Memorandum

To: Heidi Schallberg
Met Council

From: David Wasserman, Elizabeth Yarnall, Alta Planning + Design

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Subject: Systemic Safety & Risk Mapping Methods - Metropolitan Council Regional Safety Plan

Enabling safe systems requires building a proactive understanding of where safety risks are in a wider mobility system and how the impact energies of the mobility system can be kept low enough to prevent high severity collisions. Developing this understanding requires a systemic view of the collisions landscape where the built environment, roadway, and other contextual risk factors of the system are analyzed. This memorandum documents the proposed methodology for a proactive systemic safety analysis for the Met Council's Regional Safety Action plan for both bicycles and motor vehicles.

Systemic Safety Analysis

This section will outline the methodology for the Council's systemic safety analysis of bicycle and motor vehicle collisions.

Definitions

- **Systemic Safety** – Enhancing safety of a transportation system by evaluating risk factors across an entire transportation system rather than focusing only on the exact locations of individual collisions.[1] Traditionally, examining only high-crash locations or patterns often focuses safety investment in urban locations where multiple crashes in a short period occurred due to random chance. Many agencies recognize that crash-history-based safety management is not always enough to proactively improve safety. This is especially true for local and rural roads with less traffic, where crash occurrences are fewer, as well as in numerous city regions where vehicles often conflict with at-risk road users like pedestrians, bicyclists, and motorcyclists. A systemic safety approach utilizes rating systems or crash prediction models to prioritize opportunities to reduce crashes.[2]
- **Collision Characteristics** – refers to aspects of crash events that are aspects of the collision such as its mode, conflicting movements, or other characteristics.[3]
- **Exposure –** level of interaction between modes often represented as traffic volumes (vehicles per day), near miss events or nearby collisions.
- **Context -** the combination of the built environment and roadway characteristics for a roadway segment which influence mode choice and travel behaviors.

[1]Federal Highway Administration (FHWA). Potential Risk Factors. Washington, D.C. Accessible at: https://safety.fhwa.dot.gov/systemic/pdf/FHWA_SystemicApproach_PotentialRiskFactors.pdf.
[2]National Academies of Sciences, Engineering, and Medicine 2020. Guide for Quantitative Approaches to Systemic Safety Analysis. Washington, DC: The National Academies Press. https://doi.org/10.17226/26032.
[3]Federal Highway Administration (FHWA). Road Safety Fundamentals. Washington, D.C. Accessible at: https://rspcb.safety.fhwa.dot.gov/RSF/default.aspx

- **KSI** – refers to collisions that involve people being killed or seriously injured.

Previous Analysis & Plans Review

Systemic Safety Analysis conducted for the Metropolitan Council Regional Pedestrian Safety Action Plan in 2022 includes screening the roadway network to calculate crash frequencies and rates by severity associated with physical roadway characteristics, community type, as well as expected travel behaviors and traffic exposure. Using this approach, safety analysts were able to estimate likely risk factors and identify higher risk locations for specific crash types. This information was presented in a crash tree diagram and mapped along the network.

The variables used to estimate risk factors included:

- Pedestrian Crash Types
    - Intersection – Motor-vehicle turning
    - Intersection – Motor-vehicle going straight
    - Midblock (segment)
- Simplified *Thrive Community* Type
    - Rural
    - Suburban
    - Urban
- Intersection or Road Segment Features
    - Lane Configuration
    - Speed Limit
    - Traffic Volumes
    - Transit Stop Nearby
    - Traffic Control Device (Intersections Only)
    - Roadway Type / Functional Class (Segments Only)

Available Data Understanding

- Land Use Data: Parcels provided from Met, updated 2020
- Traffic Volumes: AADT at key locations
- Roadway Functional Classifications
- Roadway curvature
- Replica Traffic Volume Estimates: AADT (Typical Weekday Fall 2021) (vpd)
- Replica Speed Estimates: Free flow speeds – 66^{th} Percentile, off-peak
- Replica Modeled Bike Volumes (vehicles per day)
- Existing Bicycle Facilities
- Transit stop point locations, boardings and alightings 2013 to 2022

Proposed Approach

The Bicycle and Motor Vehicle Systemic Safety analysis will be consistent with previous evaluations of systemic safety focused on pedestrians.

