To: SCDOT, Stantec

From: Alta Planning + Design

Date: 10/29/2024

Re: SCDOT Regional Bike/Ped Safety Analysis: CMCOG

Crash Trends

This analysis uses crash data from January 1, 2018 to December 31, 2022 provided from SCDOT to the project team on June 27, 2024.

Crash Trends

The CMCOG data is organized with individual occupant rows, however this analysis focuses on crash information and therefore only utilizes the data associated with Occupant 1, a total of 167,489 crashes for the trend analysis.

The team examined the multiple trends displayed in the crash history data, and report interesting findings. Trends examined included the differences between proportions of KSI (KA) and non-KSI (BCO) bicycle and pedestrian crashes by Max Injury Code, comparing:

- Temporal
  - Crashes per year
  - Crashes per time of day
- Travel Conditions
  - Light condition
  - Road surface condition
- Driver Behaviors
  - Speeding Involved
  - Road Departure Involved
- Roadway Context
  - Functional Class of the midblock, or highest of the intersection
  - Number of lanes

The following key trends were identified from comparing the proportion of KSI and non-KSI crashes, regardless of mode.

- There is a higher proportion of fatal and severe crashes at night by time of day.
  - 34% KSI vs. 22% non-KSI from 6 PM to Midnight and
  - 19% KSI vs. 7% non-KSI Midnight to 6 AM.
- There is a higher proportion of fatal and severe crashes at night as indicated by light condition.
  - 52% KSI vs. 28% non-KSI occurred during night light conditions.
- Speeding is associated with a higher proportion of fatal and severe crashes.
  - 30% KSI vs. 6% non-KSI are associated with speeding.
- The vehicle running off the road is associated with a higher proportion of fatal and severe crashes.
  - 36% KSI vs. 16% non-KSI are associated with road departures.
- There is a higher proportion of all crashes in urban areas than rural areas. The highest proportions of all severities of crashes were located on Urban- Principal Arterial - Other and Urban - Minor Arterial type roadways. KSI crash proportions generally follow this pattern.

However, there are slightly elevated proportions of KSI crashes on Rural-Minor Arterials and Rural - Major Collectors.

- Similar patterns of crash proportions on different number of lanes were observed between all crashes, KSI and non-KSI crashes. KSI crashes are observed slightly more often on two-lane roads (48%) than non-KSI crashes (37%).
- Examining roadway functional class and number of lanes together: comparing KSI crashes to non-KSI crashes, a higher proportion of KSI crashes occurred on two-lane rural major collectors. Overall, KSI crashes and both non-KSI crashes follow a similar pattern of mostly occurring on two-lane and four-lane urban minor arterial roadways, four-lane urban - principal arterial - other roadways, and six-lane interstates.

The following key trends were identified from comparing the proportion of KSI and non-KSI crashes, for **bicycle and pedestrian crashes only**. Crash Harmful Event of Pedalcycle or Pedestrian was used to filter the crashes for this portion of the analysis.

- Even more pronounced than in the pattern for all crash modes**, there is a higher proportion of fatal and severe bicycle and pedestrian crashes at night** by time of day.
    - 47% KSI vs. 35% non-KSI bicycle and pedestrian crashes occurred from 6 PM to Midnight, and,
    - 27% KSI vs. 8% non-KSI bicycle and pedestrian crashes occurred from Midnight to 6 AM.
- Similar to all crash modes, there is a higher proportion of fatal and severe bicycle and pedestrian crashes at night as indicated by light condition.
    - 79% KSI vs. 42% non-KSI bicycle and pedestrian crashes occurred during night light conditions.
- **Slightly higher proportion of KSI bicycle and pedestrian crashes in wet conditions than dry conditions.**
    - Total of 17% of bicycle and pedestrian KSI crashes were in wet conditions, as compared to 12% of non-KSI crashes.
- **Speeding is associated with a higher proportion of fatal and severe bicycle and pedestrian crashes.**
    - 13% KSI vs. 8% non-KSI bicycle and pedestrian crashes are associated with speeding.
- Unlike crashes for all types of modes, vehicles running off the road is not associated with a higher proportion of fatal and severe bicycle and pedestrian crashes.

