Fehr & Peers

High Injury Network

Date: November 2025

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Subject: High Injury Network Methodology

A High Injury Network (HIN) refers to a collection of roadway segments within a city or region where a disproportionate number of severe traffic injuries or fatalities occur. Traffic safety countermeasures along identified HIN corridors can have the greatest effectiveness in reducing severe injuries or fatalities. Bellevue, like many other local and regional agencies, has set forth aggressive actions to eliminate traffic-related deaths and severe injuries. A HIN is a valuable tool to focus a community on the subset of the roadway network where capital, engineering, enforcement, education, and awareness investments can have the greatest potential benefit in reducing the number of severe or fatal traffic crashes. This memorandum outlines the methodology for updating the HIN in the future.

Methodology

The tool used to develop Bellevue's 2019 HIN, the updated 2025 HIN, and the 2025 High Injury Intersections (HII) is Esri's Network Screening Tool.[1] This is a recommended tool by the FHWA, and City of Bellevue's preferred tool for developing a HIN. ESRI's Network Screening Tool is fully integrated with ESRI products, enabling direct application without the need for specialized customizations, provides flexibility, and does not require custom configurations. The ESRI tool includes an option to incorporate future traffic volume data. While the initial output may display fragmented HIN corridors, post-processing can be applied to smooth the results for more effective planning and communication. Additional methodology for HIN development is the FHWA Sliding Window Tool, depicted in **Appendix A**.

[1] https://doc.arcgis.com/en/arcgis-solutions/11.1/reference/use-traffic-crash-analysis.htm

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Weighting Research

As part of the HIN process, weights are assigned to each crash type. Weights vary between different jurisdictions and land use contexts depending on the types of crashes the community would like to consider and the level of interest in analyzing non-severe or non-injury crashes. To determine the weighting to use in Bellevue, a comparison chart was developed to highlight different weighting strategies from other peer communities and leaders in the traffic safety space. Ultimately, the City of Bellevue landed on 10/2/1 weighting, outlined in the right-hand column of **Table 1**. Note that Bellevue's updated method does not include any consideration for property damage only (PDO) crashes. This is consistent with most other jurisdictions, although WSDOT includes PDO crashes with a very low weight.

Table 1. HIN Weighting Comparison

	City of Bellevue (Old)[2]	PSRC[3]	WSDOT Crash Cost Estimates[4]	Alameda County Transportation Commission[5]	City of Oakland (Motorist HIN)[6]	City of Oakland (Bike/Ped HIN)[7]	Comprehensive crash costs (2017 U.S. $)[8]	Comprehensive Crash Costs (2020 $)[9]	**Bellevue HIN Selected Weighting**
Fatality	1	1	231.31	10	3	3	$11,637,947	$11,600,000	**10**
Suspected Serious Injury	1	1	231.31	10	3	3	$674,353	$554,800	**10**
Suspected Minor Injury	0	0	16.04	5	0	1	$204,143	$151,100	**2**
Possible Injury	0	0	9.61	5	0	0	$129,001	$77,200	**1**
PDO (No Apparent Injury/Unknown)	0	0	1	0	0	0	$12,108	$3,900	**0**

[2] https://bellevuewa.gov/sites/default/files/media/pdf_document/2021/High%20Injury%20Network%20Map.pdf
[3] https://www.psrc.org/media/9177
[4] https://www.transportation.gov/sites/dot.gov/files/2022-03/Benefit%20Cost%20Analysis%20Guidance%202022%20Update.pdf
[5] https://www.alamedactc.org/wp-content/uploads/2024/09/HIN_PSN_Report.pdf
[6] https://www.oaklandca.gov/resources/high-injury-network-2024#hin-methodology
[7] https://www.oaklandca.gov/resources/high-injury-network-2024#hin-methodology
[8] Highway Safety Benefit-Cost Analysis Guide
[9] Benefit Cost Analysis Guidance 2022 Update.pdf

2025 Updates to the Bellevue HIN

Bellevue has evolved the methodology for developing the HIN to reflect changing goals of the city and the desire to plan proactively for Vision Zero. In 2019, the HIN was based solely on documented fatal and serious injury (FSI) crashes.

As part of the 2025 update, Bellevue gathered staff from multiple departments to discuss whether the HIN methodology should be changed. Relying on sporadic data around severe and fatal traffic crashes could potentially miss the underlying risk in the transportation network. Therefore, it was determined that incorporating minor and possible injury crashes into the HIN provided a more complete picture of network risk. These crashes help identify emerging safety issues, highlight high-frequency problem areas, and allow for earlier interventions before severe crashes occur.

