Ryerson University

City Building Ryerson

LANE CHANGE:

Safer Cycling Infrastructure in Toronto

A Study of Bloor-Danforth
led by Dr. Anne Harris, Associate Professor,
School of Occupational and Public Health,
Ryerson University

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METCALF FOUNDATION

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This report represents a summary and discussion of original research and analysis produced by the research team. Any errors or omissions are the responsibility of the Ryerson City Building Institute.

All photos by Ryan Shissler, Cycle Toronto, 2020

Summary

To date, the expansion of Toronto's cycling network has been frustratingly slow. But in the summer of 2020, in an historic move, 40 kilometres of on-street bike infrastructure was expedited or newly installed through ActiveTO, part of the City of Toronto's COVID-19 restart and recovery response.[1] ActiveTO introduced 15 kilometres of continuous, dedicated space for bikes along Bloor-Danforth: a critical east-west spine that mirrors the TTC Line 2 subway. However, much of this infrastructure is still considered temporary.

This study, conducted by a team of epidemiologists at Ryerson University, applied a public health lens to understand the potential impact of various cycling infrastructure designs on injuries and fatalities along the Bloor-Danforth corridor.

The study estimated that, over the next decade, fully separated cycle tracks along Bloor-Danforth could prevent between 153 and 182 injuries, when compared to baseline conditions.

The study suggests that permanent, fully separated cycling facilities can do more than facilitate mobility—they can support public health by preventing injuries and fatalities, today in the context of COVID-19 and well into the future. Some key takeaways from the study include:

- **Safety with separation:** Fully separated cycling facilities (cycle tracks) could reduce injury burden along this corridor by 89%, significantly more than partially separated infrastructure could (i.e. semi-permeable protected bike lanes or painted bike lanes).
- **Safety in numbers:** The availability of separated cycling infrastructure throughout the COVID-19 pandemic could attract higher cycling volumes, thereby preventing more injuries. Meanwhile, higher cycling volumes overall could prompt a "safety in numbers" effect, preventing even more injuries. During the COVID-19 pandemic and into the future, separated cycling infrastructure along Bloor-Danforth could offer another transportation choice to many of the 183 million annual riders on the TTC Line 2 subway.
- **Safety in permanence:** To prevent future injuries, it is crucial to make temporary infrastructure permanent. Removing temporary cycling infrastructure could have a "bait and switch" effect, actually leading to *more* injuries; temporary infrastructure attracts new users to the route, but when this protection is removed, the burden of injury could increase from pre-implementation levels.

About This Report

In collaboration with the Ryerson City Building Institute, Dr. Anne Harris (Associate Professor, Ryerson University School of Occupational and Public Health) led a research team to investigate the injury burden of cycling, with and without the installation of safer cycling infrastructure. Focusing on the Bloor-Danforth corridor from Parkside Drive to Dawes Road, the team's goal was to understand the implications of different cycling infrastructure designs (cycle tracks, protected lanes, painted lanes and no infrastructure) on injury and fatality rates. The research team completed detailed research and analysis, the full text of which is available in the Technical Report (appended).

This report provides a summary of the study, outlines the policy context and key takeaways, and offers a toolkit for those looking to conduct similar analyses. The goal of this report is to emphasize the public health benefits of dedicated and protected cycling infrastructure and to equip community members with context, evidence and tools to support dialogue, understand neighbourhood impacts and advocate for safer cycling infrastructure across the city.

A Cycling City

Toronto has many elements of a cycling city: a relatively flat terrain, moderate population and employment density, some supportive public policy in place, and growing interest in active transportation, particularly during the COVID-19 pandemic.

Many people already choose to make their daily trips by bike: according to the 2016 Census, 2.7% of Torontonians bike to work, and upwards of 25% in some downtown neighbourhoods.[2] While neighbourhoods outside the core generally have lower cycling rates and less access to safe and efficient cycling infrastructure, some have high and growing cycling rates too: between 7% and 11%.[3] Experts estimate there is still significant untapped potential for cycling, with about one third of all daily trips in the city between 1-5 kilometres long, thus considered conducive to cycling.[4]

If You Build It...

The limited cycling infrastructure that is already in place is hugely popular. The installation of cycle tracks on Richmond-Adelaide between 2014 and 2016 sparked a 1,095% increase in daily cyclist counts on these routes.[5] The 2016-2017 Bloor Street bike lane pilot attracted a 49% increase in cycling, quickly making Bloor the second highest bicycle facility by volume in the city.[6]

Surveys also show broad support for more cycling infrastructure. A 2020 Ekos poll found that 84% of Torontonians support the construction of protected bike lanes, with strong support consistent throughout all districts in the city. What's more, even people who travel primarily by car are supportive, with 76% of these respondents reporting support for protected bike lanes.[7]

Bloor Street West, west of Bathurst, north side, westbound bike lane

Lack of Infrastructure

Despite this demand for cycling infrastructure, Toronto still lacks the safe and connected network necessary to support people of all ages and abilities and throughout the city — particularly in neighbourhoods outside the core.

Toronto's Ten Year Cycling Network Plan was approved in 2016, setting out an ambitious network of 560 lane kilometres of bike lanes and cycle tracks as well as hundreds more kilometres of multi-use trails and shared lanes.[8] But its implementation has been frustratingly slow. In its first three years, only 7% of the Plan's total proposed kilometres of cycling infrastructure was actually installed.[9] This has left people on bikes vulnerable to significant risk as they move through the city, while also deterring new riders from travelling by bike, particularly more vulnerable road users, like children and older adults.

Today, Toronto residents report significant concerns about road safety, with 85% agreeing that Toronto must do more to protect vulnerable road users.[10] These concerns are well-founded; between 2006 and 2019, 684 people on bikes were killed or seriously injured on Toronto's streets.[11] Researchers suggest that road injuries are significantly under-reported, and that actual figures far exceed those published by the Toronto Police Service. With a network of safer cycling infrastructure in place, some of these injuries and fatalities could be prevented.[12]

COVID-19 and ActiveTO

The COVID-19 pandemic has revealed and exacerbated urban challenges and inequities, including on city streets. During the first weeks of the pandemic, as many people continued to make essential trips on foot and bike and others sought to avoid crowding on transit, it became increasingly clear that Toronto's existing active transportation infrastructure was insufficient and unsafe, and would remain a critical need throughout pandemic response and recovery.[13] It also became clear that an expanded network of active transportation infrastructure would be necessary to accommodate anticipated vehicular congestion as mobility restrictions were lifted and many returned to work.

In May 2020, the City of Toronto announced its ActiveTO plan to "make it easier and safer for people to get around and get outside while respecting physical distancing."[14] With the goal to support essential travel and vulnerable road users, ActiveTO rolled out a network of neighbourhood quiet streets, introduced weekend major road closures near recreational trails and expanded the cycling network significantly. In the spring and summer, the City installed 25 kilometres of new, temporary bikeways and expedited the implementation of 15 kilometres of previously approved, permanent routes. A total of 40 kilometres of new on-street cycling infrastructure was approved and installed in a matter of months. These interventions represented the single largest expansion to the cycling network in Toronto's history.[15]

Together with transit service and capacity enhancements like the RapidTO bus priority corridors, the goal of ActiveTO is to support mobility, ease congestion and expand safe transportation options during the pandemic.

All ActiveTO projects are currently considered temporary. The bikeways will remain in place through late 2021, at which point City Council will evaluate their safety, function and design, and determine the future of the ActiveTO bikeways (i.e. whether to make adjustments or enhancements for safety, accessibility and traffic flow, to make the lanes permanent, or to remove the lanes, in whole or in part.)[16]

Focus on Bloor-Danforth

ActiveTO created 15 kilometres of continuous, dedicated space for bikes on Bloor-Danforth, mirroring the TTC Line 2 subway route. Until recently, the majority of the corridor had been without cycling infrastructure, with only two small segments featuring bike lanes with some degree of separation, and others with painted bike lanes, sharrows or no infrastructure at all.