Similar to crash patterns for all modes of travel, there were higher proportions of bicycle and pedestrian crashes in urban areas than rural areas. **Highest proportions of bicycle and pedestrian crashes were associated with Urban- Principal Arterial - Other, Urban - Minor Arterial, and Urban - Local type roadways.** KSI crash proportions generally follow this pattern with the largest proportion (52% of KSI) associated with arterials: Urban - Principal Arterial - Other (31% of KSI) and Urban - Minor Arterial (21% of KSI). However, there are slightly elevated proportions of KSI crashes on Rural-Minor Arterials (6% of KSI vs. 1% of non-KSI) and Rural - Major Collectors (5% of KSI vs. 2% of non-KSI).

Similar patterns were observed between all bicycle and pedestrian crashes, KSI bicycle and pedestrian crashes and non-KSI bicycle and pedestrian crashes. **Bicycle and pedestrian crashes are most often associated with four-lane roads**, with 53% of bicycle and pedestrian KSI crashes and 47% of bicycle and pedestrian non-KSI crashes on four-lane roads. Six lane roads were associated with slightly greater proportions of KSI bicycle and pedestrian crashes than non-KSI bicycle and pedestrian crashes: 12% of KSI vs. 5% of non-KSI on six-lane roads.

Examining roadway functional class in conjunction with number of lanes provides more details on where bicycle and pedestrian crashes are occurring in CMCOG. **Figure 1** shows the relative proportions of all crashes versus bicycle and pedestrian crashes for different road types.

