HIGH INJURY NETWORK

ANALYZING COLLISION DATA TO IDENTIFY LOCATIONS FOR ROAD SAFETY IMPROVEMENTS

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EXECUTIVE SUMMARY

The City of Vancouver (CoV) experienced 66 fatal and 571 severe injury (requiring admission to hospital) collisions during the years 2015 to 2019. More than half of those collisions belong to vulnerable modes (pedestrians and cyclists). In 2012, as part of the targets of Transportation 2040 plan, CoV adopted the goal of bringing traffic-related fatalities to zero[1]. To further commit to ensuring safety of travellers, CoV later added the goal of bringing serious injuries, too, to zero, when they launched Vision Zero strategy in 2016[2]. But the first step is to determine where those collisions are occurring on the street network.

The objective of this study is to map fatal and serious collisions onto the street network of Vancouver and identify the corridors with the highest frequency of such collisions for pedestrians, cyclists, and drivers. Such corridors could then be prioritized for safety improvements. The study objective is accomplished by developing a High Injury Network (HIN).

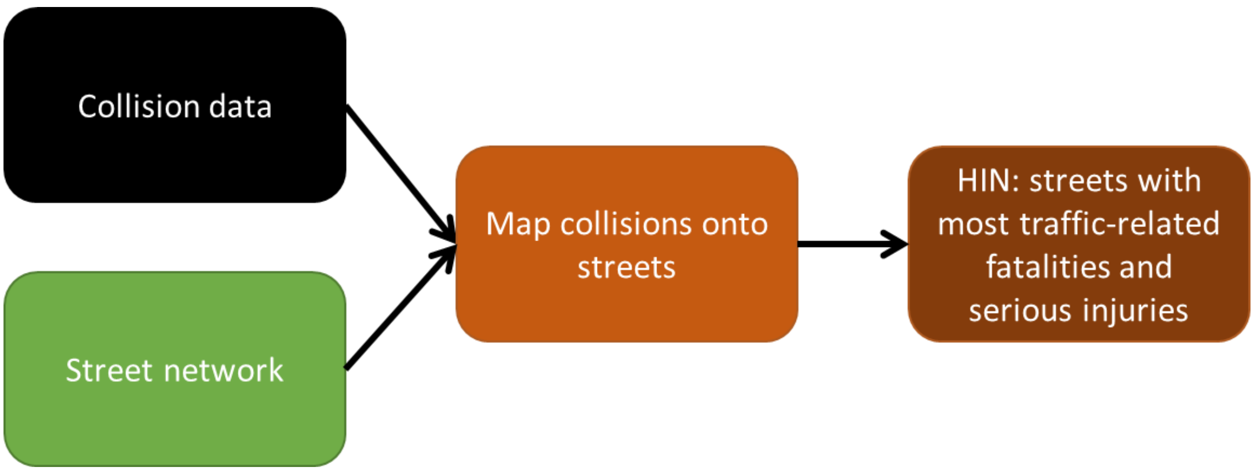
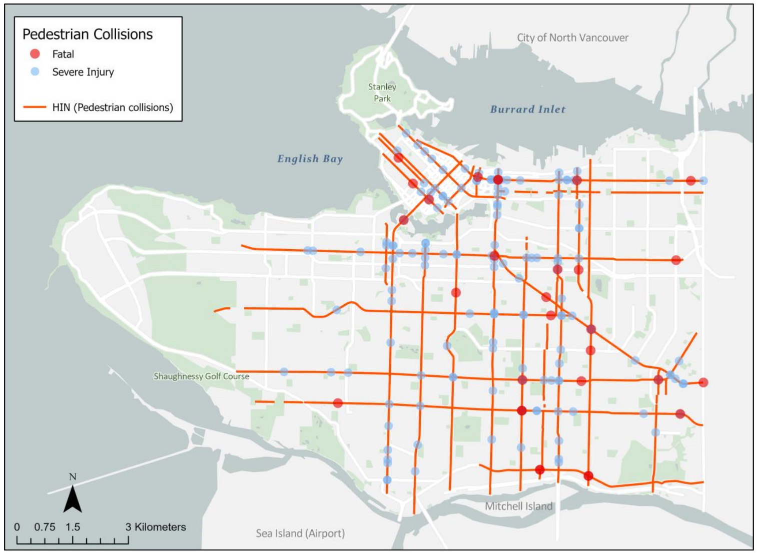


Figure 1. Study framework.

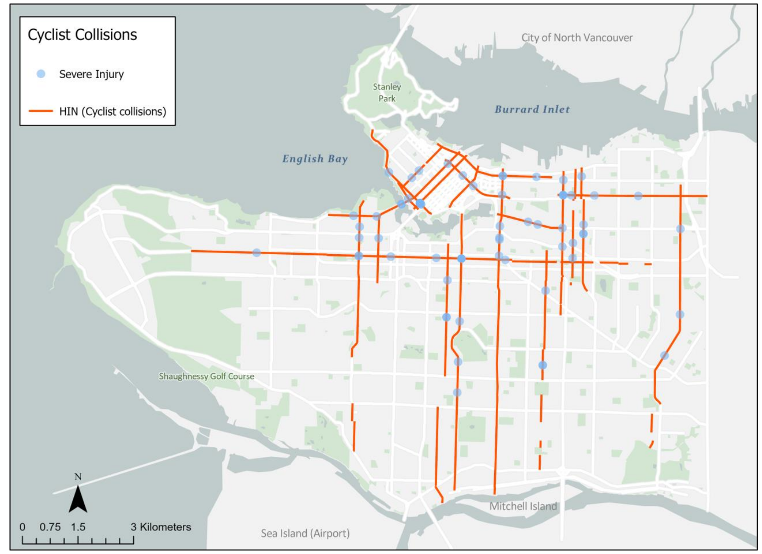
Collision data from 2015-2019 were analyzed and mapped onto the street network of CoV using ArcGIS Pro.

The results reveal that 50% of the collisions occur on only 10% of the street network. To further identify a subset of that high-collision network, four separate HINs are developed for pedestrian, cyclist, motorcyclist, and driver collisions, as illustrated in Figure 2. HINs provide the opportunity to focus the limited resources available for safety improvements towards streets identified within HINs, instead of uniformly distributing the funding throughout the network and receiving underwhelming safety benefits. As evident from Figure 2, there is not much overlap among the streets identified for four modes. Meaning, resources could be allocated to target safety improvements specific to a mode and such targeted funding may be better in meeting safety improvement expectations.

[1] Retrieved August 19, 2022, from https://vancouver.ca/files/cov/Transportation_2040_Plan_as_adopted_by_Council.pdf
[2] Retrieved August 19, 2022, from https://vancouver.ca/streets-transportation/transportation-safety.aspx

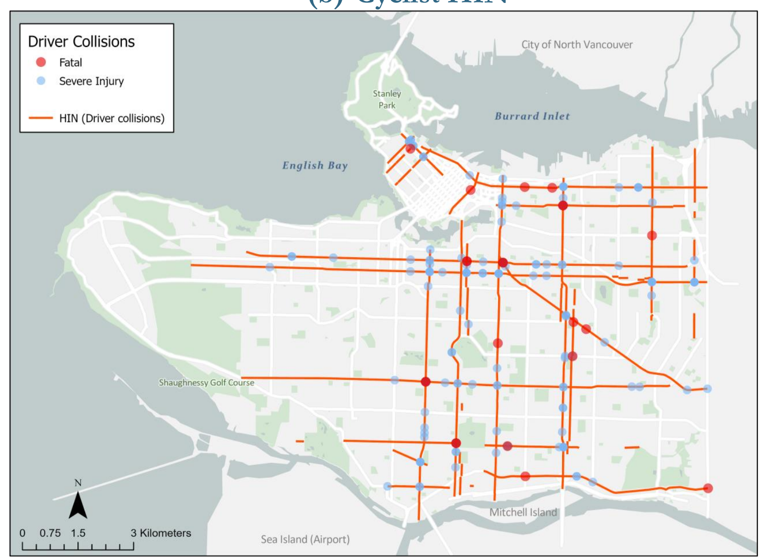


(a) Pedestrian HIN



(b) Cyclist HIN

(c) Motorcyclist HIN



(d) Driver HIN

Figure 2. High Injury Networks (HIN) for different modes of travel.

INTRODUCTION

The City of Vancouver (CoV) is safer than other major North American cities when it comes to fatal traffic collisions[3]. Despite this good standing, streets of Vancouver experienced 66 fatal and 571 severe injury collisions during the years 2015 to 2019. The number of collisions has decreased during those years but the safety could be improved further, especially for active modes of travel (pedestrians and cyclists) that experience more than 50% of fatal and severe injury collisions because they are vulnerable relative to motor vehicles. CoV, too, acknowledges the need to improve traffic safety: "we have made progress but more work is needed as fatalities and serious injuries still occur, and even one fatality is too many"[4] . This statement is the core of "Vision Zero", a strategy adopted by CoV and many other major cities around the world to bring traffic fatalities and severe injuries to zero[5].

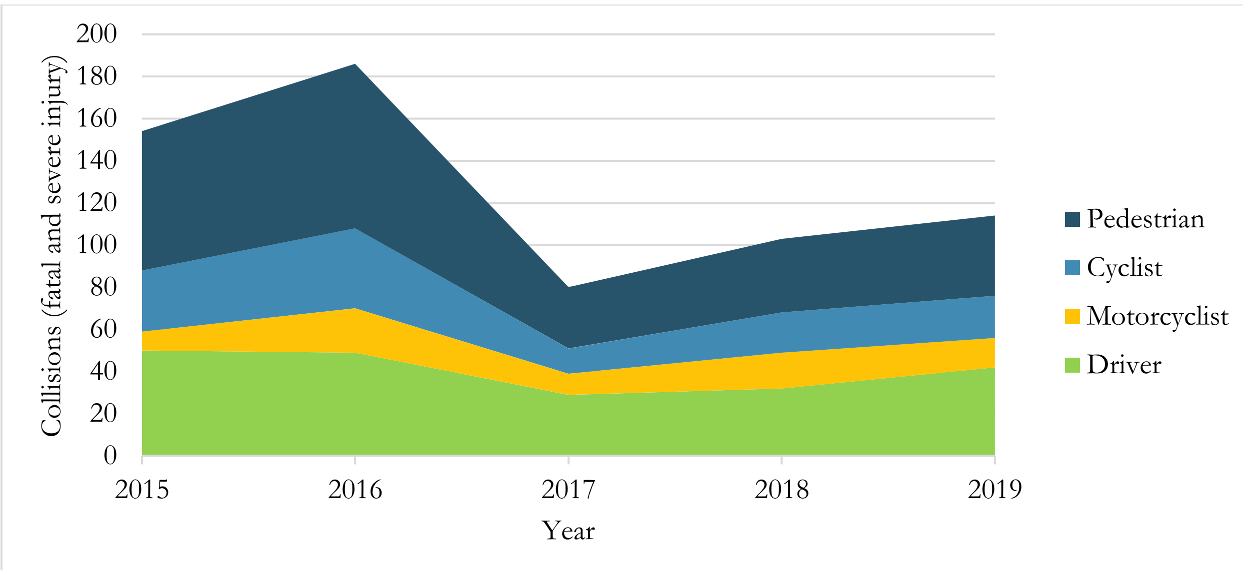


Figure 3. Active modes of travel experience more than 50% of fatal and severe injury collisions.

WHAT IS HIGH INJURY NETWORK AND WHY WE NEED IT?

To realize the goal of Vision Zero, the first step is to locate the spots on streets where fatal and severe injury collisions occur. In an ideal world of unlimited resources, funding would be allocated to all locations in need of safety improvements. But transportation agencies have to prioritize locations because of limited resources. To find and prioritize locations experiencing frequent high-severity collisions, a High Injury Network (HIN) is developed. HIN is a tool to map the fatal and severe injury collisions onto the street network[6],[7].