The contextual data that will be used to estimate Bicycle Crash Risk and Motor Vehicle Crash Risk could include:

- Crash Types
  - Severity
  - If at Intersection & Bicycle Crash
    - Motor-vehicle turning
    - Motor-vehicle going straight
  - Alcohol-Related
  - Distraction-Related
  - Speed-Related

- Simplified *Thrive Community* Type
  - Rural
  - Suburban
  - Urban

- Land Use Context
  - Commercial Area
  - Park / Undeveloped / Greenspace
  - Government / School / Non-Profit
  - Single Family Detached Residential
  - Non-Single Family Detached Residential
  - Mixed-Use Industrial or Mixed-Use Commercial
  - Mixed-Use Residential
  - Agricultural
  - Industrial / Utility / Extractive
  - Transportation

- Intersection or Road Segment Features
  - Lane Counts/Configuration
  - Existing Bicycle Facility
  - Near off-road bicycle facility
  - Speed Data (Replica Estimates)
  - Transit Stop Nearby
  - Max Ridership of Nearby Transit Stops
  - Curvature (network derived)
  - Presence or Absence of Lighting
  - Traffic Control Device (Intersections Only)
  - Roadway Type / Functional Class (Segments Only)
- Exposure
  - Vehicle Volumes AADT Data (Regional Council + Replica Estimates)
  - Bicycle Volumes (Regional Council + Replica Places)

The above contextual data will be conflated with adjacent road and bicycle network intersections and segments. For example, all parcels within 250 feet of a roadway segment will be used to tag distinct land use categories identified above. Once joined with networks and intersections, contextual factors will be tabulated against raw counts of bicycle and vehicle collision by severity.

Finally, a severity-weighted collision index will be created for the purposes of calibrating a risk index for each mode. This severity-weighted index will use used to identify key trends and relationships between risk factors and collision patterns for bicycling and vehicle travel respectively.

To create the risk index, we propose translating patterns in the cross tabulations and correlativeanalysis to identify the most important risk factors to address with near-term actions. Alta will first cross tabulate proportions of KSI and non-KSI crashes with types of each roadway segment and intersection contextual factors such as number of lanes, speeds, or behavior. This proportion will guide the assignment of a risk score for each roadway segment or intersection context, and final points will be linearly normalized so that each contextual factor category has a max of 5 points.

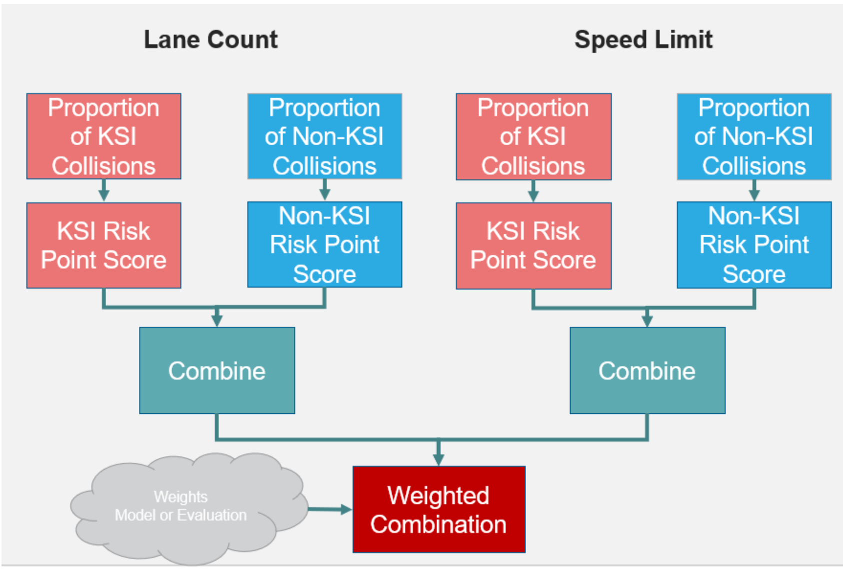


Figure 1. Visualization of how final risk scores for a particular mode will be determined.

Next, each contextual factors risks scores will be combined into a risk factor score that will enable the creation of a heat map of every segment and intersection that has multiple overlapping risk factors identified as part of the systemic analysis. The weights between risk factors will be either **equally weighted** or based on **a qualitative assessment of factors and a basic correlation analysis**. **Figure 1** identifies the anticipated process for two example contextual factors to determine final risk factor scores.