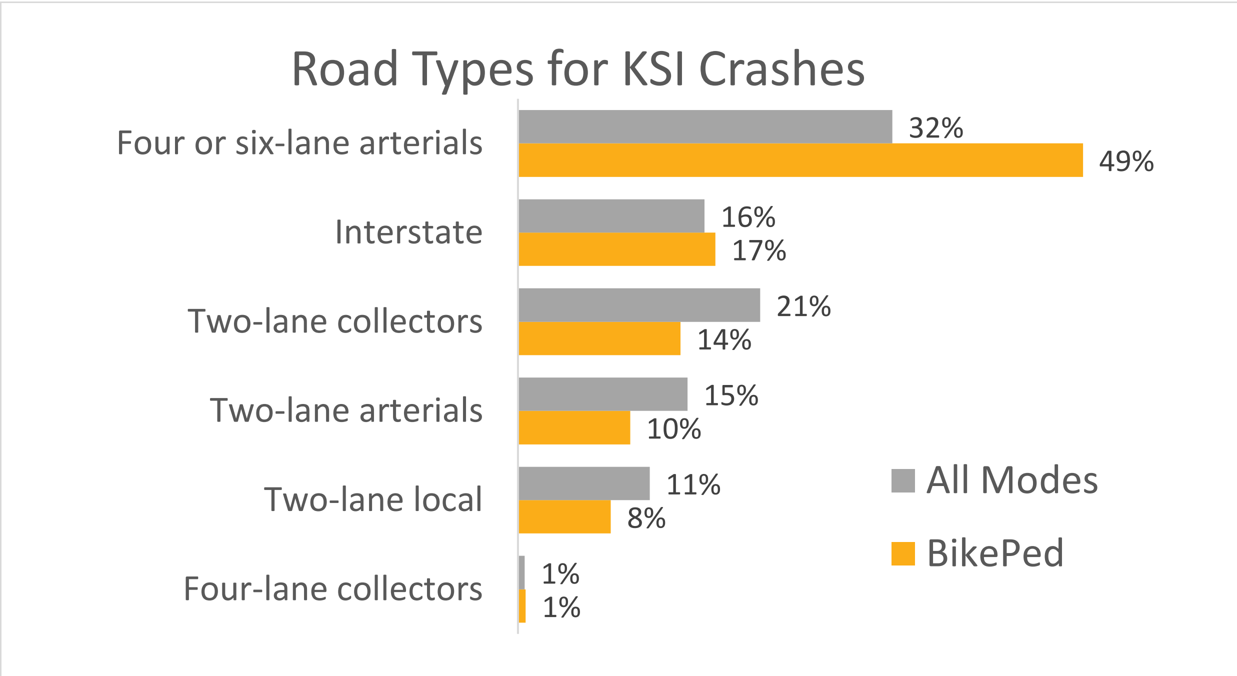


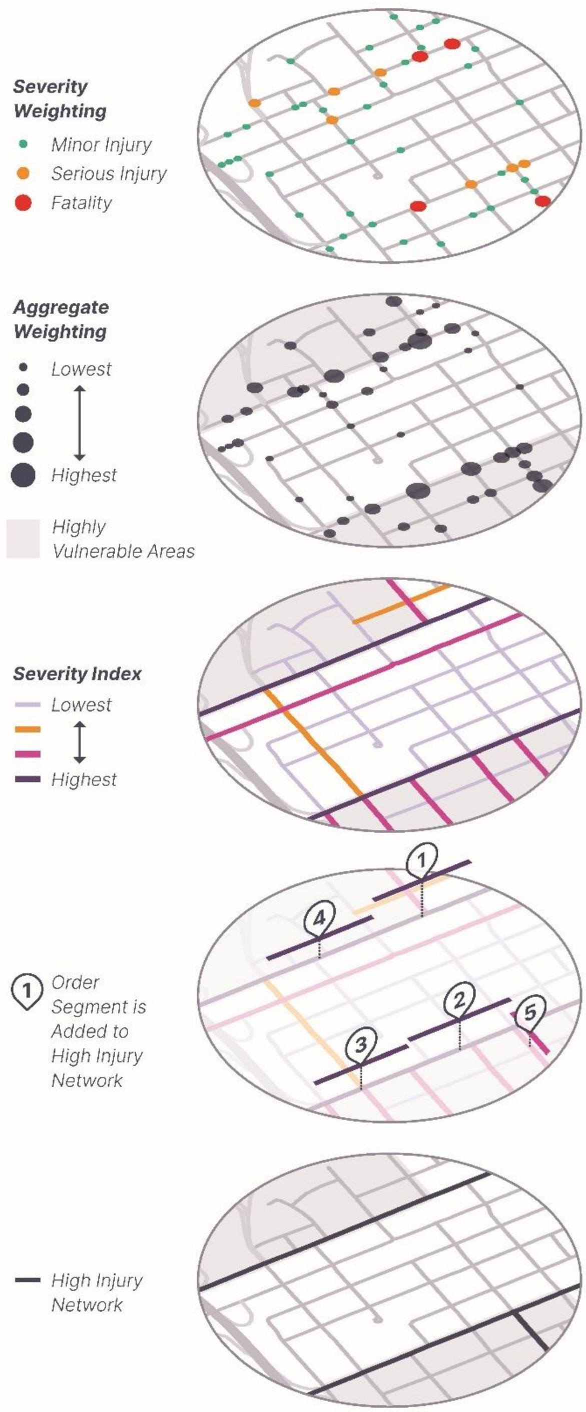
Figure 1. Comparison of all crashes and bicycle/pedestrian crashes by roadway functional class and number of lanes

Four- or six-lane arterials (49% of KSI) and Interstates (17% of KSI) in both rural and urban areas are the most important roads for fatal and severe bicycle and pedestrian crashes. It is important to note that this is slightly different from the pattern observed for all crash modes in the region, which first is also most associated with Four- or six-lane arterials (32% of KSI), then two-lane collectors (21% of KSI). Interstates are of similar importance to bicycle and pedestrian modes (17% of KSI) as all modes combined (16%).