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[3] Retrieved August 15, 2022, from https://vancouver.ca/streets-transportation/collision-injury-data.aspx
[4] Retrieved August 15, 2022, from https://vancouver.ca/streets-transportation/transportation-safety.aspx
[5] Jenn Fox, Leah Shahum, Jeff Lindley, Dana Weissman, Meghan Mitman, Richard Retting (2018). Retrieved August 15, 2022, from Vision_Zero_Core_Elements_Summary.pdf (visionzeronetwork.org)
[6] Kathleen Ferrier (2018). Retrieved August 15, 2022, from HIN for the WIN | Vision Zero Network
[7] Maxim Gladkiy (2021). Retrieved August 15, 2022, from Summarizing High Injury Networks: The What, Why, and How | NJ Bicycle and Pedestrian Resource Center (njbikeped.org)

HIN also allows the flexibility to emphasize collisions with specific characteristics. For example, collisions occurring within marginalized communities could be given more weight; such communities may have received fewer safety improvements in the past not necessarily because their streets are already safe or because they are not concerned about their community, but because they may not feel comfortable or encouraged to articulate their honest opinions. Assigning more weights helps prioritize such areas for safety improvements.

HIN is a tool to map the collisions onto the streets and identify streets that need most improvement

The cities that implemented HIN observed that collisions are disproportionately aggregated within a small percentage of their street network[8], hence the limited resources could be directed towards that HIN for safety improvements.

OBJECTIVE

The objective of this project is to identify corridors where the highest frequency of fatal and severe injuries occur for pedestrians, cyclists, and drivers so that such corridors could be prioritized for safety improvements. This objective is achieved by developing High Injury Networks (HIN), which emphasizes fatal collisions, collisions involving vulnerable road users, or collisions occurring within less equitable areas.

POLICY CONTEXT

Emphasizing the collisions involving vulnerable modes (pedestrians and cyclists) within HIN helps prioritize locations experiencing such collisions for safety improvements. Improving safety for these relatively vulnerable modes is crucial because cities are increasingly promoting these active modes and transportation practitioners are entrusted with the responsibility to ensure the streets are safe to accommodate the anticipated increase in active mode trips. Locally, one of the goals of Climate Emergency Action Plan[9] is that walking, cycling and transit is used for two-thirds of trips within Vancouver by 2030. To achieve that mode share target, it is crucial the users of these modes feel safe, and reducing frequency of collisions could help these modes to be perceived as safe.

Figure 4. It is crucial to ensure safety of active modes while promoting them. ***(Photo credit: City of Vancouver)***

[8] Kathleen Ferrier (2018). Retrieved August 15, 2022, from HIN for the WIN | Vision Zero Network

[9] City of Vancouver (2020). Retrieved August 15, 2022, from. https://vancouver.ca/files/cov/climate-emergency-action-plan-summary.pdf

METHODOLOGY

Figure 5 illustrates the analytical framework for developing HIN in ArcGIS Pro[10]. The goal is to determine a subset of street network where the highest number of collisions occur.

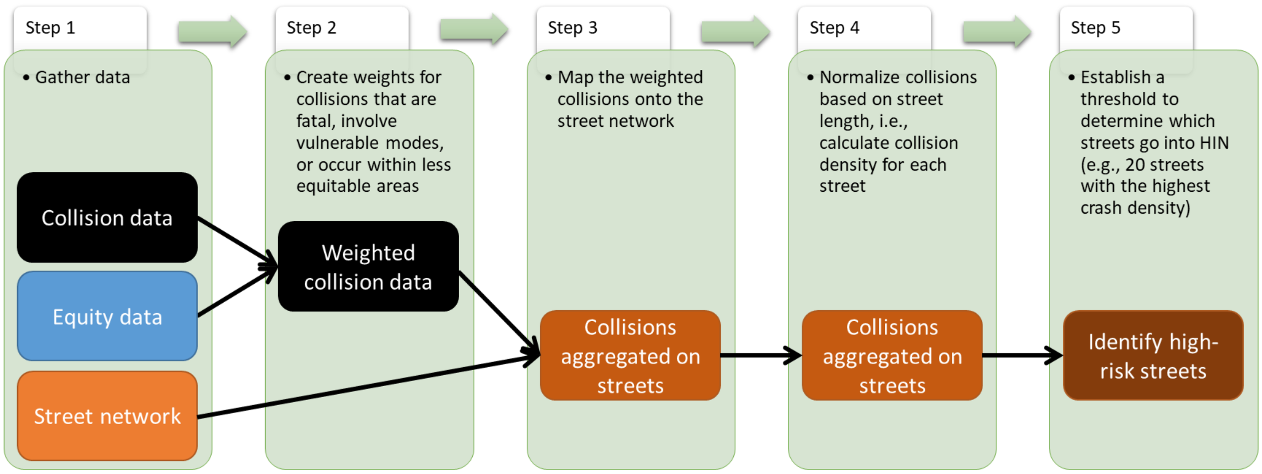

Figure 5. Framework for developing HIN.

STEP 1: DATA

Five years (2015-2019) of collision data are used for this study. HIN guidelines recommend using three to five years of most recent data but the data from 2020-2021 are not considered due to the COVID-19 pandemic most probably changing the traffic behaviour, making it hard to confidently assume the underlying safety of locations. Collision data are provided to CoV through its partners ICBC (Insurance Corporation of British Columbia), VPD (Vancouver Police Department), and VGH (Vancouver General Hospital). In accordance with HIN guidelines, only fatal and severe injury collisions are considered. The data from VPD are not used for the analysis, as they are redundant; collisions recorded in VPD data are already available in ICBC data.

The equity data are provided by CoV. CoV is divided into nine zones (as illustrated in Figure 6) and each zone is assigned an equity rank based on walk mode share, elderly, one parent, language, rent burden, First Nation, visible minority, and household income.

[10] Retrieved August 15, 2022, from Recommendations for California Statewide Guidance - High Injury Networks

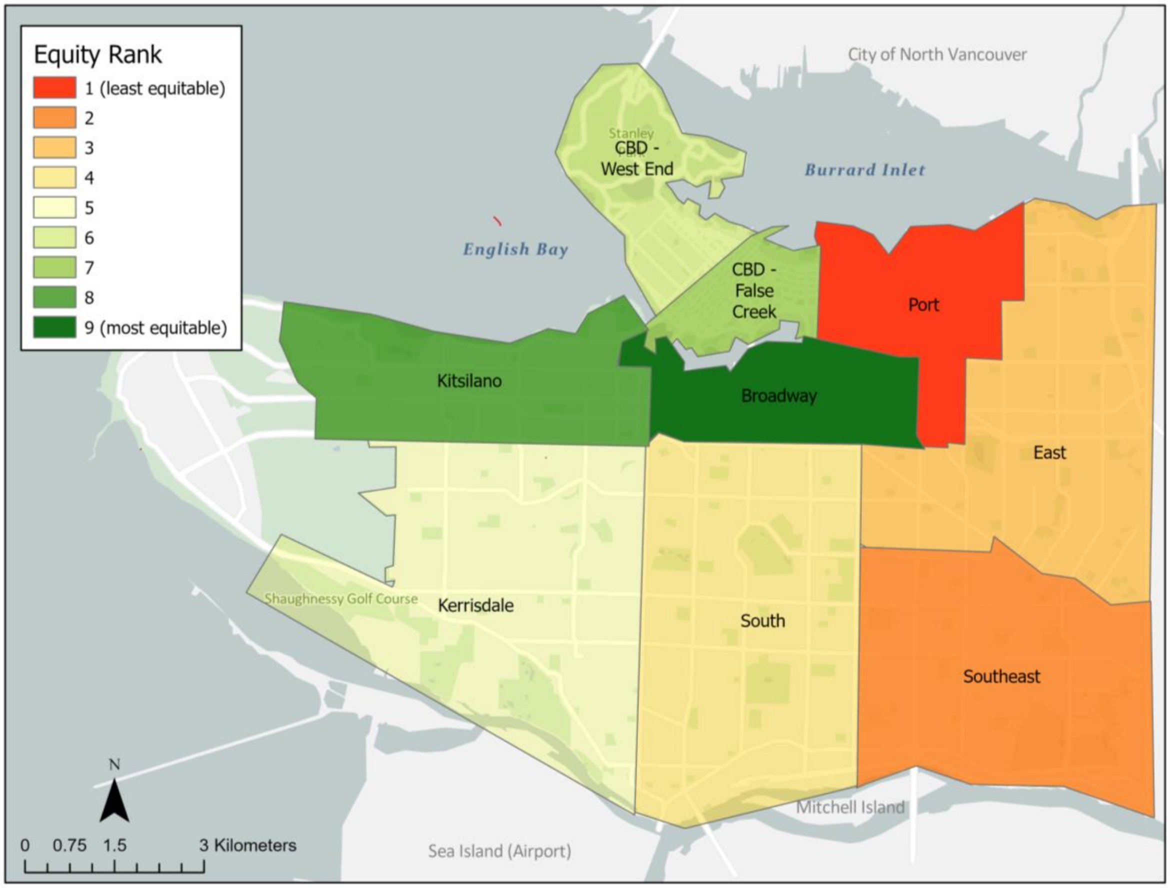

Figure 6. Equity ranking of nine zones of Vancouver.

The street network shape file is provided by CoV. Figure 7 illustrates the street network of CoV, comprised of 838 streets with a total length of 1440 kilometers (km).

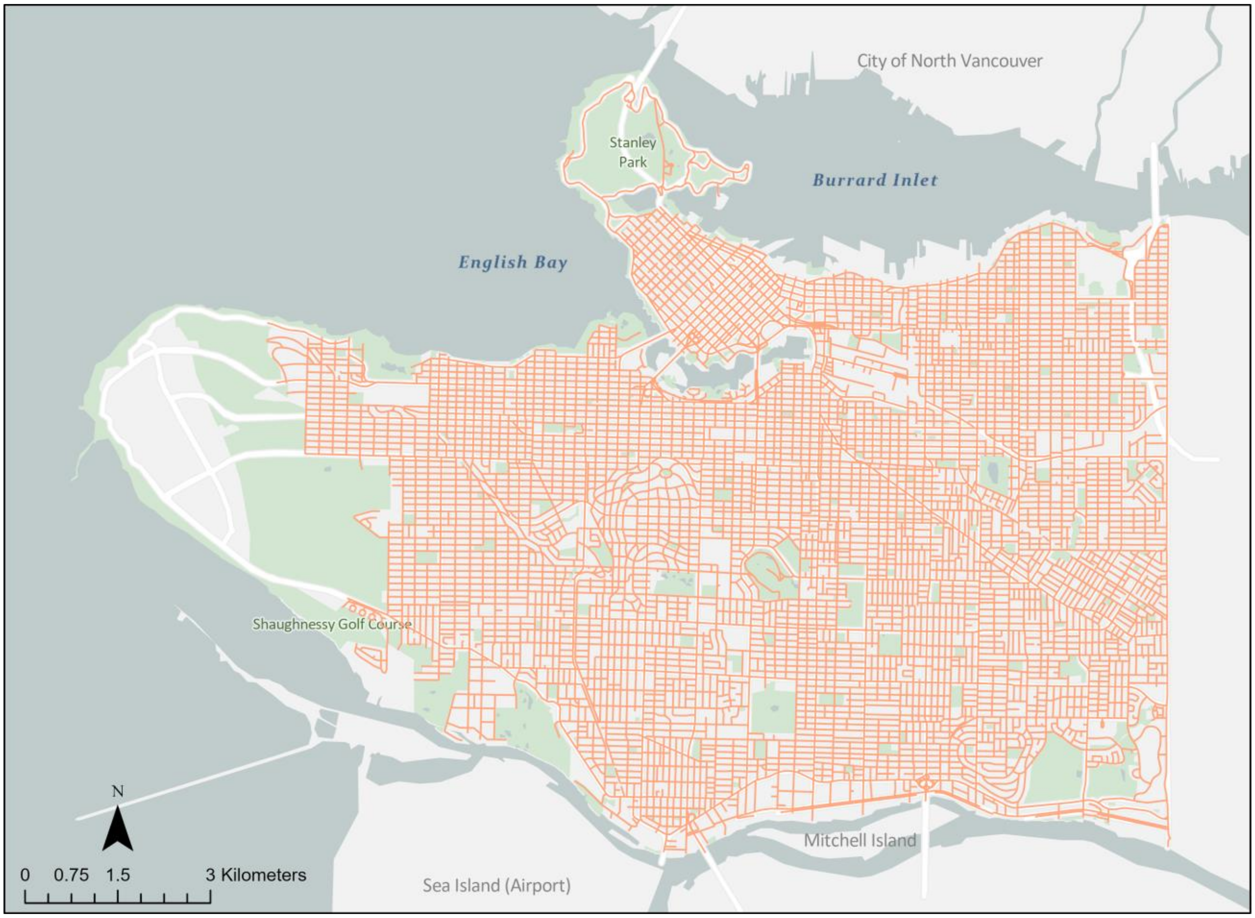

Figure 7. Street network of City of Vancouver.