Previously, all crashes involving a FSI were assigned a uniform weight of 1. However, this approach did not fully reflect the varying degrees of severity and frequency across crash types. To better align with the City's data-driven safety goals, consistency with other jurisdictions, and to ensure continued progress even as FSI crashes become less frequent, Bellevue adopted a new weighting system shown in **Table 2**.

Table 2. Comparison Between Previous and Updated Bellevue HINs

Highlights	Previous HIN	Updated HIN
Data		
Years of Data Used	2010-2019	2015-2024
Weighting		
Fatality	1	10
Serious Injury	1	10
Minor Injury	0	2
Possible Injury	0	1
Property Damage Only (PDO)	0	0
Statistics		
% FSI Capture	83%	68%
% Network Capture	8%	8%

Other than the difference in weights, one notable difference between Bellevue's previous and updated HIN is the decrease in the percentage of FSI crashes captured on the HIN. The project team investigated this difference to make sure the change in methodology was not missing FSI hot spots that would have been identified under the prior method.

The conclusion of the analysis indicates that the primary factor that reduced the percentage of FSI crashes on the HIN had to do with the updated crash data. The newer 2015-2024 crash data included FSI crashes that were more dispersed than was the case with the prior 2010-2019 dataset. Even if the methodology was not changed, the percentage of FSI crashes on the HIN would have decreased to from 83% to 75%. Therefore, the team is confident that the newer HIN method will work better as a planning and prioritization tool in the future and will retain better consistency between HIN updates since it is based on a larger dataset.

Manual Network Refinements

While the team relied on the ESRI FHWA Network Screening Tool for generating the draft HIN, manual network refinements were required to produce a logical and gridded HIN. The overall process including the manual refinement is summarized below:

1. Run the crash analysis to generate a draft of the HIN:
   - Using the ESRI FHWA Network Screening tool on Bellevue's arterial network (no local streets, ramps, or highways) split into segments that are roughly 1,320 feet long.
   - Applying weighting:
     - Fatal and serious injury crashes – 10
     - Minor injury crashes – 2
     - Possible injury crashes – 1
2. Clean the draft HIN (2015-2024 HIN):
   - Fill small gaps in the draft HIN corridors to create a logical, gridded network that lends itself to study and implementation.
   - Ensure prior segments from the 2010-2019 HIN are retained within the B-Safe/SS4A area (there is ongoing safety planning and implementation work in these areas, and it is important to retain these segments for grant funding purposes) as well as other active grant-funded projects (e.g., HSIP).

     Grant Funded Corridors[10]
     - 102nd Ave NE between NE 12th St and NE 8th St
     - NE 1st/2nd St between 100th Ave NE and 108th Ave NE
     - 108th Ave NE between NE 12th St and Main St
     - NE 12th St between 106th Ave NE and 112th Ave NE
     - NE 20th St/Northup Way between 124th Ave NE and 148th Ave NE
     - NE 20th St/Northup Way between Bel-Red Rd and 162nd Ave NE
     - NE 8th Street between 156th Avenue NE and 164th Avenue NE[11]
     - NE 8th Street between 156th Avenue NE and 164th Avenue NE[12]
   - Remove small, isolated segments, segments without or with only one FSI and limited crash history, and/or segments due to crashes concentrated mainly at intersections (see Appendix B: Map of Segments Removed from HIN).
   - Keep HIN at about 8% of the total City of Bellevue public street network.

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[10] These corridors were included in the 2025 High Injury Network (HIN) because they were part of the previous HIN and are already the focus of grant-funded safety improvement projects. Their inclusion ensures consistency between ongoing investments and the identification of network segments that may require future safety enhancements.

[11] Project awarded HSIP grant funding in October 2024 to continue design work of proposed safety solutions. For more information visit the project page.

[12] Project awarded HSIP grant funding in October 2024 to continue design work of proposed safety solutions. For more information visit the project page.

Final Network

The final Bellevue HIN using 2015-2024 crash data and the analysis/weighting process described above captured **68% of all fatal and serious injury crashes on 8% of Bellevue public streets**. It is expected that Bellevue will update its HIN every five years to incorporate new crash data. These periodic updates are important to track the effectiveness of ongoing safety investments and to identify any new areas that may emerge as a result of changing driver behavior, technology, or travel patterns. Although the methodology could be revised in future updates of the HIN, the approach developed for the 2025 HIN is expected to be viable across several future updates. A map of the 2025 HIN is included in **Figure 1**.

