Methodology

Objectives and Scope

The Risk Exposure Assessment is a risk-prediction model designed to evaluate roadway attributes that contribute to crash risk, with a specific focus on vulnerable road users (VRU), identified as pedestrians and cyclists. The primary objective is to create a comprehensive risk map of the MetroPlan region to support:

- Project identification for safety improvements
- Prioritization of safety projects specific to Vulnerable Road Users
- A visual representation of VRU risk to guide data-driven decision-making
- Understand safety risks related to infrastructure and geometry of design
- Understand the influences on exposure to crashes
- Determine if higher risks impact disadvantaged communities
- Offer predictive analysis of where crashes are most likely to occur

MetroPlan defined risk factors and exposure as the following

- A **risk factor** is a characteristic or behavior that increases the likelihood of a negative outcome. *In this case, it is the physical design of the roadway. (ex. number of through lanes)*
- **Exposure** is the condition of being exposed to something. *In this case, vulnerable road users are exposed to risk factors (road attributes).*

Peer Insights & Methodological Refinement

The MetroPlan Risk Exposure Assessment was developed with inspiration from the Indianapolis Metropolitan Planning Organization's (IMPO) Traffic Safety Risk Score Map, which was used in the 2023 Safety Action Plan Update. The IMPO analysis assessed all crashes across the roadway network to identify high-risk road attributes contributing to overall crash frequency.

In contrast, the MetroPlan Risk Exposure Assessment specifically focuses on crashes involving vulnerable road users (pedestrians and cyclists). By tailoring the methodology to VRU-related crashes, this approach provides more targeted insights into the safety challenges faced by non-motorized travelers, ensuring that risk mitigation efforts address the most critical factors influencing pedestrian and bicyclist safety.

Data Collection

Data for this analysis was sourced from multiple agencies, including the **Arizona Department of Transportation (ADOT)**, the **City of Flagstaff (COF)**, and **MetroPlan's Traffic Model**. Each dataset contributed specific attributes essential for the study.

ADOT Data

ADOT provided comprehensive road network information through its Highway Performance Monitoring System (HPMS), a federally mandated dataset submitted annually to the Federal Highway Administration (FHWA). The 2023 HPMS dataset, representing all active roads in Arizona for that year, was obtained in line format. Key attributes extracted from HPMS included:

- Number of Through Lanes
- Lane Width
- Functional Classification
- Presence of Turn Lanes (Right and Left)
- Median Type and Width
- Annual Average Daily Traffic (AADT)
- Speed Limit

The HPMS dataset maintains high spatial accuracy, ensuring that roadway attributes are only assigned to the segments where they are physically present (e.g., turn lanes are delineated only from their starting point to their endpoint).

Intersection information from HPMS was also collected, including:

- Crosswalk Type
- Turn Code
- Number of Legs
- Signalization
- Bicycle Facility
- Traffic Control

City of Flagstaff Data

To enhance roadway attribute information, MetroPlan staff collaborated with COF to acquire the Pedestrian and Bicycle Comfort Index dataset. This dataset, also provided in line format, included detailed roadway attributes within the city limits, such as:

- Functional Classification
- Speed Limit
- Number of Lanes
- Median Type
- Presence and Width of Bicycle Facilities
- Sidewalk Presence
- On-Street Parking Availability

MetroPlan Traffic Model Data

Traffic volume data was extracted from the MetroPlan Traffic Model, which provides vehicle volume estimates in line format. Additionally, data on Vulnerable Road User (VRU) activity levels were collected, represented as Traffic Analysis Zones (TAZs) in polygon format. These zones include an approximated number of VRUs within each TAZ, contributing to the assessment of pedestrian and bicycle activity.

Equity and Safety Data

To incorporate an equity perspective, staff utilized ADOT's Vulnerable Road User Safety Assessment Merged Equity Data, which provides a calculated equity score at the U.S. Census Block Group level. This dataset, in polygon format, was used for equity analysis.

For safety analysis, crash data was obtained from ADOT's AZ Crash Information System (ACIS), covering the period from 2017 to 2023. This dataset includes:

- Precise crash locations
- Types of road users involved (vehicles, pedestrians, bicyclists)
- Injury severity levels
- Additional contributing factors

Each dataset was carefully reviewed and integrated to ensure consistency and reliability in the analysis.

Data Preparation and Processing

Data preparation and processing were conducted using ArcGIS Pro, a geographic information system (GIS) tool that enables spatial and tabular analysis. The following steps were undertaken to standardize and integrate the datasets for analysis.

All spatial datasets were imported into ArcGIS Pro and clipped to the MetroPlan boundary to ensure a consistent study area and improve processing efficiency.