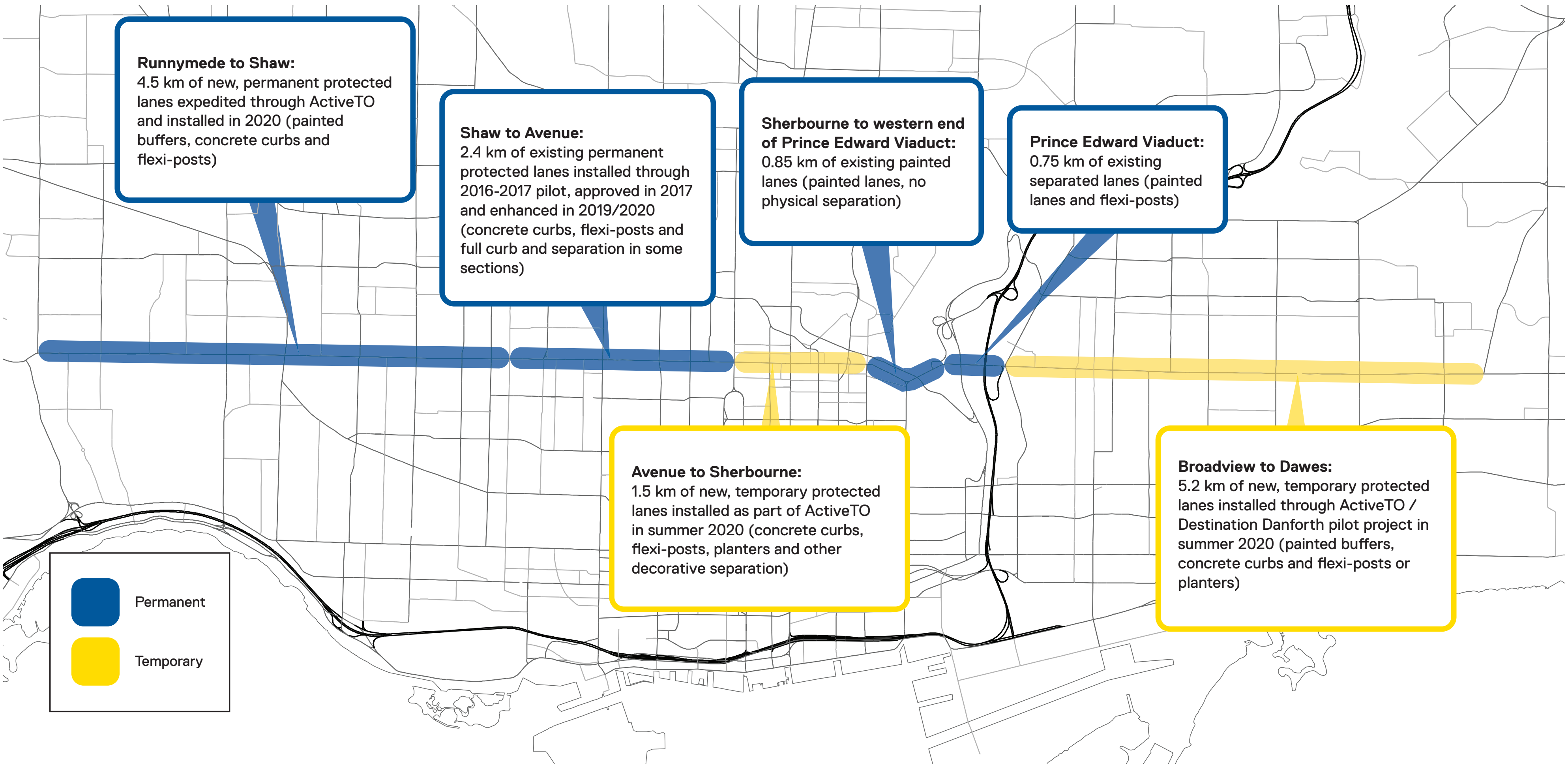
Over summer 2020, continuous cycling infrastructure was installed on Bloor-Danforth from Runnymede Road to Dawes Road. The planned 4.5-kilometre westward extension of the existing Bloor West protected bike lanes from Shaw Street to Runnymede Road was expedited for permanent installation. ActiveTO introduced new, temporary installations along the corridor, including 1.5 kilometres of protected lanes to plug the gap between Avenue Road and Sherbourne Street, and another 5.2 kilometres of protected lanes along Danforth Avenue from Broadview Avenue to Dawes Road. This eastern section, dubbed "Destination Danforth," was part of a Complete Street pilot project that featured patios, parklets, loading zones, public art, planting and other public realm improvements in addition to bike lanes, all constructed using quick-build materials.[17]

Artist rendering of bicycle lanes to be installed east of Runnymede Road. Image: City of Toronto.

Newly installed separated lane on Danforth Avenue near Broadview Avenue, south side, eastbound

Newly installed separated lane on Bloor Street East near Church Street, south side, eastbound

Bloor-Danforth Cycling Corridor, Fall 2020



Basemap provided by City of Toronto Transportation Services. Information sourced from: City of Toronto (2020). Staff Report CC21.20 - Cycling Network Plan Installations: Bloor West Bikeway Extension & ActiveTO Projects. https://www.toronto.ca/legdocs/mmis/2020/cc/bgrd/backgroundfile-147511.pdf

Highlights of Results

From fall 2019 to fall 2020, a research team led by Dr. Anne Harris conducted a study to understand the injury burden of cycling along the Bloor-Danforth corridor from Parkside Drive to Dawes Road. The study analyzed how injury burden could be impacted by different cycling infrastructure designs, including:

- Baseline conditions
- Lower Protection 1 (semi-permeable cycle tracks/protected lanes)
- Lower Protection 2 (painted bike lanes with no parked cars)
- High Protection (fully separated cycle tracks)

The analysis considered current cycling ridership figures and also projected possible future ridership scenarios, based on predicted increases in cycling in response to COVID-19. Here are some highlights of the results (see appended Technical Report for full results).

153
injuries prevented

→ At current ridership levels, **fully separated cycle tracks on Bloor-Danforth could prevent an estimated 153 serious injuries over the next decade**, when compared to no infrastructure. Partially separated cycle tracks/protected lanes could prevent an estimated 65 injuries, and painted lanes an estimated 79 injuries.

6-29
additional injuries prevented

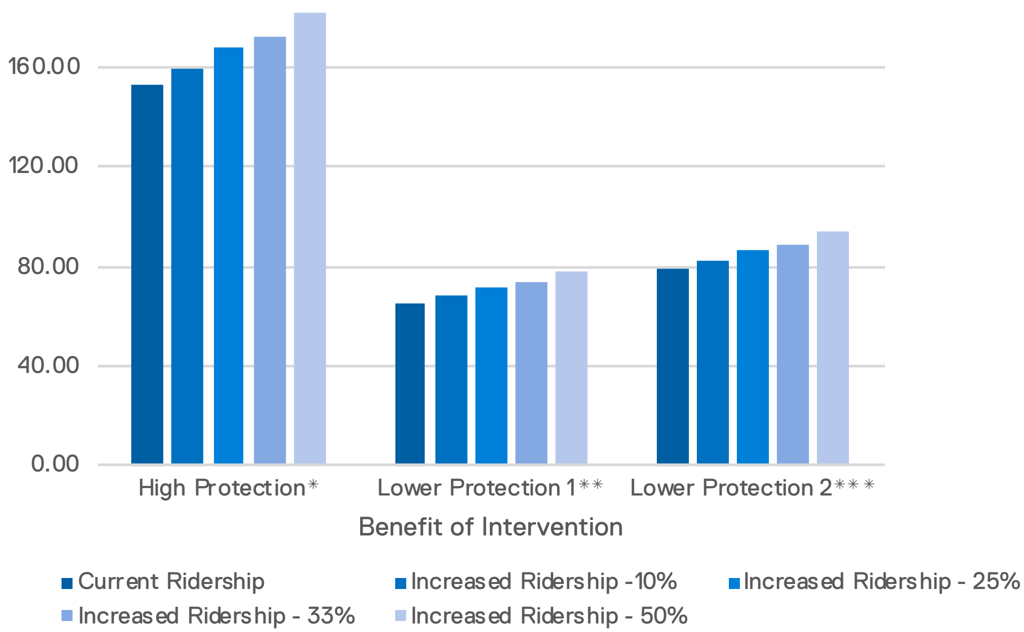
→ **If cycling ridership were to increase in response to COVID-19 or other factors, fully separated cycle tracks could prevent an additional 6 to 29 serious injuries** over the next decade, for a total of 182 injuries prevented.

89%
reduction in number of injuries

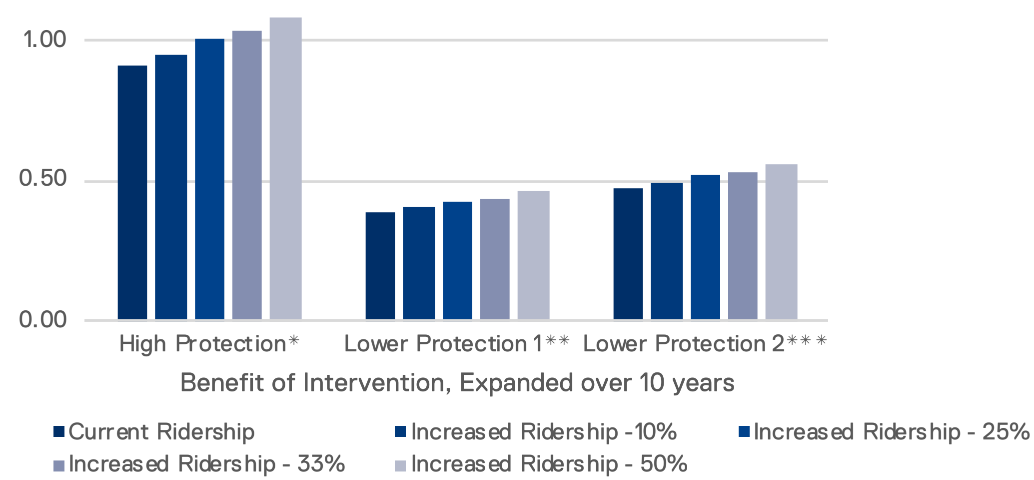
→ At current ridership levels, **fully separated cycle tracks on Bloor-Danforth could reduce the number of injuries along this corridor by 89%, when compared to no infrastructure**. Partially separated cycle tracks/protected lanes would reduce injuries by 38%, and painted bike lanes by 46%.