STEP 2: WEIGHTS

To emphasize collisions with specific characteristics, weights are assigned based on collision severity, mode of travel of victim, and whether the collision occurred in the area of disadvantaged communities:

- *Severity:* 1 fatal collision = 1.5 times a non-fatal collision.
- *Vulnerable modes:* Add 0.25 for collisions involving vulnerable road users (pedestrians and cyclist).
- *Equity:* Using the equity ranking, equity-based weights are created[11], as shown in Table 1.
- To clarify the weight assignment with examples:
  - A fatal collision of a pedestrian in Vancouver - Port is counted as 1.5 + 0.25 + 0.25 = 2 collisions.
  - A severe collision of a motorcycle in Vancouver - Broadway is counted as 1 + 0 + 0 = 1 collision.

[11] Safer Streets (2018). Retrieved August 15, 2022, from Microsoft Word - Safer Streets Final_3.7.18.docx (atlantaga.gov)

Table 1. Equity-based weights for nine zones of Vancouver

Transportation Zone	**Equity Rank**	**Equity Weight**
Port	1	0.25
Southeast	2	0.25
East	3	0.25
South	4	0.125
Kerrisdale	5	0.125
CBD - West End	6	0.125
CBD - False Creek	7	0
Kitsilano	8	0
Broadway	9	0

STEP 3: MAP

The weighted collisions are spatially joined with the street network. This join results in each street (only if associated with at least one collision) to have a total collision weight based on the number and type of collisions associated with that street.

STEP 4: NORMALIZATION

Now, each street has an aggregate collision weight but if we prioritize streets based on aggregated collision weight then the longer streets tend to come on top. But such streets might not be the most unsafe. Using collision density-based HIN provides the opportunity to include streets with relatively short lengths, which might prove to be more promising in terms of safety improvement but would have been excluded if using purely collision frequency-based HIN. Therefore, consistent with other studies, I calculate collision density to normalize the collisions based on street length:

Collision density = aggregated collision weight/street length

STEP 5: HIN

Normalizing the aggregated collisions might lead to misleading results. For example, if a street is too short and has a aggregated collision weight of one, then the collision density would be relatively high and could mislead us into believing that the street is more unsafe than reality. Being consistent with the literature and using my judgment, I filtered out streets with low aggregated collision weights and determined the streets with the highest collision density to be HIN.

RESULTS

ALL COLLISION TYPES

Recall that all analysis is performed using five-year collision data (2015 to 2019) of fatal and severe injuries for four modes of travel (pedestrians, cyclists, motorcyclists, and drivers). The objective of this study is to identify the corridors where fatal and severe injury collisions occur most frequently for different modes of travel. But before focusing on each mode, it is useful to visualize the spatial distribution of collisions of all modes across CoV. Figure 8 illustrates the heat map based on collision frequency across CoV. Most collisions are concentrated around CBD and Broadway.

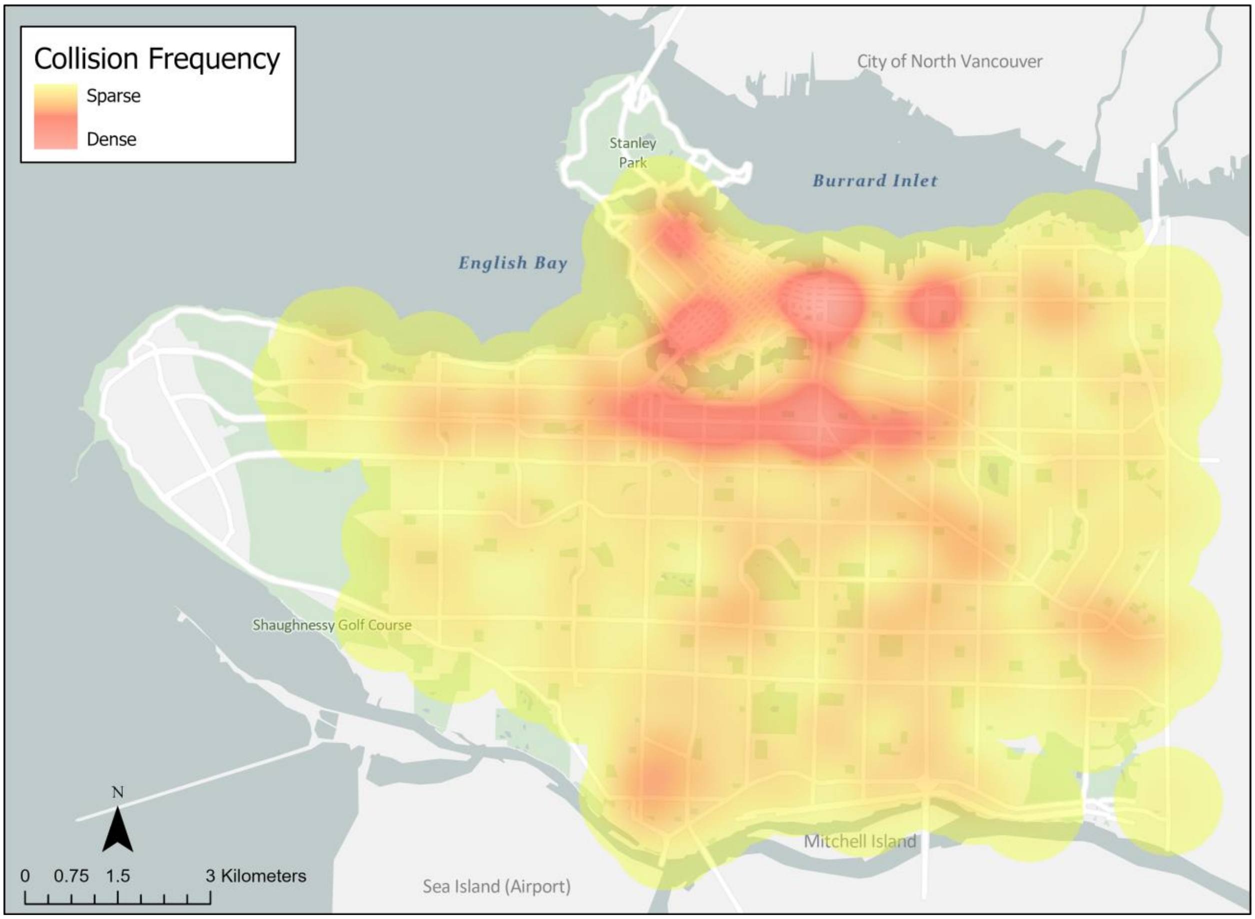

Figure 8. Heat map of collision frequency (fatal and severe injuries) across Vancouver.

Figure 9 illustrates the distribution of fatal and severe injury collisions. Fatal collisions do occur more frequently around CBD and Broadway but are not restricted to these areas. Future research could examine the relationship between fatal collisions and speed limit and traffic volume to determine the causal factors.

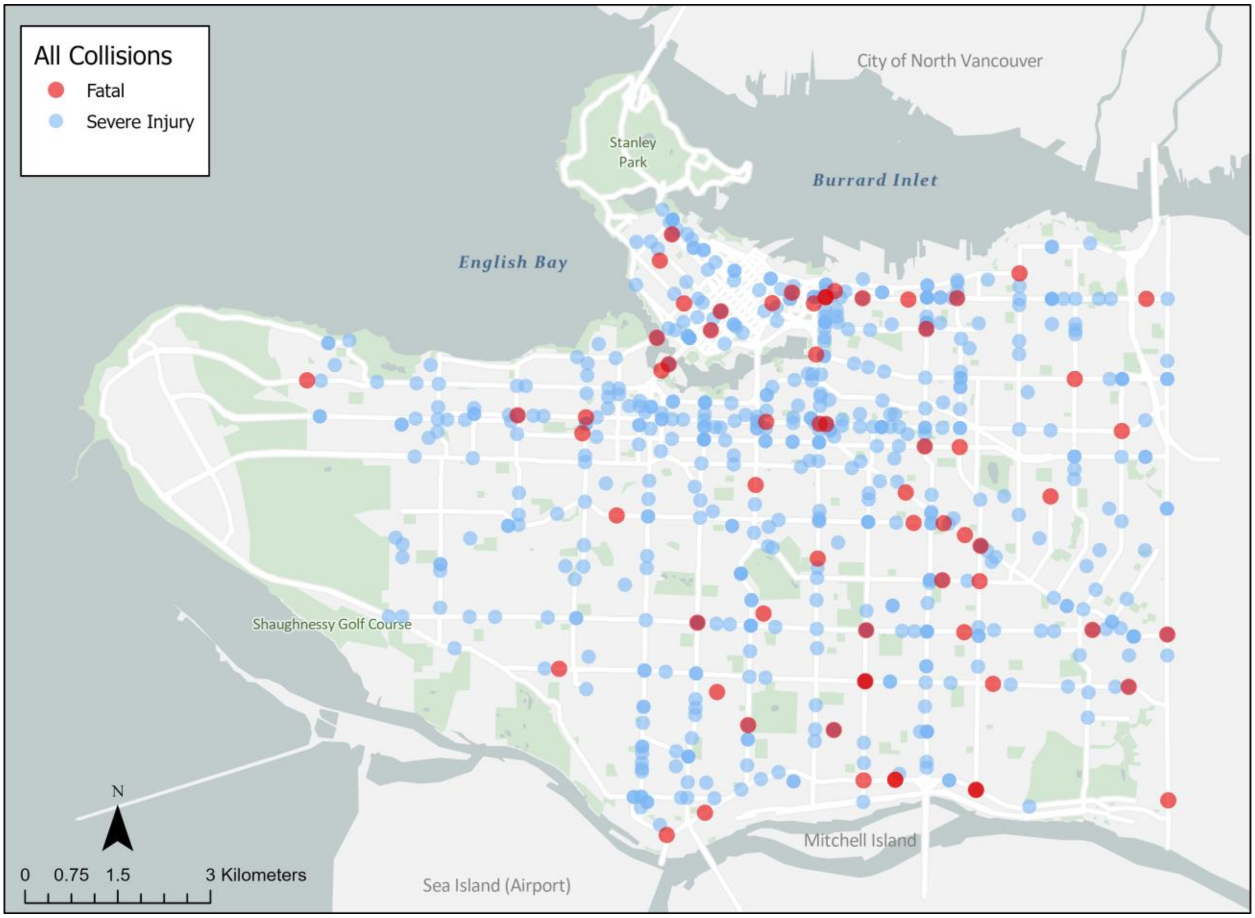

Figure 9. Collision distribution based on severity.

Figure 10 illustrates the distribution of collisions based on mode of travel. Separate figures for each mode are provided later but Figure 10 demonstrates that all modes are represented throughout CoV except cyclist collisions, which are less frequent in South.

