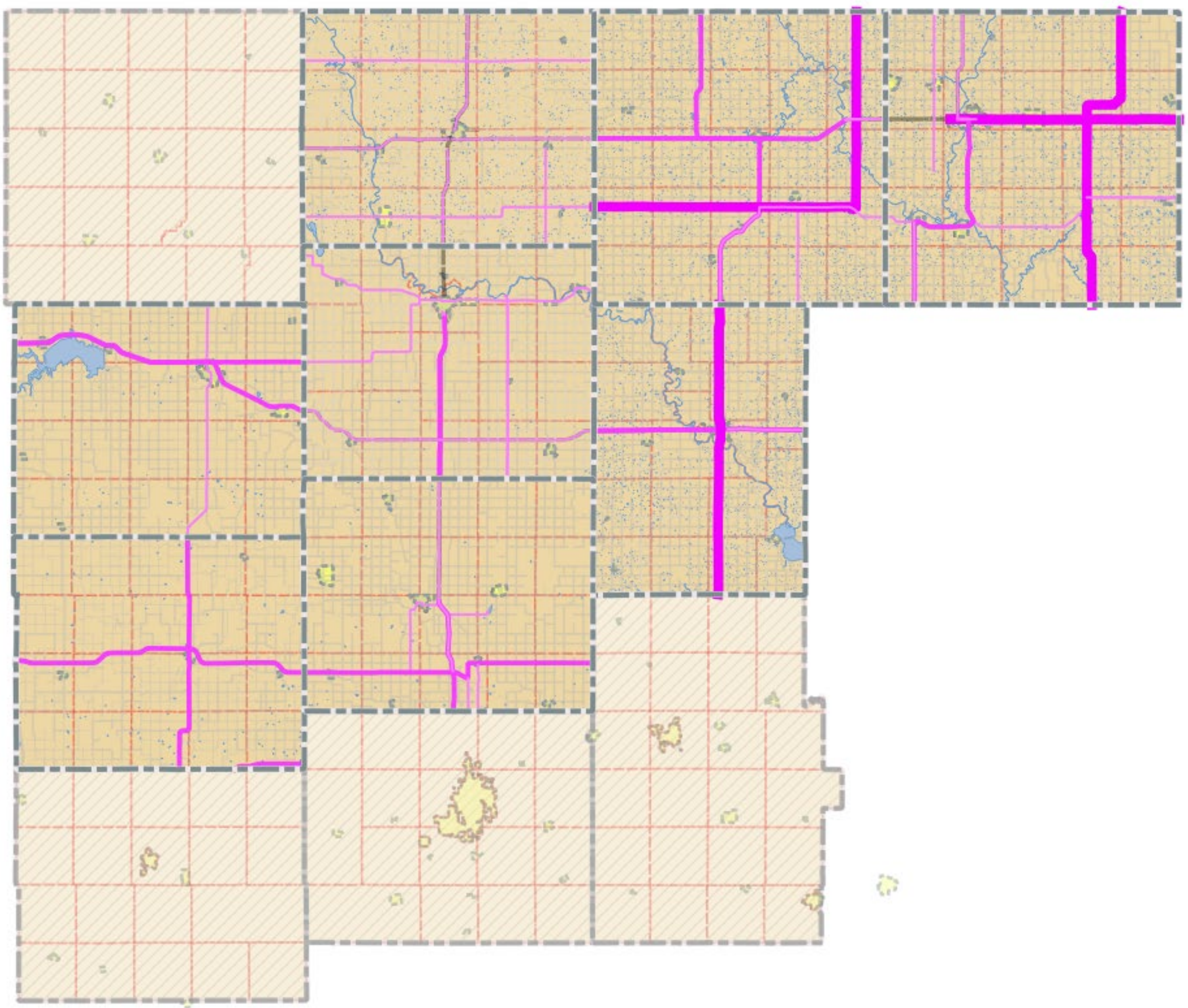
High Injury Network Basics and Data Creation



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Background

As rural communities work to address safety concerns in their local environment, access to funding resources to help address these concerns is paramount. Recent discretionary grant programs from the United States Department of Transportation like the Safe Streets for All (SS4A) program, have created opportunities for communities to study their local transportation environments and propose solutions to challenges that are contributing to fatal and serious injury automobile accidents. As part of this discretionary programming, additional planning efforts in the form of specific 'Safety Action Plan' documents are required. As one part of this planning effort, analysis of historical safety data for the area of interest, as outlined in the image below from the Safe Streets and Roads for All Self Certification Eligibility Worksheet[1], is required.

3. Safety Analysis

Does the Action Plan include **ALL** of the following?

- Analysis of existing conditions and historical trends to provide a baseline level of crashes involving fatalities and serious injuries across a jurisdiction, locality, Tribe, or region;
- Analysis of the location where there are crashes, the severity, as well as contributing factors and crash types;
- Analysis of systemic and specific safety needs, as needed (e.g., high-risk road features or specific safety needs of relevant road users); and,
- A geospatial identification (geographic or locational data using maps) of higher risk locations.

