Montreal Road Collisions

A spatial analysis of social and demographic risk factors affecting pedestrian and cyclist victims of motor-vehicle incidents

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The Problem

Each year, millions of people become victims of motor-vehicle collisions on roads around the world. In 2016 alone, approximately 1.35 million people died from traffic accidents (WHO, 2018).

On urban roads, like those in the city of Montreal, two thirds of those fatalities are cyclists and pedestrians, making them the most vulnerable road users (Bassani et al.).

This disturbing trend has consequences not only for victims' families but also for society at large in the form of social and economic costs (Blincoe et. al., 2015). In recognition of this problem, a growing number of cities have instituted public safety projects such as Vision Zero, an initiative begun in Sweden to study risk factors and improve road design with the goal of eliminating road fatalities and injuries altogether.

Project Questions

On the Island of Montreal . . .

- Is there a pattern in the distribution of road collisions involving pedestrians and cyclists?
- Is socioeconomic status associated with pedestrian and cyclist collisions?
- Are certain social and demographic factors (age, ethnicity) correlated with a higher incidence of pedestrian and cyclist collisions?
- Is the burden of fatalities evenly shared across the island?

Source Data

Data for this project came from the City of Montreal's Vision Zero open data portal located here. This data provided the geolocation of road collisions occurring between 2012–2018 and various attribute data including type, count and injury level of victims.

Social and demographic data came from the 2016 Census (Statistics Canada), accessed via the University of Toronto's CHASS Census Analyzer.

Shapefiles for the arrondissement boundaries of Montreal came from the Montreal Open Data Portal. Shapefiles for census-tract boundaries were provided by the GIS lab at Concordia University.

Why Is This Important?

The issue of road collisions is one of public health. Over the last twenty years the rate of death relative to global population has failed to improve, hovering around 18.2 deaths per 100,000 people since 2000 (WHO, 2018), and deaths overall continue to climb annually. In addition to saving lives, improving the safety of our streets may also encourage individuals to walk, cycle, and take more active modes of transportation, thereby promoting exercise and healthy habits.

Moreover, researchers argue that “those who benefit least from the motor vehicle seem disproportionately likely, given their exposure to risk, to die in road traffic collisions” (Loo, Anderson, p. 64). In other words, people who for lack of means or personal choice make public transit, walking or cycling their main mode of transport are more likely than vehicle users to die in vehicle crashes. As such, social justice must be one concern of road collision research. The effects of injury and death ripple through society beyond individuals to include their families and coworkers, who may suffer negative economic, social and psychological consequences. If affected families and communities are already socially or economically marginalized, the consequences are magnified. This issue is important in Montreal, as elsewhere, and perhaps deserves even greater attention now given the City’s current emphasis on transition to green modes of transportation.

Overview

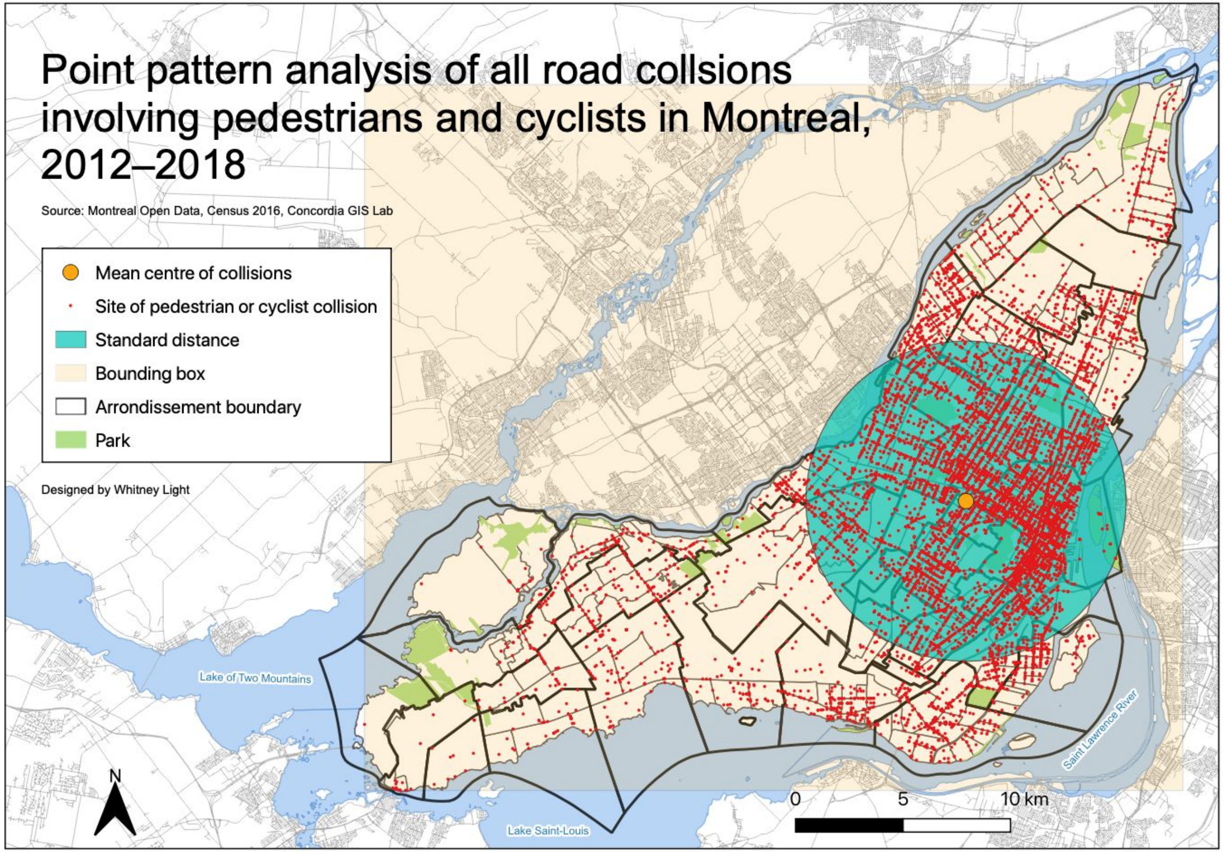
Nearest Neighbour Analysis

Observed mean distance: 35.94
Expected mean distance: 155.01
Nearest neighbour index: 0.23