Cycling Infrastructure Design	Estimated Injury Reduction
Fully separated cycle tracks	**89%**
Semi-permeable cycle tracks/protected lanes	**38%**
Painted bike lanes with no parked cars	**46%**

Number of Injuries Prevented, 10 Years



Number of Fatalities Prevented, 10 Years



High vs. Lower Protection

For this study, the relative risk of various forms of cycling infrastructure was drawn from two previous studies in Toronto and Vancouver:

- The Baseline represents no infrastructure
- * High Protection represents fully separated cycle tracks, based on Teschke et al's 2012 study of Toronto and Vancouver[18]
- ** Lower Protection 1 represents semi-permeable cycle tracks/protected lanes, based on Ling et al's 2020 study of Toronto's Richmond/Adelaide cycle tracks[19]
- *** Lower Protection 2 represents painted lanes with no parked cars, based on Teschke et al's 2012 study of Toronto and Vancouver[20]

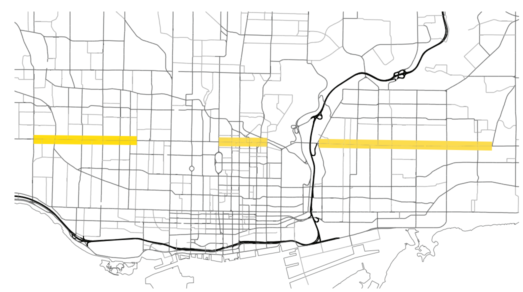
The Need for Better Data

Estimating the overall injury burden was complex, due in part to the difficulty of accessing the data necessary to calculate each individual variable in the formula. **More accurate projections would require better data**, including local data on affected routes, a population-wide travel survey, and strategies to account for the under-reporting of bicyclist injuries in police data, for example by incorporating health care utilization data to capture injury more sensitively. For full details on the study process and methods, see the appended Technical Report.

Bloor Street West, north side, eastbound, at Bellair Street

The study area included three street segments (Parkside-Shaw, Avenue-Sherbourne, Broad-view-Dawes) totalling 13.8 km, highlighted in the map below.

The study area differs slightly from the full extent of the existing Bloor-Danforth cycling corridor (15.2 km, Runnymede-Dawes), due in part to changes that occurred in the implementation of the Bloor West Bikeway Extension during the course of this study. See Technical Report (appended) for details on the street segments studied.



Toolkit: Calculating Injury Burden

The research team devised a methodology to estimate the overall injury burden along the Bloor-Danforth corridor and to understand the impacts of various cycling infrastructure designs. By replicating the methods of this study, communities have the tools to estimate the impact of various forms of cycling infrastructure on injuries and fatalities on local corridors. The resulting data can be powerful in demonstrating how safer cycling infrastructure can support public health, particularly in neighbourhoods reliant upon transit and where safer cycling infrastructure is absent or limited.

The formula below was developed to understand the effect of various scenarios, including different forms of cycling infrastructure.

Explanation

Street segment length (km)

Google Maps was used to measure the length of the relevant roadway, in kilometers, from Parkside Drive to Dawes Road (13.8 km). See map on page 9.

Total segment bicycle riders (persons)

Mean counts by day, season and year, based on manual counts conducted by the study team and Open Toronto data, were used to estimate annual cycling ridership on Bloor-Danforth from Parkside Drive to Dawes Road.

Estimates were also calculated for the number of people who may take up cycling as a result of the COVID-19 pandemic, based on a study that found 25% of TTC riders would not take the TTC unless a vaccine was developed.

Injury risk (injuries per person-km)

The Toronto-wide bicycling injury risk was determined by dividing the annual number of bicyclist injuries or fatalities by the total number of kilometres travelled by bicyclists in Toronto.

Injuries

The Toronto Police Service's Killed or Seriously Injured (KSI) open dataset was used, and corrected to account for missed injuries based on the Canadian Institute for Health Information (CIHI) and Ministry of Transportation (MTO) data.

Total kilometres travelled

The number of people who cycled annually, according to the 2014 Canadian Community Health Survey and the 2016 census from Statistics Canada, was multiplied by the average trip length based on the 2016 Transportation Tomorrow Survey.

Relative risk

The relative risk of various forms of cycling infrastructure was drawn from two previous studies of Toronto-specific infrastructure: Ling et al.'s 2020 paper and Teschke et al.'s 2012 paper. Risk values for high-protection cycle tracks, lower protection cycle tracks/protected lanes, and lower protection painted bike lanes were drawn from these papers. A value of 1 was used for baseline (no infrastructure).

The formula:

baseline injuries = street segment length (km) x total segment bicycle riders (persons) x injury risk (injuries per person-km) x relative risk

Key Takeaways

The results of this study have significant short- and long-term public health implications and offer important insights for both the Bloor-Danforth corridor and Toronto's cycling network as a whole.

→ **Fully separated cycling infrastructure supports public health:** Dedicated cycling infrastructure, fully separated from motor vehicle traffic with physical barriers, could prevent an estimated 153 to 182 injuries along Bloor-Danforth over the next decade. As Toronto moves ahead with ActiveTO and the Ten Year Cycling Plan, these findings emphasize the critical importance of safe cycling infrastructure to public health, and support the expedited implementation of a connected cycling network, equitably distributed throughout the city.

→ **Fully separated cycling infrastructure is safer:** Fully separated cycling facilities carry significantly less risk than other forms of on-street cycling infrastructure: separated cycle tracks could reduce injuries along Bloor-Danforth by 89%, whereas partially separated cycle tracks/protected lanes could reduce injuries by only 38%, and painted bike lanes by 46%. As Toronto implements its cycling plans, new on-street cycling infrastructure must feature sufficient physical separation to keep people safe.

→ **Cycling is part of an equitable COVID-19 response**: With transit capacity under pressure, cycling infrastructure is a crucial element of a coordinated COVID-19 mobility response that prioritizes essential travel and vulnerable road users. If equitably distributed throughout priority neighbourhoods and integrated with transit service enhancements, cycling facilities could offer a safe and affordable alternative to relieve crowding along the busiest routes and manage vehicular congestion.

Newly installed markings and lane on Danforth Avenue, south side, eastbound

Taking Action

With ActiveTO, Toronto joined cities around the globe in recognizing the importance of active transportation to a safe and equitable COVID-19 response and recovery. ActiveTO represents the single largest expansion to Toronto's cycling network in history, received support from the vast majority of Council members, and was installed in a matter of months, demonstrating that rapid implementation is possible.[21]

But ActiveTO bikeways, including much of Bloor-Danforth, are considered temporary. And the projects don't go far enough to provide safe infrastructure to neighbourhoods outside the core. While the pandemic has disproportionately impacted poor and racialized communities, these communities still face significant disparities when it comes to access to active transportation infrastructure and safety in public space.[22] The City of Toronto will monitor and make adjustments to existing ActiveTO projects in the coming months, and City Council will vote in late 2021 on whether to make the bikeways permanent, with adjustments and enhancements.

In the short term, with ActiveTO bikeways in place and more people cycling, now is the time to:

- Push City Council to make existing ActiveTO bikeways, including Bloor-Danforth, permanent and fully separated
- In collaboration with communities, support the further expansion of a connected network of fully separated cycling facilities, equitably distributed in neighbourhoods throughout the city to respond to the needs of the most vulnerable road users

In the longer term, as the City moves ahead with its Ten Year Cycling Network Plan, it will be important to:

- Emphasize the significant public health benefits of safer on-street cycling infrastructure, and support the implementation of fully separated cycling facilities on all new routes
- Position investment in cycling infrastructure as not only a strategy to facilitate low-carbon mobility, but as a means to prevent road injuries and fatalities
- Develop a robust data collection and monitoring plan to effectively report on the safety and performance of new and existing cycling infrastructure to build accountability, transparency and continuous improvement

Looking west across the Prince Edward Viaduct

Endnotes

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Estimating bicycling injuries preventable by separated bicycling infrastructure – case study of Bloor-Danforth corridor, Toronto

A technical report submitted to City Building Ryerson

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1.0 Project origins, impetus, and modification by COVID-19 pandemic

This work was planned in conjunction with Ryerson University's City Building Institute (CBI, now City Building Ryerson), with funding provided by the Metcalf Foundation. The project began in 2019, with a mandate to estimate the bicycling injuries that could be prevented if separated bicycling infrastructure were implemented on a key route in Toronto. A focus on injuries prevented enabled a cost-effective and timely report. However, it should be noted that prevention of bicyclist injuries and fatalities is only one of several benefits of separated bicycling infrastructure (1), with others including diversion/attraction to active, low-carbon, low-pollution modes of transportation (2), and increased physical activity (3).