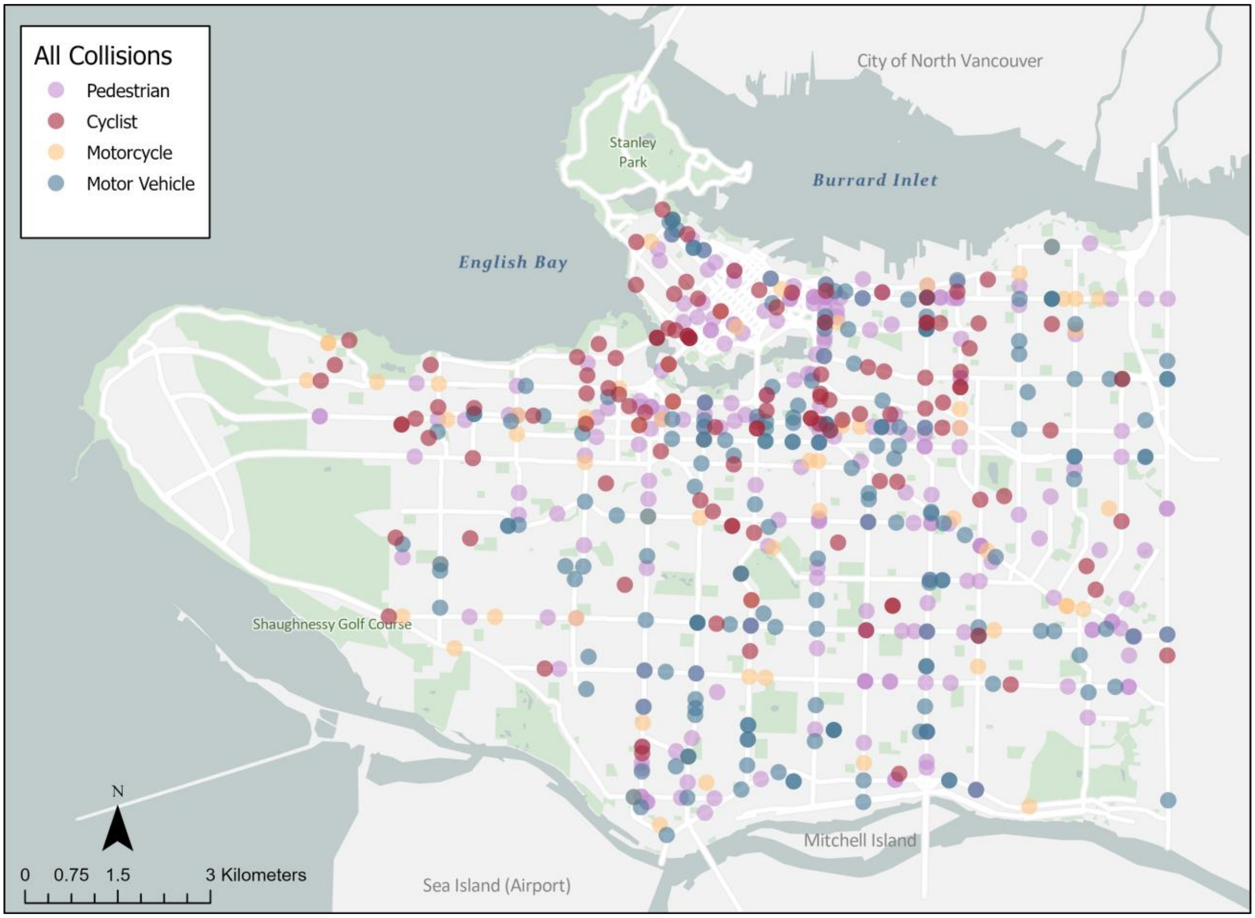

Figure 10. Collision distribution based on mode of travel of collision victim.

Figure 11 illustrates the association of equity zones and concentration of collisions. A few other cities have observed collisions to be disproportionately aggregated in disadvantaged areas[12]. But as evident from Figure 11, CoV does not seem to follow that pattern as strongly; 20% of total collisions occur in South, which ranks fourth on the equity scale, closely followed by 17% collisions in Broadway, which is the most equitable zone. In fact, the Pearson correlation coefficient between the frequency of collisions and equity ranking is 0.08, which is a weak correlation and indicates that relatively equitable zones actually experience more collisions. This bivariate relationship certainly paints a good picture of CoV, though it should be noted that this analysis is not controlling for any other factors such as traffic volume or area of the equity zones, which are most probably affecting collision frequency.

The least equitable zones (Port, East, and South) still account for 33% of the collisions though. Hence, weights are assigned to the collisions occurring in such inequitable areas so that they could be prioritized for allocating safety funds.

[12] Kathleen Ferrier (2018). Retrieved August 15, 2022, from HIN for the WIN | Vision Zero Network

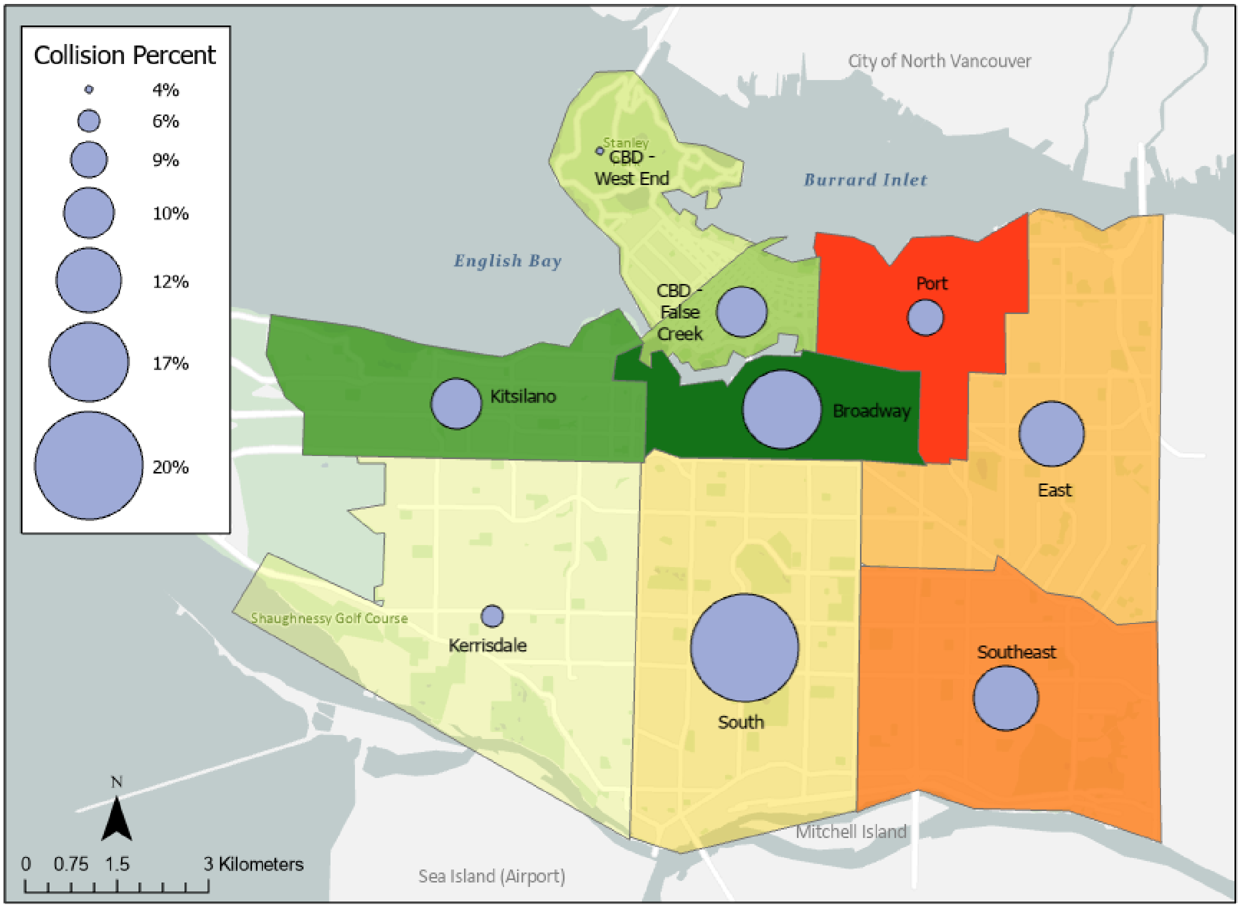

Figure 11. Aggregated collisions across nine equity zones of City of Vancouver.

Figure 12 illustrates the distribution of aggregated collision counts across streets of Vancouver. As evident, most collisions occur on a few streets. In fact, the ten streets illustrated in Figure 13 account for 50% of the collisions (fatal and severe). In other words, 50% of the collisions occur on 10% of the street network. Other studies have also observed majority of the collisions to be aggregated on a fraction of the network[13].

50% of the collisions occur on 10% of the street network

[13] Kathleen Ferrier (2018). Retrieved August 15, 2022, from HIN for the WIN | Vision Zero Network

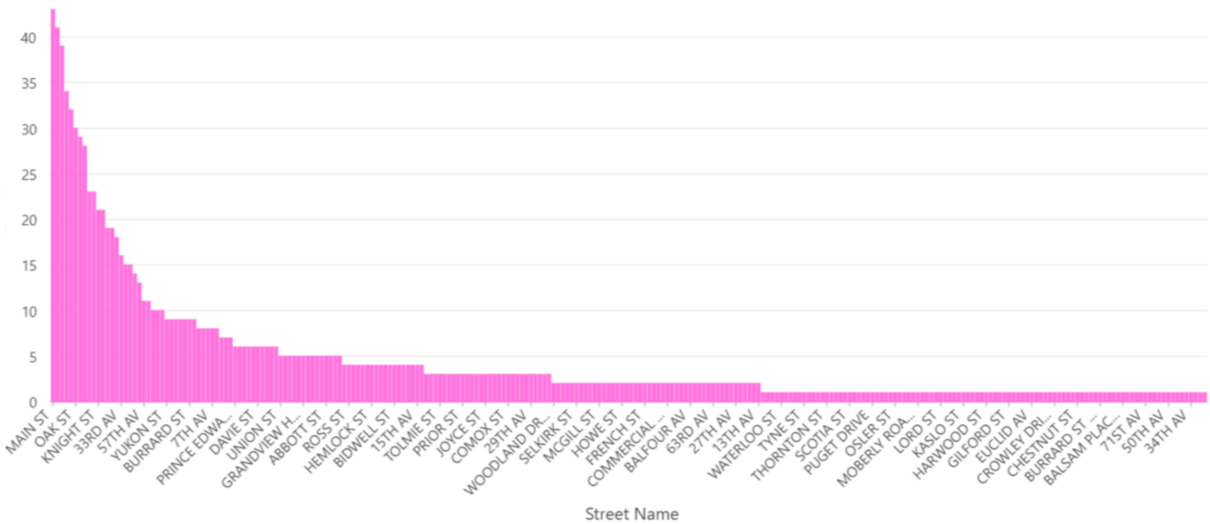

Figure 12. Aggregated collision counts across streets of Vancouver.

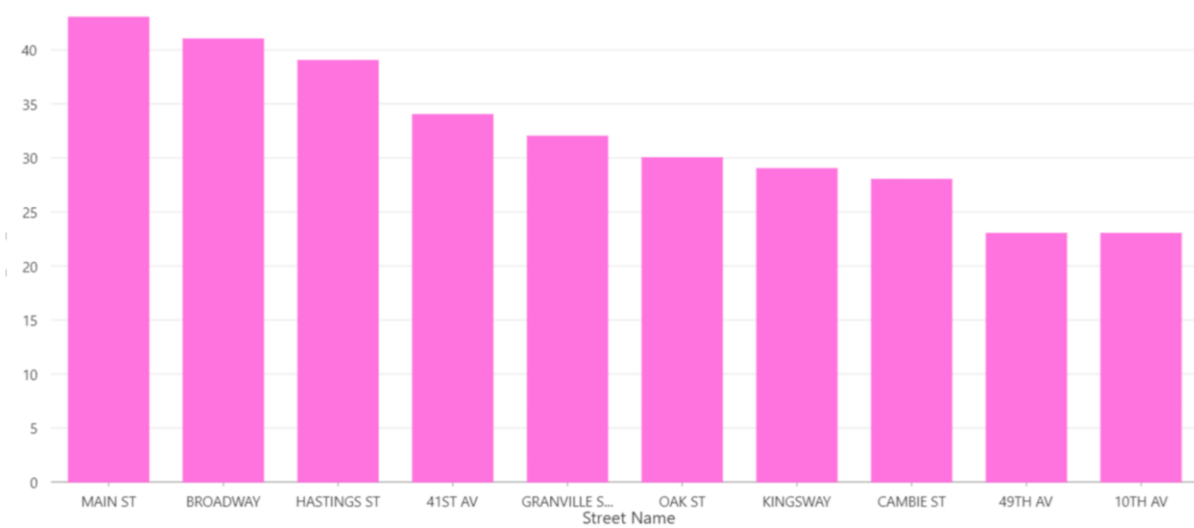

Figure 13. Ten streets with the highest aggregated collision counts.