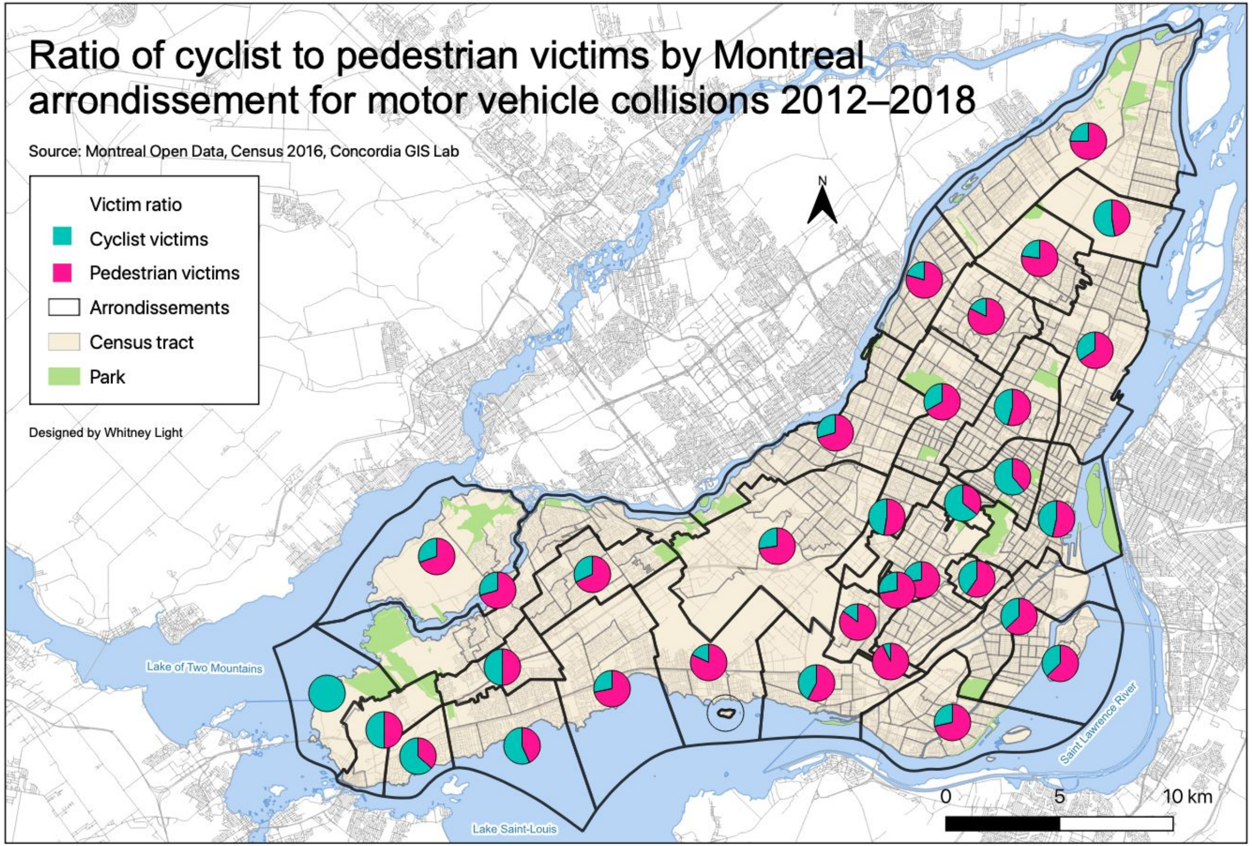
Number of points: 13003

Z-Score: -167.57

The Z-Score is less than the Z value of a normal distribution (+/- 1.96 for alpha = 0.05). A cluster pattern exists.



Overview


Ratio of cyclist to pedestrian victims by Montreal arrondissement for motor vehicle collisions 2012–2018
Source: Montreal Open Data, Census 2016, Concordia GIS Lab
Victim ratio
Cyclist victims
Pedestrian victims
Arrondissements
Census tract
Park
Designed by Whitney Light
N
Lake of Two Mountains
Lake Saint-Louis
Saint Lawrence River
0
5
10 km

Overview

Before we launched into analysis, it was important to check whether the distribution of pedestrian and cyclist collisions could be random (a matter of chance). Our hypothesis, based on a common sense notion of some streets being more dangerous than others, was that the distribution is not random and would show evidence of clustering.

Indeed, we found evidence of clustering, using a nearest neighbour and point pattern analysis. Nearest neighbour analysis revealed a highly negative Z-score, suggesting a high degree of clustering. The point pattern analysis helped visualize the pattern, showing a concentration of collisions mid-island and spanning the width of the island, with a mean centre located in Le Plateau Mont-Royal.

We also wanted to know if we should approach the analysis using all pedestrian and cyclist collisions together, or conduct separate analyses for pedestrian collisions and cyclist collisions. This was the reasoning behind creating a pie-chart map showing the ratio of pedestrian to cyclist collisions in each arrondissement. The pie-chart map reveals an interesting pattern to the ratios. Arrondissements surrounding the Downtown and in the far West of the island show a higher proportion of cyclist collisions, while most other areas are dominated by pedestrian collisions. There could be many reasons for this: perhaps a combination of high traffic density and cyclist commuters downtown makes for an environment particularly dangerous for cyclists. Perhaps the overall dominance of pedestrian collisions reflects fewer cycle commuters in outlying areas, or the fact that cyclists leave their home areas relatively safely but encounter danger near workplaces or shopping areas Downtown.