Mapping analysis included creation of draft High-Injury Network, using the approach summarized in **Figure 2** and in the next section.

Alta Civic Analytics Explainer

Determining the High Injury Network



Severity Weighting

One goal of a High Injury Network (HIN) is to identify an improvable subset of a community's streets that address the majority of collisions where a victim is Killed or Severely Injured (KSI). To achieve this, KSI collisions are assigned higher scores so they have more "weight" relative to collisions with less tragic outcomes.

Other Considerations

These scores can also be modified to include other considerations such as whether collisions involve vulnerable road users (bicyclists and pedestrians) or occur in socially vulnerable communities. These factors can be directly incorporated into the weights associated with each collision.

Severity Index

After weights are developed, they are associated to the network, aggregated, and normalized so that we can understand the relative intensities of collisions of concern.*

Accumulated Collisions by Severity Index

Once an index is created, we progressively add segments to the HIN in the order indicated by the Severity index. As more segments are added to the network, we look at KSI (or other collisions of interest) directly on the network, and track the percentage of collisions on the network relative to the percentage of its length.

High Injury Network

At some point, a final High Injury Network determination is found based on stakeholder feedback and a qualitative review of when each additional mile added to the HIN starts to see a decreasing rate of severe collisions being added.

*There are many methods available develop a final index including kernel density estimation (euclidean or network based), rolling window analysis, or aggregations to a segment normalized by network miles.

Figure 2. High Injury Network approach

High Injury Network (HIN)

Overview and Purpose

A High Injury Network (HIN) illustrates that improving a small number of roadways can often address the majority of injury-causing crashes. This approach moves beyond typical crash history and allows for a better understanding of the types of roadways in South Carolina where users are most at risk.

Alta will develop such a HIN for each region, focusing on local and state-owned roadways, i.e. not federally managed roadways or limited-access state-owned roadways. This memo explains Alta's approach to analyzing crash data and developing the HIN.

The HIN will use data from all vehicle-, bicycle-, and pedestrian-involved crashes. It is not mode-specific due to low numbers of crashes involving bicyclists or pedestrians. However, active modes will be weighted more heavily than other types of crashes.

Data Inputs

HIN development required two data sets: Crashes and Prepared Roadway Network.

Crashes

Five-year crash data (2018 through 2022) of all crashes within the region, provided by SCDOT.

- Crashes were clipped to within the region boundary, only Occupant_U = 1 crashes, which duplicates were removed with Delete Identical.
- Inclusive of all modes of travel.
- Included all types of crash severity.
- Crashes officially associated with federally managed limited-access roadways and ramps and limited-access state-managed roadways were not included, as bicycles and pedestrians are not allowed on these roadways. Therefore, crashes with SMS_Main_R = Interstate were removed from the dataset.
- Bicycle and pedestrian crashes associated with limited-access ramps where they intersect with the network were maintained in the analysis.

Prepared Roadway Network

LRS street centerline network each region, provided by SCDOT.

- Filter to roadways clipped within region boundary.
- Federally managed limited-access roadways and ramps and limited-access state-managed roadways are not included, as bicycles and pedestrians are not allowed on these roadways. Therefore, roads with RouteTypeN = Interstate were removed from the network.

HIN Methodology

Prepared Street Network

Manually examined US Highways and found some double carriages there, none were expressways. Selected the segments along double areas and added road_character field with 1 for divided and 999 for not divided.

Consolidated dual-carriage (divided) roadways so that split roads are represented as one line. We used an automated routine with tools similar to ArcGIS Pro's Merge Divided Roadways, and then performed a manual clean of those remaining. Key IDs were introduced at each stage of segmentation so that any dropped attributes can be associated back to the network later if required.

Planarized all the roadways so that segments would be split at intersections.

