



Evaluating regional variation in neighbourhood socioeconomic inequalities in motor vehicle injury collisions

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ABSTRACT

Disadvantaged communities have higher rates of traffic injury. Our goal was to measure regional variation in the association between small-area socioeconomic deprivation and motor vehicle crashes resulting in injury within British Columbia, Canada.

We analyzed road traffic injury crashes from universal auto insurance claims (2019–2023) across 16 urban regions of British Columbia, aggregated by census dissemination areas (DAs). We measured socioeconomic deprivation using the Vancouver Area Neighbourhood Deprivation Index, a normalized score combining seven health-related sociodemographic variables applied to the 2021 Canadian census. We examined associations between deprivation and three injury crash types (motor vehicle, bicycle-motor vehicle, and pedestrian-motor vehicle) using Bayesian spatial regression models.

Increased socioeconomic deprivation was consistently associated with higher injury crash incidence across all crash types, with regional variation in the strength of the relationship. Among the most populous regions, a one standard deviation increase in deprivation was associated with injury crash increases from 17 % (95 % Credible Interval [CI]: 12 %–21 %) in Vancouver-Fraser Valley to 51 % (95 % CI: 36 %–68 %) in the Okanagan region. Similar patterns were observed for cyclist injuries, from 10 % (95 % CI: 4 %–16 %) in Vancouver-Fraser Valley to 64 % (95 % CI: 38 %–93 %) in Okanagan, and for pedestrian injuries, from 17 % (95 % CI: 11 %–24 %) in Vancouver-Fraser Valley to 77 % (95 % CI: 48 %–110 %) in Okanagan. Smaller regions had wide credible intervals and more uncertainty in associations.

To address spatial inequalities, prioritization of the placement of road safety interventions should incorporate equity considerations, as well as area-level interventions that address fundamental risk factors of traffic volume and speed.

1. Background

Road traffic injuries are a leading cause of preventable death and disability in Canada. Over the last decade, road crashes have resulted in an average of just under 1900 deaths and 10,000 serious injuries annually, leading to far-reaching health, economic and social consequences. A growing body of evidence highlights stark inequalities in these burdens, with disadvantaged populations and neighbourhoods disproportionately impacted (Branion-Calles et al., 2024; Morency et al.,

2012; Rothman et al., 2020; Lord et al., 2010; Brussoni et al., 2018; Rajabali et al., 2019).

Canadian traffic injury research to date has taken two distinct approaches to quantifying and characterizing disparities: a population-based approach and a spatial approach. A population-based approach is characterized by comparing different groups of people, while a spatial approach compares different places. Population-based approaches have consistently observed inequalities in road traffic injury; with higher rates among lower-income populations and Indigenous groups, in

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particular (Branion-Calles et al., 2024; Lord et al., 2010; Brussoni et al., 2018; Burrows et al., 2012). These studies are important for establishing and understanding the existence of inequalities for different populations, but the spatial environment may independently impact risk.

Studies that address spatial dimensions of road traffic injury inequalities in Canada are limited in geographic scale or spatial resolution, such as being constrained to a single municipality or using large spatial units of analysis. Studies limited to a single urban area have found a socioeconomic gradient in injury incidence with lower socioeconomic status areas having greater incidence of road traffic injury (Morency et al., 2012; Rothman et al., 2020; Lord et al., 2010). Other studies conducted at a provincial level have used large spatial units and have also found an overall socioeconomic gradient (Brussoni et al., 2018; Rajabali et al., 2019; Kmet et al., 2003; Brubacher et al., 2016). However, studies at the provincial level cannot capture regional heterogeneity in this relationship, where some regions may have strong associations driving the overall pattern, others may demonstrate weaker associations or even inverse relationships.

Furthermore, much of existing Canadian research on traffic injury inequality focuses on a single type of road traffic injury: either motor vehicle occupant injury (Burrows et al., 2012; Kmet et al., 2003; Alphonsus et al., 2018), pedestrian injury (Lord et al., 2010) or even

specifically child pedestrian injury (Rothman et al., 2020). As a result, these studies do not allow for direct comparison of socioeconomic inequalities across different types of road users.

Our research fills these gaps by applying a spatial approach to quantify small-area inequalities in road traffic injury across different metropolitan regions of the Canadian province of British Columbia (BC). We analyze three crash types that result in an injury and involve different road users: motor vehicle, cyclist-motor vehicle, and pedestrian-motor vehicle injury crashes. For each injury crash type, we examine the association between small-area deprivation and road traffic injury incidence within 16 urban regions, allowing us to determine whether the strength of these relationships varies regionally. This multi-modal analysis provides new insights into patterns of inequalities in traffic injury incidence across different urban contexts.

2. Materials and methods

We conducted an ecological (i.e., group-level) cross-sectional study of the associations between small-area deprivation and road traffic injury outcomes in urban areas of the province of British Columbia, Canada using data from 2019 to 2023.

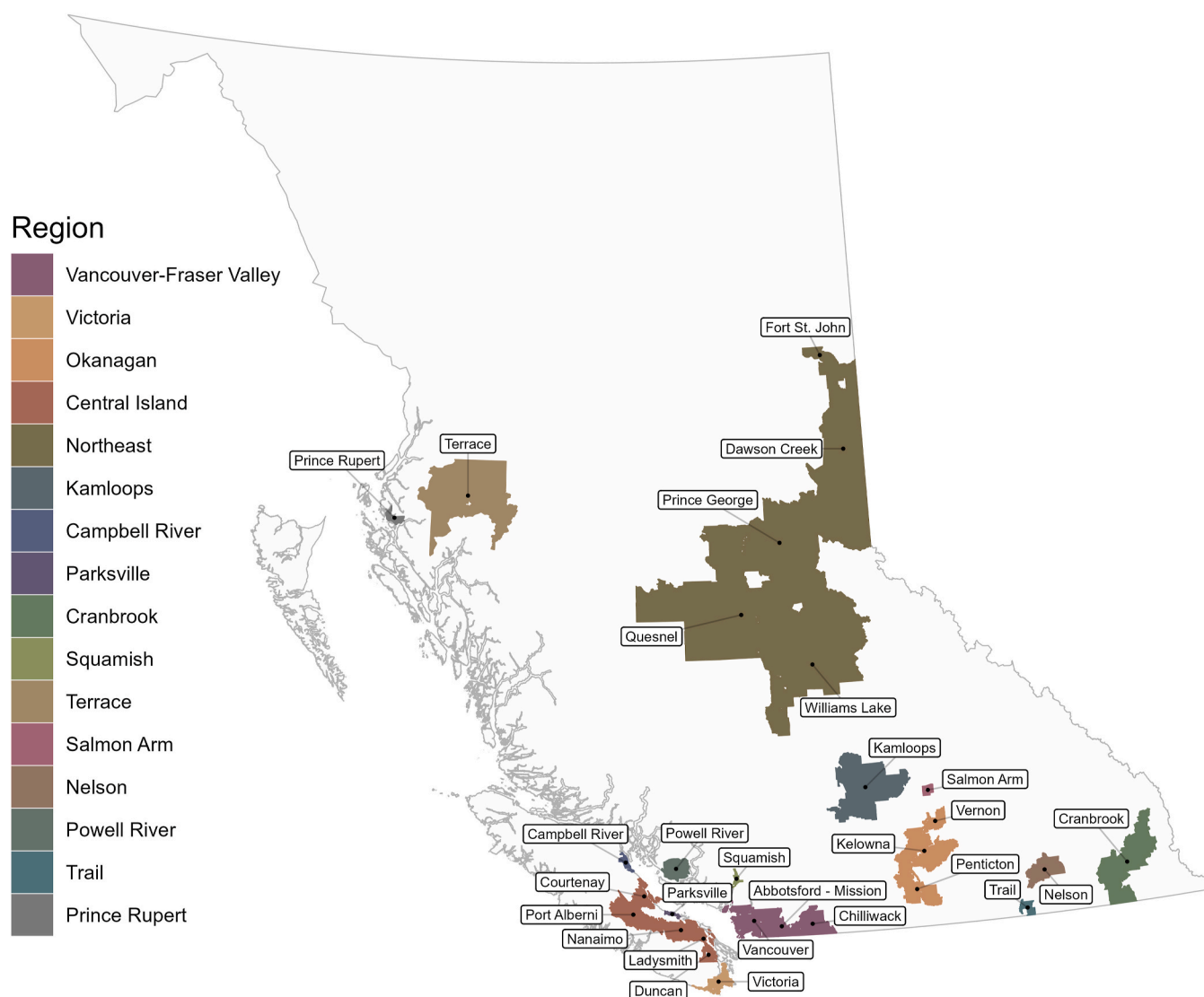


Fig. 1. Regional grouping of census metropolitan and agglomeration areas. Labelled points represent census metropolitan area and census agglomeration centroids. See Supplementary Web Map S1 for interactive version.