Figure 1: USDOT Self Certification Worksheet Excerpt

This guidance in the worksheet is provided for communities who have pre-existing transportation planning documents that they wish to assess for compliance with topical areas necessary for the document to serve as a Safety Action Plan for the purposes of applying for SS4A implementation funding.

[1] Safe Streets and Roads for All Self-Certification Eligibility Worksheet, https://www.transportation.gov/sites/dot.gov/files/2025-03/SS4A_FY25-Self-Certification-Worksheet.pdf.

As part of the specific safety analysis outlined above, this guidance document is focused on the final bullet point; 'a geospatial identification (geographic or locational data using maps) of higher risk locations.' The process outlined here will detail the creation of a 'High Injury Network' (HIN) utilizing GIS processes and tools, that satisfy this requirement.

Reference Examples

During the research effort, the NADO Research Foundation team reviewed Safety Action Plan documents from across the country and specifically evaluated their individual processes for developing High Injury Network data and mapping that would communicate the locations of highest risk. A sample of the documents reviewed in this process is offered below. These documents were selected to highlight because they provided some level of detail regarding the methodology utilized to create their High Injury Network information. Please note that not all the documents referenced here were created for or by stakeholders in rural or small metro communities; many of these documents represent planning efforts in mid or large-scale metro areas. This does not diminish the value of the data processes utilized.

AMATS – Akron, Ohio - https://amatsplanning.org/safe-streets-4-all/

Toledo, Ohio - https://cdn.toledo.oh.gov/uploads/documents/Public-Service/Transportation/2023-Toledo-Vision-Zero-Plan-Draft.pdf

CORPO – Columbus, Ohio - https://www.morpc.org/programs-services/corpo-safety-action-plan/

PlanRVA – Richmond, Virginia - https://planrva.org/wp-content/uploads/RRTPO_VZ2022_DRAFT_2022February.pdf

Mid Region COG – Albuquerque, New Mexico - https://www.mrcog-nm.gov/570/High-Fatal-and-Injury-Network

Indy MPO – Indianapolis, Indiana - https://www.indympo.org/resources/safety

Fort Collins, Colorado - https://www.fcgov.com/traffic/visionzero

Pinellas County, Florida - https://forwardpinellas.org/safestreets/wp-content/uploads/2021/03/6-Safe-Streets-Pinellas-Action-Plan-High-Injury-Network.pdf

Data and Software Specifications

The analysis described here requires access to a desktop GIS software application package capable of general geoprocessing tasks and display of mapping information. The processes described in this process document are able to be completed in common GIS software packages (i.e. ArcGIS Pro, QGIS), without the requirement of extensions or other additional purchases. Access to a spreadsheet application capable of creating pivot tables, such as Microsoft Excel, is also required for one step of the outlined process.

While there is no required format for this data, there are some general best practices that practitioners can follow. Many of these are drawn from a 2022 case study published by the Federal Highway Administration Office of Safety – Roadway Safety Data Program entitled 'California's High Injury Network and Planning for Zero,' performed by Vanhasse Hangen Brustlin, Inc. (VHB).[2] The report contains items that were included in the State of California's Strategic Highway Safety Plan (SHSP) implementation guidance, and utilized in agency reports published prior to the existence of the SS4A program. Recognizing the experience of these agencies in developing HIN data, the following components were recognized and pulled directly from the report by the NADO research team:

- **Years of Crash Data**: The HIN should typically use between 3 and 5 years of data with up to 10 for smaller jurisdictions.
- **Share of Road Network**: The HIN should represent a subset of the road network (typically 5 to 20 percent of road mileage and no more than 50 percent).
- **Collision Density**: Corridors should capture a significant number of fatal and serious injury crashes (typically 40 percent or more).
- **Roadway Facility Types**: The HIN should focus on roads which the agency has the ability to set speed limits or conduct enforcement.

In the completion of individual HIN datasets, it may not be possible to achieve each of these considerations, but they are provided as reference guidelines for producing valuable and comparable datasets.

When considering what individual data products are needed to complete a High Injury Network analysis, only a few items are absolutely required. At a minimum, the following:

- **Crash Data** - A collection (3 to 5 years) of crash data that includes information on fatal and serious injury crashes. If this data is tabular in nature, it should include coordinate information so the data can be visualized on a map. The format of data delivery formats (GIS files, spreadsheets, databases, etc.) will vary from state to state. Similarly, the attribute information contained in the crash data will also vary from jurisdiction to jurisdiction. The inclusion of additional attribute data will provide the opportunity for extended analysis, but is not required for the completion

[2] California's High Injury Network and Planning For Zero, https://highways.dot.gov/sites/fhwa.dot.gov/files/2022-10/California%20HIN_Case%20Study_Final%20Draft.pdf.

of a basic analysis. Specifically, the inclusion of information that would indicate whether incidents are intersection related or not is useful, but also not required.