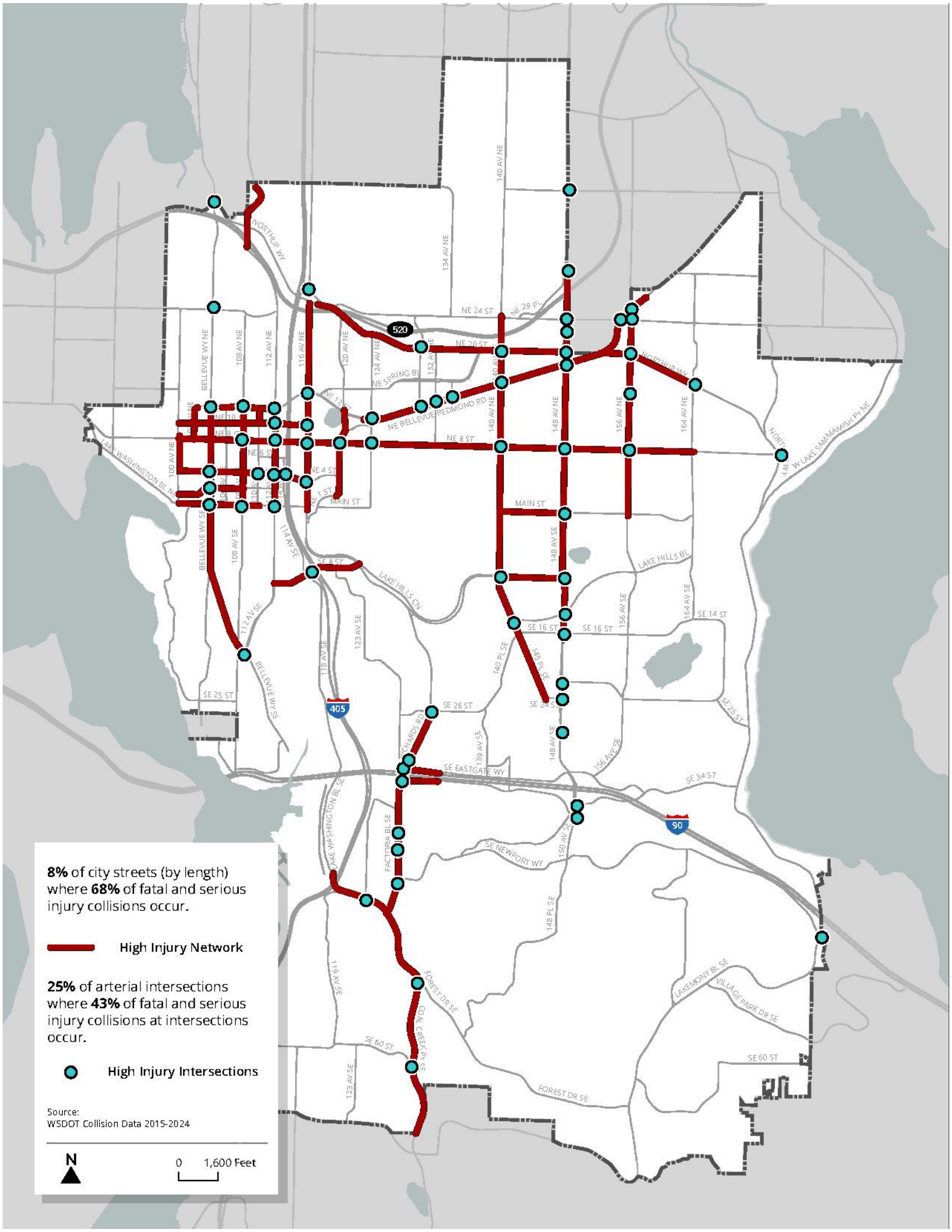
In Bellevue, 68% of all fatal and serious injury crashes occur on 8% of the public street network (as measured by length).

High Injury Intersections

High Injury Intersections have a disproportionately high number of serious and fatal crashes relative to other intersections in the arterial network. As a part of this process, Bellevue developed High Injury Intersections (HII) using ESRI's FHWA Network Screening tool using the weighting identified in **Table 2**. Most of the High Injury Intersections fall along the High Injury Network, they provide an additional screening tool for Bellevue to prioritize the intersections with the highest weight of crashes for funding and implementation. This is particularly helpful when considering safety countermeasures that are specific to intersections (e.g., traffic signal timing and phasing adjustments, intersection corner modifications, etc.).

In Bellevue, 43% of fatal and serious injury intersection crashes are concentrated at 25% of arterial intersections, identified as High Injury Intersections (HII).