2.1. Study area

Our study area boundaries include all urban centres in the Canadian province of British Columbia, identified using the definition provided by Statistics Canada of Census Metropolitan Area (CMA) or Census Agglomeration (CA) (Statistics Canada, 2023). Every CMA/CA has a core population of at least 10,000 residents and boundaries defined by commuting flow patterns (Statistics Canada, 2023). As such, a single CMA/CA can encompass a diverse range of urban forms, from large cities with populations over 600,000 to small rural areas and Indigenous reserves with fewer than 300 residents.

In BC there are 28 distinct CMAs or CAs, within which there are 61 municipalities and 102 adjacent fringe areas. Collectively, these 28 regions are home to 4.4 million people, just under 90 % of the total provincial population. We grouped BC's 28 CMAs and CAs into 16 regions based on spatial contiguity (Fig. 1). This approach provided a consistent method for combining areas, addressing potential border effects between adjacent urban areas, and improved statistical power for region-specific estimates, while preserving meaningful geographic distinctions across BC's diverse urban contexts. These regions are used to test regional variation, and all modelling was conducted with the small-area geography described below.

2.2. Spatial unit of analysis

Our spatial unit of analysis was the 2021 Canadian census dissemination area (DA) boundaries, the smallest geographic units for which census data are publicly available (Statistics Canada). DAs are delineated to include approximately 400–700 residents. In our study area we analyzed 6225 census dissemination areas (DAs), with a median population of 591 and interquartile range of 198.

2.3. Injury crash data

We used 2019–2023 crash claims from the Insurance Corporation of British Columbia (ICBC) (Insurance Corporation of British Columbia, 2024). ICBC is a universal auto-insurance provider and the most comprehensive source of motor-vehicle crash data in the province (Branion-Calles et al., 2025a). ICBC crash data include incidents with at least one motor vehicle, and do not capture other types of road traffic crashes (e.g. single bicycle crashes, pedestrian falls). In this analysis we focus on *injury crashes* (at least one injury in a crash) and exclude property damage only crashes.

For each dissemination area (DA) we counted injury crashes in three categories: (i) total injury crashes, (ii) injury crashes involving a bicyclist, and (iii) injury crashes involving a pedestrian. Crashes that occurred within 10 m of a DA border were split equally between neighbouring DAs, and any remainder was randomly assigned, preventing double-counting while preserving integer totals. Approximately 64 % of injury crashes occurred on a DA border and 4.7 % required random allocation. The spatial distribution of each outcome within each region can be seen in the interactive map in Supplementary Web Map S1.

2.4. Deprivation data

We used the Vancouver Area Deprivation Index (VanDIX), applied to 2021 Census data, as our measure of socioeconomic deprivation. This index originated from a 2005 survey of eighteen provincial medical health officers from the province of British Columbia, who identified key socioeconomic factors influencing health status in the province (Bell et al., 2007; Bell and Hayes, 2012). These factors are weighted by their relative importance and include (i) proportion without high school completion (25 %), (ii) unemployment rate (21.4 %), (iii) proportion with university completion (17.9 %), (iv) proportion of single-parent families (14.3 %), (v) average income (8.9 %), (vi) proportion of homeowners (8.9 %), and (vii) participation rates (3.6 %).

We calculated the VanDIX for each DA in the study area and computed standardized values, such that each unit increase in the standardized VanDIX score represents one standard deviation and zero represents the average score across DAs. The interactive map in Supplementary Web Map S1 shows the spatial distribution of VanDIX scores within each region. In Supplementary Fig. S2 we visualized how each component variable is distributed across standardized categories of the index (< -1 SD, -1 to 0 SD, 0 to 1 SD, and > 1 SD from mean) in ridgeline plots to aid interpretation of the VanDIX score.

2.5. Built environment data

For each DA, we measured built environment data from road network and cycling infrastructure data, including total lane length of roads, proportion of lane length classified as arterial or highway, number of intersections, presence of bicycling infrastructure, and population.

We used the BC Digital Road Atlas to capture road network characteristics (Government of British Columbia, 2022). Each road segment includes classifications that we simplified to local, collector, arterial, and highway/freeways. To assess road capacity, we calculated total lane length. We created a 5-m buffer around each DA to assign roads. When roads formed boundaries between DAs, we divided the lane length equally among them.

To count intersections, we referenced road junction data from the 2021 CanMap Content Suite (DMTI Spatial Inc and Network, 2021). We defined intersections as junctions of three or more roads and counted them within a 5-m buffer of each DA. Intersections at DA boundaries were assigned to each adjacent DA.

We assessed bicycling infrastructure using polyline data from the Canadian Bikeway Comfort and Safety (Can-BICS) project, based on Open Street Map data from 2022 (Ferster and Beairisto, 2022; Winters et al., 2022). Can-BICS data included dedicated cycling infrastructure (separated bike paths, cycle tracks, local street bikeways, paved multi-use paths, and painted bike lanes). Each DA was coded for the presence or absence of cycling infrastructure using a 5-m buffer.

The spatial distribution of built environment characteristics within each region is mapped in Supplementary Web Map S1.

2.6. Statistical analysis

We fit Bayesian spatial count models using Integrated Nested Laplace Approximation (INLA) in R 4.4.1 (with the R-INLA v24.10.29 package), modeling DA-level counts of (i) all injury crashes, (ii) bicycle-involved injury crashes, and (iii) pedestrian-involved injury. We model each outcome as a function of VanDIX, region, and their interaction to test whether deprivation gradients differ across the province's sixteen regions. For all-injury crashes we used a Poisson BYM2 model with DA-level random effects consisting of an unstructured and a spatially structured term (Riebler et al., 2016; Simpson et al., 2017). For bicycle- and pedestrian-injury crashes we used a zero-inflated Poisson BYM2 model. These specifications had the lowest WAIC among the tested combinations of error distribution (Poisson vs. ZIP) and random-effects structure (none, unstructured, BYM2) for each outcome (Supplementary Table S1). Neighbourhoods were defined by Queen contiguity, and the spatial term followed a conditional autoregressive (CAR) distribution that models each area's random effect conditional on its neighbours' random effects. Specifically let Y_i denote the injury crash count in DA i . For all injury crashes we assumed

$$Y_i \sim \text{Poisson}(\lambda_i)$$

$$\log(\lambda_i) = \beta_0 + \beta_1 \text{VanDIX}_i + \sum_{k=2}^{16} \beta_{2k} \text{Region}_i + \sum_{k=2}^{16} \beta_{3k} \text{VanDIX}_i \times \text{Region}_i + u_i + v_i$$

Where u_i is the spatially structured random effect and v_i is the unstructured random effect. The bicycle and pedestrian models use the same log linear predictor but incorporate a ZIP specification, where $Y_i \sim 0$ with probability π (intercept only logit) and $Y_i \sim \text{Poisson}(\lambda_i)$ with probability $1 - \pi$. For each model, we used penalized complexity priors for the precision and mixing parameters (Riebler et al., 2016). We set the precision prior so that the probability of the marginal standard deviation exceeding 1 was 0.001, and we set the mixing prior so that the spatially structured random effect explained more than half of the marginal variability with probability 0.5. Fixed effect coefficients had Gaussian priors with mean equal to 0 and precisions equal to 0 for the intercept and 0.001 otherwise.