- **Roadway Data (Spatial)** – A spatial dataset of road features that represents the jurisdiction of interest for the project that will allow the crash locations to be visualized in relation to roadway segments. Optimally this data will include roadway attributes including name and jurisdiction (i.e. U.S., State, County, Local) or any comparable uniquely identifiable information that will allow readers of the plan to understand what segments are being highlighted as areas of concern.

The sample work that the NADO research team completed for this effort utilized data that was freely available for public use. Crash data was generally retrieved from online dashboards or state department of transportation/highway safety websites or GIS data portals. On occasion the information had to be requested via email from transportation representatives directly.

The road data utilized in most cases was from the U.S. Census Bureau TIGER/Line Shapefiles.[3] This road data is available for every county in the United States.

HIN Data and Map Creation Process

Once the necessary data and software have been collected, the data and map creation process can commence. Below are outlined the key phases and steps of the process as utilized by the NADO Research Foundation.

Map and Data Preparation

1. Create a new map document and add your roadway data and other base data that will inform the HIN map. Add the crash data GIS files or import the tabular data using the import text or delimited data feature of your software package.

2. Once the initial data is loaded, evaluate the crash data for any incidents that do not have spatial coordinates, or any incidents that may appear outside of the area of focus. It is recommended to remove any such features from the crash data set for the purposes of this analysis.

[3] U.S. Census Bureau – TIGER/Line Shapefiles; https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

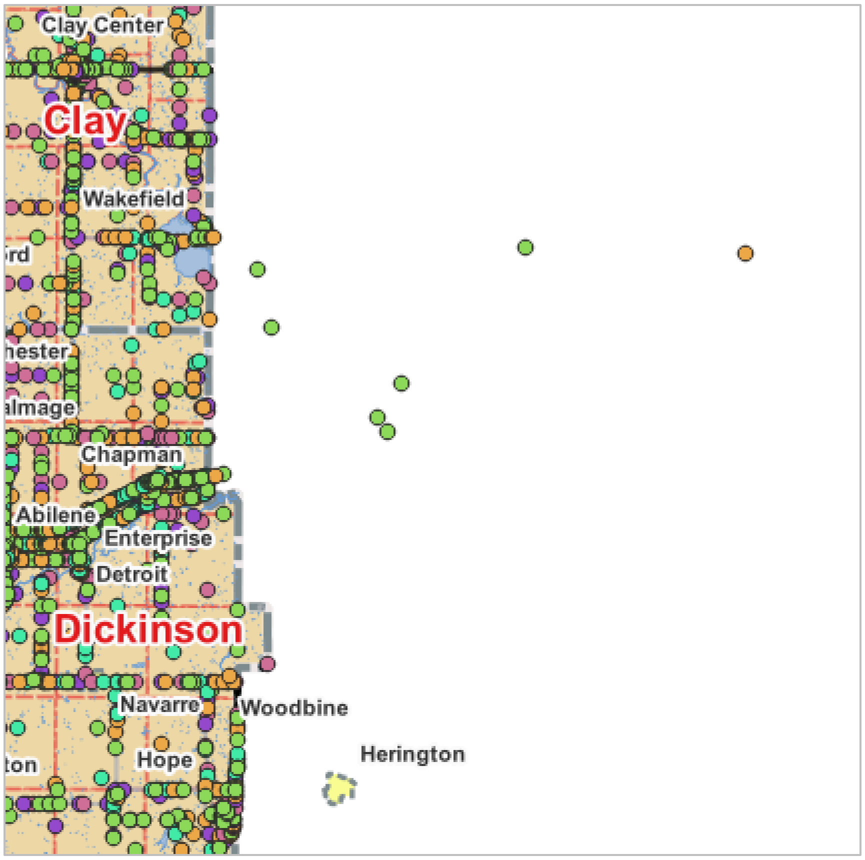

Figure 2: Crash Incidents Outside of Focus Area

173	ULL	NULL	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	NULL	100	NULL	NULL	SIDNEY MANNING BLVD
174	ULL	Private property	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	NULL	NULL	NULL	NULL	PRIVATE PROPERTY
175	ULL	NULL	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	NULL	1320	NULL	NULL	Van Hoosen
176	ULL	NULL	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	4	NULL	NULL	NULL	S Main St
177	ULL	Private property	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	NULL	NULL	NULL	NULL	DOLLAR GENERAL PARKING LOT
178	ULL	Private property	NULL	NULL	-1	NULL	NULL	NULL	-1	-1	1	NULL	NULL	NULL	SUMMERCHASE APARTMENTS
179	ULL	1200	NULL	IV0021720069	0.52	1200	7107	7262	31.029628	-85.478239	NULL	2640	-1	NULL	JUNCTION RD
180	ULL	AL0015	26	AL0000150000	25.95	S015	7175	8440	31.14266	-86.701981	NULL	172	788	NULL	US-29
181	ULL	1003	NULL	IV0000510053	2.51	1003	7674	7672	31.02891	-86.70461	NULL	721	100	NULL	Wing Road
182	ULL	1002	NULL	IV0000040053	16.88	1002	7674	7686	31.029451	-86.714542	NULL	3168	309	NULL	Bradley Road
183	ULL	AL0015	25.2	AL0000150000	25.15	S015	7177	7175	31.144577	-86.715242	NULL	1579	788	NULL	US-29
184	ULL	1002	NULL	IV0000040053	16.7	1002	8164	7687	31.030989	-86.716885	NULL	100	309	NULL	Bradley Rd