Constructing a Socioeconomic Score, Part 1

Why?

A growing body of road collision research has found association between socioeconomic deprivation and risk of injury and death (Loo, Anderson, p. 60–64). We wanted to know if we would find such associations in Montreal, since this could offer clues to how the City should go about reducing the risk pedestrians and cyclists face and take steps to improve the safety of already marginalized groups in society.

How?

There are many ways to construct a socioeconomic score, of varying complexity. We used factors that were repeatedly mentioned in road collision literature as contributors to deprivation leading to road injury: unemployment, low educational attainment, low income, single parenting, population density (Loo, Anderson; Abdalla; Nagata et al.). We weighted each factor equally in the construction of a score, as it was beyond our scope to determine whether some factors play a greater role than others.

Importantly, we used census data to construct a score that estimates area (census tract) characteristics. Another type of road collision analysis would look at socioeconomic characteristics of individuals. The latter type of study has shown even stronger association between deprivation and risk of injury or death (Loo, Anderson, p. 63).

Constructing a Socioeconomic Score, Part 2

Using Census 2016 data for each Montreal census tract, we gathered:

- unemployment rate (4 bins)
- % low-income households after tax (4 bins)
- % lone-parent households (5 bins)
- % pop over 24 years with only high school or less (5 bins)
- population density (4 bins)

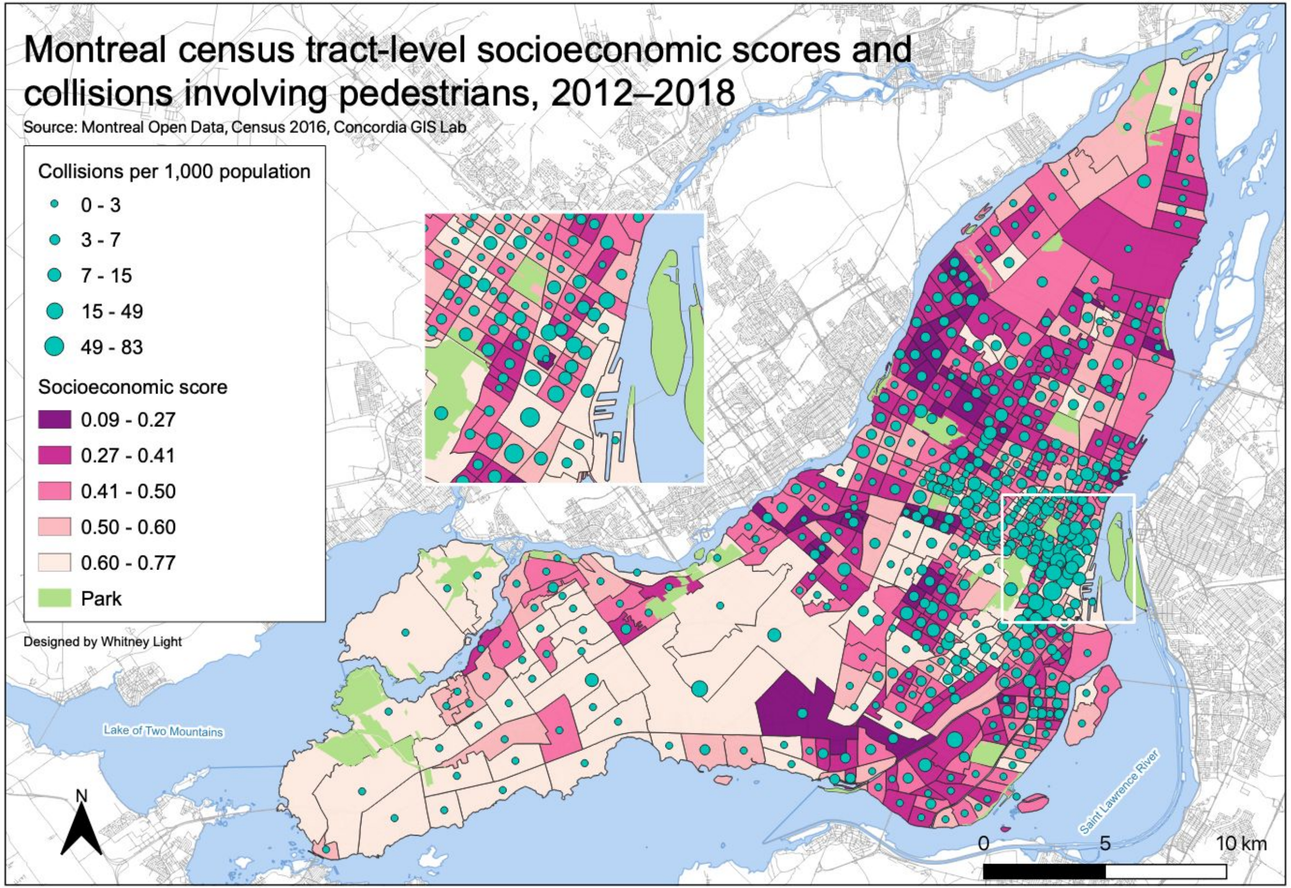
Using Jenkspy algorithm for Python, each census tract was ranked on each factor (on the basis of 4 bins or 5 bins). Next, ranks are summed across rows, such that each census tract received a score between 5 (lowest possible score, i.e. 1 x 5 factors) and 22 (highest possible score, i.e. (4*3) + (5* 2)). Dividing all scores by 22 created a socioeconomic score with theoretical maximum 1.