Because DA crash counts reflect both exposure (how much travel occurs) and risk per unit of exposure (how dangerous the road environment is), we fit three nested specifications to progressively separate these components: unadjusted, minimally adjusted, and fully adjusted. The unadjusted model included only VanDIX, region, and their interaction, so the deprivation effect will consist of differences in both exposure and risk. In the minimally adjusted model we added log-transformed total lane length as a covariate—rather than an offset—to allow a non-linear association (Popescu and Sayed, 2017) and to proxy motor-vehicle exposure. Consistently collected measures of motor vehicle exposure (e.g. vehicle kilometers travelled, average annual daily traffic) are not available province wide at the dissemination area level. The fully adjusted model incorporated additional variables associated with exposure to compensate for limitations in lane length. Namely, lane length implicitly assumes uniform volume per unit length. These additional variables included arterial/highway lane length proportion, cycling-infrastructure presence, number of intersections, and population. Posterior means and 95 % credible intervals for all fixed effects and key hyperparameters are reported in Supplementary Table S2–S4.

We calculated region-specific incidence rate ratios (IRRs) to summarise the deprivation effect. Because VanDIX was standardized, the IRR is the multiplicative change in the expected DA-level crash count associated with a one-standard-deviation increase in VanDIX within that region. For the reference region, $\text{IRR} = e^{\beta_1}$. For any other region k , $\text{IRR} = e^{\beta_1 + \beta_{3k}}$. For each model we drew 5000 posterior samples and for each draw exponentiated β_1 (reference region) or $\beta_1 + \beta_{3k}$ (region k). The posterior mean of these exponentiated draws was taken as the IRR point estimate and the 2.5th and 97.5th percentiles as the 95 % credible interval (CI). We compared IRRs across regions and, within each region, across the unadjusted, minimally adjusted, and fully adjusted models to see how accounting for exposure and built-environment factors altered the deprivation gradient.

Residual spatial variation was then examined by mapping $u_i + v_i$ from the adjusted models; this represents unexplained risk after accounting for fixed effects. Significant hot- and cold-spots were identified with the Getis-Ord G_i^* Statistic (99,999 permutations; $p < 0.001$), available in Supplementary Web Map S1.

Our final aggregated spatial dataset and analytic code are publicly available (Branion-Calles).

3. Results

3.1. Regional population, road network, built environment, and injury crash characteristics

The 16 contiguous regional metropolitan areas represented a mix of different urban contexts with variation in geographic size, population, and built environment characteristics between regions (Fig. 1, Table 1).

The Vancouver-Fraser Valley region was the most populous and dense area in the study, containing 66 % of the study area population (2.9 million residents), 36 % of the total road lane kilometers (26,100 km), and only 4 % of the total land area (4000 km²) (Table 1). The average DA population density in this region was 6116 people per

square kilometer, 83 % higher than Victoria, the next densest region. Between 2019 and 2023, the region experienced 78 % of the study area's total injury crashes (162,519), 72 % of bicycle-involved injury crashes, and 78 % of pedestrian-involved injury crashes (Table 2). Within this region, 3 % of DAs had zero recorded traffic injury crashes, while 52 % had zero bicycle-involved crashes and 39 % had zero pedestrian-involved crashes.

The mid-sized metropolitan regions—Victoria, Okanagan, Central Island and Kamloops—were on average considerably less dense than Vancouver-Fraser Valley. These areas collectively made up 25 % of the total study area population (1.1 million), with populations ranging from 112,800 in Kamloops to 394,400 in Victoria (Table 1). They accounted for 31 % of the total road lane kilometres (from 3800 km in Kamloops to 7200 km in Okanagan) and 15 % of the total land area (from 680 km² in Victoria to 5600 km² in Kamloops) (Table 1). Between 2019 and 2023, these mid-sized regions collectively experienced 18 % of the study area's total crashes (from 3545 in Kamloops to 12,913 in Okanagan), 25 % of bicycle-involved crashes (from 76 in Kamloops to 1024 in Victoria), and 18 % of pedestrian-involved crashes (from 167 in Kamloops to 715 in Victoria) (Table 2).

The Northeast region stands apart from the mid-sized regions based on its vast geographic extent and lane kilometres, despite having a comparable overall population to Kamloops. It had 4 % of the study area population (179,490), 22 % of the lane kilometres (16,210 km) and 63 % of the land area (63,682 km²) (Table 1). As such, its population density was much lower than the other regions. Between 2019 and 2023, the Northeast reported 2 % (3803) of total injury crashes, 1 % (77) of cyclist crashes and 1.5 % (163) of pedestrian crashes (Table 2).

The remaining 10 regions were small urban regions that collectively contained 5 % of the study population, with populations between approximately 12,800 in Prince Rupert and 40,300 in Campbell River (Table 1). These regions comprised 10 % of the road lane kilometers in the study area (from 292.2 km in Prince Rupert to 1483 km in Cranbrook) and 17 % of the land area (from 81.8 km² in Parksville to 9681 km² in Terrace) (Table 1). Between 2019 and 2023, these small metropolitan areas accounted for 2 % (4171) of injury crashes, 1.9 % (136) of cyclist-involved injury crashes, and 2.4 % (249) of pedestrian-involved injury crashes (Table 2).

3.2. Inequalities in road traffic injury crashes

Our analysis revealed a consistent positive association between small-area neighbourhood deprivation and injury crash incidence across regions of the province for nearly all crash types and model specifications (Fig. 2, Tables 3–5). All results presented below come from our adjusted models, which controlled for population, road network length, bicycle infrastructure, number of intersections, and arterial and highway proportions.

In the most populous contiguous metropolitan region of the province, Vancouver-Fraser Valley, we found that a one standard deviation increase in socioeconomic deprivation was associated with a 17 % increase in injury crash incidence (95 % CI: 12 %, 21 %) (Table 3), a 10 % increase in bicycle-motor vehicle injury crash incidence (95 % CI: 4 %, 16 %) (Table 4), and a 17 % increase in pedestrian-motor vehicle injury crash incidence (95 % CI: 11 %, 24 %) (Table 5).

Compared to Vancouver, there were greater inequalities in mid-sized regions, except for motor vehicle crash associations in Victoria and Kamloops which were similar. For all motor vehicle crashes, each standard deviation increase in VanDIX was associated with a 17–51 % increase in crash incidence, with Okanagan showing the strongest relationship (51 %, 95 % CI: 36 %, 67 %) and Kamloops the weakest (17 %, 95 % CI: 4.0 %, 43 %). For bicycle crashes, there was a 16–64 % higher incidence for each standard deviation increase in VanDIX. Okanagan had the strongest association (64 %, 95 % CI: 38 %, 93 %) and Victoria the weakest (16 %, 95 % CI: 1 %, 33 %). The pedestrian crash association was consistently more pronounced, with a 32–77 % higher

Table 1
Summary statistics for population characteristics, socioeconomic indicators and built environment characteristics overall and by region. Values are presented as totals, means with standard deviations (SD), or prevalences where appropriate.