Preliminary calculations and data cleaning were performed to refine attribute values:

- Speed Adjustment: An estimated average speed was calculated as *(Speed Limit + 7)*.
- Median Width Processing: Median width values were adjusted by computing the difference between the average start median and average end median.

To streamline processing, non-essential attributes such as HOV lanes and Milepost data were removed. These attributes were excluded because they were either not relevant to the scope of the analysis or did not contribute meaningful insights to the study's objectives.

ADOT's Highway Performance Monitoring System (HPMS) dataset stores roadway attributes across multiple layers, rather than in a single, unified dataset. Since each attribute exists as a separate line feature, a method was needed to consolidate these attributes while preserving their spatial extents. The following steps were performed:

1. The Feature to Point tool was used to place a point at each location where a roadway attribute changed (i.e., at every line break in the road network). This step ensured that attributes could later be joined accurately without altering their original extents.
2. Each attribute layer was split at these generated points. This process ensured that when multiple attributes were combined, their individual start and end locations remained intact.
3. A spatial join was performed to merge all segmented attribute layers with a reference road network containing only the roadway geometry. This step created a single, continuous dataset that retained all relevant attributes while maintaining spatial accuracy.

This method ensured that each attribute retained its precise extent while allowing for a single, comprehensive road network to be used in the analysis. The final dataset included:

- Number of Lanes
- Functional Classification
- Median Type
- Median Width
- Presence of Right and Left Turn Lanes
- Annual Average Daily Traffic (AADT)

In processing City of Flagstaff Data, non-essential fields were removed, and field names were standardized for clarity and consistency. A similar analysis, as was conducted for ADOT roads, was done for COF data to ensure spatial extent.

Crash data were filtered to only include crashes involving a bicycle or pedestrian.

To process MetroPlan Traffic Model Data:

- Vehicle volume data were filtered to exclude irrelevant fields.
- Bicycle and pedestrian activity counts were aggregated in tabular format before being imported into ArcGIS Pro for spatial analysis.

Some attributes had to be manually created, such as sidewalks that exist outside of city limits. This process was completed through satellite imagery reference and digitizing.

By applying this approach, datasets were standardized and cleaned, ensuring consistency and accuracy in subsequent analyses.

Data Integration and Analysis

To facilitate a unified scoring and analysis framework, ADOT and COF road network datasets were merged into a single roadway network containing attributes from both sources. Roads from both datasets were exported together, ensuring all relevant fields were retained.

In some cases, particularly for divided roadways with landscaped medians, roads were represented as two separate one-directional segments instead of a single bi-directional road. To correct this, the Merge Divided Roads tool was applied, consolidating divided boulevards while maintaining attribute integrity for all other road types.

Once the network was unified, new fields were created to standardize attributes across both datasets, prioritizing COF data where applicable. The final set of attributes included:

- Functional Class
- Through Lanes
- Right Turn Lanes
- Left Turn Lanes
- Speed Limit
- Average Speed
- AADT
- Lane Width
- Median Type
- Bike Facility Presence
- Bike Facility Width
- Sidewalk Presence
- Parking Presence

This process resulted in a single, spatially accurate dataset that streamlined further analysis.

Vulnerable Road User (VRU) Density Calculation

To assess the density of vulnerable road users (VRUs) within Traffic Analysis Zones (TAZs):

1. TAZ area (in square miles) was calculated.
2. VRU activity counts were divided by the square mileage of each TAZ to generate a VRU density metric.
3. The Summarize Nearby tool was then used to assign VRU activity levels to road network segments falling within (and average for roads between) each TAZ.

Vehicle Volume and Equity Data Integration

- Vehicle volume data from MetroPlan's Traffic Model was transferred to the combined road network using the Transfer Attributes tool. After transfer, data accuracy was verified.

- Polygonal datasets, such as Equity Area designations, were spatially joined to the road network to enable equity-based analysis.

Crash Data Processing

To ensure spatial accuracy, crash data was first snapped to the road network before integration. For crashes occurring at intersections:

- Each crash was evenly distributed across the intersection's legs to reflect proportional risk exposure.
    - *Example:* A single crash at a four-way intersection was assigned 0.25 crash value per leg.
- The crash value field was then spatially joined to the road network and summed, providing a total crash count per segment.

Final Road Segment Processing

To facilitate length-based calculations, each road segment's length (in U.S. survey miles) was computed and applied to the road network as a final processing step.

This structured approach ensured a fully integrated, spatially accurate, and analysis-ready dataset, enabling robust scoring and evaluation.