Figure 1. Bellevue 2015-2024 HIN and HII Map

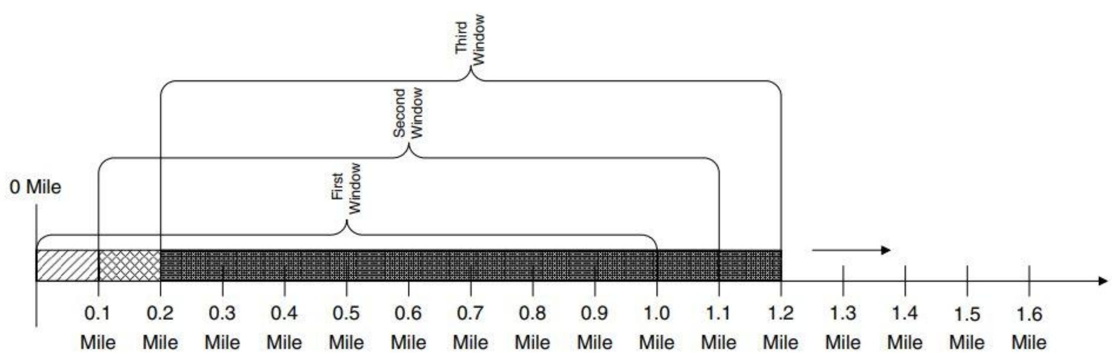


Appendix A: Fehr & Peers Sliding Window Tool

The Sliding Window tool was considered during the methodology process and is presented as a reference, but it was not used.

The recommended method to develop a HIN further processes crash data using the "Sliding Window" method. This method, which is recommended in the FHWA's Highway Safety Manual, can be used to perform network screening along roadway corridor segments as an alternative methodology to FHWA's Network Screening tool. This method is documented in detail by the Texas A&M Transportation Institute and has been used by many jurisdictions around the world.[13] The Sliding Window approach works by creating "windows" of a specific length in GIS that measures the severity and density of collisions within a 50-foot buffer around the segment. The process is repeated by "sliding" the window a defined distance along the corridor and repeating the analysis. Through this method, discontinuities in the data are smoothed out, which help to address known errors where the precise crash locations are not known or properly recorded. **Figure 2** shows a simplified visualization of the Sliding Window method. The resulting Sliding Window network generates a more continuous network that better captures where historical crash records can be used to identify a logical, citywide network of roadways that may warrant additional evaluation and traffic safety investments.

Figure 2. Sliding window visualization



There is no standardized method to apply the Sliding Window approach. Based on crash density, the variation in adjacent land uses (some land uses generate substantially more bicycle/pedestrian trips than others), the geometry of the road network (curvature, slopes, visibility), frequency of major intersections, etc., each community is encouraged to identify the Sliding Window parameters that work best given local context. Therefore, the study team tested several window and shift lengths to identify which parameters provided a good balance in terms of generating a logical network of roadways that can be aligned with funding and policy interventions versus creating an overly-expansive network that would not focus safety interventions in the areas that need it most. Based on the road network and project context, a window length of 1,320 ft (0.25 miles) and a shift length of 528 ft (0.1 miles) were selected for the updated HIN.

[13] Texas A&M Transportation Institute, "Statewide Implementation of Innovative Safety Analysis Tools in Identifying Highway Safety Improvement Projects," https://static.tti.tamu.edu/tti.tamu.edu/documents/5-6912-01-R1.pdf

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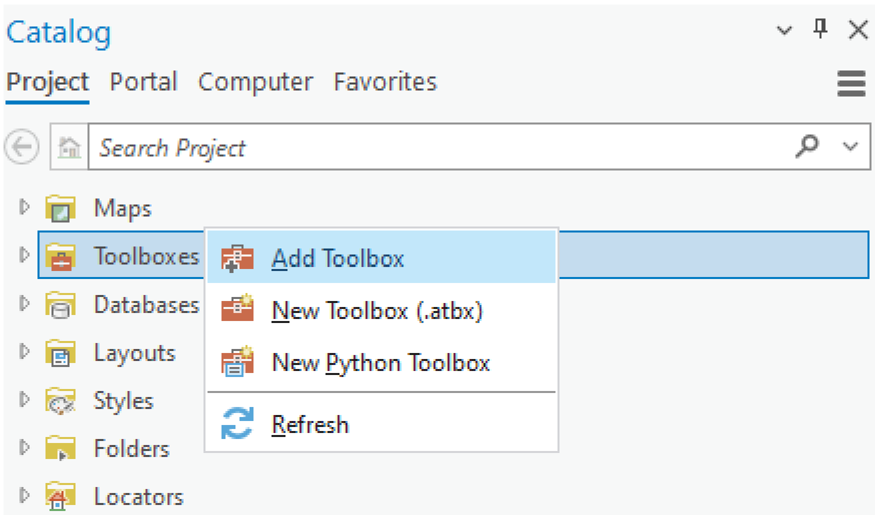
Fehr & Peers used the above methodology to create a series of HINs based on 2015-2024 crash data within the City of Bellevue. The tool was delivered on 5/21/25.