Region	Number of DAs	Population Characteristics					Built Environment and Road Network Characteristics					Area Deprivation
		Total Land Area (1000 Km2)	Mean Land Area by DA (SD)	Total Population (1000s)	Mean Population by DA (SD)	Mean Population Density by DA (SD)	Total Lane Kilometers (1000s)	Mean Lane Kilometers by DA (SD)	Mean % Major Road Lane Kilometers by DA (SD)	Mean Total Intersections by DA (SD)	% of DAs With Any Bicycle Infrastructure ^a	Mean VanDIX ^b (SD)
Total Study Area	6225	100.2	16.1 (274.8)	4438.7	713 (467.9)	4593.9 (6308.9)	71.7	11.5 (30.3)	14.3 (17.4)	30.9 (47.6)	64.5 %	0 (1)
Vancouver-Fraser Valley	3944	4.0	1 (11.4)	2930.6	743 (512.5)	6115.8 (7349.1)	26.1	6.6 (11)	15.4 (18.6)	24.8 (17.9)	74.3 %	−0.1 (1)
Victoria	563	0.7	1.2 (6.2)	394.4	700.5 (428.5)	3335 (2976.5)	4.8	8.6 (9.6)	11.1 (13.9)	26.5 (18.2)	68.2 %	−0.4 (0.8)
Okanagan	433	4.9	11.4 (68.5)	331.9	766.4 (478.4)	1906.1 (1808.9)	7.2	16.6 (25.8)	11.6 (14.3)	34.8 (26.1)	60.7 %	0 (0.9)
Central Island	419	4.0	9.6 (75.9)	264.5	631.2 (306.4)	1416.5 (1141.3)	6.3	15.1 (16.7)	10.7 (14.8)	40.4 (37.2)	42.2 %	0.3 (1)
Northeast	320	63.7	199 (1142.5)	179.5	560.9 (258.2)	1192.6 (1302)	16.2	50.7 (101.8)	12.3 (13.9)	69.7 (150.2)	29.4 %	0.7 (1.1)
Kamloops	162	5.6	34.8 (184.4)	112.8	696.3 (347)	1931 (1422.5)	3.8	23.6 (52.3)	22.9 (18.4)	47.9 (54.6)	48.1 %	0.2 (1.1)
Campbell River	68	0.2	2.5 (7.8)	40.3	592.1 (279.5)	1430.7 (980.9)	0.8	11.4 (11.2)	17.6 (16.9)	30.8 (17.2)	10.3 %	0.4 (1)
Parksville	51	0.1	1.6 (3.1)	31.1	608.9 (181.4)	1152.4 (903.7)	0.8	14.8 (11.8)	12.6 (11)	36.2 (15.8)	43.1 %	−0.3 (0.7)
Cranbrook	47	4.6	97 (341.7)	27	575.2 (224.1)	1515.8 (1272.9)	1.5	31.6 (62.6)	7.4 (13.6)	123.4 (247.3)	31.9 %	0.2 (1)
Squamish	26	0.1	4 (8.6)	23.8	916.1 (508)	1682.8 (1491.8)	0.4	16.3 (20.4)	9.6 (19.5)	37.2 (26.1)	76.9 %	−0.9 (0.6)
Terrace	42	9.7	230.5 (749.3)	19.5	465 (98)	864.8 (993.4)	1.2	28.8 (51.7)	14.2 (18.7)	33.4 (23.5)	2.4 %	0.5 (1.3)
Salmon Arm	30	0.2	5.2 (9.9)	19.4	647.7 (225.5)	1048 (1019.7)	0.5	17.2 (11.1)	11.1 (10.3)	44.2 (16.5)	60 %	0.2 (1)
Nelson	34	1.2	35.9 (74.4)	19.1	562.3 (114.8)	1085.4 (1065.8)	0.7	20.9 (17.7)	16.3 (17)	39 (18.1)	17.6 %	−0.3 (0.7)
Powell River	33	0.8	24.2 (109)	17.8	539.5 (105.3)	867.9 (708.3)	0.6	17.1 (24.7)	11 (12.6)	39.4 (21.3)	0 %	0.3 (0.7)
Trail	24	0.3	11.6 (33)	14.3	594.5 (170.7)	851 (769.8)	0.5	21.2 (24.9)	17.2 (14.5)	46.7 (15.5)	0 %	0 (1)
Prince Rupert	29	0.2	8 (31.6)	12.8	440.3 (109.3)	2077 (1256.4)	0.3	10.1 (18.5)	11.6 (16.5)	28 (20.6)	0 %	1.1 (0.9)

DA = Dissemination Area; SD = Standard Deviation; VanDIX = Vancouver Area Deprivation Index.

^a Bicycle infrastructure refers to separated bicycle paths, cycle tracks, local street bikeways, paved multi-use paths, and painted bike lanes based on Can-BICs data and definitions.

^b > 0 is above average deprivation while <0 is below average deprivation.

Table 2

Regional summary statistics for all injury crashes, cyclist involved injury crashes and pedestrian involved injury crashes.

Region	All Injury Crashes			Cyclist-Motor vehicle Injury Crashes			Pedestrian-Motor vehicle injury crashes		
	Total Injury Crashes	Median Injury Crashes (IQR)	% of DAs with 0 Injury Crashes	Total Cycling Injury Crashes	% of DAs with 0 Cycling Injury Crashes	Median Cycling Injury Crashes (IQR)	Total Pedestrian Injury Crashes	Median Pedestrian Injury Crashes (IQR)	% of DAs with 0 Pedestrian Injury Crashes
Total Study Area	208,048	12 (27)	3.9 %	7144	56.4 %	0 (1)	10,336	1 (2)	46.7 %
Vancouver-Fraser Valley	162,519	15 (33)	2.76 %	5192	51.9 %	0 (1)	8070	1 (2)	39 %
Victoria	12,347	10 (19)	3.91 %	1024	39.6 %	1 (2)	715	0 (2)	50.4 %
Okanagan	12,913	10 (23)	4.62 %	476	58 %	0 (1)	555	0 (1)	55.2 %
Central Island	8750	8 (16.5)	3.58 %	201	69.7 %	0 (1)	415	0 (1)	59.4 %
Northeast	3803	5 (10)	10.3 %	39	89.7 %	0 (0)	165	0 (1)	72.8 %
Kamloops	3545	7 (16)	7.41 %	76	68.5 %	0 (1)	167	0 (1)	63.6 %
Campbell River	953	8.5 (14.2)	1.47 %	38	64.7 %	0 (1)	67	0 (1)	52.9 %
Parksville	504	8 (10)	13.7 %	20	76.5 %	0 (0)	29	0 (0.5)	74.5 %
Cranbrook	509	5 (7)	2.13 %	11	85.1 %	0 (0)	17	0 (0)	78.7 %
Squamish	446	5 (15.5)	11.5 %	25	53.8 %	0 (1.75)	18	0 (1)	69.2 %
Terrace	324	3 (4)	16.7 %	5	90.5 %	0 (0)	15	0 (0)	76.2 %
Salmon Arm	403	8.5 (12.8)	0 %	10	70 %	0 (1)	12	0 (0.75)	73.3 %
Nelson	312	4 (7.5)	23.5 %	10	79.4 %	0 (0)	17	0 (0)	82.4 %
Powell River	328	7 (6)	0 %	10	81.8 %	0 (0)	31	0 (1)	57.6 %
Trail	219	4 (7.25)	4.17 %	3	87.5 %	0 (0)	17	0 (1)	58.3 %
Prince Rupert	173	3 (6)	13.8 %	4	89.7 %	0 (0)	26	0 (1)	58.6 %

DA = Dissemination Area; IQR = Interquartile Range.