Scoring Development

Tabular Analysis of Attributes

To identify trends and assess roadway risk, all attributes and fields were exported to CSV format for tabular analysis. The percentage of total roadway length for each attribute was compared against its percentage of total crashes using Length in Miles as the denominator.

Risk Factor Calculation

A risk factor was determined for each attribute using the following formula:

Risk Factor= (% of crashes×100)/(% of total roadway length×100). The below table demonstrates an example of outcomes related to functional class and number of through lanes.

Functional Class	Length MI	# of Crashes	% of Length	% of Crashes	Risk Factor
Commercial Local	7.81	39	2%	8%	5.5
Industrial Local	6.27	4	1%	1%	0.6
Local	138.93	0	27%	0%	0.0
Major Arterial	12.61	93	2%	20%	8.0
Major Collector	53.70	117	10%	25%	2.4
Minor Arterial	57.12	127	11%	27%	2.4
Minor Collector	97.73	51	19%	11%	0.6
Principal Arterial - Other	3.45	5	1%	1%	1.6
Residential Local	139.87	39	27%	8%	0.3

Through Lanes	Length MI	# of Crashes	% of Length	% of Crashes	Risk Factor
1	119.51		10%	0%	0.0
2	1084.65	198	86%	41%	0.5
3	22.94	83	2%	17%	9.3
4	11.54	54	1%	11%	12.1
5	13.37	123	1%	25%	23.7
6	2.09	28	0%	6%	35.1

This method accounts for proportional representation, ensuring that attributes with a disproportionate share of crashes relative to their roadway length were identified. Once all attributes were analyzed, they were ranked in order of risk factors to highlight the highest-risk roadway characteristics.

Category	Type	% of L	% of Cras	Risk Facto
Through Lanes	6	0%	6%	35.1
Through Lanes	5	1%	25%	23.7
Median Type	TWLTL	3%	45%	14.8
Equity	Medium Equity	1.2%	17.8%	14.3
Left Turn	TRUE	2%	32%	13.7
Parking Presence	One side	1%	7%	12.5
Through Lanes	4	1%	11%	12.1
Bike Facility Width	Narrow width	0.5%	6.2%	11.7
Right Turn	TRUE	2%	20%	11.6
Parking Presence	None	7%	70%	9.9
Through Lanes	3	2%	17%	9.3
Speed Limit	30 - 40	5.4%	49.6%	9.2
Bike Facility Width	Standard width	4.0%	35.7%	8.9
Equity	Low Equity	1.3%	11.1%	8.7
Functional Class	Major Arterial	2%	20%	8.0
Equity	High Equity	2.0%	15.6%	7.8
AADT Class	20k+	2.4%	17.4%	7.4

Validation and Contextual Analysis

The highest-ranking risk factors were further researched and discussed internally and with city partners to:

- Assess accuracy: Determining whether an attribute contributes directly to roadway risk or if its presence correlates with other high-risk factors.
- Identify co-linearity: Some attributes may not inherently increase crash risk but appear with another attribute with a high-risk factor in a high-risk areas.

Determining Co-Linearity

Co-linearity occurs when two or more attributes are highly correlated, meaning that their presence consistently overlaps, making it difficult to determine which factor is actually influencing crash risk. To assess co-linearity in the dataset, the following steps were taken:

1. Correlation Analysis – Attributes were compared against each other. If two attributes had a strong correlation (e.g., roads with on-street parking consistently had lower speed limits), their individual contributions to crash risk were examined further.
    - For example, the presence of parking was determined to be correlated to Functional Class, and thus, Functional Class was used as the risk factor. Sidewalks were also determined to be related to Functional Class.
2. Geospatial Overlap – High-risk attributes were mapped and visually analyzed to identify patterns. If multiple attributes frequently appeared on the same road segments, this suggested possible co-linearity.

Comparative Risk Assessment – Attributes with high risk factors were evaluated in isolation and in combination to determine whether an attribute independently contributed to risk or was simply present alongside another high-risk characteristic.

Removed Attributes Include;

- Parking Presence – Correlated to Functional Class
- Sidewalk Presence – Correlated to Functional Class
- Road Network Density – Not Determinative of Risk
- Bike Facility Presence – Not as highly correlated as Bike Facility Width
- School, Emergency Housing and Transit Stop Walksheds – Not Determinative of Risk

Some risk exposure models include levels of VRU activity. MetroPlan elected not to use this for two reasons: 1) Lack of data; 2) Intent to map risk conditions, as opposed to exposure. Should exposure be introduced in the future, the use of pedestrian and bicycle demand estimates from the MetroPlan Regional Transportation Model is a potential source.