Interpretation:

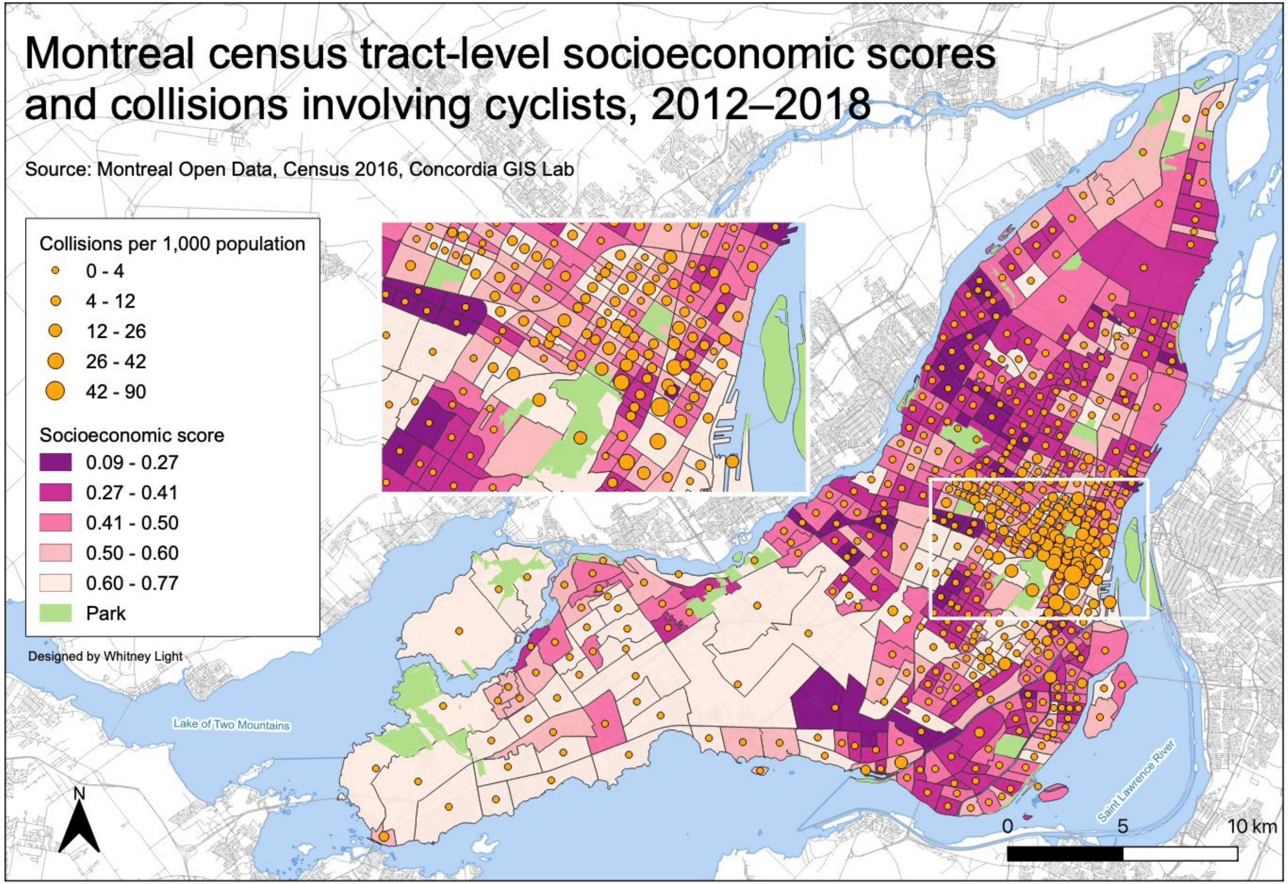
Low score = socioeconomically deprived area

High score = relatively high socioeconomic status

Pedestrian Victims



Cyclist Victims



Discussion of Analysis 1

Can we identify any trends?