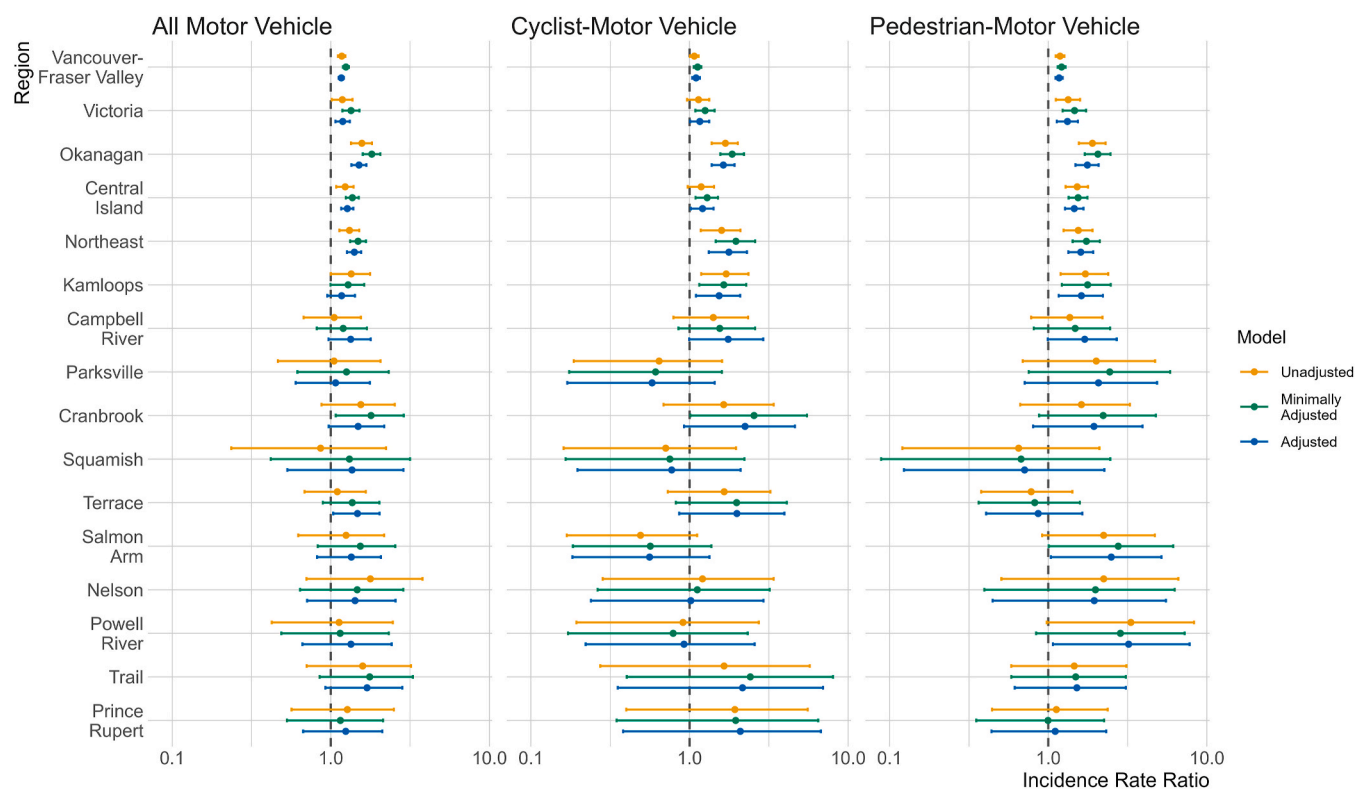


Fig. 2. Results of Poisson spatial regressions quantifying the multiplicative change in injury crash incidence (Incidence Rate Ratio) for a one standard deviation increase in neighbourhood deprivation measured by the Vancouver Area Deprivation Index (VanDIX). We calculated an incidence rate ratio for each region and injury crash type (all crashes, cyclist-motor vehicle, pedestrian-motor vehicle) using three different model specifications including an unadjusted (spatial random effects only), minimally adjusted (adding lane length), and fully adjusted (adding road classification, number of intersections, cycling infrastructure presence, and population) models. Zero-inflated Poisson models were used for cyclist-motor vehicle and pedestrian-motor vehicle injury crashes. Error bars represent 95 % credible intervals.

crash incidence per standard deviation increase in VanDIX. The pedestrian crash association was highest in the Okanagan (77 %, 95 % CI: 48 %, 110 %) and lowest in Victoria (32 %, 95 % CI: 13 %, 54 %).

Kamloops had modest associations for all crashes but substantially stronger associations for crashes involving a bicycle or pedestrian (54 % higher for bicycle crashes and 62 % higher for pedestrian crashes).

Table 3

Incidence Rate Ratios (IRR) with 95 % Credible Intervals for motor vehicle injury crashes in relation to a standard deviation increase in deprivation, measured by the Vancouver Area Deprivation Index (VanDIX). Results are shown for different statistical models including unadjusted, minimally adjusted and adjusted. **Bolded** IRRs indicate their 95 % credible interval excludes the null value of 1.

Term	Region	Incidence Rate Ratio (95 % Credible Interval) – per one unit change in the standard deviation of VanDIX		
		Unadjusted ^a	Minimally Adjusted ^b	Adjusted ^c
VanDIX	Vancouver-Fraser Valley	1.17 (1.11, 1.24)	1.25 (1.19, 1.30)	1.17 (1.12, 1.21)
	Victoria	1.18 (1.01, 1.37)	1.34 (1.18, 1.52)	1.19 (1.07, 1.32)
	Okanagan	1.57 (1.34, 1.82)	1.81 (1.60, 2.05)	1.51 (1.36, 1.68)
	Central Island	1.23 (1.08, 1.39)	1.37 (1.25, 1.51)	1.27 (1.16, 1.38)
	Northeast	1.31 (1.13, 1.50)	1.49 (1.32, 1.67)	1.41 (1.27, 1.56)
	Kamloops	1.34 (1.00, 1.76)	1.29 (1.00, 1.63)	1.17 (0.96, 1.43)
	Campbell River	1.05 (0.67, 1.55)	1.19 (0.82, 1.69)	1.34 (0.98, 1.79)
	Parksville	1.03 (0.45, 2.00)	1.25 (0.61, 2.29)	1.06 (0.59, 1.77)
	Cranbrook	1.53 (0.86, 2.54)	1.77 (1.06, 2.84)	1.49 (0.98, 2.15)
	Squamish	0.87 (0.25, 2.28)	1.32 (0.40, 3.30)	1.37 (0.54, 2.87)
	Terrace	1.09 (0.68, 1.67)	1.37 (0.89, 2.01)	1.47 (1.02, 2.01)
	Salmon Arm	1.24 (0.63, 2.19)	1.53 (0.82, 2.63)	1.35 (0.82, 2.05)
	Nelson	1.78 (0.70, 3.73)	1.47 (0.64, 2.87)	1.42 (0.71, 2.56)
	Powell River	1.14 (0.43, 2.46)	1.15 (0.50, 2.31)	1.34 (0.68, 2.39)
	Trail	1.59 (0.70, 3.14)	1.76 (0.87, 3.22)	1.70 (0.93, 2.82)
	Prince Rupert	1.27 (0.56, 2.45)	1.16 (0.55, 2.17)	1.24 (0.66, 2.09)

VanDIX = Vancouver Area Deprivation Index.

^a Poisson model fit with idd and spatial random effect at dissemination area level.

^b Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes.

^c Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes; (ii) proportion of lanes classified as highway or arterial; (iii) number of intersections; (iv) presence of bicycling infrastructure; (v) total population.

In the Northeast region, deprivation was strongly associated with crash rates across all categories, with increases of 41 % (95 % CI: 27 %, 56 %) for all motor vehicle crashes, 78 % (95 % CI: 34 %, 134 %) for bicycle-motor vehicle crashes, and 60 % (95 % CI: 33 %, 92 %) for pedestrian-motor vehicle crashes per standard deviation increase in deprivation.

For smaller metropolitan regions, associations between deprivation and crash rates showed greater variability, with wider credible intervals. For all motor vehicle crashes, associations ranged from an incidence increase of 6 % (Parksville: 6 %, 95 % CI: -40.8 %, 77.0 %) to 70 % (Trail: 70 %, 95 % CI: -7 %, 182 %), with a notable positive association in Terrace (47 %, 95 % CI: 2 %, 101 %). Bicycle-motor vehicle crash associations ranged from a 44 % decrease (Salmon Arm: -44 %, 95 % CI: -81.4 %, 32 %) to a 122 % increase (Cranbrook: 122 %, 95 % CI: -7.2 %, 353 %). The strongest associations were observed for pedestrian-motor vehicle crashes in Salmon Arm (149 %, 95 % CI: 6 %, 420 %) and Powell River (223 %, 95 % CI: 5 %, 659 %).