Consultation with stakeholders in summer 2019 led to the selection of the Bloor-Danforth corridor for this analysis, with a focus on the stretch between High Park and Dawes Rd, and in particular on three segments with no existing bicycling infrastructure at the time of study initiation: Parkside Drive to Shaw, Avenue Rd to Sherbourne Ave, and Broadview Ave to Dawes Rd. Data collection on volume counts at select locations began in Fall 2019. Data collection was planned to continue through summer 2020. See Figure 1 for a highlighted map of the study area.

The COVID-19 pandemic affected this project. First, all data collection ceased as of March 2020, as per Ryerson University directives to ensure the safety of research staff. We adapted by complementing collected data with secondary data sources. Secondly, the pandemic precipitated a rapid expansion of bicycling infrastructure along this corridor (more details in the accompanying City Building Ryerson Report). Different types of infrastructure have been implemented along the corridor, with some treatments designated as "temporary". In light of this, our results may be considered possible benchmarks of the injury prevention benefit of this installation program, depending on the final designs and with the assumption it is made permanent.

The methods we use here are highly generalized, such that they could be easily adapted to make estimates for other corridors and locations. The methods make a number of adaptations to accommodate for a lack of ideal empirical data. As such, several of our recommendations are concerned with the routine collection and summary of a wider range of transportation safety data.

2.0 Literature Review

To examine the safety benefits for each type of infrastructure, we referred to a comprehensive literature review on bicycling infrastructure from 2009 (4). We supplemented by performing an additional review of recent studies published after 2009. To identify more recent literature, we used four background studies (4-7) and identified additional studies that had cited them using Google Scholar's built-in citation explorer. This allowed us to filter results to post-2009 and examine papers relevance from their title and abstract. We reviewed and extracted data from relevant papers. The intended goal of this process was to develop a summary effect of each infrastructure's odds ratio (OR) or relative risk (RR) of injury or crash while bicycling.

However, the development of an overall summary effect for each form of infrastructure proved difficult. Selected studies had highly variable methodology, making it difficult to compare across study results.

Several studies did not adequately control for bicyclist volume before and after the implementation of infrastructure (8, 9). An increase in bicyclist volume following installation of safer infrastructure may confer greater number of injuries or crashes due to the increase in volume, but ultimately result in a lower overall RR of injury or collision if bicyclist volume was appropriately controlled for. Another difficulty in determining a summary effect for each type of bicycling infrastructure was due to the differences of infrastructure across study locations, with each study locale having different implementation design and (sometimes) different nomenclature, and these were often categorized in ways that made across-study comparison difficult. For instance, one Australian paper by Meuleners et al. stratified cycle lanes by "formal marked cycle lanes" and "no formal cycle lane" (10). Another study examined did not report findings that were not statistically significant (11). These differences made it difficult to compare across studies.

Individual results may also demonstrate idiosyncrasies related to implementation rather than overall effects of a type of design. For example, results from Cicchino et al. (12) provided OR for risk of collision on one-way cycle tracks with high and light separation from the roadway, as well as two-way cycle tracks with light separation. Results from this study indicate that two-way cycle tracks with light separation increase one's risk of collision over 11 times (12). However, this result was primarily driven by a single stretch two-way cycle track in Washington D.C., the oldest cycle track in the city, which was responsible for more than half of the overall injuries in this category (12, 13). Thus, this result may be more indicative of poor implementation rather than the relative dangers of cycle tracks. For a full summary of reviewed study characteristics, see Appendix 1.

As a result of the challenges in comparing study results, we made the decision to draw our relative risk estimates from the two studies that collected data in Toronto. We suggest that these studies are most relevant to our study area, and most applicable to future impacts of bicycling infrastructure on the Bloor-Danforth corridor, albeit with limitations we will discuss below. Teschke et al. used a case-crossover design (6), while Ling et al.'s study used a before-after design (5). While the designs of the studies are quite different, critically each control for exposure to risk or traffic volumes. Ling et al. directly accounted for bicyclist volume in their analysis, whereas Teschke et al.'s case-crossover design accounts for exposure to risk by comparing injury locations to randomly selected route locations within individuals (5, 6, 14). Teschke et al. (6) found cycle tracks (defined as *physically separated* cycle lanes) offered the greatest protection compared to routes with no infrastructure and parked cars, OR of 0.11 (95% confidence interval, CI: 0.02, 0.54). Based on site observations conducted at injury locations compared to locations on the same trip with no injury, they found painted cycle lanes without parked cars offered less protection: OR of 0.54 (95% CI: 0.29, 1.01). At the time of data collection for this case-crossover study, Toronto had not yet implemented its approach to "cycle tracks". We note that Toronto's "cycle tracks" have not always been fully physically separated, although this is definitionally a requirement for "cycle tracks" (15). Instead "cycle tracks" in Toronto have employed a variety of styles of separated, permeable or semipermeable infrastructure, such as wider painted buffer lanes, "flexi-posts"[1], spaced out planters, and intermittent grade separation (5). A variety of styles of Toronto "cycle tracks" implemented in 2013 and 2014 were assessed directly by Ling et al. (5). Ling et al. (5) used police data to ascertain injury events before and after implementation, concluding a protective association of OR=0.62 (95% CI: 0.44,

[1] Flexible plastic posts designed to fold to street level when pushed. Toronto local nomenclature often labels flexi-posts as "bollards", but this usage is idiosyncratic given that bollards are definitionally inflexible.

0.89) for cycle tracks overall. While the study designs are not directly comparable between Ling et al. and Teschke et al., we speculate that the difference in protective effects noted by these two studies may, in part, reflect the relative permeability of 2013 and 2014 installed infrastructure along Toronto cycle tracks, compared to the more stringent definition of physical separation used by Teschke et al. Therefore, for the purposes of this analysis we have used the Teschke et al. (6) cycle track association (full physical separation) to approximate relative risk (RR) for a "high protection scenario" and the Ling et al. (5) cycle track association and Teschke et al. (6) painted lane associations to approximate RR for "lower protection" (without full physical separation) scenarios.

3.0 Study location: Bloor-Danforth

The study location includes Bloor St from High Park east to Shaw St, Avenue Road to Sherbourne, and Danforth Ave from Broadview Ave east to Dawes Ave. These segments were selected as sections of Bloor-Danforth without separated bicycling infrastructure at the time of project inception (2019). See Figure 1.

3.1 Bicycle Volume Counting Method Overview

Our key task was to estimate total annual count of bicyclists for each segment along the Bloor-Danforth. We collected field observed manual count data over 7 months (Sept 11, 2019 to March 13, 2020). These field observations had to be stopped due to COVID-19 restrictions, leaving a data gap for the high season of bicycling in Toronto. We then used a modelling process that combined our manual count data with diurnal and annual patterns quantified from City of Toronto bicycle traffic count stations on adjacent segments of the Bloor-Danforth.

3.2 Field Observations – Manual Counts

To assess bicyclist volume along the Bloor-Danforth corridor for the selected segments, manual counts were performed by a research assistant (RA). The RA stood near the intersection of 6 cross-streets (Parkside, Shaw, Avenue, Sherbourne, Broadview, Dawes) along the study area (Bloor St to Danforth Ave), and used a standardized form to record the number of bicyclists (Appendix 2). Observations were conducted in 20-minute increments, where the RA counted bicyclist volume on one side of the street (e.g. eastbound), before moving to the other side of the street to record bicyclists travelling in the other direction (e.g. westbound). RA observations were conducted from September 11, 2019 to March 13, 2020. Over this period, there were 316 observations with 186 on weekdays, for a total of 103.33 observation hours over 7 months; however, this was interrupted due to the COVID-19 pandemic. These observation periods were later extrapolated to form an hourly count for each cross-street.

Count data was analyzed in R version 3.6.3. A scatter plot was created with a regression line fitted to show bicyclist count by direction and street segment over hour of day (Figure 2). A second scatter plot was created plotting aggregated monthly count divided by the number of observation periods for each month and cross-street (Figure 3).

Bicyclist count by gender (as assessed by visual impression only) was collected. In all observation periods combined, the RA recorded 2396 men (69.4% of total), 1032 women (29.9% of total) and 25 bicyclists whose gender was not apparent (0.7% of total). In addition to bicyclist counts by gender, the research assistant assessed a variety of other variables, such as presence of child passengers, weather condition (sunny, clear; cloudy, road dry; cloudy, road wet; rain; snow; and fog), temperature (in Celsius), sunrise and sunset time, and observed light condition (dawn, daylight, dusk/twilight, dark). See Appendix 2 for an example data collection sheet. A subset of descriptive statistics on the collected data are presented in Table 1 for mean observed bicyclist counts by month and cross-street.