The steps to be taken to run this tool are outlined below.

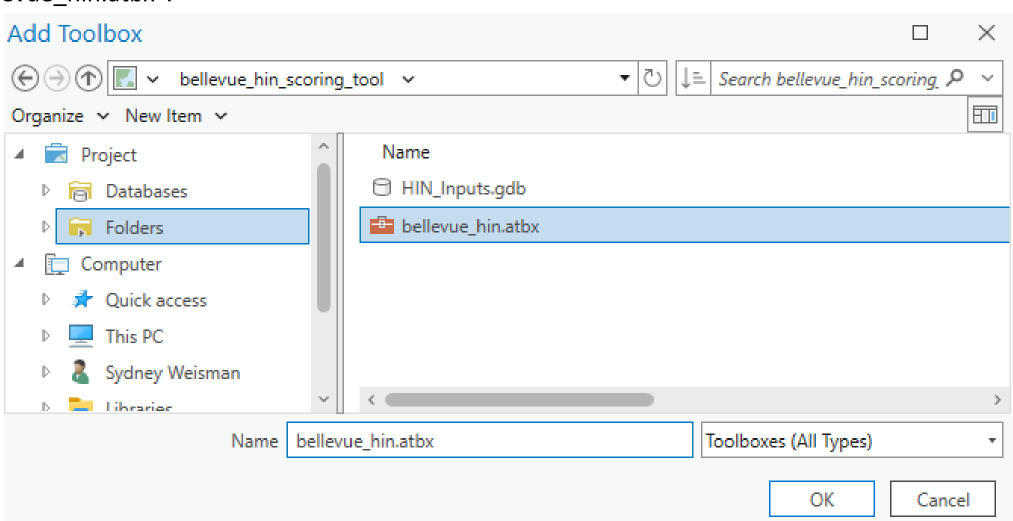
Steps for Bellevue's Updated HIN Methodology Using the Sliding Window Methodology:

Note: This tool was developed by Fehr & Peers on behalf of the City of Bellevue. This proprietary tool may not be shared with consultants or jurisdictions outside of City of Bellevue staff.

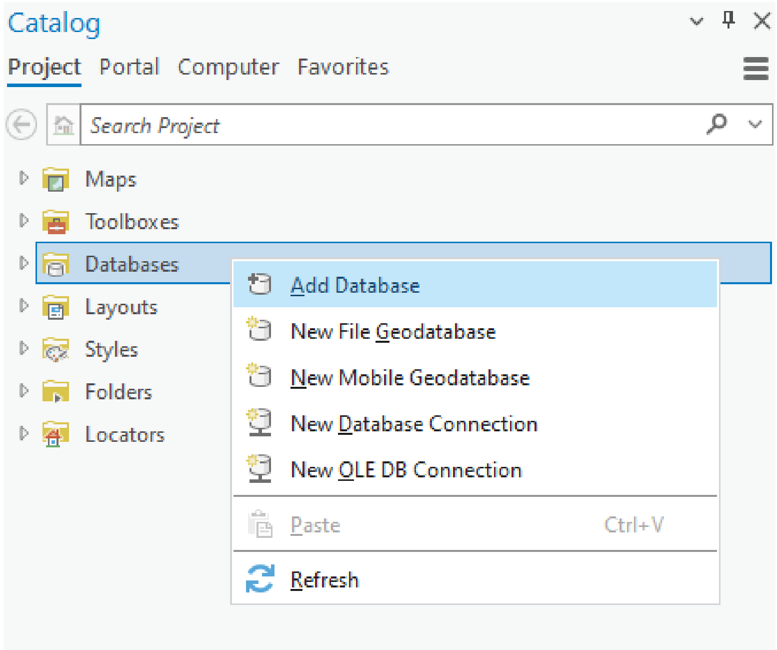
0) Connect the toolbox and geodatabase to your ArcGIS Pro file.
   a) Under the "Catalog" pane, right click on "Toolboxes" and select "Add Toolbox".