To work through an example, let's assume we are looking at profiles of speeds and lanes. We would propose that points be created for these categories based on the concentration of collisions within each profile, such that the category that is the most concentrated is assigned 5 points as show in **Table 1**

Table 1: This table shows how different lane groupings tabulated fractions would be used to assign points to a contextual risk factor. With each fraction being multiplied by the max points available for KSI vs. Non-KSI points, summed, and then linearly normalized to 5 points for the max category. This Final Risk Factor Point score would be then put into a weighted combination with other contextual risk factors for a risk index created for each mode.

Lanes Categories	KSI Fraction	Non-KSI Fraction	Max KSI Points	Max Non-KSI Points	KSI Points	Non-KSI Points	Raw Risk Factor Points	Final Risk Factor Points
"0-2"	10%	17%	4	1	0.4	0.17	0.57	**0.9**
"3-4"	66%	50%	4	1	2.64	0.5	3.14	**5**
"5-6"	13%	23%	4	1	0.52	0.23	0.75	**1.2**
"7+"	10%	10%	4	1	0.4	0.1	0.5	**0.80**

Assuming these types of four-lane road segments may have a risk score of 5, and roadway segments posted at 35 miles-per-hour may have a risk score of 1.6, a qualitative assessment of weights provides us with relative importance of 0.25 for roadway segment number of lanes and 0.75 for roadway segment speed. Therefore, the total risk score would be:

$$Total\ Risk\ Score\ for\ four\ lane, 35\ mph\ roadway\ segments = (\alpha) * (\varepsilon) + (\beta) * (\tau)$$

$$Total\ Risk\ Score\ for\ four\ lane, 35\ mph\ roadway\ segments = 5 * 0.25 + 3.5 * 0.75$$

$$Total\ Risk\ Score\ for\ four\ lane, 35\ mph\ roadway\ segments = 2.5$$

Where:

α = cross-tabulated risk score of four-lane roads

β = assessment derived weight of four-lane roads

ε = cross-tabulated risk score of 35 mph roads

τ = assessment derived weight for importance of 35 mph roads

Once total risk scores are determined for each roadway segment and intersection type, a heat map will be generated displaying risk scores for segments and intersections for bicyclist and vehicles.

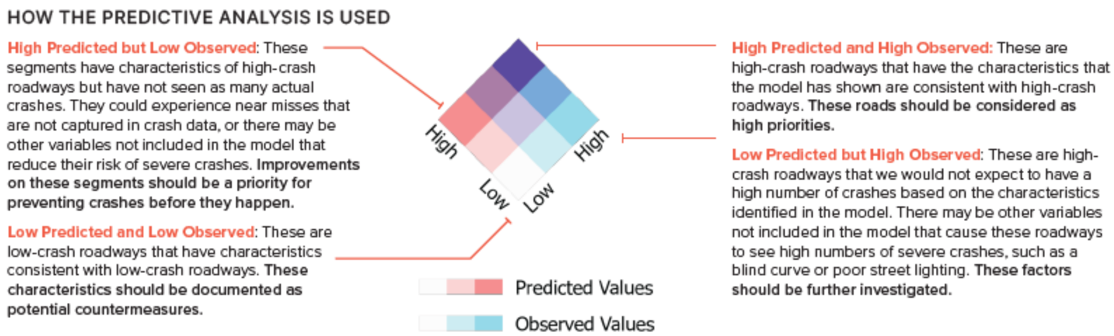
Additional Guidance on Process

Background

The intent of the Systemic Safety Analysis is to serve as a data-driven, comprehensive evaluation of what is causing fatal and serious injury crashes in the Met Council region. While it draws from the HIN, the systemic analysis factors in contextual roadway characteristics that will help pinpoint the type of roadways causing these types of crashes. To quantify the impact of these contextual factors, the approach described below was used (this is consistent with the Pedestrian Safety Action Plan approach).

Both observed (historical crashes) and predictive (contextual factors) were considered in developing the Crash Risk Index (CRI). The Crash Rate Index was developed for both vehicular and bike crashes (two CRIs total). Considering both observed and historical crashes allows the following:

- Leaning on historical crashes and the HIN in determining where to focus current safety improvements on.
- Proactively identifying roadway characteristics that inherently contribute to injury crashes, particularly fatal and serious injury crashes.