Table 1: *Descriptive statistics of bicyclist volume observed in 20-minute counts on Bloor-Danforth from September 11, 2019 to March 13, 2020* performed by research assistant.*

		Number of Observations	**Mean (count per 20-minutes)**[1]	**Standard Deviation (count per 20-minutes)**	**Interquartile Range (count per 20-minutes)**
Month	September, 2019	52	31.90	25.80	40.75
	October, 2019	46	16.70	18.10	19.50
	November, 2019	42	7.26	5.67	10.75
	December, 2019	42	4.29	3.80	5.00
	January, 2020	58	4.48	4.67	5.75
	February, 2020	68	3.57	3.22	4.00
	March, 2020	8	4.75	3.88	6.25
	April-August, 2020*	0	NA	NA	NA
Cross-Street[2]	Bloor-Parkside	58	4.10	4.11	5.00
	Bloor-Shaw	40	18.48	19.78	16.75
	Bloor-Avenue	44	19.73	19.52	15.25
	Bloor-Sherbourne	68	11.16	16.27	7.25
	Danforth-Broadview	54	12.56	20.90	9.00
	Danforth-Dawes	52	3.29	3.82	3.00

[1]Mean monthly count is based on the sum of all manual bicyclist counts, conducted in 20-minute intervals, divided by the number of observations for that month.
[2]Following the COVID-19 pandemic, the City of Toronto made several changes to the cross-streets above, including installation of temporary cycle tracks, bike lanes, and closing streets to motor vehicle traffic.
[3]Data collection curtailed due to the COVID-19 pandemic.

While these counts provided richer information on bicyclist volumes along the area of interest, collection was forced to stop due to the COVID-19 pandemic. To account for the limited time frame of manual counts (particularly the lack of collection during high season), a model of diurnal and daily bicyclist volume was created using the City of Toronto's Open Data (Bicyclist Volume dataset) (16). This was applied to our count data to estimate annual volumes. The open dataset volume came from loop (rather than manual) counts stations at cross-streets along Bloor street. The open dataset provided bicyclist volume counts every 15-minutes at select locations. Models were created to generate patterns of change diurnally (over a 24-hour period, stratified by season, weekday, and direction of travel) and annually (over 365 days). We describe the data and methods for estimating bicycling volumes in more detail in the subsequent sections.

3.3 City of Toronto Count Locations

The City of Toronto provides total bicycling volumes (assessed by loop counters) for both eastbound and westbound directions in 15-minute increments at three locations along the Bloor-Danforth corridor as part of their open data catalogue. Count locations include Huron and Bloor, Markham and Bloor, and Castle Frank and Bloor. These locations are selected by the City for the presence of bicycling infrastructure – our adjacent segments were selected for the absence of infrastructure. However, we reasoned that diurnal and seasonal patterns would be comparable between these sites and our count locations, even if the volume might be different. We considered one year's worth of City of Toronto count data, from March 1, 2018 to February 28, 2019 to develop our diurnal and annual change models of bicycling volume.

3.4 Expanding Manual Counts

For each segment along the Bloor-Danforth we estimated total annual bicycling volume using a method that expanded our manual count data to annual counts based on the diurnal and annual patterns quantified from the three City-operated count stations. The method involved a two-step process, where for each location and direction we: (1) expanded manual counts to an estimate of the daily volume and (2) expanded estimates of the daily volume to estimates of annual volumes.

3.4.1 Expanding manual counts to daily volumes

Manual counts were expanded to estimates of a daily volume by first quantifying diurnal patterns in bicycling by aggregating counts by hour of the day (0 to 23) and stratifying the data by season (winter, spring, summer, fall), direction of travel (eastbound, westbound) and day of the week (weekday, weekend). Then we fit a LOESS smoother to each of these stratifications to quantify patterns of hourly bicycling volume (Appendix 3, Figure 1). We will refer to each of these individual curves as hourly curves for the remainder of the document. To estimate the total daily bicycling volume for the specific date we observed bicyclists we combine our twenty-minute counts with the hourly curves. Below we illustrate our method in detail.

For a given day we define hourly time periods within a day as h = 1, 2, … ,24. Each observed twenty minute directional count c falls within a given time period h based on the time at which the count was started. The time h in which observed directional counts fall we define as oh:

$$hc_{oh} = c_{oh} \times 3$$

Where, hc_{oh} is the estimated directional counts at hour oh, and c_{oh} is the observed twenty-minute count within hour oh.

Next, for each value hc_{oh}, we calculated an expansion factor, EF, based on the hourly curve with matching characteristics based on the season, direction of travel and day of the week. Specifically, for a matched hourly curve, we take the sum of predicted volume at the hth hour of the day, pv_h, divided by the predicted volume at time oh, pv_{oh}:

$$EF = \sum_{h=1}^{24} \frac{pv_h}{pv_{oh}}$$

Finally, to obtain the total estimated daily directional volume, DDV, we multiply hc_{oh} by EF:

$$DDV = hc_{oh} \times EF$$

To illustrate the process, consider the following example: on Monday, September 23, 2019 between 8:35 and 8:55 AM we observed 98 bicyclists travelling eastbound on Bloor at the intersection of Bloor and Avenue Road. We estimate the counts during the entire hour:

$$hc_{oh} = 98 \times 3 = 294$$

Then we find the hourly curve that matches our observed counts based on season (fall), direction of travel (eastbound) and day of the week (weekday) (Appendix 3, Figure 2A). To obtain the expansion factor, EF, we divide each value of pv_h by pv_{oh} (Appendix 3, Figure 2B) and sum these values:

$$EF = \frac{14}{145} + \cdots + \frac{24}{145} = 10.425$$

Finally, to estimate DDV we multiply hc_{oh} by EF:

$$DDV = 294 \times 10.425 \sim 3{,}065$$

In this example, taking into account the patterns in eastbound bicycling ridership on an average fall weekday, we estimate from 98 observed bicyclists over a twenty-minute period that there are just over 3,000 bicyclists total for that day. We applied this method to each 20-minute counts to obtain a dataset of estimated daily bicycling volumes for a specific date, location, and direction of travel (Appendix 3, Figure 3).

3.4.2 Expanded daily volumes to annual volumes

The next step was to expand our estimates of daily counts to annual counts, based on the annual patterns in the City measured counts along Bloor. First, we aggregated daily bicycling volumes observed on City counters by day of year (e.g., January 1 = 1 and December 31 = 365) and stratify by direction of travel. Next, we quantify the annual pattern in daily bicycling volumes by fitting a LOESS smoother to these data (Appendix 3, Figure 5).

We then applied these curves to our estimates of daily bicycling volume for each location and direction of travel. For each location and direction, we create adjustment factors using the midpoint date between the earliest and latest date for which we have estimates of daily volume as a reference. We then multiplied the average predicted daily count by the adjustment factors for each location and direction to obtain estimates of daily bicycling volumes for each day of the year (Appendix 3, Figure 5). Estimated daily bicycling volumes were summed to obtain an estimate of annual bicycling counts for each location and direction (Table 2).

Table 2: *Estimated annual bicycling volumes based on combining manual count data with diurnal and annual patterns in bicycling volume quantified from nearby City of Toronto bicyclist counter data.*

Location	Volume Eastbound	Volume Westbound	Total Volume (Annual)
Bloor-Avenue	795,452	668,174	1,463,626
Bloor-Shaw	525,760	538,821	1,064,581
Bloor-Sherbourne	428,063	577,791	1,005,854
Danforth-Broadview	458,601	405,211	863,812
Danforth-Dawes	129,722	169,574	299,295
Bloor-Parkside	150,695	144,924	295,618

4.0 Injury Burden

We implemented a simplified method of estimating injuries using the following formula:

baseline injuries = street segment length (km)* x *total segment bicycle riders (persons)* x *injury risk (injuries per person-km)* x *relative risk (RR)

Difference in injury burden between no intervention (RR=1) can be tested against optimal effect of protected infrastructure (RR=0.11). We can also manipulate the expected number of users, expand the kilometers implemented, and adjust baseline injury risk depending on area of interest. While simplified, this formula is customizable and allows for implementation in other study locations. Data analyses presented below were conducted in R version 3.6.3. Below, we will demonstrate how we estimated values to use for each of the formula components.

4.1 Street Segment Length and Total Segment Bicycle Riders

We first estimated the number of total segment bicycle riders along each segment (total number of bicyclists riding the observed segment). Rider counts are the values from the extrapolated count model for each segment (e.g., Table 2). To summarize segment endpoint estimates in an estimate of total riders across the complete segment, we used the mean of segment endpoint estimates. For example,

[number of bicyclists at Parkside + number of bicyclists at Shaw]/2

is the mean of the two endpoints and gives an estimate of the total bicyclists along that segment.

