase, driveway accesses should decrease to limit the amount of additional exposure.

Driveways and intersections spaced close together can contribute to lack of intersection sight distance for those accessing major streets on the side streets and at the driveways. Although this analysis does not establish a recommended minimum spacing distance, driveways and intersections should be spaced such that vehicles do not impede the needed lines of sight for each intersection or driveway.

Closure of excess driveways should be considered as opportunities arise to reduce conflict points and potential exposure on the transportation system.

INTERSECTION OFFSET (VEHICLE-ONLY)

Intersection offset refers to locations where two approaches to an intersection are not lined up directly across from each other. This leads to confusion as to when and where vehicles are turning, particularly on the minor street approaches.

ENVIRONMENTAL FACTORS

LIGHTING (VEHICLE-ONLY AND VULNERABLE ROAD USER)

In many locations in Red Wing, lighting is provided but may not provide adequate illumination in dark conditions to provide needed visibility for all roadway users. This is of particular importance at intersections, which is where the majority of potential conflicts between roadway users occur.

At many residential intersections, a single light is provided intending to illuminate the intersection, as show in Exhibit 5. Although this study did not analyze lighting patterns at each intersection, it is likely based on experience in the community that these lights have not been installed such that the entire intersection, including all crosswalks, are illuminated by the light. Care must also be taken not to over-illuminate the intersection as well and thus illuminate items that should not be, such as adjacent houses.

At many commercial intersections or those with increased roadway widths, additional lighting units are often provided. In some of these locations, the side street and crosswalks may still not be adequately illuminated as is the case in the example shown in Exhibit 6.

Exhibit 5: Example of Single Residential Intersection Light (Potter Street at W 6th Street) – Google Streetview Image

Exhibit 6: Example of Commercial Area Lighting (Tyler Road S at Kosec Drive) – Google Streetview Image

AREAS OF INCREASED PEDESTRIAN AND BICYCLIST ACTIVITY (VULNERABLE ROAD USER)

The VRU high injury network almost entirely is located within areas of increased pedestrian and bicyclist activity:

- Within the non-busing areas of a public school (1 mile radius of elementary school, 1.5 mile radius of a middle school, and 2 mile radius of a high school)
- Within 1/4 mile of a commercial district (such as downtown and Tyler Road areas)
- Within 1/4 mile of a park

These land use features generate pedestrian and bicyclist activity that increases potential exposure of vulnerable road users to vehicle traffic.

INCOMPLETE ADJACENT SIDEWALK NETWORK AND/OR MISSING CROSSINGS (VULNERABLE ROAD USER)

Significant portions of the City of Red Wing lack complete sidewalk and/or trail networks. Where these networks are lacking, pedestrians typically will walk in the street, increasing exposure risk to vehicle traffic. Similarly, in areas lacking crosswalks (ramps and/or striping), visibility of pedestrians by vehicle drivers is reduced leading to increased safety concern.