The graphic above was developed by Alta for the Knoxville Regional TPO Safety Action Plan predictive analysis approach. It demonstrates the intent of factoring both historical crashes and contextual factors into calculating a crash risk index, and how each "quadrant" of results can be interpreted in analysis and prioritization.

Risk Factors & Thresholds

While several contextual risk factors were evaluated (as documented in the methodology memo), the team selected AADTs, number of lanes, and posted speed limit to integrate into the Crash Rate Index based on the following:

- The contextual factors that influenced safety the most in the Met Council region.
- The availability and completeness of contextual datasets to map risk factors in areas with no crash history.

The thresholds for each of the contextual factors were determined based on the following:

- The dataset distribution patterns for each contextual factor.
- Federal guidance for volume, speed, and number of lanes thresholds, which is also tied to the appropriate type of countermeasures.

Analysis

The analysis separated roadway segments (midblock) from intersections given the very different crash types, contributing factors, and needed safety improvements. The category bins shown in Tables 1 through 4 were determined for each of the three contextual factors (lanes, AADT, and posted speed). Each table includes the actual number of crashes, versus the percentage. The tables also show the number and percentage of crashes broken down by fatal and serious injury (K+A) crashes versus minor injury crashes.

Final Crash Rate Index (CRI) scores for each roadway segment in the Met Council region were calculated using the following formula: "Segment Lanes CRI + Segment Speed CRI + Segment AADT CRI."

Historical injury crashes were also factored into the analysis. Fatal and serious injury crashes were weighted 4 times as much as minor injury crashes. This serves two purposes:

- Maintain the focus on prioritizing fatal and serious injury crash locations, where causes, and consequently solutions, could vary from more minor or non-injury crashes.
- Acknowledge that some minor injury crashes, when clustered in some locations, may further confirm the crash-prone characteristics of a particular roadway.

It is important to note that aside from fatal and serious injury crash weighting, no other weighting was applied to these three contextual factors, to remain as objective as possible. However, the roadway segments were normalized by segment length. This means that the risk factors with higher "risk densities" are weighted more heavily in the result of the analysis.

Finally, the top 1% of each Crash Rate Index was selected to represent the segments and intersections that have both high observed crashes and high predictive characteristics.

Crate Rate Index Scoring Details

Tables 1-4 show the factors that were developed for each of the four Crash Rate Indexes (bike intersection Crash Rate Index, bike segment Crash Rate Index, vehicle intersection Crash Rate Index, and vehicle segment Crash Rate Index) based on the methodology described above. The following is a clarification of the different columns in the tables:

- Each table contains the 3 contextual factors integrated into the Crash Rate Index: number of lanes, posted speed, and AADT.
- The thresholds column are the category breakdowns for each contextual factors, determined based on industry practice and the natural breaks in the data.
- The proportion of network length is the normalization factor that was applied to account for the segment length so as not to skew results.
- The proportion of K+A crashes is the percentage of fatal and serious injury crashes for the specific category. The percentages under each contextual factor should roughly add up to 100% (may not be exactly 100% due to rounding).
- The proportion of minor crashes is the percentage of minor crashes for the specific category. The percentages under each contextual factor should roughly add up to 100% (may not be exactly 100% due to rounding).

Table 2. Intersection Crash Rate Index (CRI), Bike mode

Contextual Factor	Threshold	Proportion of Network Length	Proportion of K+A crashes	Proportion of Minor crashes	Raw K+A Score	Raw Minor Score	Final Score K+A *(Raw x4)*	Final Score Minor *(Raw x1)*	Final CRI
Lanes	1-2	90.87%	57%	62%	0.63	0.68	2.51	0.68	3.19
	3-4	8.72%	19%	21%	2.21	2.44	8.82	2.44	11.26
	5-6	0.37%	4.5%	3%	12.14	7.86	48.54	7.86	56.41
	6+	0.04%	19%	14%	464.75	342.00	1859.00	342.00	2201.00
Speed	<25 MPH	14.60%	9%	14%	0.61	0.99	2.46	0.99	3.44
	25-30 MPH	43.63%	40%	45%	0.93	1.04	3.70	1.04	4.74
	30-35 MPH	25.67%	26%	20%	1.00	0.79	4.00	0.79	4.78
	35-40 MPH	4.01%	6%	7%	1.60	1.71	6.39	1.71	8.10
	>40 MPH	12.09%	19%	13%	1.54	1.10	6.15	1.10	7.25
AADT	<9,000	91.37%	71%	74%	0.77	0.81	3.09	0.81	3.90
	9000-15,000	4.68%	19%	16%	4.11	3.33	16.44	3.33	19.76
	>15,000	3.95%	10%	0.1%	2.60	2.62	10.39	2.62	13.01