Figure 3: Crash Incidents Without Coordinate Information

Leaving these incidents in the analysis dataset will be problematic in later steps when crashes are being spatially related to roadway segments. This could cause roadway segments to be incorrectly identified as associated with these events that are not accurately located.

2a. (Optional) If you are using TIGER data as your roadway dataset, adding an attribute field to calculate the road lengths in miles can be helpful. This can be done by dividing the 'Shape_Len' field by 1609.34.

3. Once the crash data is imported and edited as described above, query or filter the crash data for only fatal or serious injury incidents. Most states use the KABCO injury classification scale to classify crash incidents.[4] *(Note: Some states may not specify injury severity in the crash data, if this is the case use the classifications that are available but note that the values and scoring created later will be elevated due to the increased number of incidents utilized in the calculations. More information on state classification scales and definitions can be found at https://highways.dot.gov/media/20141.)*[5]

4. Export the fatal and serious injury incidents from Step 3 to a new layer.

4a. (Optional) To examine incidents related to intersections independently from incidents related to roadway segments, query or filter the fatal and serious injury layer created in step 4 on any attributes that would indicate whether incidents were intersection related. Export the resulting fatal/serious injury and intersection related incident to a new layer and remove those values from the original exported layer. It is recommended to end up with two discrete data layers; one with fatal and serious injury incidents NOT related to intersections (roadway segments) and one data layer with fatal and serious injury incidents related to intersections (intersection attribute = true). For most accurate results, these layers should not have overlapping crash incidents.

4b. (Optional) To support intersection analysis, and in instances where TIGER Census TIGER road data is in use, and no external intersection point layer exists, one can be created. Utilize the 'Line Intersection' tool in the processing toolbox in QGIS or the 'Intersect' tool in ArcGIS pro (Toolboxes>Analysis Tools>Overlays>Intersect) to create a basic intersection point layer.[6] *(Note: The resulting intersection points only generally represent locations where road line features intersect in the data being utilized in the map, and may not be reflective of traffic or physical conditions.)* Once the intersection layer is created, it is recommended to utilize a 'clean' function to remove coincident duplicate features. (One intersection 'point' can actually be many points stacked on top of each other based on the number of features that are intersected.) Utilize the 'Delete Duplicate Geometries' toolbox in QGIS, or the 'Delete Identical' tool in ArcGIS Pro (Toolboxes>Data Management Tools>General>Delete Identical) with the geometry field selected to remove these duplicate features.

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[4] Model Minimum Uniform Crash Criteria (MMUCC), 4th Edition Definitions; https://highways.dot.gov/media/20141.

[5] KABCO Injury Classification Scale and Definitions; https://highways.dot.gov/media/20141.

[6] ESRI Technical Support, Create points on line intersections in ArcGIS Pro; https://support.esri.com/en-us/knowledge-base/how-to-create-points-on-line-intersections-in-arcgis-pr-000025044.

5. At this point the process of relating fatal and serious crash incidents to specific roadway segments in the road data layer within the area of interest can begin. This analysis will be completed using the processed subset of crash data that has been created in steps 3 and 4.

With the map displaying both the road data layer and the processed crash data layer, a spatial join will be utilized in order to join attributes from the nearest spatial neighbor. In this case we will be spatially joining identifiable attributes **from** road segments **to** crash data points.

In QGIS, utilize the processing tool 'Join Attributes by Nearest', in this scenario the 'Input Layer' is the crash points, and 'Input 2' is the road data.