When comparing our three modeling approaches, we observed a

Table 4

Incidence Rate Ratios (IRR) with 95 % Credible Intervals for bicycle-motor vehicle injury crashes in relation to a standard deviation increase in deprivation, measured by the Vancouver Area Deprivation Index (VanDIX). Results are shown for different statistical models including unadjusted, minimally adjusted and adjusted. **Bolded** IRRs indicate those where the 95 % credible interval excludes the null value of 1.

Term	Region	Incidence Rate Ratio (95 % Credible Interval) – per one unit change in the standard deviation of VanDIX		
		Unadjusted ^a	Minimally Adjusted ^b	Adjusted ^c
VanDIX	Vancouver-Fraser Valley	1.07 (1.01, 1.14)	1.12 (1.06, 1.19)	1.10 (1.04, 1.16)
	Victoria	1.14 (0.97, 1.33)	1.26 (1.08, 1.44)	1.16 (1.01, 1.32)
	Okanagan	1.68 (1.37, 2.03)	1.86 (1.55, 2.21)	1.64 (1.38, 1.93)
	Central Island	1.18 (0.97, 1.42)	1.29 (1.09, 1.52)	1.21 (1.02, 1.42)
	Northeast	1.60 (1.19, 2.10)	1.96 (1.45, 2.60)	1.78 (1.34, 2.34)
	Kamloops	1.71 (1.19, 2.39)	1.65 (1.15, 2.29)	1.54 (1.10, 2.11)
	Campbell River	1.41 (0.80, 2.3)	1.56 (0.86, 2.59)	1.77 (0.99, 2.92)
	Parksville	0.63 (0.19, 1.56)	0.63 (0.17, 1.68)	0.58 (0.17, 1.42)
	Cranbrook	1.67 (0.66, 3.47)	2.56 (1.01, 5.30)	2.22 (0.93, 4.53)
	Squamish	0.71 (0.17, 1.98)	0.74 (0.16, 2.12)	0.77 (0.19, 2.17)
	Terrace	1.65 (0.70, 3.29)	1.97 (0.85, 3.96)	1.96 (0.87, 3.86)
	Salmon Arm	0.49 (0.16, 1.12)	0.56 (0.18, 1.29)	0.56 (0.19, 1.32)
	Nelson	1.20 (0.30, 3.30)	1.13 (0.26, 3.36)	0.99 (0.23, 2.78)
	Powell River	0.91 (0.20, 2.65)	0.77 (0.17, 2.25)	0.89 (0.21, 2.50)
	Trail	1.66 (0.29, 5.56)	2.44 (0.41, 8.02)	2.19 (0.37, 7.64)
	Prince Rupert	1.92 (0.40, 5.67)	2.04 (0.34, 6.67)	2.05 (0.37, 6.90)

VanDIX = Vancouver Area Deprivation Index.

^a Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level.

^b Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes.

^c Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes; (ii) proportion of lanes classified as highway or arterial; (iii) number of intersections; (iv) presence of bicycling infrastructure; (v) total population.

consistent pattern across most regions and crash types reflecting minimal confounding by the additional covariates in most regions (Fig. 2, Tables 3–5). The minimally adjusted models, which controlled only for total road lane length, typically produced the highest IRRs compared to both unadjusted and adjusted models. For example, in Vancouver-Fraser Valley, the IRRs for all motor vehicle crashes were 1.17 (unadjusted), 1.25 (minimally adjusted), and 1.17 (adjusted). The unadjusted and adjusted models often produced similar IRRs despite different specifications.

The sum of the spatially structured and unstructured random effect from the adjusted BYM2 models represented the total unexplained variation in injury crash counts after adjustment for fixed effects. When we mapped this value and identified significant spatial clusters, we found high values (representing more injury crashes than expected after adjustment) tended to significantly cluster in more dense urban areas, whereas low values (fewer injury crashes than expected) tended to cluster in less dense areas (Fig. 3, Supplementary Web Map S1).

Table 5

Incidence Rate Ratios (IRR) with 95 % Credible Intervals for pedestrian-motor vehicle injury crashes in relation to a standard deviation increase in deprivation, measured by the Vancouver Area Deprivation Index (VanDIX). Results are shown for different statistical models including unadjusted, minimally adjusted and adjusted.

Term	Region	Incidence Rate Ratio (95 % Credible Interval) – per one unit change in the standard deviation of VanDIX		
		Unadjusted ^a	Minimally Adjusted ^b	Adjusted ^c
VanDIX	Vancouver-Fraser Valley	1.19 (1.12, 1.27)	1.21 (1.15, 1.28)	1.17 (1.11, 1.24)
	Victoria	1.34 (1.12, 1.59)	1.46 (1.24, 1.71)	1.32 (1.13, 1.54)
	Okanagan	1.90 (1.57, 2.31)	2.06 (1.71, 2.47)	1.77 (1.48, 2.10)
	Central Island	1.52 (1.29, 1.79)	1.54 (1.35, 1.76)	1.46 (1.28, 1.66)
	Northeast	1.54 (1.26, 1.88)	1.73 (1.42, 2.09)	1.60 (1.33, 1.92)
	Kamloops	1.70 (1.20, 2.32)	1.78 (1.23, 2.49)	1.62 (1.15, 2.19)
	Campbell River	1.36 (0.79, 2.21)	1.47 (0.83, 2.42)	1.71 (0.99, 2.76)
	Parksville	2.00 (0.67, 4.61)	2.50 (0.79, 6.11)	2.09 (0.73, 4.91)
	Cranbrook	1.60 (0.67, 3.26)	2.20 (0.84, 4.66)	1.97 (0.82, 3.92)
	Squamish	0.66 (0.12, 2.13)	0.67 (0.09, 2.57)	0.68 (0.12, 2.23)
	Terrace	0.79 (0.38, 1.46)	0.83 (0.37, 1.61)	0.87 (0.42, 1.61)
	Salmon Arm	2.22 (0.89, 4.68)	2.78 (1.03, 6.11)	2.49 (1.06, 5.20)
	Nelson	2.23 (0.52, 6.30)	1.96 (0.38, 6.16)	1.98 (0.45, 5.69)
	Powell River	3.32 (0.97, 8.59)	2.85 (0.86, 7.04)	3.23 (1.05, 7.59)
	Trail	1.46 (0.59, 3.10)	1.51 (0.58, 3.20)	1.51 (0.64, 3.11)
	Prince Rupert	1.12 (0.45, 2.35)	0.98 (0.35, 2.18)	1.11 (0.44, 2.36)

VanDIX = Vancouver Area Deprivation Index.

^a Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level.

^b Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes.

^c Zero-Inflated Poisson model fit with idd and spatial random effect at dissemination area level + adjusted for (i) total length of road lanes; (ii) proportion of lanes classified as highway or arterial; (iii) number of intersections; (iv) presence of bicycling infrastructure; (v) total population.

4. Discussion

Our small-area geographic analysis identified consistent spatial inequalities in road traffic injury crashes across all regions in our study area. We found the extent of inequality was greater depending on the region and type of crash. Mid-sized regions, particularly the Okanagan, exhibited the greatest inequalities. Smaller regions showed more variable results with greater statistical uncertainty, though several demonstrated strong associations for pedestrian-involved crashes. Our study makes a unique contribution by comparing inequality patterns across multiple urban areas using consistent methodology, enabling direct comparisons across regions.

Our finding that increased deprivation is associated with higher traffic injury crash incidence is consistent with previous Canadian research and builds on this by evaluating the regional variation in this relationship. Our results are directionally consistent with both population-based studies (Branion-Calles et al., 2024; Lord et al., 2010; Brussoni et al., 2018; Burrows et al., 2012) and past research on spatial inequalities in traffic injury outcomes in Canada (Morency et al., 2012;

Rothman et al., 2020; Lord et al., 2010; Brussoni et al., 2018; Rajabali et al., 2019; Brubacher et al., 2016) which find that increased deprivation is associated with higher traffic injury incidence. Methodological differences (e.g. study area, unit of analysis, deprivation metric, outcome, data sources, statistical approaches) complicate direct comparisons across traffic injury inequality studies.