Table 3. Midblock / Segment Crash Rate Index (CRII), Bike mode

Contextual Factor	Threshold	Proportion of Network Length	Proportion of K+A crashes	Proportion of Minor crashes	Raw K+A Score	Raw Minor Score	Final Score K+A *(Raw 4)*	Final Score Minor *(Raw x1)*	Final CRI
Lanes	1-2	92.18%	60%	71%	0.65	0.77	2.60	0.77	3.38
	3-4	7.49%	13%	9%	1.78	1.25	7.12	1.25	8.37
	5-6	0.31%	0.00%	1%	0.00	3.55	0.00	3.55	3.55
	6+	0.02%	24%	15%	1222.00	773.50	4888.00	773.50	5661.50
Speed	<25 MPH	15.31%	11%	12%	0.73	0.79	2.90	0.79	3.70
	25-30 MPH	38.52%	42%	40%	1.10	1.05	4.38	1.05	5.43
	30-35 MPH	23.72%	9%	28%	0.37	1.19	1.50	1.19	2.69
	35-40 MPH	3.63%	18%	7%	4.90	1.98	19.59	1.98	21.57
	>40 MPH	18.82%	20%	12%	1.06	0.65	4.25	0.65	4.90
AADT	<9,000	91.44%	71%	81%	0.78	0.89	3.11	0.89	4.00
	9000-15,000	3.37%	18%	11%	5.28	3.28	21.10	3.28	24.38
	>15,000	5.19%	11%	8%	2.14	1.49	8.56	1.49	10.05