HIN: ALL MODES OF TRAVEL

Recall that the HIN is developed by assigning the aggregated collision weights to each street. The collision weights are then normalized based on street length to calculate collision density. All HINs in this study are developed based on collision density. Figure 14 illustrates the HIN of 50 most unsafe streets considering all four modes of travel.

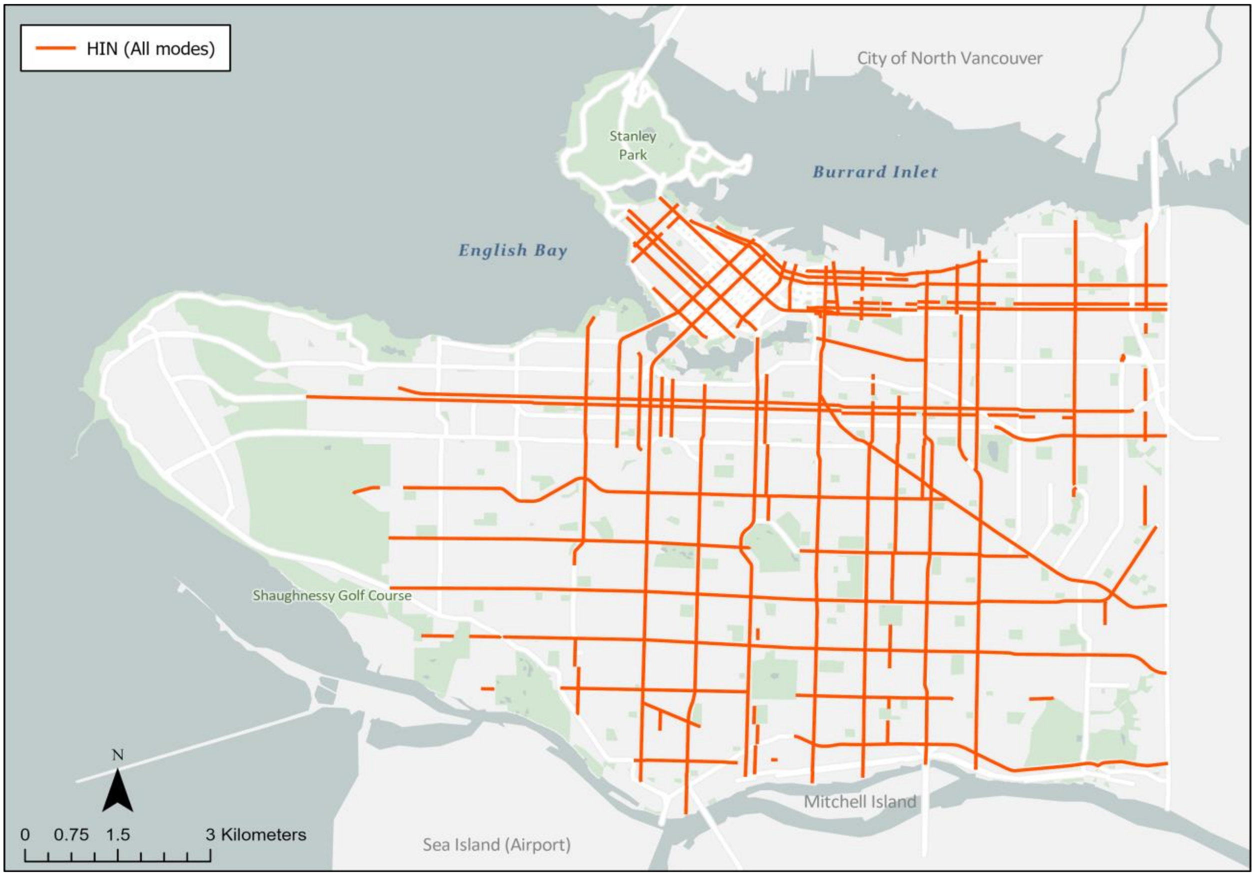

Figure 14. HIN for all modes.

To improve safety by devising safety countermeasures, it is important to locate the collision spots along the streets of HIN and investigate the primary causal factor. Investigation of causal factors is beyond the scope of this study but Figure 15 illustrates the collisions associated with the HIN.

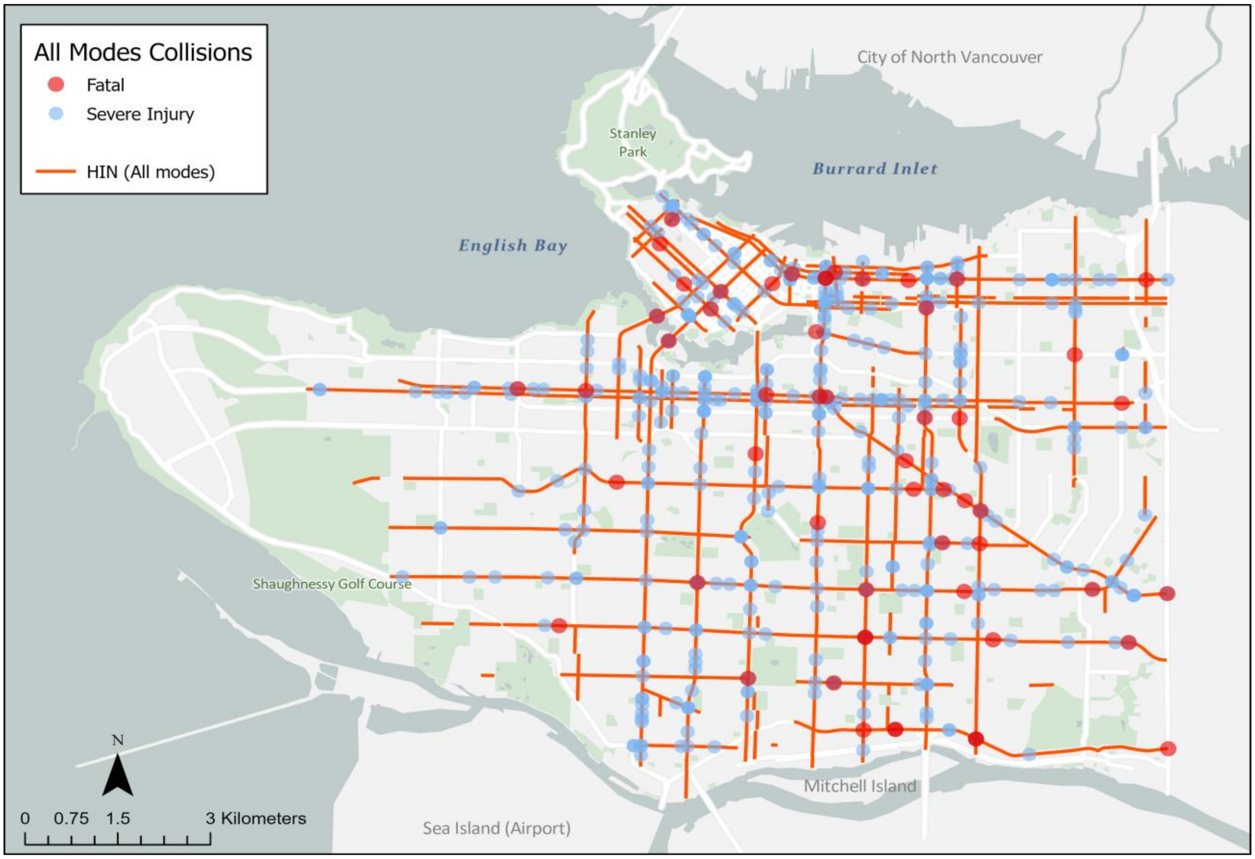

Figure 15. Least safe spots on each street of HIN.

The streets with the highest collision densities are prioritized for safety improvements. Table 2 gives the names of the 15 streets within HIN with the highest collision density. The policy makers could justify allocating funding to these streets first with a potential to see the most improvement in safety with that funding.

Table 2. Top 15 streets in HIN with the highest collision density

Street name	Total collision weight	Street length (km)	Collision density (collisions per km)
Rupert Off Ramp	4.0	0.1	34.2
Rupert Bus Lane	4.0	0.1	27.8
Abbott St	6.8	0.8	8.3
Hastings St	55.0	8.1	6.8
Denman St	7.0	1.0	6.8
Commercial Drive	22.8	3.4	6.7
Gore Av	6.0	0.9	6.7
Clark Drive	26.0	3.9	6.7
Main St	53.9	8.8	6.1
Kingsway	41.0	6.9	6.0
Princess Av	4.8	0.8	5.9

Pacific St	7.0	1.2	5.7
Bidwell St	5.5	1.0	5.6
Knight St	29.0	5.6	5.2
Oak St	35.4	7.3	4.8

HIN prioritizes streets where the most fatal and severe injuries occur (normalized for street length), but there could be other factors as well that further affect prioritization within HIN. One such factor is the proximity of HIN to schools, since children are vulnerable road users. HIN could be used to identify the schools which are located on HIN and hence exposed to relatively high risk of collisions. There are 163 schools in CoV and 69 of them (42%) are located within 50 meters of HIN, as illustrated in Figure 17.

Figure 16. Streets in HIN close to schools could be prioritized for safety improvements. ***(Photo credit: City of Vancouver)***

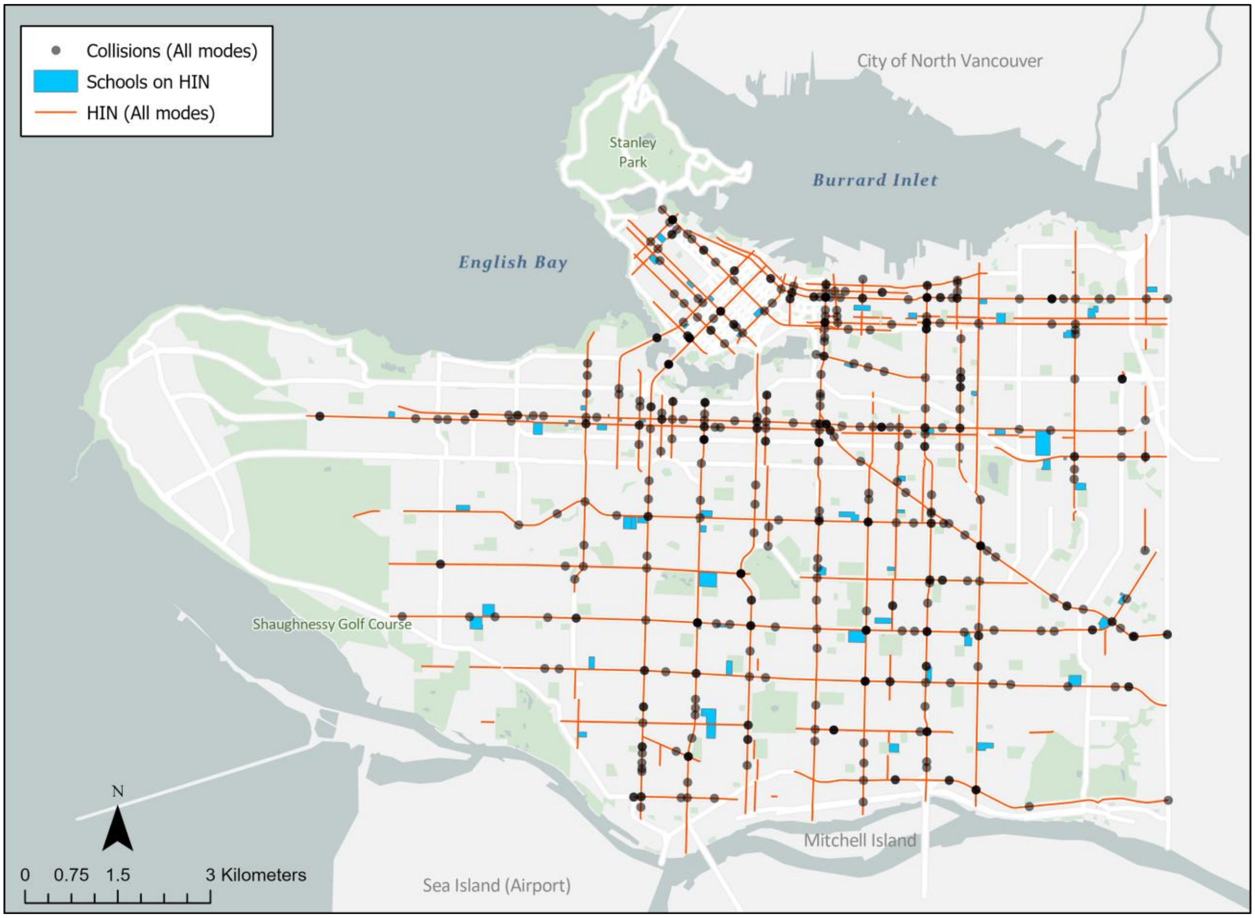

Figure 17. Schools located on HIN.