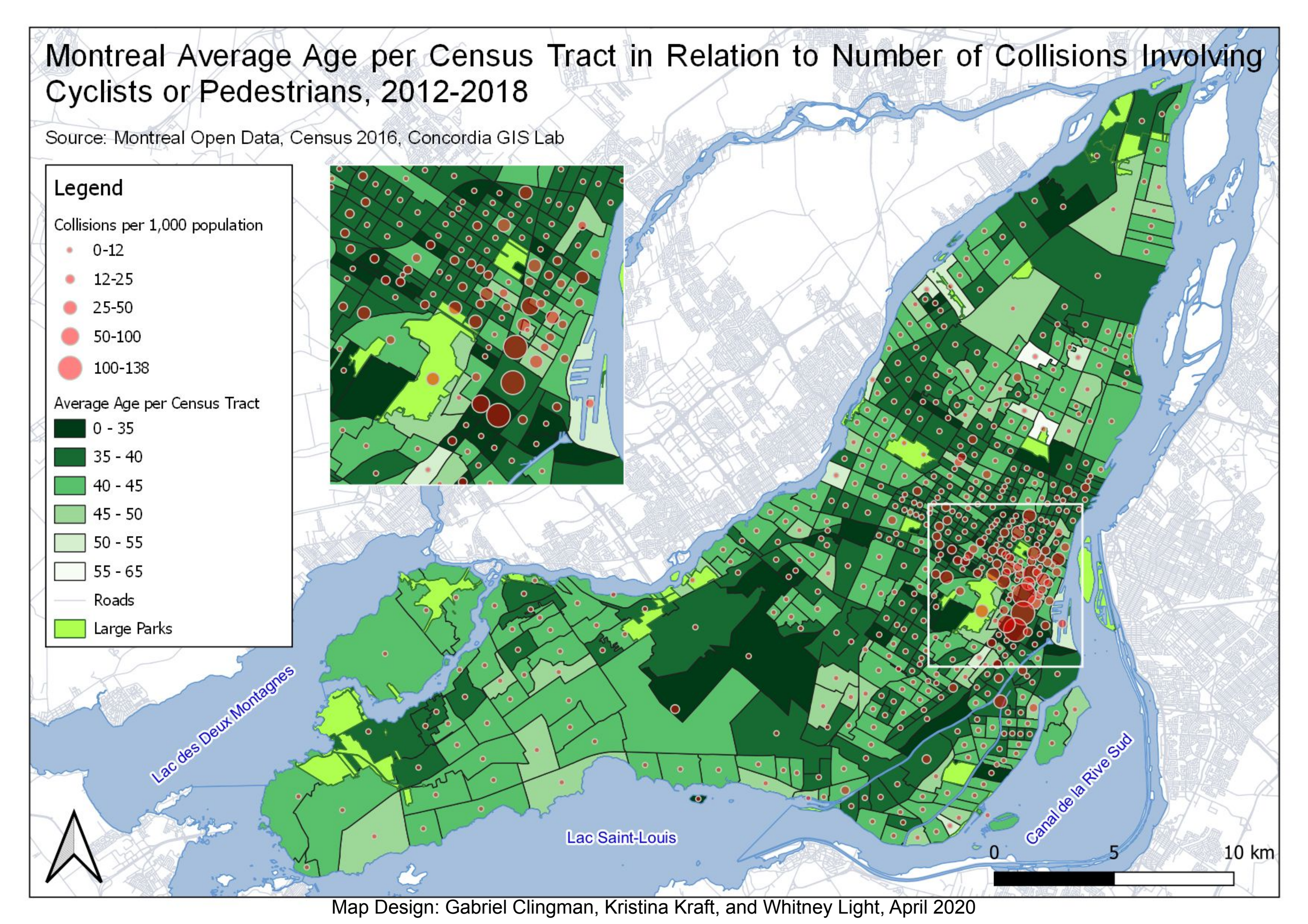
- Socioeconomic score does not appear strongly associated with higher rates of collision per 1,000 population, for cyclists or pedestrian victims. Rates of collision are similar for high and low socioeconomic areas.
- Collisions occur at a higher rate per 1,000 population in the Downtown area. Other factors are likely at work, such as traffic density, density of shops and workplaces, amount of movement in and out of the area.
- Similar rates of collision occur on census tracts of vastly different size. This raises the question of whether simple normalization by population is meaningful. In fact, there are good reasons to suspect that it is not. We might wonder, should a problem (collisions) that is greatly bound up with the movement of people and vehicles and with traffic infrastructure, weather conditions, etc. be treated the same way as, for example, incidences of an inherited disease? That is, does population accurately reflect exposure to risk?

Other Social and Demographic Risk Factors

Additional risk factors identified in road collision literature include: population age (higher risk for children and the elderly), ethnicity and gender.

Using raw census data, we investigated the incidence of collisions in each census tract with respect to age and the percentage of visible minorities. The number of collisions was normalized by total population. We performed various statistical analyses to see which factors, if any, were correlated with a high or low incidence of collisions.

Average Age



Montreal Average Age per Census Tract in Relation to Number of Collisions Involving Cyclists or Pedestrians, 2012-2018
Source: Montreal Open Data, Census 2016, Concordia GIS Lab
Legend
Collisions per 1,000 population
0-12
12-25
25-50
50-100
100-138
Average Age per Census Tract
0 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 65
Roads
Large Parks
Lac des Deux Montagnes
Lac Saint-Louis
Canal de la Rive Sud
0
5
10 km
Map Design: Gabriel Clingman, Kristina Kraft, and Whitney Light, April 2020