Table 4. Intersection Crash Rate Index (CRI), Motor Vehicle mode

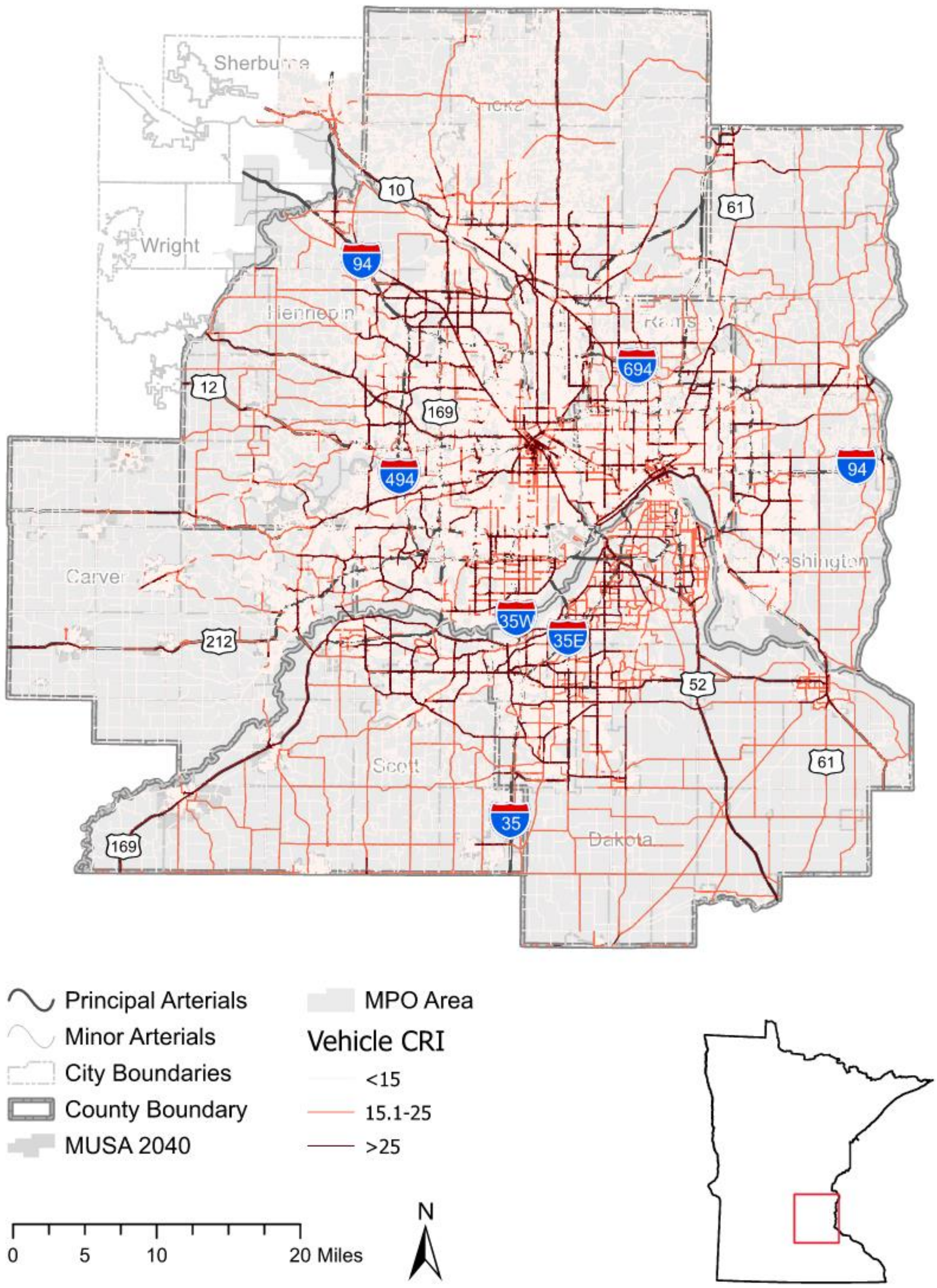
Contextual Factor	Threshold	Proportion of Network Length	Proportion of K+A crashes	Proportion of Minor crashes	Raw K+A Score	Raw Minor Score	Final Score K+A *(Raw x4)*	Final Score Minor *(Raw x1)*	Final CRI
Lanes	1-2	90.87%	65%	61%	0.72	0.67	2.87	0.67	3.54
	3-4	8.72%	28%	33%	3.19	3.75	12.75	3.75	16.49
	5-6	0.37%	5%	5%	13.51	13.54	54.05	13.54	67.59
	6+	0.04%	1.5%	1%	37.25	31.00	149.00	31.00	180.00
Speed	<25 MPH	14.60%	11%	10%	0.72	0.71	2.90	0.71	3.61
	25-30 MPH	43.63%	38%	37%	0.85	0.84	3.42	0.84	4.26
	30-35 MPH	25.67%	16%	19%	0.61	0.74	2.45	0.74	3.19
	35-40 MPH	4.01%	7%	8%	1.85	2.02	7.38	2.02	9.41
	>40 MPH	12.09%	29%	26%	2.40	2.13	9.60	2.13	11.73
AADT	<9,000	91.37%	69%	66%	0.75	0.72	3.02	0.72	3.74
	9000-15,000	4.68%	16%	17%	3.43	3.71	13.71	3.71	17.42
	>15,000	3.95%	15%	17%	3.81	4.28	15.25	4.28	19.53

Table 5. Midblock / Segment Crash Rate Index (CRI), Motor Vehicle mode

Contextual Factor	Threshold	Proportion of Network Length	Proportion of K+A crashes	Proportion of Minor crashes	Raw K+A Score	Raw Minor Score	Final Score K+A *(Raw x4)*	Final Score Minor *(Raw x1)*	Final CRI
Lanes	1-2	92.18%	75%	70%	0.82	0.76	3.27	0.76	4.04
	3-4	7.49%	19.5%	24%	2.60	3.22	10.40	3.22	13.63
	5-6	0.31%	3%	3.55%	8.97	11.45	35.87	11.45	47.32
	6+	0.02%	0.6%	0.75%	29.00	37.50	116.00	37.50	153.50
Speed	<25 MPH	15.31%	9%	9%	0.61	0.60	2.46	0.60	3.06
	25-30 MPH	38.52%	25%	24%	0.66	0.62	2.62	0.62	3.24
	30-35 MPH	23.72%	11.5%	18%	0.49	0.77	1.94	0.77	2.72
	35-40 MPH	3.63%	8.5%	10%	2.35	2.88	9.41	2.88	12.29
	>40 MPH	18.82%	45%	38%	2.41	2.02	9.63	2.02	11.65
AADT	<9,000	91.44%	66%	59%	0.72	0.65	2.87	0.65	3.51
	9000-15,000	3.37%	16%	15%	4.67	4.55	18.68	4.55	23.24
	>15,000	5.19%	19%	25%	3.61	4.91	14.42	4.91	19.33

The following figures illustrate the regional Crash Rate Index Maps.