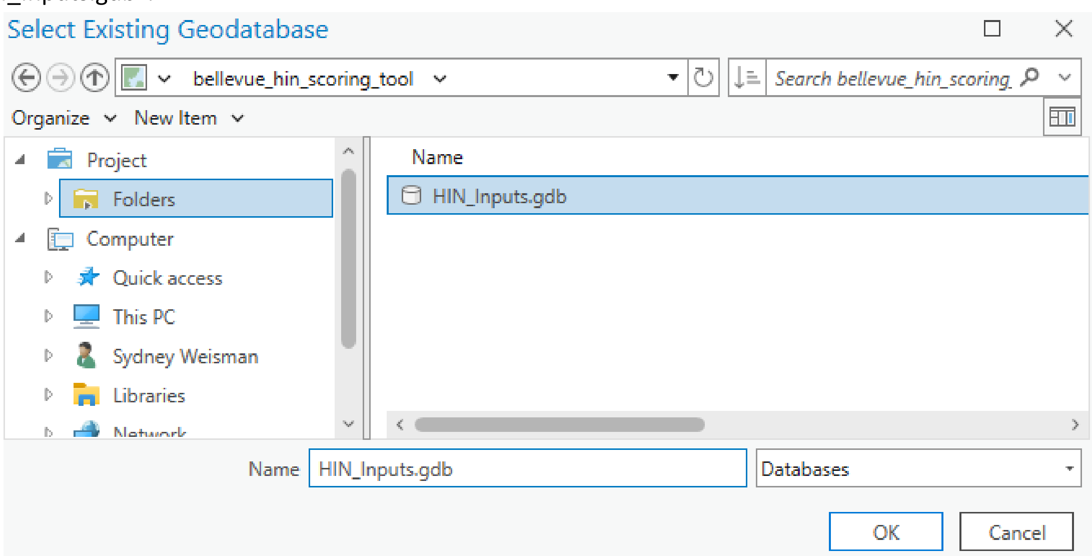
   b) Navigate to the location where you saved the folder "bellevue_hin_scoring_tool" and select the file "bellevue_hin.atbx".



   c) Now you have the bellevue_hin toolbox in your ArcGIS Pro file. Follow similar steps to add in the geodatabase.
   d) Under the "Catalog" pane, right click on "Databases" and select "Add Database".



e) Navigate to the location where you saved the folder "bellevue_hin_scoring_tool" and select the file "HIN_Inputs.gdb".



f) Now you have the HIN_Inputs geodatabase in your ArcGIS Pro file.

1) Pull a refined 10-year crash dataset.

This will be your base crash dataset you will use for your analysis and HIN development. Having accurate and clean crash data is critical for accurate HIN development.

a) Compile all 10 years of crash data into one feature class.

b) Only include the following fields (remove all other fields):

i) WSDOT Report Number (retaining to ensure relationship with original crash dataset)

ii) Most Severe Injury Type as cleaned by the City of Bellevue (each collision should have a single injury type)

iii) Collision Type by Injured Person as cleaned by the City of Bellevue (each collision should have a single mode in this field).

2) Create a new field in the crash dataset called "InjuryWeights".

This field will be used to convert the text based "Most Severe Injury Type" to a weighted integer which is used in the aggregation of collision scores by segment in a later step.

a) Field type = Double

3) Calculate weighting factors to apply to each crash in the new field "InjuryWeights".

This step in the process will be used to weight the crashes used. You can test different weights in this step. In the steps outlined below, we placed an "X" to show that the City of Bellevue may experiment with different test weights.

a) Use select by attributes to select all **FSI (fatal and suspected serious injury)** crashes.

i) Run calculate field on the selected crashes to apply **"X"** to the field "InjuryWeights".

b) Use select by attributes to select all **Suspected Minor Injury crashes.**

i) Run calculate field on the selected crashes to apply **"X"** to the field "InjuryWeights".

c) Use select by attributes to select all **Possible Injury crashes.**

i) Run calculate field on the selected crashes to apply **"X"** to the field "InjuryWeights".

d) Use select by attributes to select **all other crashes (PDO or Other).**

i) Run Calculate Field on the selected crashes to apply **"X"** to the field "InjuryWeights".

4) **QC Checkpoint**: make sure that all crashes have the correct value in the field "InjuryWeights" associated with crash severity type.

a) FSI crashes = X

b) Suspected Minor Injury crashes = X

c) Possible Injury crashes = X

d) All other crashes = X

5) Bring the Fehr & Peers sliding window arterial network into your working map based on the chosen window and shift length:

This step offers two network segment options to develop the HIN. Option 1 uses the segmentation developed for the 2025 Citywide HIN and is applied well for broader, citywide high injury location identification. Option 2 uses a more granular segmentation (i.e. a shorter segment length and shift) and is applied for more specific location-based assessments along corridors or within specific areas of the City.

a) Option 1: Citywide Network

i) Window Length: 1,320 feet

ii) Shift Length: 528 feet

b) Option 2: Focused Analysis Network

i) Window Length: 660 feet

ii) Shift Length: 264 feet

6) Run the **HIN Scoring Tool** using the following parameters.