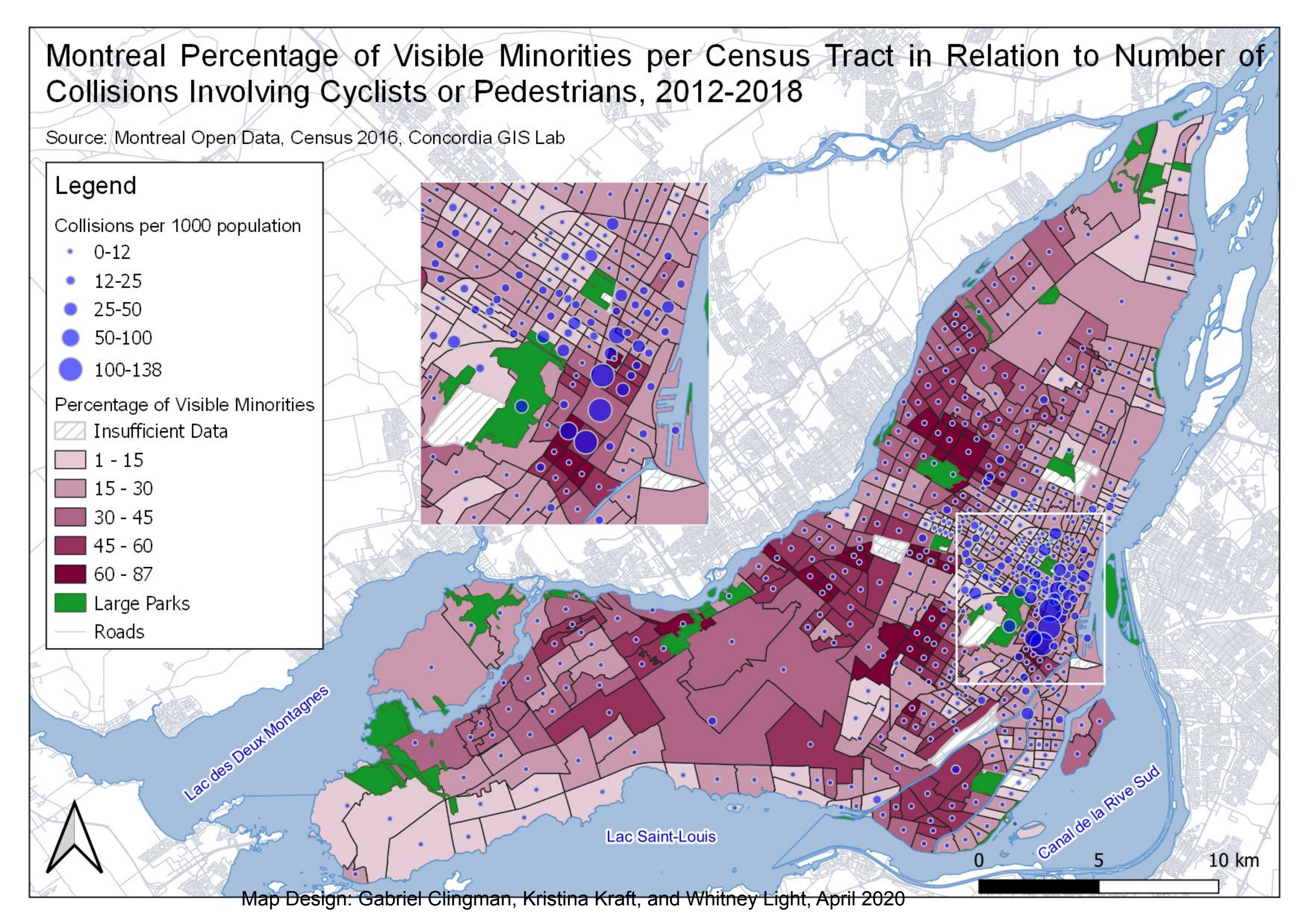
What is the spatial relationship between age and the incidence of collisions?

Age appears to be negatively correlated with the incidence of collisions involving pedestrians or cyclists.

In census tracts with greater than 50 collisions per 1000 people, the average age is 36. In census tracts with an average age greater than 50, the average number of collisions per 1000 people is 6.1.

This proved to be somewhat counterintuitive to our hypothesis that a higher average age within census tracts would be associated with greater incidence of collisions. In Canada, almost 43% of pedestrian fatalities were aged 56 or older (H.M. SImpson p.217). In Montreal, areas with younger population tend to have greater population density, so this likely affected our findings.

Visible Minorities



Visible Minorities and the Incidence of Collisions

In census tracts with greater than 50 collisions per 1000 population, the percentage of visible minorities is 40.9%. While census tracts with greater than 100 collisions per 1000 population averaged 42.9% visible minorities.

In census tracts with an average of 20 collisions or less per 1000 population, the percentage of visible minorities is 29.9%.

From our analysis, it appears that census tracts with a greater percentage of visible minorities have a higher rate of collisions. The results support previous research by Zhu and Lee, which states, “The distribution of walkable/bikeable and safe environments is inequitable across neighborhoods with different income statuses and ethnicity compositions” (p. 287).

Limits of Analysis

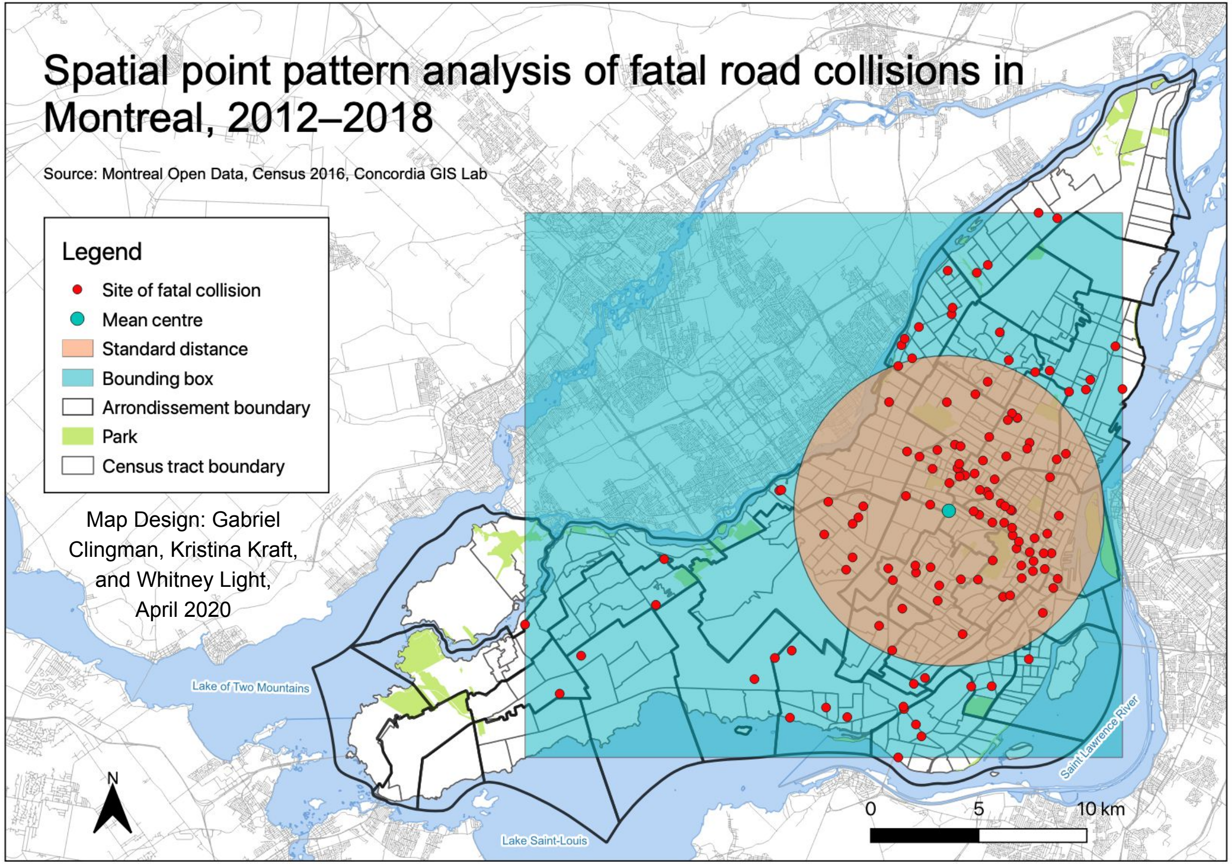
Population is not an ideal way to normalize collision data, but it's what we had available. According to Loo and Anderson, road collision per population is "not a true rate" (p. 207). Furthermore,