The second aspect of the segment-person-km calculation is to determine the number of kilometres bicycled along each street segment. This was done by multiplying the length of the segment (e.g. Parkside to Shaw) by the number of local bicycle riders. Segment length was measured using Google Maps built-in measure distance tool. These steps were conducted for each segment and summed to provide a total estimated bicyclist count and overall segment person-km (Table 3).

Table 3: *Street segment length, estimated bicyclist volume and segment person-km*

Street Segment	Length (km)	Estimated Bicyclist Volume	Segment Person-km
Parkside-Shaw	3.1	680,100	2,081,106.0
Avenue-Sherbourne	1.4	1,234,740	1,778,025.6
Broadview-Dawes	5.2	581,554	3,024,080.8
Total	9.7	2,496,394	6,883,212.4

4.1.1 Accounting for COVID-19 volume changes

Finally, we derived estimates to account for the possible effect COVID-19 may have on bicycling volume in Toronto. It was hypothesized that bicycling volume would increase, particularly if residents are deterred from public transit. A preliminary survey of public transit users in Toronto revealed of those who stopped taking public transportation due to COVID-19, 23% would not ride TTC until a vaccine is available (17). There are emerging data suggesting bicyclist ridership has increased during the pandemic. City bicycle shops have noted a shortage of bicycles for sale, indicating ridership is increasing (18). Finally, the new infrastructure being implemented on Bloor-Danforth can be predicted to attract riders. For this study, estimates were created for a range of new riders as a percentage of the total bicyclist volume. New rider volumes were estimated at 10%, 25%, 33%, and 50% of current ridership. Estimates were conducted by taking the total street segment length and multiplying by the respective percentage increase. Ridership estimates were also adjusted for the effect of safety-in-numbers, which posits as bicyclist volume increases motor vehicle drivers will drive slower and exercise more caution around bicyclists (19).

4.2 Injury risk

We used an estimate of Toronto-wide bicycling injury risk. For this estimate there are two data requirements: (i) an estimate of the number of injuries among Toronto bicyclists in a given time period (numerator), and (ii) an estimate of the exposure to risk (the person-kilometres of bicycling that occurred) in that same time period (denominator). The number of injuries can then be divided by the exposure to obtain an estimate of risk:

$$Risk = \frac{\#\ of\ Injuries}{Exposure}$$

Thus, we first estimated the numerator (the number of bicyclist injuries or fatalities across Toronto), and then the denominator (the total number of kilometres travelled by bicyclists in Toronto).

4.2.1 Risk Numerator – Number of Injuries

Toronto Police Services (TPS) records bicyclist collisions in their open Killed or Seriously Injured (KSI) dataset (20), which is a subset of all police-reported collisions. Several studies have noted police data does not capture all road injuries, with injuries to bicyclists and pedestrians even more likely to be missed than injuries to motor vehicle users (21). Fatalities are assumed to be more accurate as police data are more likely to record road fatalities (21). To account for incomplete police records of injuries to bicyclists, we applied a correction factor described further below. The publicly available KSI dataset provides data for injuries and fatalities between 2006-2019 for all road users. We tallied the subset of collisions involving bicyclists between 2014-2017 to match the year range of health care databases used to assess missing injuries.

To account for injuries missing in police data, we estimated an Ontario-wide correction factor, a ratio of reported bicyclist collisions (compiled by Ministry of Transportation of Ontario, MTO) to records of emergency department visits for bicycling injuries. Because fatalities are rare and because the publicly-available tabulations of health care data do not include a separate fatalities count, we limited our correction factor calculations to non-fatal incidents. MTO data stands in here for "police-reported", and we are assuming that MTO collisions and TPS KSI data miss about the same proportion of bicyclist injuries. However, because the TPS KSI is a subset of reported collisions only including "serious injuries", this is likely a conservative assumption (a higher proportion of minor injuries are likely missing from TPS KSI data than MTO collisions).

We compiled the number the number of emergency department (ED) visits for bicycling injury from datasets provided by the Canadian Institute for Health Information (CIHI) (22-25). This was compared (MTO) summaries of reported non-fatal bicycling collisions for Ontario (26-29). We assumed health care utilization data (e.g. CIHI reported ED visits) would provide greater sensitivity of injuries involving bicyclists than police reported collisions (e.g., MTO or TPS). We divided total CIHI recorded bicyclist ED visits from 2014-2017 and the number of MTO recorded non-fatal bicyclist collisions over the same period. This gave us an approximate ratio of unreported to reported injuries, which we used as the correction factor. The calculated factor was ~ 11.2, meaning for every 12 bicyclist injuries resulting in ED visits, there was 1 reported non-fatal collision in MTO records. We then assumed this Ontario-wide ratio would apply to Toronto police data. From 2014-2017, TPS recorded 181 serious injuries and 12 fatalities in their collision data. We applied the correction factor to estimate ~2020 non-fatal bicyclist injuries in Toronto for the years 2014-2017, or ~504 injuries each year in Toronto bicyclists. (Table 4).

Table 4: *Correction factor for Toronto Police Services (TPS) recorded injuries using MTO and CIHI recorded injuries, 2014-2017*

Data Source	Reported Count (2014-2017)
MTO non-fatal bicyclist collisions	8450
CIHI ED visits for bicycling injury	94,298
TPS KSI count	181
Correction factor (Ratio CIHI : MTO)	11.2
TPS – Estimated Injuries w/ Correction	2019.9

Abbreviations: MTO is Ministry of Transportation Ontario, CIHI is Canadian Institute for Health Information, TPS is Toronto Police Services and KSI is Killed or Seriously Injured.

4.2.2 Risk Denominator – Total Kilometres Cycled

Following the calculation of corrected bicyclist injuries in Toronto, calculations were performed to determine the total number of kilometres cycled in a year by Toronto bicyclists. To determine this, the Transportation Tomorrow Survey (TTS) was used to estimate average trip length for bicycle trips and Canadian Community Health Survey (CCHS) data was used to estimate the number of bicycle trips taken by Toronto residents in a year (30, 31). TTS asks participants for the trip length between their origin and destination, home, and work, whereas the CCHS surveys Canadians on the number of bicycling trips taken.

Average bicycling trip length was calculated using values from the TTS. The TTS is a survey conducted by municipal and provincial government agencies every 5-years since 1986 to collect information on urban travel in the Greater Golden Horseshoe Area (GGHA), an area encompassing municipalities from the Greater Toronto-Hamilton Area and other smaller cities and counties in the Barrie area (30). While this study was primarily interested in bicyclist trips in Toronto, we used the total summary data for all included regions on the assumption that bicycling trip lengths may be comparable throughout the region. The last cycle was conducted in 2016. Data was downloaded from the TTS website for trip lengths using Manhattan lengths, which are measured at right angles to simulate city blocks (32). TTS provided expanded weights reflecting the number of people each respondent accounts for meaning no manual weighting was conducted. TTS data was filtered to only include participants who noted their main mode of transportation as bicycling. A weighted mean was calculated to determine the average trip length in the GGHA. Average trip length was found to be 4.30 km.

Next, data from the CCHS was used to determine the total number of bicycling trips taken by Torontonians in one year. The CCHS is a national cross-sectional survey which collects information related to health status, healthcare utilization and health determinants in Canadians over the age of 12 (31). Data from the CCHS is collected every year but each cycle encompasses two-years (e.g. 2007-2008) with the last CCHS cycle conducted in 2018 (31). However, due to changes in the way data was collected for bicyclist trip information the 2014 CCHS cycle was used instead (33). The 2014 CCHS public use microdata file (PUMF) was subset to respondents within Toronto's public health unit (PHU, the geographical unit available in CCHS PUMF). Four variables selected for analysis, two concerning bicycling behaviour and two concerning the overall number of trips made using a bicycle. The first two variables concerned the number of times respondents cycled for leisure (PAC 1D) or cycled to school/work (PAC 8) in the last 3-months (33). Weights for each variable were summed to find the number of people who cycled for leisure or utilitarian purposes in the past 3-months. Following this, the second set of variables asked respondents the number of times they had cycled for leisure (PAC 2D) or to school/work (PAC 8A) in the previous 3-months (33). To determine the total number of trips, a weighted sum was calculated for the number of trips using respondent sample weights. Finally, the number of people who cycled for leisure or to school and work were multiplied by their respective number of trips to provide the total number of trips taken in the 3-months. The total number of trips taken in 3-months was 11,759,951.

Once the average trip length and number of trips were determined, the two values were multiplied to find the total number of kilometres travelled. This value was multiplied by 4 to provide an annual number of kilometres travelled, which was 202,318,197 km.