The challenge of cross-study comparison is evident when examining three previous British Columbia based studies. Lord et al. (2010) compared age-adjusted population-based incidence rates of pedestrians with severe trauma (Injury Severity Score >12) from motor vehicle collisions between neighbourhood deprivation quintiles using VanDIX (Lord et al., 2010). They found more than twice the rate of severe pedestrian-motor vehicle trauma in the most deprived versus least deprived census tract quintiles in the Metro Vancouver area. Our study found that a one-standard-deviation increase in deprivation in a larger but overlapping region was associated with a 17 % increase in pedestrian-motor vehicle crashes. However, our studies had different outcomes (severe trauma versus injury crashes), data sources (trauma registry versus auto insurance claims), time periods (2001–2006 versus 2019–2023), approaches to quantifying inequality (both used VanDIX, but considered quintiles versus standard deviation), and methods of controlling for confounding (age-adjusted rates versus spatial regression).

Similarly, Rajabali et al. (2019) examined age-standardized, population-based road traffic injury rates but compared individual socioeconomic indicators (income, employment, education) rather than a composite deprivation measure (Rajabali et al., 2019). They aggregated their data to Forward Sortation Areas based on residential locations, and used hospital admission data to identify injuries. They found mixed results between various individual measures of socioeconomic status and injury outcomes, but did identify substantial inequalities based on education levels, particularly for pedestrians. This does correspond with the VanDIX measure to some degree, given it assigns education-related variables the highest weight.

Brubacher et al. (2016), as part of a larger provincial road safety analysis, quantified the association between VanDIX and motor-vehicle injury crashes within police patrol zones (roughly equivalent to municipalities). They estimated that an interquartile range increase (0.6 units) in VanDIX was associated with a 17.6 % increase in all injuries, 24.1 % in cyclist injuries, and 25.9 % in pedestrian injuries across the province. Our estimated ranges of increased crash incidence per standard deviation of deprivation are consistent with these provincial results, while extending their work by demonstrating significant regional heterogeneity—with increases ranging from 17 % to 51 % for all injuries, 10 %–64 % for bicycle crashes, and 17 %–77 % for pedestrian crashes across the most populated regions. Again however, comparisons are complicated by differences in spatial units of analysis, confounding controls, time periods, highlighting the importance of consistent methodology in these comparisons.

While our study demonstrates that a socioeconomic gradient exists in traffic injuries across communities in the province, these are statistical associations that require understanding of the mechanism of action. Traffic injury incidence at any given geographic aggregation (e.g. intersection, neighbourhood, city etc.) stems from three basic causes: (i) the total exposure to risk within each geography (i.e., the total number of trips or kilometres travelled for each mode), (ii) risk of crash involvement per unit of exposure to risk, and (iii) the risk of injury when a crash occurs. Higher total exposure for each transportation mode within a given geographic area, combined with increased crash and subsequent injury risk, will lead to more injuries among users of those modes. For example, if two areas have the same crash and injury risk per trip, the area with fewer trips made by car, walking or bicycle (i.e. exposure to risk) will experience fewer crashes involving these groups.

Systemic differences in the built environment between more and less deprived areas likely contribute to the spatial patterns of inequality we observed through all three causal pathways. More deprived geographic

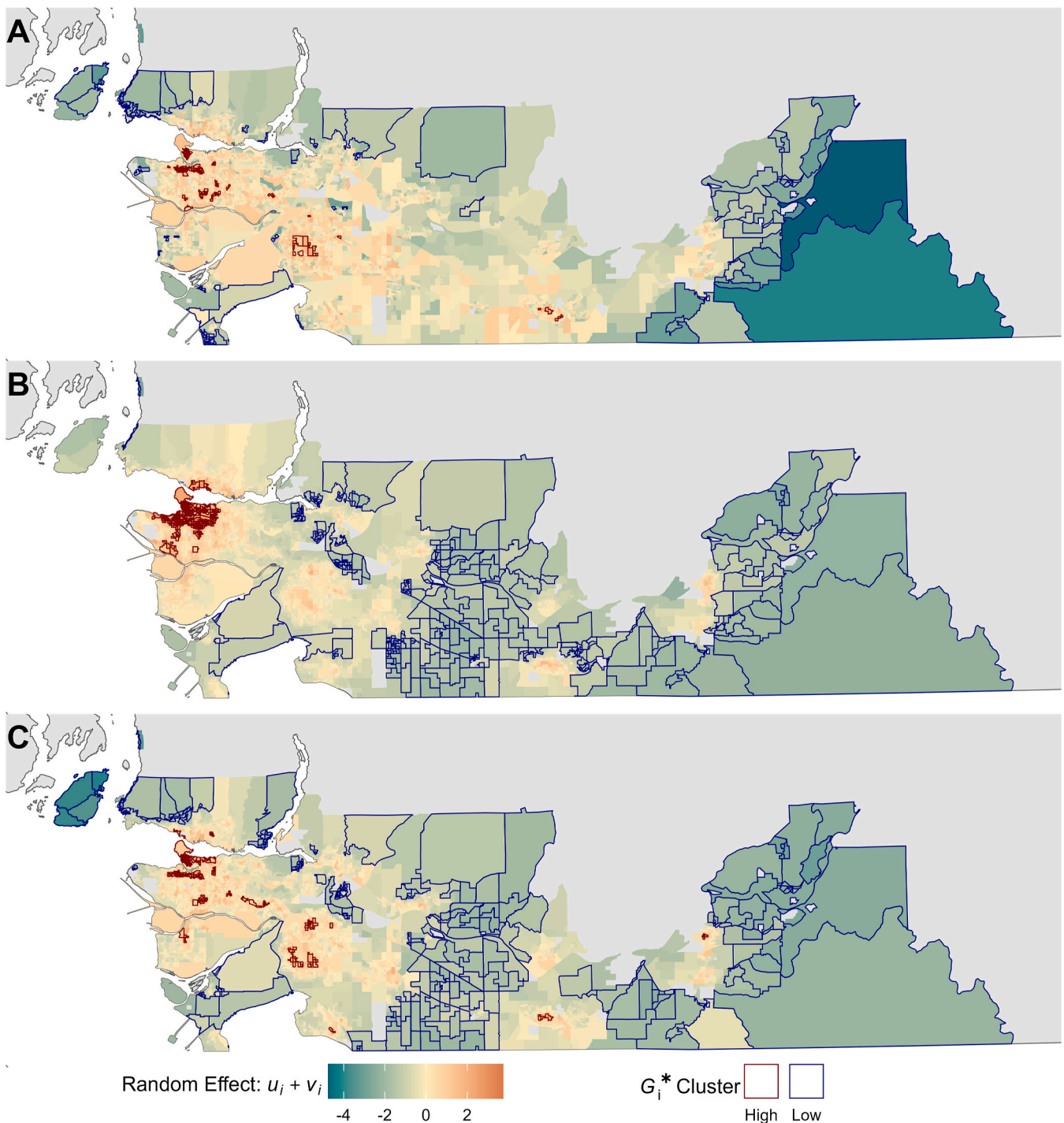


Fig. 3. Maps of the combined spatial and unstructured random effects (u_i and v_i) from the modified Besag-York-Mollie model in the Vancouver-Fraser Valley region for A) all injury crashes, B) cyclist-involved injury crashes, and C) pedestrian-involved injury crashes. The random effects mapped here are derived from the adjusted models which account for road lane length, deprivation, other road network, and built environment characteristics. The values represent unexplained crash variation after consideration of these adjustment factors. Significant spatial clusters were identified using the Getis-Ord G_i^* statistic with 99,999 permutations and a pseudo-significance threshold of 0.001. We found that significant clusters of high values (indicating more injury crashes than expected) were often in denser urban areas, while clusters of low values (indicating fewer injury crashes) were in less dense neighbourhoods. Only the Vancouver-Fraser Valley region is shown here; see Supplementary Web Map S1 for all regions, which demonstrate similar spatial patterning.