> "In general, the smaller is the jurisdiction, the higher is the likelihood that the assumption of the local population being a good measure of people's exposure to road traffic does not hold. Similarly, the lower are the barriers for the movement of people across jurisdictions, the higher is the likelihood that this assumption does not hold." (Loo, Anderson, p. 208)

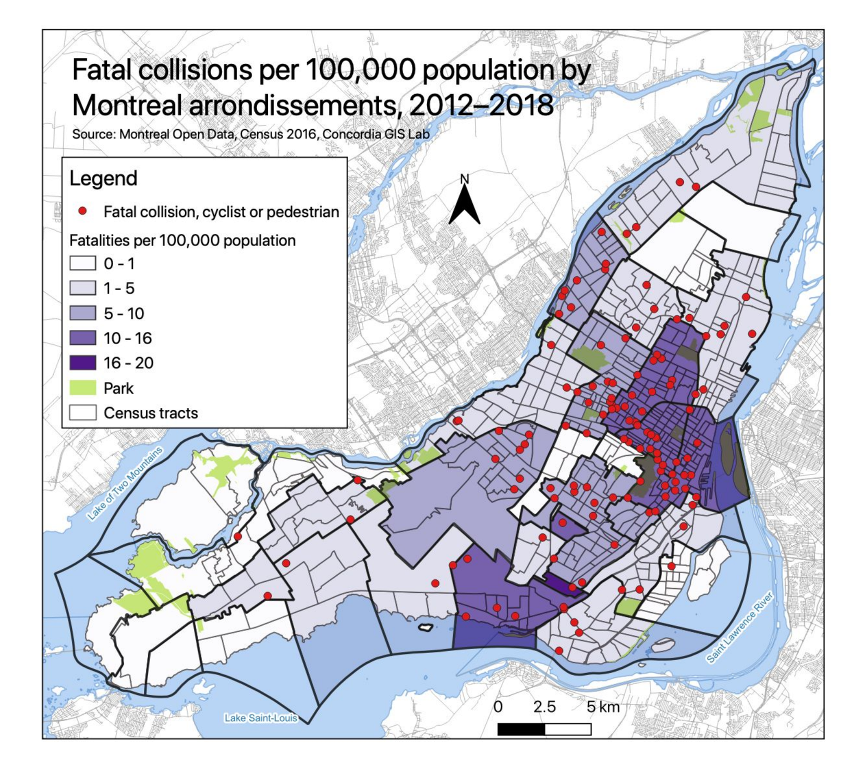
Population does not account for differences in mode of transport and length of journey. For example, if a large number of people in an area use the metro or bus, this changes their traffic exposure. How long are people actually on the road and how?

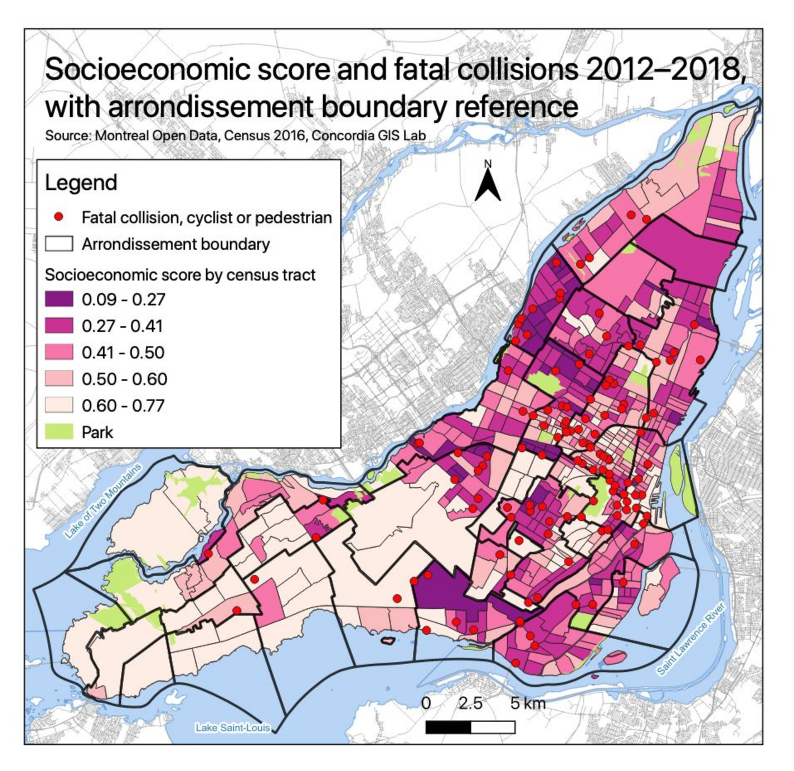
Alternative View

Is the burden of fatalities evenly shared?