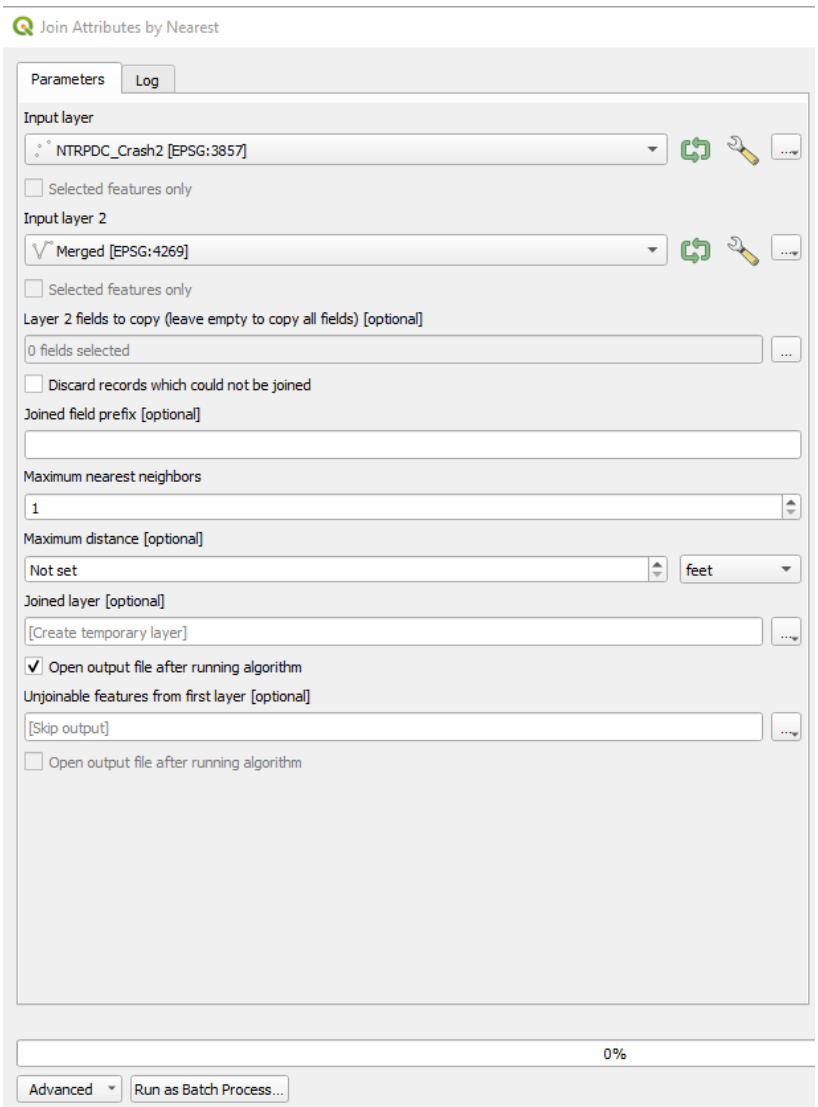

Figure 4: QGIS - Join Attributes by Nearest Dialogue

Note that the 'Maximum Nearest Neighbors' value is set to one, as this will relate each crash incident to **only one** road segment. The 'Maximum Distance' value was left blank in this instance. If you wish to limit how far a crash incident can be from a road segment in order to be spatially related for the purposes of the analysis, enter a suitable value here.

The QGIS process described above is nearly identical in ArcGIS Pro. Right click the crash data layer and select 'spatial join' and follow the dialogue, using 'closest geodesic' as the match option.

In either scenario, it will be necessary to retain some attributes from the road dataset in this process, optimally the FID and/or other unique identifying value for each road segment. These unique values will be utilized in the next step. In the QGIS dialogue example provided in Figure 4, you will select these fields in the dialogue entry that says 'Layer 2 fields to copy.' With these selections made, complete the spatial join, and export a new joined crash point layer. In the new layer, there will be attributes indicating the ID of the nearest feature, and the map unit distance between the road segment and that linked incident.

Note: This process will create duplicate crash features for each coincident road feature that is present in the road data set; this is especially true for scenarios where the U.S. Census Bureau TIGER data is utilized. In this data set, a road may visually appear as a single line feature, but multiple features exist for individual road classifications. This is best depicted in the image below. As illustrated, State Route 1 is also Main Street, and an incident anywhere on this segment will be shown as one incident on State Route 1 and one incident on Main Street.

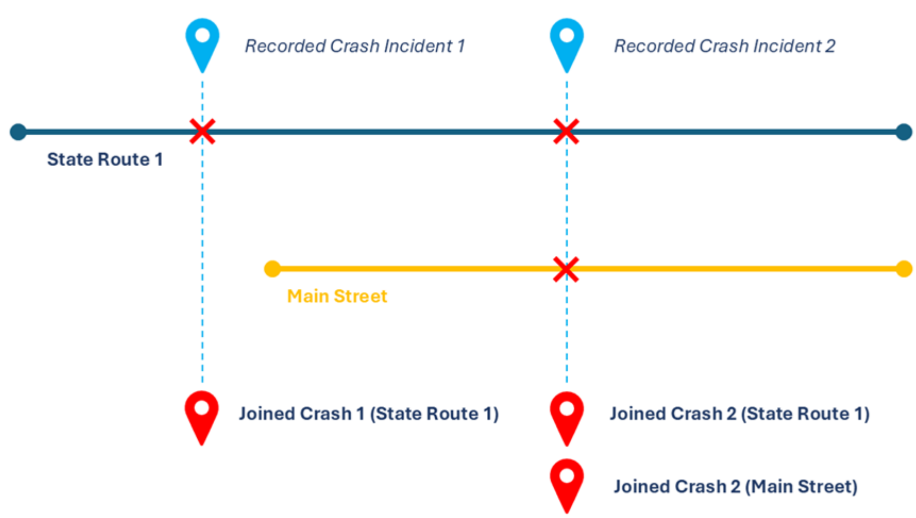

Figure 5: Crash Features on Coincident Road Segments

While condition in figure 5 is technically correct, it may be confusing to readers of the final safety document. It is recommended to note this appropriately within the text of the document.