Divided centerlines into ½ mile segments for roads within one mile of a municipal area and one-mile segments elsewhere. Shorter segments are appropriate in urban areas where crashes happen more frequently, and allow for more granularity in pinpointing high-injury corridors. Longer segments in are more appropriate in rural areas where crashes are sparser. Segment-level crash data was be normalized for segment length, but not by traffic volumes. Crash counts were also reported per segment.

Created a unique ID for each roadway segment. Rural_ID and Urban_ID which are ultimately merged into HIN_ID_combo.

Create a "Rolling Window / Sliding Window" feature class where the lines are extended over each road segment. This is a temporary feature class for analysis purposes. Roadways were extended 300 ft in each direction. Lines overlap with their neighbors. This process allows rolling window statistics to be calculated on each road segment. The benefits of rolling window analysis are that they reduce the impact that dead-end streets, network segmentation artifacts, or anomalous crashes have on the final HIN. Fundamentally, it better captures the linear corridor crash patterns where they exist (Fitzpatrick, 2018)[1]. This methodology is illustrated in **Figure 3.**

After rolling, the segments were aligned back to the original LRS dataset, to ensure overlaps along the roadway.

Prepared Crash Data
Further limited the crash dataset to those within 50 feet of the LRS roadways.

Weighted each crash based on the most serious injury sustained by any individual involved in the crash. This effectively prioritizes areas where more serious crashes are occurring to identify areas where the most serious injuries can be reduced. These proportions are based on the ratio of the average cost to society from fatal and serious crashes compared to minor injury crashes. While some analyses may weight serious crashes higher in proportion to minor crashes, that can lead to every segment with a fatal crash being represented on the HIN. Using this ratio avoids overweighting fatal crashes that occur as isolated events so that the HIN can represent roadways with patterns of severe crashes. [2]

- Fatal injury (K): 7.0
- Serious injury (A): 2.0
- Minor injury (B): 1.5
- Possible injury (C): 1.0
- Property damage only (O): 0.5

[1] These patterns would consider crashes sometimes not directly on a particular segment in other to smooth out analysis results. Examples of this type of analysis are provided by FHWA in their Guide Book on High Pedestrian Crash Locations.

[2] There are many calculations of average cost of severe and fatal crashes. The ratio shown here is based off of the FHWA's *Crash Costs for Safety Analysis* (Harmon et al, 2018), table 17. The weights shown here are proportional to the average of the square root of costs to society of each crash type compared to the baseline of minor-injury crashes. Source: https://safety.fhwa.dot.gov/hsip/docs/fhwasa17071.pdf.