Alternative View | Is the burden of fatalities evenly shared?





Is the burden of fatalities evenly shared?

Nearest Neighbour Analysis

Observed mean distance: 738.82
Expected mean distance: 1166.10
Nearest neighbour index: 0.63
Number of points: 128

Z-Score: -7.93

The Z-Score is less than the Z value of a normal distribution (+/- 1.96 for alpha = 0.05). A cluster pattern exists.

No. First, a nearest neighbour analysis and point pattern analysis shows that the distribution of fatalities is not random. There is evidence of clustering.

The collision data set only contains 128 fatalities, so we aggregated them over arrondissements rather than census tracts. As before, the count of fatalities was normalized by population (arrondissement total), and the rate expressed per 100,000 population.

From this view, the burden of fatalities is in central arrondissements.

The highest fatality rates (>9.8 per 100,000) occur in Lachine, Le Plateau Mont-Royal, Ville Marie, Rosemont-La-Petite-Patrie, Montreal Ouest, Hampstead. Moderately high rates (5.3–9.8) occur in Cote-des-Neiges, Saint Laurent, Montreal Nord and Villeray-Parc-Extension.

Visual comparison with the socioeconomic score reference map suggests association between the burden of fatalities and low socioeconomic score. Can this be verified?

Fatality Rates and Low Socioeconomic Score

Using intersection, we can count the number of census tracts with low socioeconomic score that fall within arrondissements displaying high rates of fatal collisions for cyclists and pedestrians.

For this purpose, we define low socioeconomic score as below 0.41 (two lowest classes, 284 census tracts). High rates of fatality are defined as >= 10 per 100,000 (two highest classes, 6 arrondissements). Moderate rates are defined as 5–10 per 100,000 (one class, 10 arrondissements).

- 15% of census tracts with low socioeconomic score fall in arrondissements with the highest fatality rates.
- 49% of census tracts with low socioeconomic score fall in arrondissements with moderately high fatality rates.

These results are not conclusive due to the limited data set and areal generalization of census tracts to arrondissements, but they do suggest that further research in this direction is warranted.

Recommendations

- Efforts to reduce pedestrian and cyclist injury should start in central arrondissements encompassing the Downtown and Plateau, in census tracts showing a collision rate higher than 26 per 1,000 population over the years 2012–2018.
- Create separate campaigns/education programs aimed at reducing pedestrian victims and cyclist victims. Direct cyclist programming at neighbourhoods where majority of commuters are cyclists, pedestrian programming where majority are pedestrians.
- Improve the collection and publication of enrichment data--data other than collision counts--to better understand the multiple interactions that lead to an accident. A greater diversity of data can improve collision analysis by providing researchers new elements to evaluate.
- Toward accounting for the effect of mobility on road collision data: Collect location data on motorists and victims involved in collisions, such as home address/starting point and destination.
- Focus road improvement on areas with a greater number of collisions.
- Reduce speed limits in areas with high collision rates.
- Tailored policies should target areas with younger population as well as areas with more visible minorities.

Directions for Future Analysis

- Geospatially weighted regression analysis of factors associated with risk of road collision injury.
- Analysis of other social and demographic factors, such as gender and ethnicity.
- Collisions should be normalized by the total number of cyclists and pedestrians instead of total population.
- The built infrastructure should be addressed (e.g. protected vs. unprotected bike lanes, sidewalks, timed crosswalks, and street lights).

References

Abdalla IM. 1997. An investigation into the relationships between area social characteristics and road accident casualties. Accident Anal Prev 29 (5): 583-593.

Blincoe LJ, Miller TR, Zaloshnja E, Lawrence BA. May 2015. The economic and societal impact of motor vehicle crashes, 2010, revised. Report No. DOT HS 812 013. Washington, DC: National Highway Traffic Safety Administration.

Bassani M, Rossetti L, Catani L. 2019. Spatial analysis of road crashes involving vulnerable road users in support of road safety management strategies. Transportation Research Procedia 45: 394-401.

Chen D, Getis A. 1998. Point pattern analysis. San Diego (CA): Department of Geography, San Diego State U. Available at: <http://ceadserv1.nku.edu/longa//geomed/ppa/doc/html/ppa.html>.

Delmelle EC, Thill J, Ha H. 2012. Spatial epidemiologic analysis of relative collision risk factors among urban bicyclists and pedestrians. *Transportation* 39: 433–448.

Global status report on road safety 2018: summary. Geneva: World Health Organization; 2018 (WHO/NMH/NVI/18.20). Licence: CC BY-NC-SA 3.0 IGO)

References

H.M. Simpson, L. Pagé-Valin & R.A. Warren. 1978. A Data Base on Traffic Fatalities, Canadian Society of Forensic Science Journal, 11:3, 215-220, DOI: 10.1080/00085030.1978.10756864

Loo B, Anderson TK. 2016. Spatial analysis methods of road traffic collisions. Boca Raton (FL): CRC Press.

Nagata T, Takamori A, Berg H Y, Hasselberg M. 2012. Comparing the impact of socio-demographic factors associated with traffic injury among older road users and the general population in Japan. *BMC Public Health* 12: 887.

van Beeck EF, Mackenbach JP, Looman CW, Kunst AE. 1991. Determinants of traffic accident mortality in The Netherlands: a geographical analysis.*Int J Epidemiol* 20(3): 698-706.

Zhu, X.M., Lee, C., 2008. Walkability and safety around elementary schools: economic and ethnic disparities. Am. J. Prev. Med. 34, 282–290.