6. With the new spatially joined crash point layer in your map, open the attribute table and export it to a .csv or spreadsheet. (If using a .csv, resave the file as an .xlsx in order to gain full file functionality.)

With the exported file open in Excel, select all the attribute data and insert a pivot table on a separate sheet in the workbook. The purpose of utilizing a pivot table is to summarize the number of fatal and serious injury incidents related to each unique road segment FID (row) in the spatially joined dataset. This will create a numeric value for each type of incident that will be used in a later step.

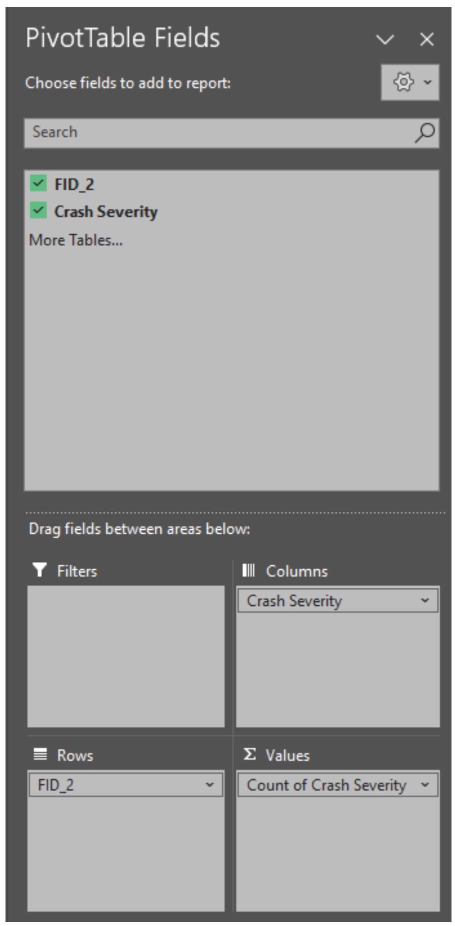

Figure 6: Example Pivot Table Field Configuration

Count of Crash Severity	Column Labels		
Row Labels	Fatal Injury	Suspected Serious Injury	Grand Total
163		1	1
209		1	1
417		2	2
468		1	1
808	2	9	11
816		4	4
834		3	3
908		1	1
970		1	1
978		2	2
1046		1	1
1095	1		1
1116		1	1
1122		2	2
1132		1	1
1140		1	1

Figure 7: Pivot Table with Road Segment FIDs and Incident Counts

A successful result of this step in Excel will result in a pivot table that looks similar to Figure 7 above. ('Row Labels' above are the unique FID values for road segments.) Reading the table in Figure 7 above gives us the following example: road segment 808 had two fatal incidents and nine suspected serious injury incidents, for a total of 11 incidents for which this segment was the closest road feature. Ensure that a 'Grand Total' value is included in the pivot table.

Copy this table and paste it in a new worksheet or export it to a new workbook for use in the next step.

7. With the new worksheet or workbook from step 6 prepared, go back to the map and complete a join between the road data and this new workbook/worksheet using the FID field in the spatial data and the FID field in the newly exported workbook/worksheet. You may wish to export this joined layer as a new dataset.

The goal here is to join the totals of both the number of the nearest fatal and severe injury incidents back to the road data so it can be used in a basic scoring calculation.

8. With this join complete, add a numeric attribute field to the road layer exported at the end of step six called 'HIN_pts.'

This is the scoring value that the HIN segments will be symbolized on and ultimately will represent a final data set for local review. It is important to note that this step can be modified in many ways, and the documents reviewed by the NADO research team indicated a number of approaches to ultimately provide a comparative score to these locations. Feel free to experiment here and generate a value that best fits the available data. Offered below is a very simple scoring formula.

In order to calculate the 'HIN_pts' value, we will use a simple formula in the field calculator tool of the GIS software:

(# of Fatal Incidents *2) + # of Serious Injury Incidents = HIN Points

This formula gives more weight to fatal incidents in the scoring criteria. This is only a suggestion and can be modified based on local priorities and perspectives.

9. With the 'HIN_Pts' attribute calculated, symbolize the resulting road data layer by this value. Ascending HIN_Pts values were symbolized by color and feature weight.