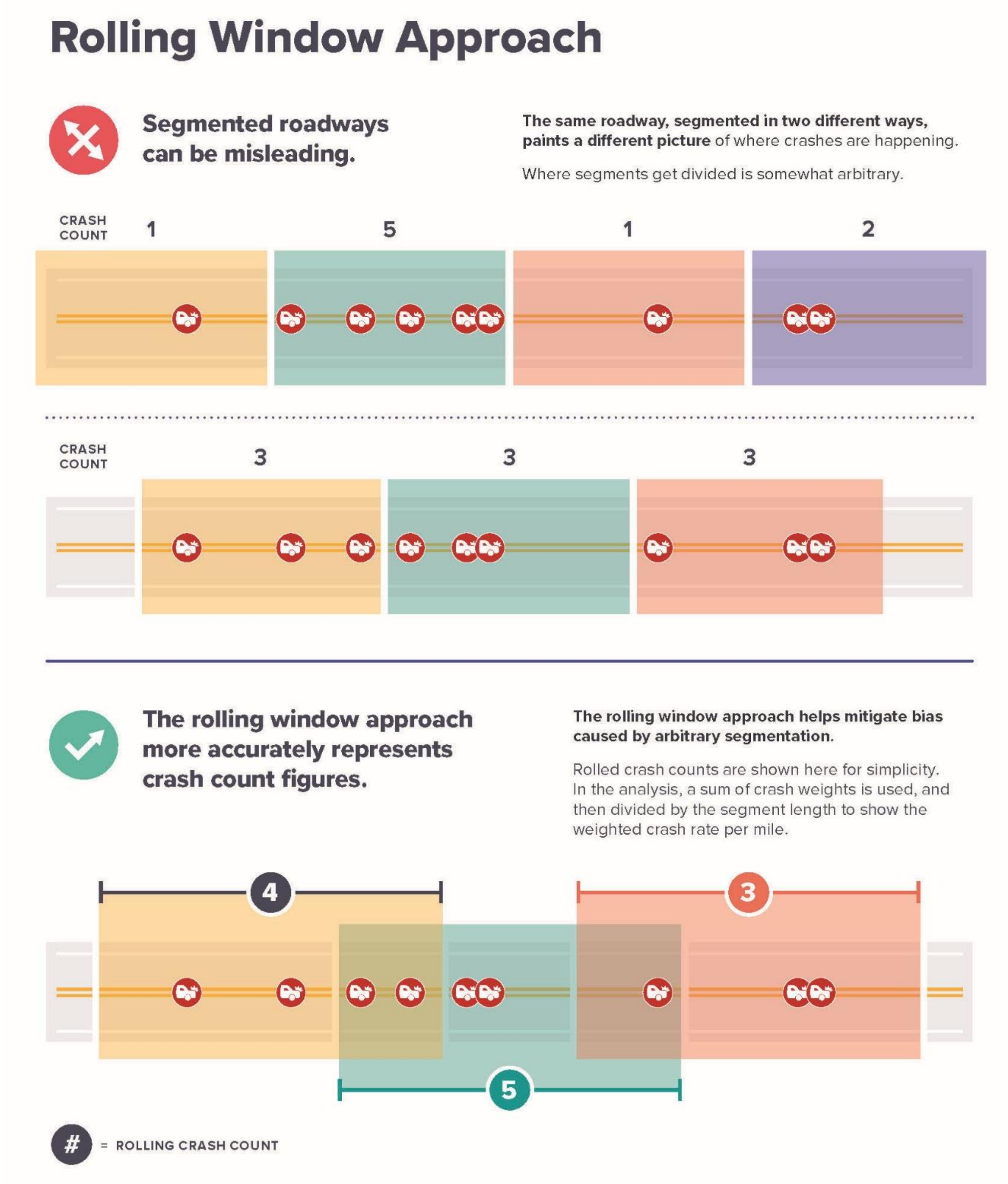


Figure 3: The rolling window approach

Snapped all crashes within 250 feet of the street centerline network to the prepared network segments (see Step 1). This distance accounts for a margin of error in crash coordinates. It also captures crashes on dual carriage roadways that occur far from the now-consolidated centerline (such as wide highways) but is not large enough to capture crashes that occurred in parking lots adjacent to roadways.

Apply Rolling Window Analysis
Spatially joined the crash layer to the rolling window road network.

Calculate the summed rolling crash weight for each rolling road segment. This sums the weight of crashes on each rolling segment to reflect total crash severity on each segment.

Join the rolling crash weight from the rolling window layer back to the segmented centerline network using the unique ID to show rolling crash weight per road mile on each original ½ mile or 1 mile segment. This normalizes the crash weight for the road length. However, for the purpose of calculating crash weight per road mile, counted any rolled segments of less than 0.15 miles as 0.15 miles to avoid overrepresenting crashes on small road segments, as dividing by very small numbers yields very large numbers. See Figure 3 for an explanation of the process.

Accumulate Crashes
Beginning with segments with the highest crash weight per mile, progressively add segments to the HIN. Analysts calculate the length in miles for each segment as it is added and keeping track of the cumulative miles in the HIN and the number of crashes occurring on those segments. The process stops when the designated threshold of crashes has been accumulated.

A threshold of 60% is used as a starting point, and is adjusted after examining initial outputs.

Examine initial output
Decide the threshold for the percentage of crashes included in the HIN based on the natural inflection point or plateau in the data.