*This step aggregates collision data to the network and assigns a total collision score to each segment. The output is a scored sliding window network that highlights high injury segments and can be further refined into discrete corridors that make up the HIN. The **Threshold** parameter plays a key role in determining the optimal subset of segments for further analysis. Refer to the guidance below and the tooltip in ArcGIS Pro for additional support.*

a) Collision Dataset: input the refined crash dataset from Step 1.

b) Sliding Window Network: input either the #5a or #5b network.

c) Collision Score Field: input the new collision score field created in Step 2.

d) Road Name Field: input the field that includes the roadway name from the Analysis networks provided by FP (OfficialSt).

e) Search Radius: define a search radius to be used to assign collisions to roadways. For example, "50 US Survey Feet".

f) Percentile Threshold: define a threshold value to identify high scoring segments in the outputs of the tool. Commonly used thresholds include 85^{th}, 90^{th}, and 95^{th} percentiles. The input value must be between 0 and 1. For example, 95^{th} percentile would be 0.95. A lower percentile will yield a higher portion of the network as high scoring segments.

g) Output Feature Class: select the folder and name where you would like to save the result.

7) Using a Definition Query, filter to the top scoring windows that were identified in Step 6 where the scores fall at or above the defined percentile threshold using the field "threshold_flag". Segments with a "threshold_flag" value of 1 are defined as high scoring segments.

This step is important for QA/QC purposes, as outlined in Step 8. It also helps isolate high-scoring segments, making it easier to identify and merge overlapping or closely spaced segments into continuous corridors.

8) **QAQC Checkpoint**: Review results from **HIN Scoring Tool** against crash data.

a) Symbolize the results of the HIN Scoring Tool by weight (segment_score) using graduated colors (higher weight = darker color).

b) Symbolize crashes by severity type (FSI, Suspected Minor Injury, and Possible Injury) and overlay on top of the results of the HIN Scoring Tool.

c) Confirm that the areas of the network that score above the defined percentile threshold align with areas that have clusters of crashes, particularly FSI crashes.

9) Create a copy of the network filtered to only high scoring segments where the scores fall at or above the defined percentile threshold. Use the Export Features tool to create the copy and save it in your preferred geodatabase.

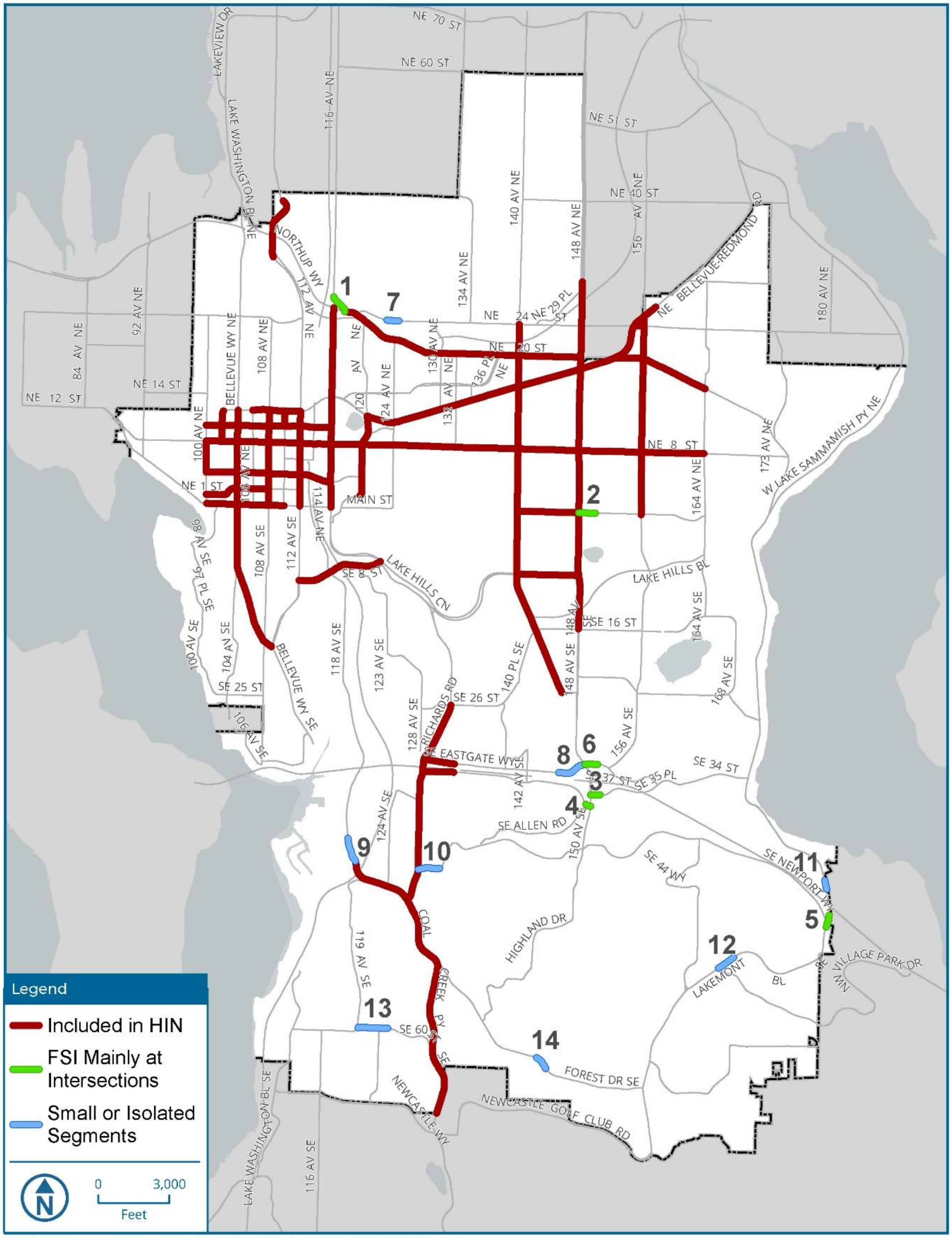
Creating a copy of the isolated high scoring segments ensures that further geoprocessing does not modify the original output of the HIN Scoring Tool.