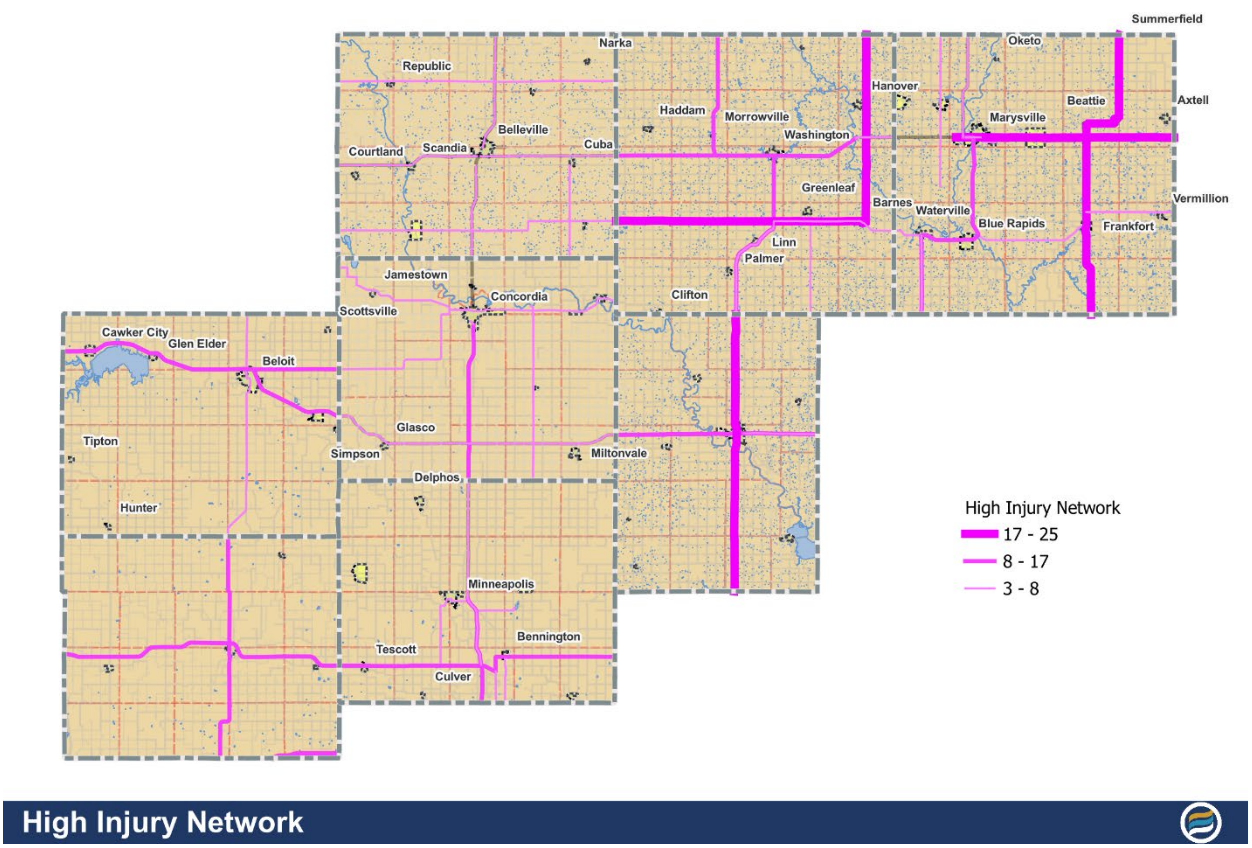

Figure 8: Sample HIN Map - North Central Kansas

It is recommended to review the resulting data and determine what values ultimately represent the areas of highest concern based on this analysis. As stated earlier, the High Injury Network should represent between 5% and 20% of the total road miles in the area of interest. In order to meet this guidance, some values like those with low HIN scores of zero or one may be omitted from the map. In the example offered in Figure 8 above, HIN scores between 3 and 25 were considered to be the areas of concern. As depicted above this represented 1,890 of 22,156 road miles in the region, roughly 8.5%. Road segments with a HIN score of less than 3 were not visualized on the map.

This level of analysis gives the organization broad ability to make recommendations along any of the general corridor areas identified by the analysis, regardless of jurisdiction or road type. If your organization desires to only produce results or recommendations for certain road classifications (i.e. only county roads, only municipal roads, etc.) filter your data accordingly to display those segments and values.

10. As a final step, the research team recommends reviewing this data with local stakeholders that are familiar with the travel patterns, behavior, and incidents in these locations to ensure that the data analysis is reflective of real-world conditions.

10a. (Optional) If there are no concerns with the road segmentation and segment lengths utilized in the road data GIS layer, a higher resolution version of the HIN based on a number of incidents per mile of road segment can be produced using the data produced in step 9. Utilizing field calculator, simply take the final 'HIN_Pts' attribute value generated in step 9 and divide it by the segment distance value in the road data layer. Create a new attribute field to store this resulting value. Symbolize the map based on this new calculated value.

The data produced in this optional step will be more closely focused on specific segments in more localized areas, based on how the road data is segmented. Figure 9 shows the result of this at the region level and Figure10 provides a detailed example showing Beloit Kansas.

This information could be utilized for much more localized recommendations for improvements and countermeasures based on the smaller scale of the data output. As stated in step 10, this data should also be reviewed with local stakeholders familiar with conditions on the ground relative to locations that are highlighted through this additional process.