This represents the point at which adding more roadways to the HIN has diminishing returns in terms of identifying more crashes. Since the segments with the most severe crashes get selected for the HIN first, adding crashes to the HIN requires progressively more and more roadway segments. Thus, the threshold helps to strike a balance between accounting for as many crashes as possible while limiting the number of segments selected for the HIN.

The goal is to find the smallest share of the roadway network that accounts for the largest number of severe crashes. A small crash percentage may indicate that the selected HIN will not address enough crashes, while a large share of the roadway network is likely too large of an area in which to focus safety improvements.

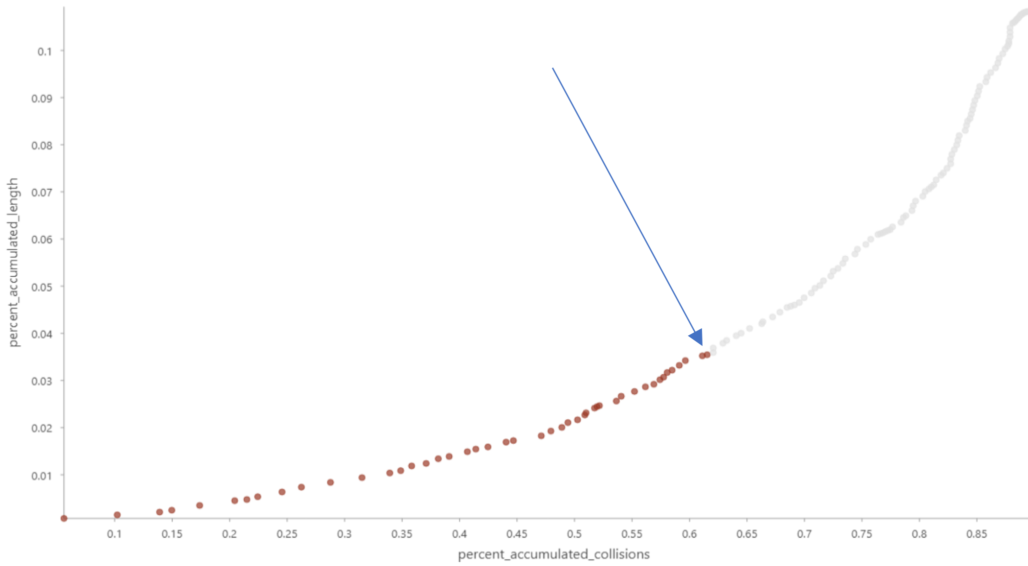


Figure 4: Example of a graph of accumulated collisions and accumulated length. Collisions selected for the HIN are represented in red.

Final Refinement
Examined the map of qualifying HIN segments and performed manual cleaning output from the tool for a maximum of 6-8 hours per region. The primary focus of the smoothing was to fill small gaps in otherwise contiguous networks on major roadways. Segments added during smoothing are indicated with a '2' value in the HIN field; segments removed with a '3' value in the HIN field.

Calculated the percent of roadway miles and the percent of crashes accounted for in the final HIN. These percentages show decision makers that safety investments in a small share of the road network can help to prevent the majority of crashes in the region.

Charted the two percentages as a line chart such as the one depicted in Figure 4. These charts function like Lorenz curves that enable us to understand how crashes are unevenly distributed on the road network and how cumulative collision counts change as more centerline length is added to the high injury network. It provides a visual justification for the threshold of crashes chosen for inclusion in the HIN. Where the line slope changes sharply, this often indicates a point at which continuing to add segments to the network has diminishing returns in terms of capturing more crashes.

Initially, a break point of 77.0% of all crashes on 11.4% of the network was chosen. After smoothing, the HIN includes 77.4% of all crashes occurring along 11.7% of the roadway network mileage. These HIN segments are therefore representing the highest potential return on investment for appropriate safety countermeasures, also known as a systemic safety analysis.