42% of schools are located within 50 meters of HIN

Table 3 provides the list of 15 schools that are located on the streets with highest collision density. All these streets are already included in Table 2 to be prioritized for safety improvement.

Table 3. 15 schools located within 50 meters of HIN streets with highest collision density

School name	**School address**	**HIN street name**	**Collision density (collisions per km)**
Alexander Academy	688 W Hastings St	Hastings St	6.8
Sir William MacDonald Community	1950 E Hastings St	Hastings St	6.8
King George Secondary	1755 Barclay St	Denman St	6.8
Stratford Hall	3000 Commercial Drive	Commercial Drive	6.7
Queen Alexandra Elementary	1300 E Broadway	Clark Drive	6.7
General Brock Elementary	4860 Main St	Main St	6.1
Sir Guy Carleton Community Elementary	3250 Kingsway	Kingsway	6.0

Lord Strathcona Community Elementary	592 E Pender St	Princess Av	5.9
Lord Roberts Elementary	1100 Bidwell St	Bidwell St	5.6
King George Secondary	1755 Barclay St	Bidwell St	5.6
Sir Sandford Fleming Elementary	1401 E 49th Av	Knight St	5.2
Vancouver Talmud Torah Elementary	998 W 26th Av	Oak St	4.8
Eric Hamber Secondary	5025 Willow St	Oak St	4.8
Emily Carr Elementary	4070 Oak St	Oak St	4.8
Westside Montessori	4157 Oak St	Oak St	4.8

PEDESTRIAN COLLISIONS

Note: In the rest of the subsections within Results, I follow the same sequence of first presenting the distribution of collisions of a specific mode across CoV and then illustrating the HIN and list of most promising streets for safety improvement.

Figure 18 illustrates the distribution of fatal and severe injury pedestrian collisions. This distribution serves as a starting point to obtain the map of most unsafe corridors for pedestrians.

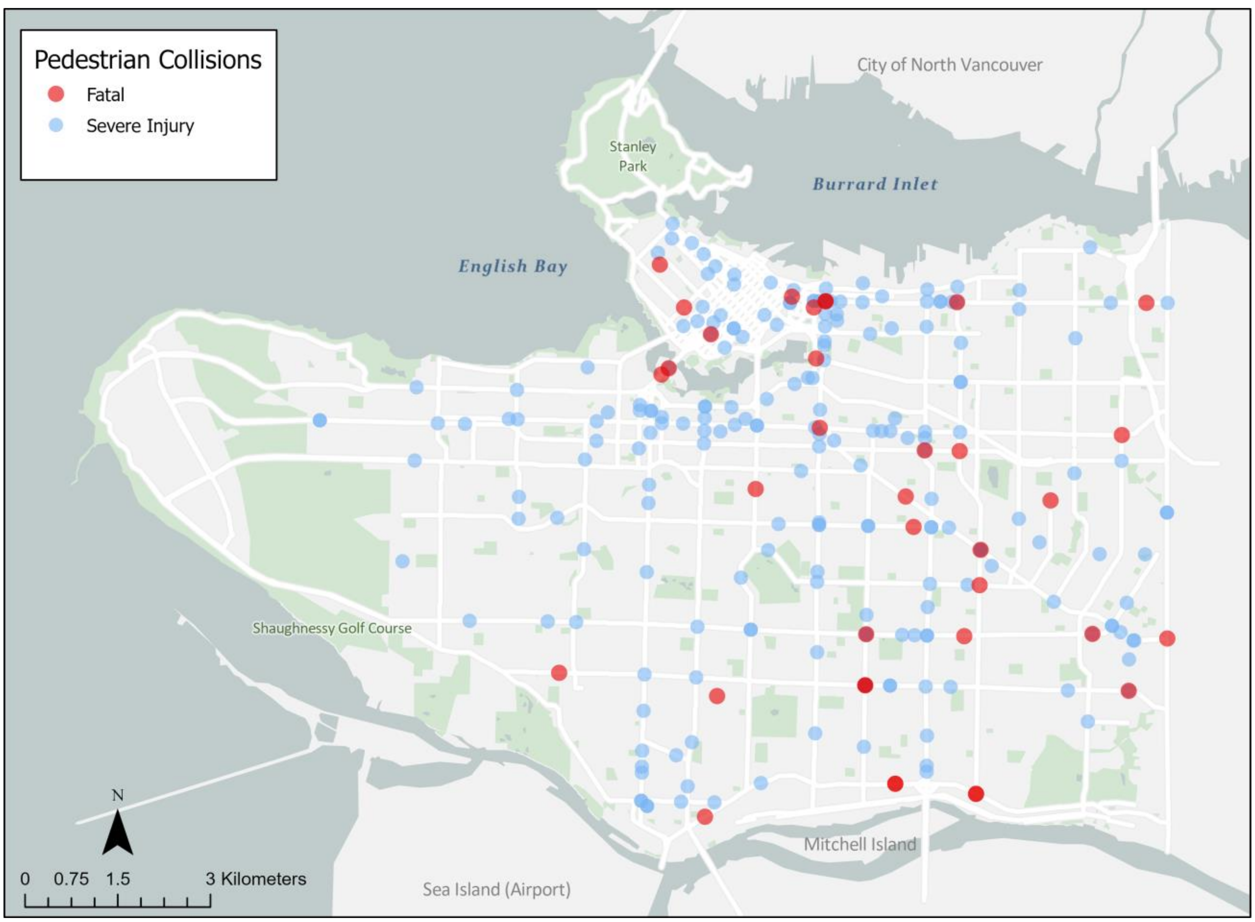

Figure 18. Pedestrian collision distribution based on severity.

HIN: PEDESTRIANS

Figure 19 illustrates the pedestrian HIN of 25 streets with the highest collision density and the associated collision spots for further investigation.

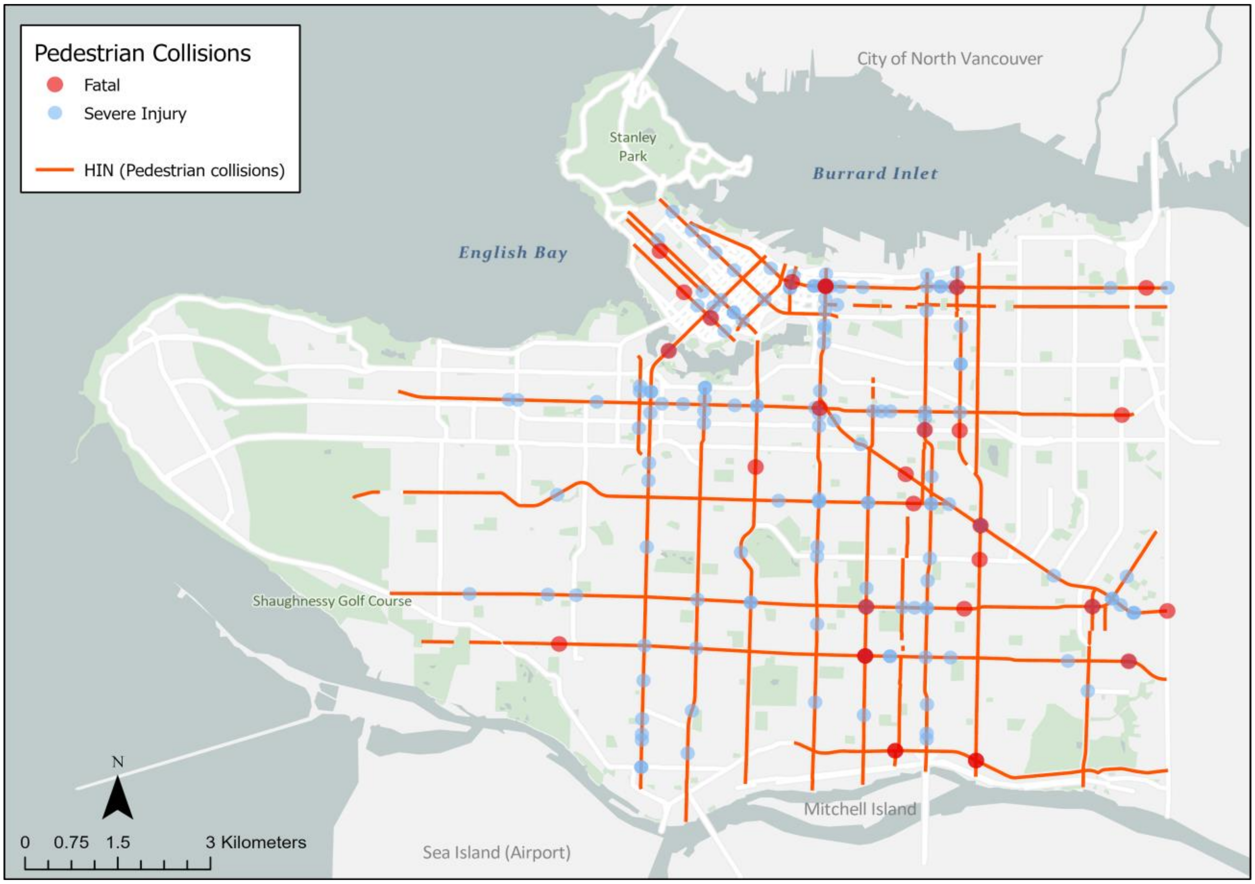

Figure 19. Pedestrian HIN with least safe spots on each street of HIN.

Table 4. Top 10 streets in pedestrian HIN with the highest collision density

Street name	**Total collision weight**	**Street length (km)**	**Collision density (collisions per km)**
Abbott St	5.5	0.8	6.7
Hastings St	34.3	8.1	4.2
Commercial Drive	13.0	3.4	3.9
Main St	31.1	8.8	3.5
Kingsway	23.5	6.9	3.4
Davie St	7.4	2.3	3.2
Knight St	16.5	5.6	3.0
Fraser St	17.9	6.7	2.7
Clark Drive	10.0	3.9	2.6
Granville St	23.0	9.7	2.4