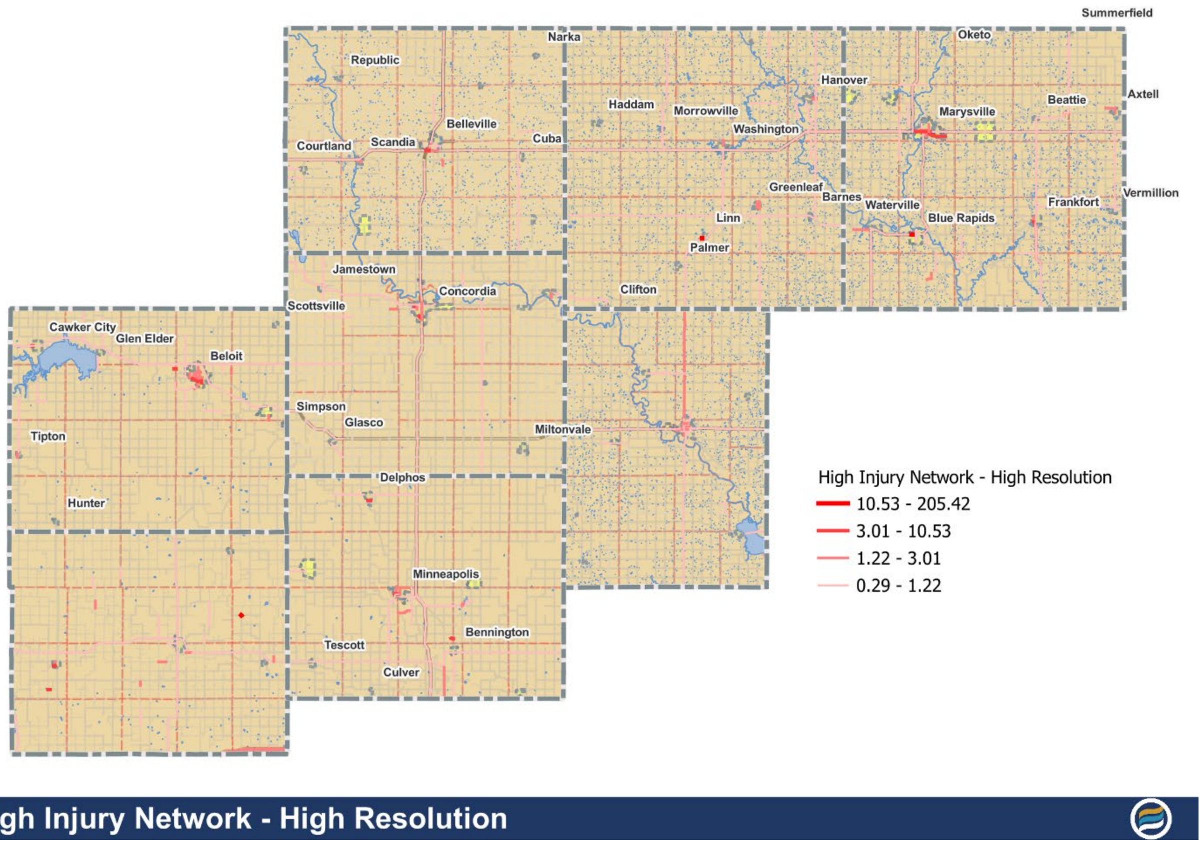

Figure 9: Sample HIN Map – High Resolution – North Central Kansas

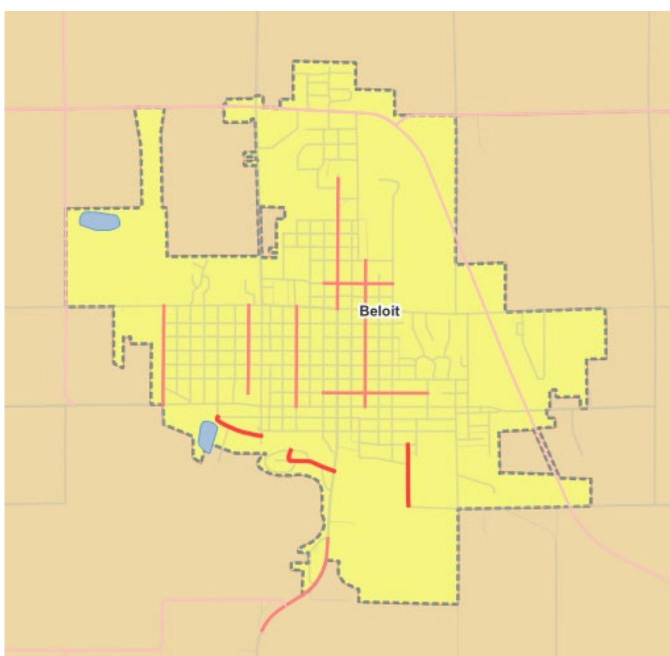

Figure 10: Beloit Kansas - HIN High Resolution Map Example