Figure 1 Regional Crash Rate Index Map – Motor Vehicle



**For a more detailed view of the Map, see the AGOL Online Project Map. Some locations may include two layers.*

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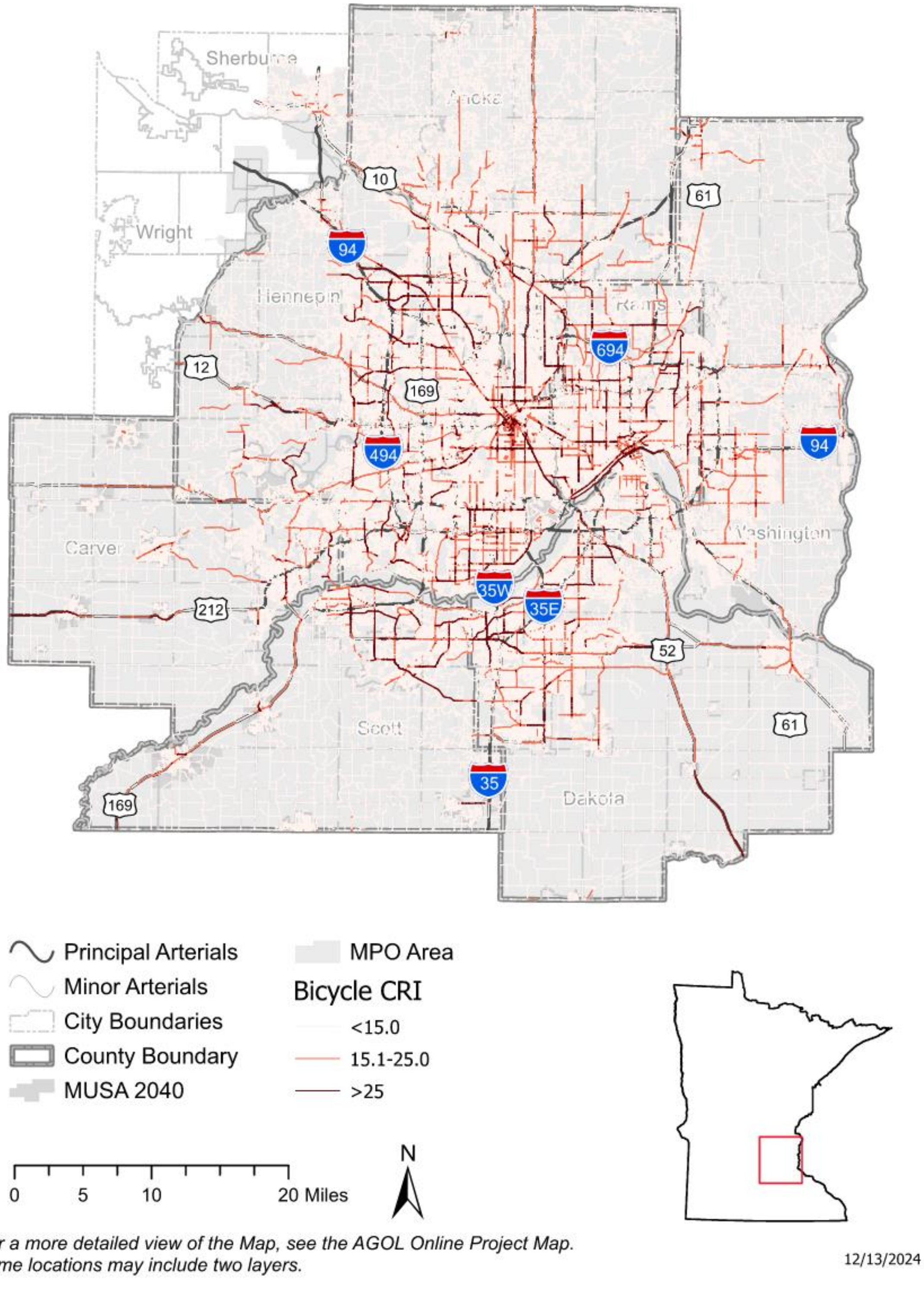
Figure 2. Regional Crash Rate Index Map – Bicycle



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Some locations may include two layers.

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