4.2.3 Safety-in-Numbers Effect

As mentioned in Section 4.1, there may be more bicyclists on Toronto roads during and following the COVID-19 pandemic, as more people turn to bicycling instead of public transportation. However, an increase in bicyclists may not confer a proportional increase in injuries. For instance, 50% more local bicycle riders do not increase injury burden by 50%. Instead injury burden may increase by 19%, due to the safety-in-numbers effect. The safety-in-numbers effect posits as bicycle ridership increases, injuries do not increase as steadily because motor vehicle drivers proceed slower and with more caution when a road has a greater number of bicyclists (19). We took the adjustment factor for safety-in-numbers effect from Elvik and Bjørnskau (34), where an increase in bicyclist volume is risen to the power of 0.43. For this study, a 50% increase in ridership would confer $1.5^{0.43}$ x injury burden at baseline.

4.3 Relative Risk: Literature Sources

Finally, the formula for determining injury burden can be adjusted for the effect of infrastructure. This study used RR estimates from two studies using Toronto data, Ling et al. (5) and Teschke et al. (6). Estimates for the RR of "high protection" scenario cycle tracks (e.g. grade separation, concrete blocks, inflexible, true bollards) were taken from Teschke et al. (6) (OR=0.11, 95% CI: 0.02, 0.54). The estimate for the "lower protection 1" used estimates from Ling et al. (5) (OR=0.62, 95% CI: 0.44, 0.89) drawn from data on Toronto "cycle tracks" as implemented in 2013 and 2014. Finally, painted cycle lanes with no parked cars were termed "lower protection 2". RR for this category used results from Teschke et al. (6) painted cycle lanes (OR=0.54, 95% CI: 0.29, 1.01).

5.0 Key Findings

Following the creation of the algorithm, overall injury and fatality burden were calculated for baseline (no bicycling infrastructure), high protection (6), and lower protection (5) estimates. Injuries and fatalities prevented by each intervention type were also computed by subtracting intervention estimates of injury burden (e.g. high protection) from baseline. In addition, the number of injuries prevented were extrapolated to demonstrate the effect of infrastructure over several years. Environmental interventions, such as safer bicycling infrastructure, continue to benefit local bicycle riders for as long as the infrastructure is maintained (35). See Tables 5 and 6, and Figures 4 and 5 for a summary of the effect of bicycling interventions on injury and fatality burden.

Results for the effect of bicycling infrastructure on injury burden demonstrate the largest reductions in injury burden by implementing high protection, fully separated bicycling infrastructure. If the City of Toronto were to install high protection cycle tracks along these segments of the Bloor-Danforth corridor, injury burden would fall from almost 172 injuries over 10 years to over 18 over 10 years. The number of injuries prevented by high protection infrastructure would number nearly 153 over a 10 year period (see Table 6 and Figure 5A).

Burden for bicyclist fatalities were also calculated for the above RR estimates and show similar patterns. Fatalities are rare in any scenario, but the reduction in fatalities becomes apparent if protected bicycling infrastructure remains in place for over 10 years. High protection cycle tracks are estimated to prevent ~1 fatality over 10 years. However, it is important to note that ridership along Bloor-Danforth may change over this time. This could result in more prevented injuries and fatalities (see Table 6, Figure 5A and 5B).

As mentioned in Section 4.1 there may be more bicyclists on Toronto roads during and following the COVID-19 pandemic, as more people turn to bicycling instead of public transportation. The effect of injury or fatality burden can be seen in Tables 6 and 7 "Increased Ridership" estimates. However, one may notice increased ridership does not increase injury or fatality burden at a proportional rate. For instance, 50% more ridership does not increase injury burden by 50%, due to the safety-in-numbers effect (18). At baseline, a 50% increase in ridership would suggest over 204 injuries occur every 10 years along Bloor-Danforth. Once adjusted for installation of high or lower protection infrastructure, injury burden would range from 22/10 years (high protection) to 126/10 years (lower protection 1), and burden of fatalities would span from 0.13/10 years to 0.75/10 years. Benefits of infrastructure accrue over time. For instance, in a scenario where ridership rose by 50% ridership over 10 years, high protection cycle tracks would prevent 182 injuries and ~1 fatality. Conversely, lower protection cycle tracks would prevent over 77 injuries and 0.4 fatalities. Lower protection bike lanes would prevent 94 injuries and 0.5 fatalities.

Table 5: *Estimated injury and fatality* ***burden*** *along Bloor-Danforth, with and without installation of safer bicycling infrastructure over 10 years. These estimates are visualized in Figure 4.*

10 Year Injury Burden				
Ridership Projection	**Baseline**	**High Protection***	**Lower protection 1****	**Lower protection 2*****
Current Ridership	171.8	18.9	106.5	92.8
Increased Ridership -10%	179.0	19.7	111.0	96.7
Increased Ridership - 25%	189.1	20.8	117.2	102.1
Increased Ridership - 33%	194.2	21.4	120.4	104.9
Increased Ridership - 50%	204.5	22.5	126.8	110.4
10 Year Fatality Burden				
Ridership Projection	**Baseline**	**High Protection***	**Lower protection 1****	**Lower protection 2*****
Current Ridership	1.0	0.1	0.6	0.5
Increased Ridership -10%	1.1	0.1	0.7	0.6
Increased Ridership - 25%	1.1	0.1	0.7	0.6
Increased Ridership - 33%	1.2	0.1	0.7	0.6
Increased Ridership - 50%	1.2	0.1	0.8	0.6

* Cycle tracks, per Teschke et al.
** Cycle tracks, per Ling et al.
*** Bike lanes, per Teschke et al.

Table 6: *Predicted injuries and fatalities* ***prevented*** *annually and over 10 years based on installation of safer bicycling infrastructure. These estimates are visualized in Figure 4.*

10 Year Injuries Prevented			
Ridership Projection	**High Protection***	**Lower protection 1****	**Lower protection 2*****
Current Ridership	152.9	65.3	79.0
Increased Ridership -10%	159.3	68.0	82.3
Increased Ridership - 25%	168.3	71.9	87.0
Increased Ridership - 33%	172.9	73.8	89.3
Increased Ridership - 50%	182.0	77.7	94.1
10-Year Fatalities Prevented			
Ridership Projection	**High Protection***	**Lower protection 1****	**Lower protection 2*****
Current Ridership	0.9	0.4	0.5
Increased Ridership -10%	1.0	0.4	0.5
Increased Ridership - 25%	1.0	0.4	0.5
Increased Ridership - 33%	1.0	0.4	0.5
Increased Ridership - 50%	1.1	0.5	0.6

* Cycle tracks, per Teschke et al.
** Cycle tracks, per Ling et al.
*** Bike lanes, per Teschke et al.

6.0 Caveats and Limitations of Approach

The methods used here can be applied to other geographic areas. Our spreadsheet (Appendix 4) can be adjusted to fit local data. Because we used a simplified, city-wide estimate of injury risk, this same estimate can be used at other locations. However, ours was a high-level analysis, and there are several limitations that need to be acknowledged when interpreting our results.

This project is focused on a single location/corridor – the choice of location for analysis may influence results and data availability. Our focus on Bloor-Danforth was determined in 2019 after discussion with stakeholders including community groups and City officials. The corridor was considered to be a primary target for intervention – an accurate assessment given its selection for street reallocation intervention during COVID-19 response. Although manual count data collection was interrupted due to COVID-19 restrictions, secondary data (City of Toronto count station data) was available because this had been an existing corridor of interest. Future analyses might rely even more heavily on primary data collection if the locations do not have existing automated count programs.

Choice of location priorities for interventions for community members, planners, transportation engineers, policy-makers and activists is a complex and organic process beyond the scope of this limited analysis. However, it is recommended that future prioritizations give prominence to equity considerations (36, 37) in addition to considerations of existing ridership, safety, connectedness, and accessibility.

We only included in our analysis segments of Bloor-Danforth without bicycling-specific infrastructure at the start of the study. If our results are used to assess the benefit of the latest infrastructural improvements, they may underestimate injuries prevented. The excluded sections of Bloor with existing infrastructure will likely experience reduced risk from a safety in numbers effect and from direct infrastructural improvements on these segments (e.g. more complete physical separation). As such, we think this is a conservative bias.

In our risk calculations **we applied an estimate of injury risk across the City of Toronto** to estimate the baseline number of injuries along the Bloor-Danforth. In reality, crash/injury risk is heterogenous over space and time, and injury risk along the Bloor-Danforth corridor will likely differ from city-wide risk. Baseline injury risk may itself be affected by changes in infrastructure, addition of new users, or changes in motor vehicle volumes and speed. A changing population of bicyclists may also affect baseline risk city-wide. Greater attention to equity, connectedness of infrastructure networks and could have positive effects on trends in baseline injury risk, which could complement the simplified risk reduction of physical separation assumed in our analysis.