CYCLIST COLLISIONS

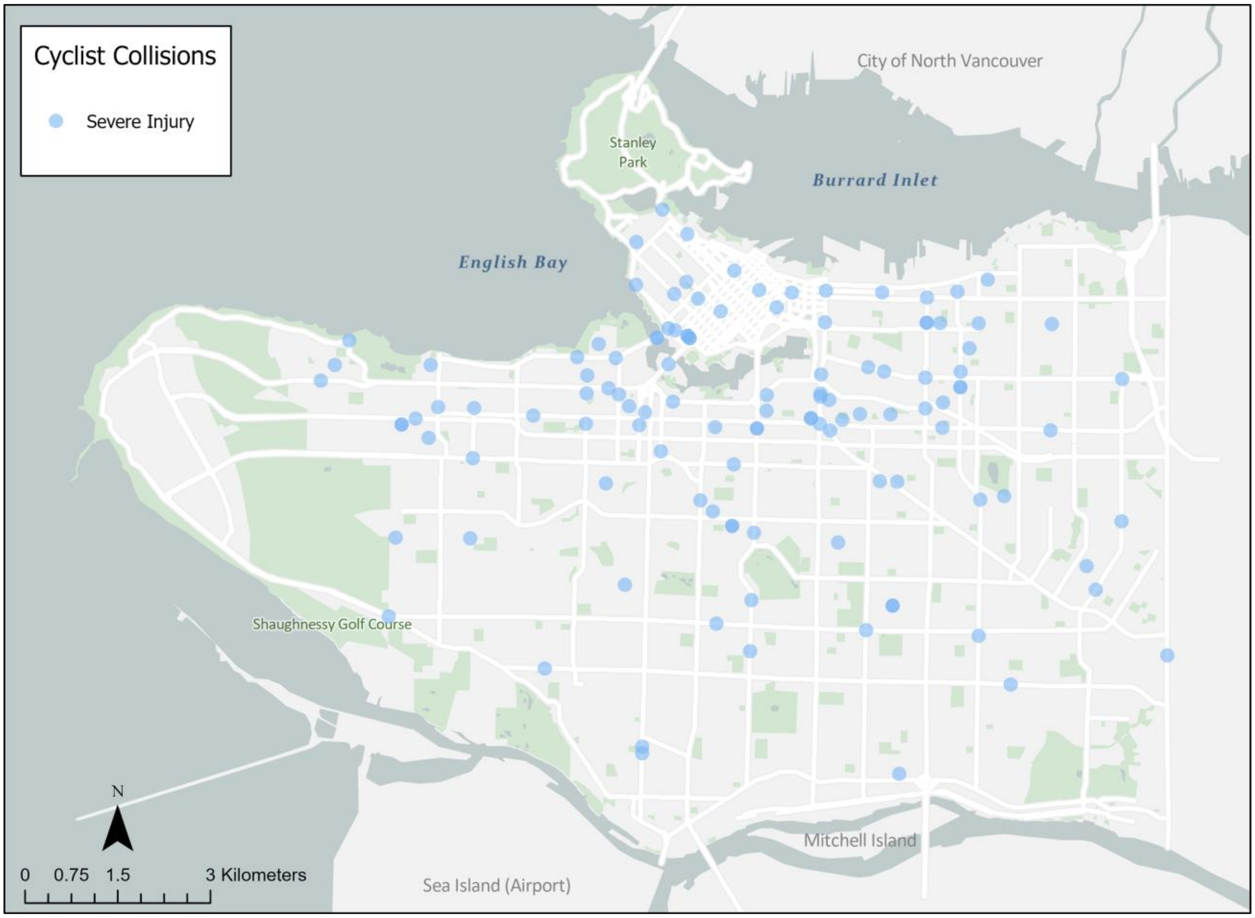

Figure 20. Cyclist collision distribution.

Figure 21 illustrates the cyclist collisions usually occur either where there are no bike lanes or local bike lanes. Such maps may not be directly useful for developing HIN but could be useful to prioritize streets once HIN is developed.

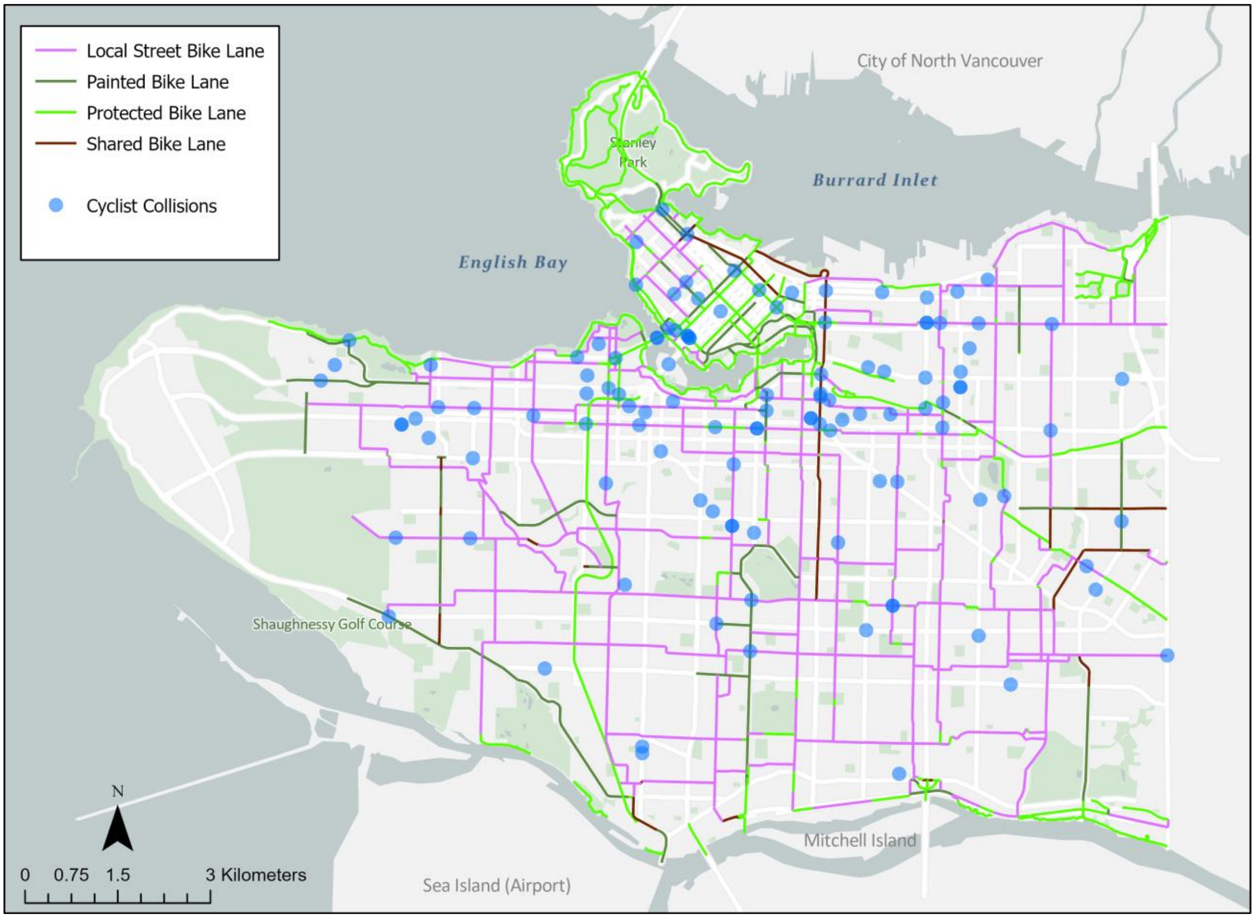

Figure 21. Proximity of cyclist collisions to bike lanes.

HIN: CYCLISTS

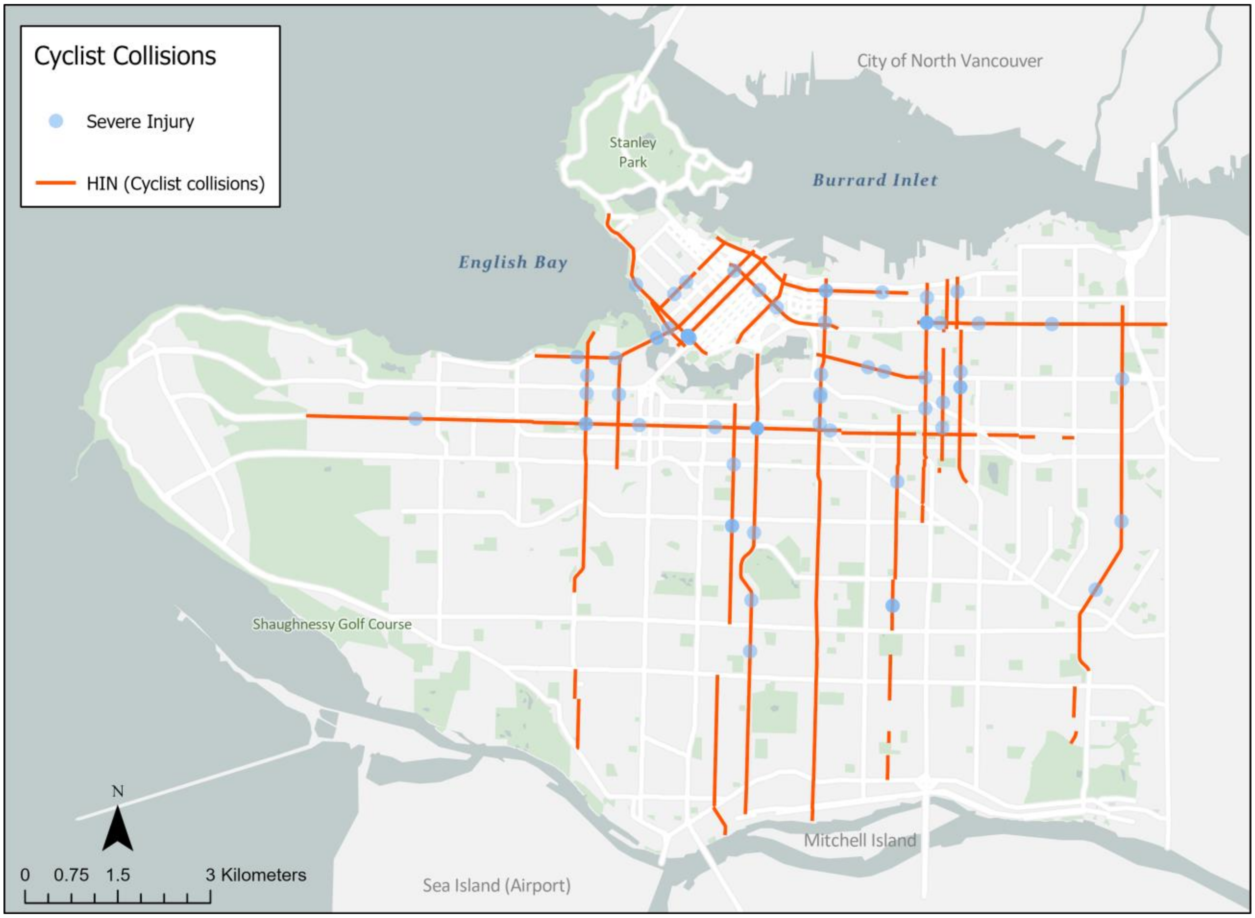

Figure 22. Cyclist HIN with least safe spots on each street of HIN.

Table 5. Top 10 streets in cyclist HIN with the highest collision density

Street name	**Total collision weight**	**Street length (km)**	**Collision density (collisions per km)**
Pacific St	5.0	1.2	4.1
Terminal Av	3.8	1.8	2.1
Bute St	2.8	1.5	1.9
Adanac St	7.5	4.0	1.9
Cornwall Av	2.5	1.4	1.8
Commercial Drive	6.0	3.4	1.8
Clark Drive	5.8	3.9	1.5
Howe St	2.5	2.0	1.2
Dunsmuir St	2.5	2.1	1.2
Burrard St	5.0	4.6	1.1

MOTORCYCLIST COLLISIONS

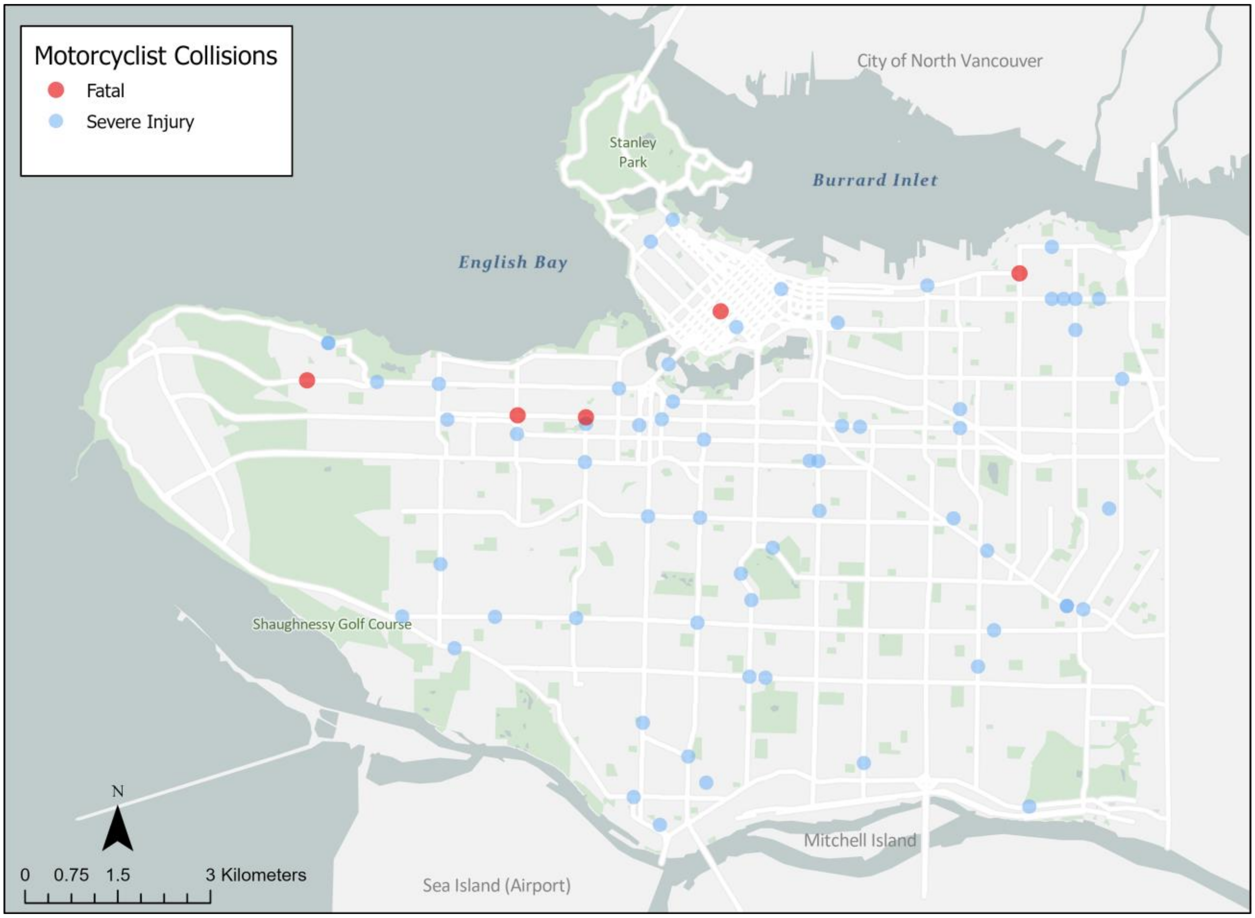

Figure 23. Motorcyclist collision distribution based on severity.