areas tend to be exposed to greater volumes and speeds of motor vehicle traffic (Morency et al., 2012; Rothman et al., 2020; Tian et al., 2013; Cobley et al., 2021; Dumbaugh et al., 2022), with greater proportions of larger vehicles like trucks and buses (Kheirbek et al., 2016). Greater traffic volumes for specific modes of transport in an area will result in more collisions involving those modes in absolute numbers (Elvik and

Goel, 2019), while higher speeds are one of the fundamental risk factors for both crash risk and severity of outcomes (Aarts et al., 2006; Kim et al., 2007; Elvik, 2012; Hussain et al., 2019). A large share of the motor-vehicle traffic on high-speed, high volume roads in these deprived areas, are likely to be residents of other areas of a region, who might be less cautious than they would be in their own neighbourhoods

(Dumbaugh et al., 2022). More deprived areas also tend to have fewer traffic calming and safety infrastructure features (Rothman et al., 2020) and worse maintenance of road surfaces (e.g. potholes) (Alphonsus et al., 2018), increasing both the risk of crash, speed of motor vehicle traffic, and subsequently the likelihood of injury given a crash occurs. Other differences such as enforcement practices (Lu et al., 2012), differential access to safe bicycling infrastructure (Winters et al., 2018) or neighbourhood walkability (Johnson and Lu, 2011) may also drive inequalities. The variability we observed in mid-sized regions and for vulnerable road users may reflect variations in built environment conditions.

Our results demonstrate that controlling for road length alone will, unsurprisingly, not adequately control for exposure to risk, that is the traffic volume of different modes within a DA. Our minimally adjusted models (controlling only for road length) produced higher IRRs than both unadjusted and adjusted models across most regions and crash types. This pattern is likely related to our spatial unit of analysis. DAs are standardized by population rather than geographic size, resulting in less densely populated areas being larger and likely containing more lane kilometres. When controlling only for road length in minimally adjusted models, we implicitly treat each kilometer as having equal traffic volume, potentially 'overcorrecting' in less dense areas where each road kilometer likely carries less traffic. If these larger, less dense areas also tend to be more socioeconomically deprived on average, the minimally adjusted models may artificially amplify the estimated associations between deprivation and traffic injury incidence. Although using equal-sized grid cells as alternative spatial units could mitigate this issue, such an approach would require transferring census data to different spatial units through weighting algorithms, thereby introducing uncertainty in both the deprivation metric and other census-based variables (Cui et al., 2025; Reibel and Bufalino, 2005). This methodological limitation underscores the challenge of controlling for exposure across diverse urban contexts, where motor vehicle volume data are not reliable and/or available.

While minimally adjusted models may overestimate inequalities, the reduction in IRRs observed in many regions in the adjusted models suggests that incorporating additional built environment characteristics, such as road classification, better differentiates traffic exposure levels between neighbourhoods. This aligns with an analysis of Metro Vancouver road traffic counts using the same road classification scheme, which found significant differences in traffic volume by road class, though with substantial variation within classes (Setton et al., 2005). However, examination of the spatial distribution of random effects from our adjusted models shows underpredictions clustering in denser urban neighbourhoods, and overpredictions in peripheral neighbourhoods. Denser urban neighbourhoods tend to have higher traffic density (volume per unit of road length) compared to larger more peripheral neighbourhoods, suggesting our covariates are not fully capturing differences in exposure. The impact of this limitation on our estimates of the association between deprivation and traffic injury crash incidence is dependent on how the road density correlates with deprivation, and could bias our estimates of risk in either direction. While direct measurements of traffic volume would improve future analyses, such data does not exist at the resolution needed for small-area analyses on a provincial scale.

Our results demonstrate that injury crashes are disproportionately concentrated in more deprived areas, and we suggest that prioritization of road-safety interventions should incorporate an equity lens and consider the geographic scale of interventions (Plasencia and Borrell, 2001; Pearson et al., 2025). Spatial inequalities likely persist partly because municipalities and provincial agencies in British Columbia have historically focused on micro-scale interventions—engineering treatments at high-risk intersections or segments—that improve safety where installed (Sayed et al., 2016), but do little to reduce the average risk across whole neighbourhoods or regions (Fuller and Morency, 2013). Macro-scale interventions that act on the broader network—such as

city-wide speed-limit reductions and enforcement—should complement ongoing micro-scale treatments by lowering overall motor-vehicle traffic volume and speed, the fundamental causes of road traffic injury (Elvik, 2012; Fuller and Morency, 2013). Implementing 30 km/h traffic calming zones, by lowering posted speed limits and/or strategically placing traffic calming measures, offers a relatively inexpensive pathway to reducing inequalities, particularly if rollout is prioritized in higher risk and more deprived neighbourhoods (Yannis and Michelaraki, 2024). Wealthier neighbourhoods in BC have been more successful at securing traffic-calming measures (Pearson et al., 2025). Our analysis shows inequalities in every region, underscoring the need for province-wide macroscale interventions that give higher priority to deprived areas.

Our study has strengths and limitations. Strengths include a comprehensive comparison across diverse urban regions using a large provincial dataset, revealing substantial regional heterogeneity in inequality that are obscured in province-wide analyses or not possible in a single-city analysis. We used a unique universal auto-insurance claims dataset which provides much greater coverage of motor vehicle-involved injuries than more commonly used police reported data (Branion-Calles et al., 2025a). We used a small-area analysis with spatial modeling approaches to enable detailed evaluation of spatial inequality patterns that the use of larger spatial units would obscure. Our study also has limitations. The smaller, less populated regions, have greater uncertainty in the estimated association between deprivation and traffic injury crashes, as reflected by wide credible intervals that include 1. This uncertainty, largely due to fewer DAs and less statistical power, may prevent a recognition of inequality in these communities, even where the effect size is large, which could inhibit future policy actions. Although auto-insurance claims data are the most complete dataset for motor vehicle occupant injury, they under-represent pedestrian and cyclist injuries and do not include fall-related injuries which account for more than half of serious injuries to pedestrians and cyclists (Branion-Calles et al., 2025b). Auto-insurance claims are based on self-report and may misclassify injury severity, and have previously been shown to disproportionately miss lower-income individuals injured in a traffic crash (Branion-Calles et al., 2025a). The associations we observed may be conservative if lower income individuals, whose injuries tend to be missing from insurance claims, are more likely to travel and/or be injured in more deprived neighbourhoods. We also analyze crashes from 2019 to 2023, while built environment data are from 2021 to 2022. As our study is cross-sectional and based on aggregation of road injury data over a five year period, the results are subject to temporal instability and may change over time (Mannering, 2018). While our models attempted to account for traffic exposure differences, limitations remain in controlling for these factors as discussed above. Nevertheless, our unadjusted models accurately represent differences in the burden of injury across neighbourhoods, regardless of the contributing causal factors.

5. Conclusions

We reveal traffic injury inequalities across diverse urban contexts in British Columbia, demonstrating the importance of incorporating equity into road safety planning and interventions. Future research should focus on examining causal mechanisms underlying these inequalities and evaluating whether interventions implemented in an equitable manner effectively reduce disparities in traffic injury burden.

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CRedit authorship contribution statement

Michael Branion-Calles: Conceptualization, Formal analysis,

Methodology, Visualization, Writing – original draft. **Somayeh Momenyan**: Methodology, Writing – review & editing. **Shannon Erdelyi**: Methodology, Writing – review & editing. **Herbert Chan**: Conceptualization, Resources, Writing – review & editing. **Kevin Man-augh**: Writing – review & editing. **Meghan Winters**: Writing – review & editing. **M. Anne Harris**: Writing – review & editing. **Jeffrey R. Brubacher**: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.healthplace.2025.103586>.

Data availability

Our final aggregated spatial dataset and analytic code are publicly available in a Github repository <https://github.com/mbcalles/Area-Level-Deprivation-Traffic-Injury>.

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