Addressing Co-Linearity in the Final Risk Score

To ensure that co-linearity did not distort the final risk assessment:

- Redundant or dependent variables were consolidated where appropriate. If an attribute was highly correlated with another, the attribute with the most direct relationship to crashes was prioritized.
- Weight adjustments were applied for attributes that showed dependency on another factor.

The final risk score was developed based on this structured, data-driven approach:

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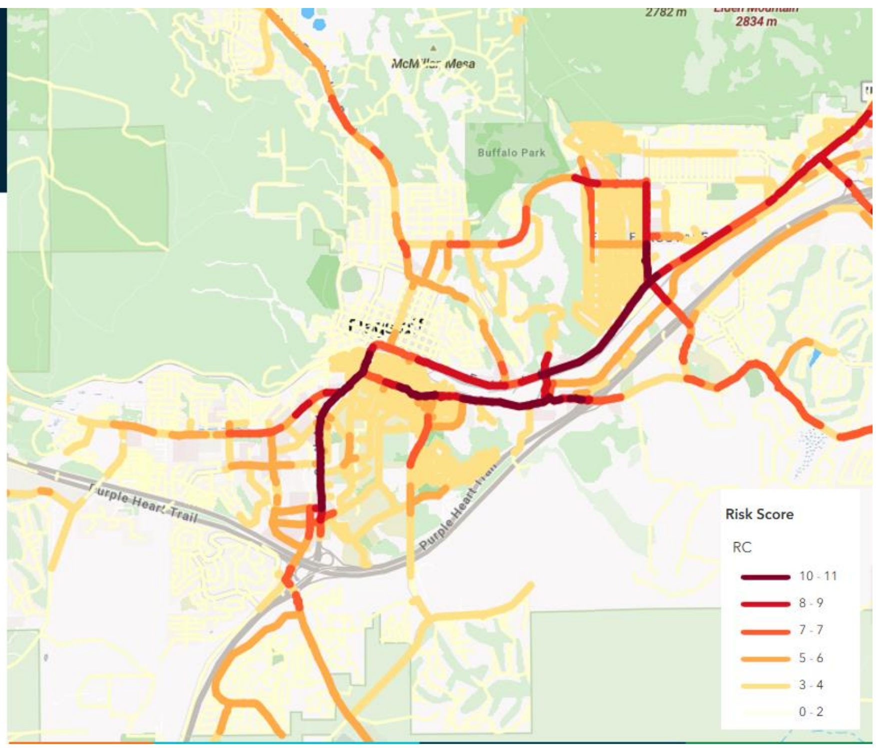
Risk Score

Attributes		Points
Equity Area	No	0
	Yes	2
Through Lanes	1-2	0
	3-4	1
	5-6	3
Right Turn	Not Dedicated	0
	Dedicated	1
Left Turn	Not Dedicated	0
	Dedicated	1
Bike Facility Width	Extra Width	0
	Narrow/ No Bike Lane	1
Median Type	TWLTL	1
	No Median	0
Speed Limit	Less than 30MPH	0
	30MPH+	1
Vehicle Volume	<10k	0
	10-20k	1
	20k+	2
Total Points Possible		12



Limitations

While every effort was made to ensure the accuracy of the Risk Exposure assessment, MetroPlan acknowledges that there are certain limitations:

1. **Data Accuracy & Availability –** The assessment relies on available roadway, crash, and environmental data, which may contain errors, omissions, or inconsistencies. Data limitations, such as incomplete crash reporting or misclassified roadway attributes, can impact results.
2. **Generalization of Risk Factors –** Risk factors are analyzed at the network level, meaning localized conditions (ex. temporary roadwork, weather, driver behavior) are not individually assessed. The model provides relative risk levels rather than predicting specific crash occurrences.
3. **Static Nature**– The assessment is based on historical crash and roadway data, meaning it does not account for real-time changes. While the risk exposure assessment will be updated over time as new data becomes available, this is contingent upon reliant data being updated.
4. **Limitations in VRU Crash Data –** Not all pedestrian and cyclist incidents are reported, particularly near-miss events or low-severity crashes. Underreporting may result in an undervalued risk for some areas.

Disclaimer

This tool is intended to support decision-making and project prioritization but should not be used as the sole determinant for policy or infrastructure changes. Field assessments, community input, and additional analyses should complement findings from the Risk Exposure Assessment to ensure a comprehensive approach to improving roadway safety.

MetroPlan makes no guarantees, representations, or warranties regarding the accuracy, completeness, or reliability of the data or analysis contained in this tool. Users assume all responsibility for the interpretation and application of the results.