HIN: MOTORCYCLISTS

Figure 24. Motorcyclist HIN with least safe spots on each street of HIN.

Table 6. Top 10 streets in motorcyclist HIN with the highest collision density

Street name	**Total collision weight**	**Street length (km)**	**Collision density (collision per km)**
Denman St	2.3	1.0	2.2
Nelson St	3.6	2.9	1.2
Killarney St	2.5	2.6	0.9
Dundas St	1.8	2.0	0.9
NW Marine Drive	2.0	2.3	0.9
Blanca St	1.5	1.9	0.8
Hastings St	6.0	8.1	0.7
Commercial Drive	2.5	3.4	0.7
Kingsway	5.0	6.9	0.7
Broadway	7.3	11.9	0.6

DRIVER COLLISIONS

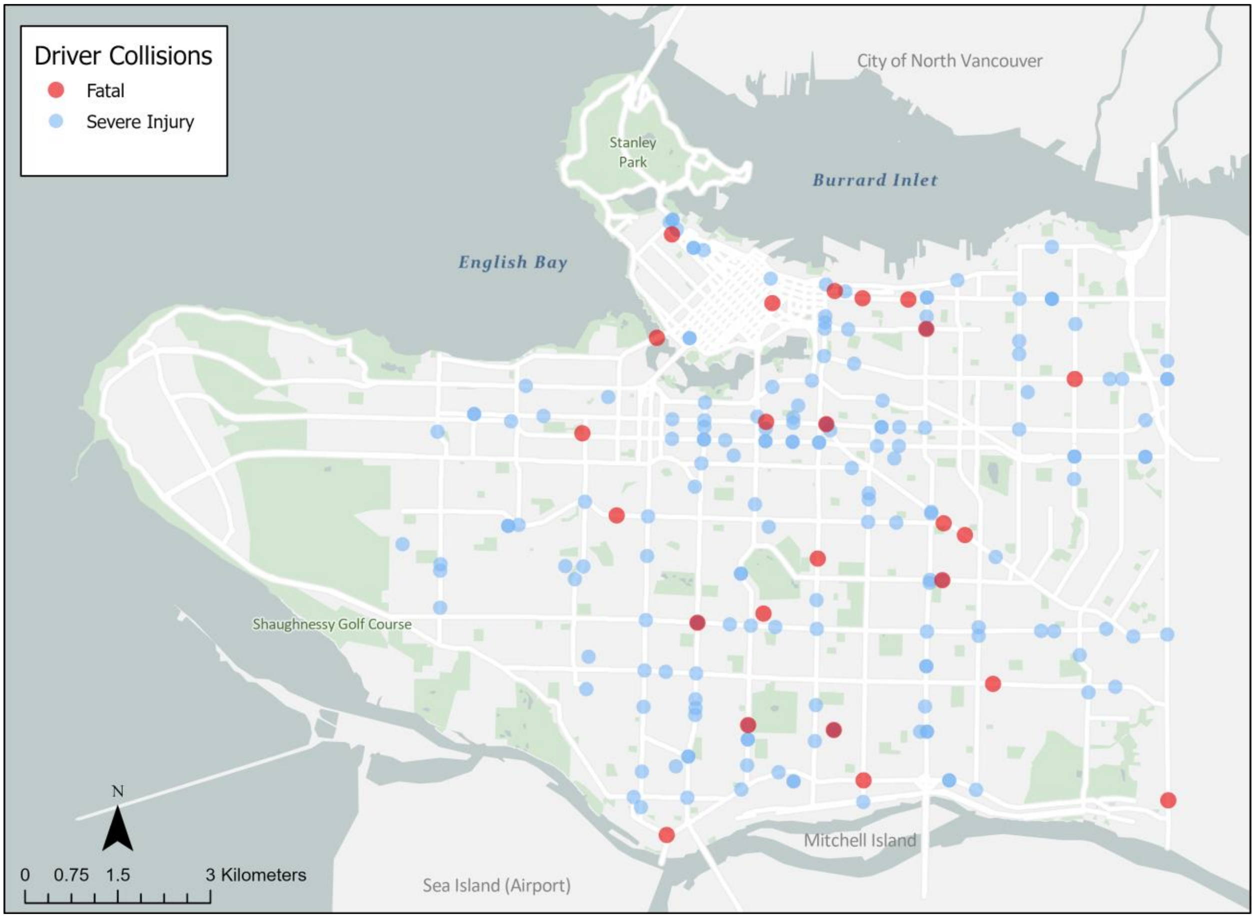

Figure 25. Driver collision distribution based on severity.

HIN: DRIVERS

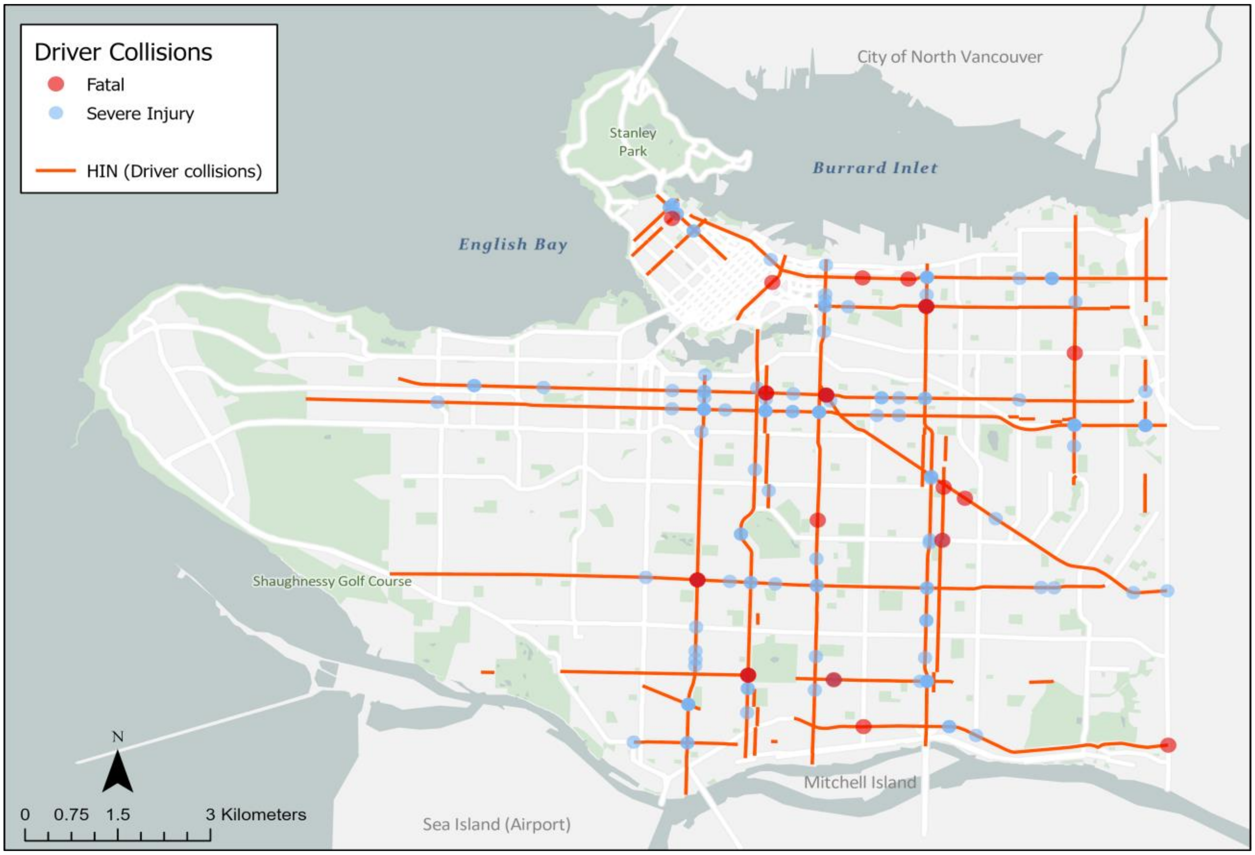

Figure 26. Driver HIN with least safe spots on each street of HIN.

Table 7. Top 15 streets in driver HIN with the highest collision density

Street name	Total collision weight	Street length (km)	Collision density (collision per km)
Denman St	3.4	1.0	3.3
Bidwell St	2.8	1.0	2.8
Oak St	17.9	7.3	2.4
Clark Drive	9.0	3.9	2.3
Knight St	12.5	5.6	2.2
Park Drive	2.3	1.0	2.2
Prior St	2.3	1.3	1.8
Grandview Hwy	5.0	2.9	1.8
Broughton St	2.3	1.3	1.7
57th Av	10.4	6.2	1.7
Kingsway	11.3	6.9	1.6
Main St	13.1	8.8	1.5
Hastings St	12.0	8.1	1.5
Yukon St	5.6	3.8	1.5
Cambie St	13.1	9.0	1.5

SUMMARY

The objective of this study was to develop HINs for the least safe corridors for pedestrians, cyclists, and drivers and identify the most promising streets in terms of potential for safety improvement. Investigation of causal factors of collisions was beyond the scope of this study. Nevertheless, this study still offers useful starting points.

- 50% of the collisions (fatal and severe injury from all four modes) occur on 10% of the street network. Limited resources available for safety improvements could be allocated focusing on streets identified within HINs.
- Though collisions are not aggregated in marginalized areas to an extent observed in other major cities, CoV could still use the opportunity to improve 33% of the collisions aggregated in the three least equitable areas by expending less resources than more equitable areas.
- 42% of the schools in Vancouver are located within 50 meters of HIN. CoV can initiate contact with relevant stakeholders to attract funding for education programs for students or street design changes near schools.
- There is not much overlap among the streets identified for priority safety improvements from HINs of four modes. Meaning, resources could be allocated to target safety improvements specific to a mode and such targeted funding may be better in meeting improvement expectations.

NEXT STEPS

- HINs have provided the information about where the collisions are occurring more frequently. The next step in the Vision Zero strategy would be to investigate why the collisions are occurring. Once the causal factors are determined, specific safety countermeasures could be implemented.
- It would be interesting to include the collision data from 2020-2021 and examine if COVID-19 changed HINs. The cyclist HIN, specifically, might change if people engaged more in recreational cycling or travelled on less common routes.
- Normalization was performed using street length due to lack of quality traffic volume data for active modes of travel. Collecting such data is resource intensive but could be useful for developing HINs that focus on active modes.
- Efforts should be made to automate the process of HIN development so that HIN could be updated every year using new collision data.