10) Dissolve segments that overlap by roadway name (complete this on the copy of the defined percentile segments that was created in Step 9). In the Dissolve geoprocessing tool, make sure to uncheck "Create multipart features".

    This step dissolves overlapping high scoring segments into unified corridors. Segments in close proximity can then be connected to form continuous corridors.

11) Review the weighted network against the crash data.
    a) Remove segments that have two or under FSI and/or few crashes.
    b) Clip edges of segments that have few crashes.
12) Manually connect dissolved segments if they are within a fixed distance of each other. A typical distance used to connect segments is typically ½ mile or less. Using the Editing tools in ArcGIS Pro, create a new line feature between segments with the same name and make sure that both end points snap to the connected segments. Once the sketch is complete, open the attribute table and copy the exact roadway name into the NULL roadway name attribute of the added segment.
13) Perform a final Dissolve on the edited network in Step 12. The result of the Dissolve reflects the updated HIN.

Appendix B. Map of Segments Removed from HIN



Date: 11/3/2025 File Name: V:\TransDeptGIS\ArcGIS\Planning\VZAP\HIN_2015_2024\HIN_Removed.mxd

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Table 3. Segments and Reasoning for Not Including in the HIN

ID	Street Name	Extent 1	Extent 2	Reason for Not Including in the 2025 HIN
1	116th Ave NE	115th Ave NE	Northup Way	High weighted crash rate mainly due to crashes at the intersection of 116th Ave NE and 115th Ave NE; captured by HII
2	Main St	148th Ave	150th Ave NE	High weighted crash rate mainly due to crashes at the intersection of 148th Ave and Main St, captured by HII
3	SE 37th St	150th Ave SE	I-90 East On-Ramp	High weighted crash rate mainly due to crashes at the intersection of SE 37th St and 150th Ave SE; captured by HII
4	SE 36th St / SE 38th St	West of SE Allen Rd	150th Ave SE	High weighted crash rate mainly due to crashes at the intersection of SE 38th St and 150th Ave SE; captured by HII
5	Lakemont Blvd SE	I-90 East Off-Ramp	SE Newport Way	High weighted crash rate mainly due to crashes at the intersection of Lakemont Blvd SE and I-90 East Off-Ramp; captured by HII
6	SE Newport Way	148th Ave SE	Driveway between 148th Ave SE and 156th Ave SE	High weighted crash rate mainly due to crashes at the driveway between 148th Ave SE and 156th Ave SE; no FSI crashes
7	NE 24th St	SR 520 Trail Connection	124th Pl NE	Small isolated segment
8	SE Eastgate Way	146th Pl SE	148th Ave SE	Small isolated segment
9	Lake Washington Blvd SE	North of Newport Ky	120th Ave SE	Small isolated segment
10	SE Newport Way	Factoria Blvd SE	130th Pl SE	Small isolated segment
11	Lakemont Blvd SE	W Lk Sammamish Pkwy SE	I-90 West On-Ramp	Small isolated segment
12	Lakemont Blvd SE	171st Ave SE	Village Park Dr SE	Small isolated segment
13	Se 60th St	119th Ave SE	125th Ave SE	Small isolated segment
14	Forest Dr SE	West of SE 63rd St	SE 63rd St	Small isolated segment