For the numerator of our injury risk calculation, we were concerned about bicyclist injuries not reported to police. These could include bicyclists crashes not directly involving a motor vehicle (these are not required to be police-reported) and any crashes the parties involved did not contact police to report, and any attempted reports police may have missed. To address injuries not recorded in police data, we **developed a correction factor based on the ratio of police-reported collisions to emergency department visits for the province of Ontario**. The proportion of hospital injuries captured by police data in Toronto may not be the same as the proportion across the entire province compiled by the Ministry of Transportation of Ontario (MTO), because MTO compiles and reports a range of collision severity and not only those collisions deemed "serious". Unfortunately, Toronto-specific hospital injury data are not available publicly to derive a Toronto-specific calculation. The emergency department visit data we used does not include crashes and injuries that resulted in minor injuries that did not require a trip to hospital, but includes bicycling injuries that occur in non-transportation contexts (e.g. injuries to mountain bikers) and may include some injury events that required multiple emergency department visits. The extent to which non-transportation-based bicycling injuries occur is not yet known (separate research is being conducted on this question by members of our team), but is expected to be small relative to the minor injuries uncaptured in the data used here that don't require any hospital treatment (38).

Related to the denominator of injury risk calculation, there is some uncertainty in our estimates of person-kilometres travelled within the city of Toronto, which relied on a simplified combination of CCHS and TTS data. Combining data from these surveys invites some concern, as TTS data reflects interviews from the GGHA and data from the CCHS was filtered to include respondents within Toronto's PHU.

Our estimates of bicycling volume along the Bloor-Danforth corridor rely on multiple layers of assumptions. In particular we assumed that: (i) our observed twenty minute counts are constant for the hour in which they were conducted; (ii) diurnal patterns we quantified from hourly bicycling volumes data at nearby City operated counters apply to the locations we observed; (iii) annual patterns we quantified from daily bicycling volumes data at nearby City operated counters apply to the locations we observed.

We used a simplified method of accounting for "safety-in-numbers", wherein increased rider volume is assumed to confer protective benefits (34). We note that the before-after design used by Ling et al. (5), and the resulting measure of association (OR) considered a safety-in-numbers benefit because the "after" comparison scenario includes attracted volume. We think including the accounting method therefore is a conservative bias on our estimates of injuries prevented under this scenario.

We used odds ratios estimated in two reference studies (5, 6) to estimate approximate relative risks. This entails an **assumption that relative risks and odds ratios will be similar** for these infrastructure designs. Epidemiologically, this assumption depends on the generalizability of the original study population and the overall incidence of the outcome (39). These assumptions can be addressed by our reliance on reference studies that collected data on Toronto cyclists and the low overall incidence of bicycling injury.

A more difficult to assess assumption **is whether Toronto cycle track designs deemed "protected" will hold the same protective effect as that observed in our reference stud**y (40). Given that effects of infrastructure can vary strongly by implementation and design (12), it will be crucial to monitor impacts and problems with any implemented protected designs. For example, we note that infrastructure can form an unintentional obstruction, as Teschke et al found with Vancouver traffic calming circles (6, 40). In Toronto, some infrastructure may form obstructions if it is easily dislodged or moved into bicycle lanes (e.g. moveable concrete wheel stops, flexi-posts or planters). Our reference studies also pre-dated the implementation of new parking orientations, with parked cars between moving motor vehicle lanes and bicycle lanes. We would encourage a new Toronto primary collection study using a case-crossover design to provide crucial data on the could local context of implementation.

This analysis **did not differentiate injuries that occur at intersections from injuries that occur at other road locations**. The definition of "intersection-related" crashes is complex. Police definitions of "intersection" and "mid-block" collisions may not incorporate a fine enough scale for bicycling injuries and over-estimate intersection-related crashes in high density networks with a high frequency of junctions. In an analysis of bicycling injuries presenting to Toronto and Vancouver emergency departments, Harris et al. (40) determined 211 of 690 injuries (~31%) to be "intersection related". The approximated relative risk used in this current analysis is based on an aggregate association that did not differentiate between intersection and non-intersection injuries (6). This previous case-crossover analysis did not note statistically significant protective associations with intersection designs, but the study was limited to observing intersection designs already implemented in the study cities, which did not include bicycling-protected designs (40). For full protective and injury prevention benefits of infrastructure, separated designs are needed at intersections along the study route (41, 42).

Lastly, we acknowledge that **this analysis is limited to a narrow construction of "safety" as prevention of bicycling injuries and fatalities**. Separated bicycling infrastructure may confer injury prevention benefits to other road users including motor vehicle occupants (e.g. if speed is reduced) and pedestrians (through additional separations). But we recognize that injury prevention is not the only definition of safety. Concepts of bicycling safety can be framed by personal experiences, including harassment and violence other than traffic violence, particularly as experienced by marginalized and racialized people (43). This report is limited in its ability to assess equity around use of the selected corridor and the full range of safety concepts. A holistic and comprehensive construction of safety and experiences of the diverse community is needed to ensure infrastructure is designed, implemented, enforced and evaluated appropriately.

7.0 Key Conclusions

The number of bicyclist injuries prevented depends on infrastructure implementation. If full separation is implemented throughout the route, with physical barriers, the resulting protective effect is stronger than more permeable designs.

The number of bicyclist injuries prevented depends on unobstructed routes. For example, any closure of lanes for construction imposes increase risk. Obstructions in general increase risk and will reduce the number of injuries prevented from the projections here. Attention should be paid to potential for infrastructure to become obstructions (e.g. through damage or motor vehicle collision) to the dedicated bicyclist space.

The number of bicyclist injuries prevented depends on permanency of infrastructure. We showed the effect of infrastructure over time periods of 10 years. One of the most important public health benefits of infrastructure interventions is that they provide passive protection that accrues over time. A crucial concern on removal of "temporary" infrastructure is a "bait and switch effect" wherein new users are attracted to bicycling on the route and the burden of injury is actually increased from pre-implementation when the protective infrastructure is removed. Permanent infrastructure will ensure injury prevention benefits accrue over time.

The number of bicyclist injuries prevented depends on bicycle volumes. We estimated "current" or pre-pandemic volumes. However, we also examined the impact of increased volume of bicycles due to mid and post-pandemic reluctance to use public transit, and attraction to installed infrastructure. More users will mean more injuries prevented. More users can also lead to a safety in numbers effect, preventing an even greater number of injuries.

The number of bicyclist injuries prevented depends on baseline risk of injury. We calculated a broad estimate of baseline risk of injury for Toronto bicyclists per kilometre traveled. We discussed the limitations of data inputs to this calculation. Having the best possible data inputs to accurately characterize injury risk to Toronto bicyclists will be crucial for tracking the overall safety benefits of the collection of safer infrastructure initiatives.

Changes in baseline risk of bicycling injury will affect the accuracy of predictions. Systemic trends may affect baseline risk for cyclists. For instance, if overall motor vehicle volumes decline, or speeds are reduced, baseline risk will be affected. Similarly, during the projection time window, impacts including changing population of riders, equity considerations in where infrastructure is implemented, connectedness/disconnectedness of infrastructure could affect baseline and local injury risks.

The number of bicyclist injuries prevented depends on intersection design. Our simplified projections are based primarily on the effect of infrastructure on non-intersection locations. For full safety benefits, protected intersection designs will be required.

Accurate projections require better data. Methods of assessing implementation should consider under-reporting of bicyclist injuries in police data. Along with local data collection on target routes, two particular suggestions are to incorporating health care utilization data to capture injury more sensitively, routine collection of all-mode volume counts, and a new population-wide travel survey.

7.1 Future Directions

The injury burden algorithm can be applied to other areas of Toronto and other cities. Our algorithm could be adapted to estimate injury burden along other routes in Toronto. Use of the algorithm will be more straightforward for routes with complete volume counts (see data collection expansion below). Relative risk estimates could be customized for use in other cities if data are available on the protective effects of local infrastructure implementations.

Routine collection and reporting of relevant data is needed. As discussed above, we relied on a variety of data sources to approximate numerators and denominators of risk. For numerator (injury count data), routine collection and reporting of injury data - beyond that reported to police - is recommended. Health care utilization data is an important addition, and this should be supplemented by standardized injury surveys conducted at regular intervals to capture otherwise unreported injuries. For denominator data, we recommended expanded locations of volume count data collection more detailed demographic data for all modes of transportation. For example, City of Toronto focuses bicyclist counts on routes with existing bicycling infrastructure (or locations targeted for expansion). Volume counts throughout the city are needed. Automated counts do not entail demographic detail, so these could be supplemented with with manual counts, including those made with video footage (44) to enable a visual assessment of gender and age mix. Finally, to enable comparison and consistent data (for example on exposure to risk, volumes and km travelled and a range of sociodemographic characteristics) between cities and regions in Canada, we recommend the adoption of a national trip diary travel survey, comparable to those conducted in U.S., U.K. and E.U. (45).

8.0 List of Figures, Tables and Appendices

9.0 Figures

Tables (in-text)

11.0 Supplemental appendices

  - Figure 4: Annual pattern in daily bicycling volumes by direction of travel
  - Figure 5: Estimated daily bicycling volumes by day of year for each location and direction of travel. Points represent the estimated daily count derived from observed data, while the line represents the estimated volume based on annual patterns in daily bicycling from City of Toronto counters.
- Appendix 4: Injury Burden Spreadsheet

9.0 Figures

Figure 1

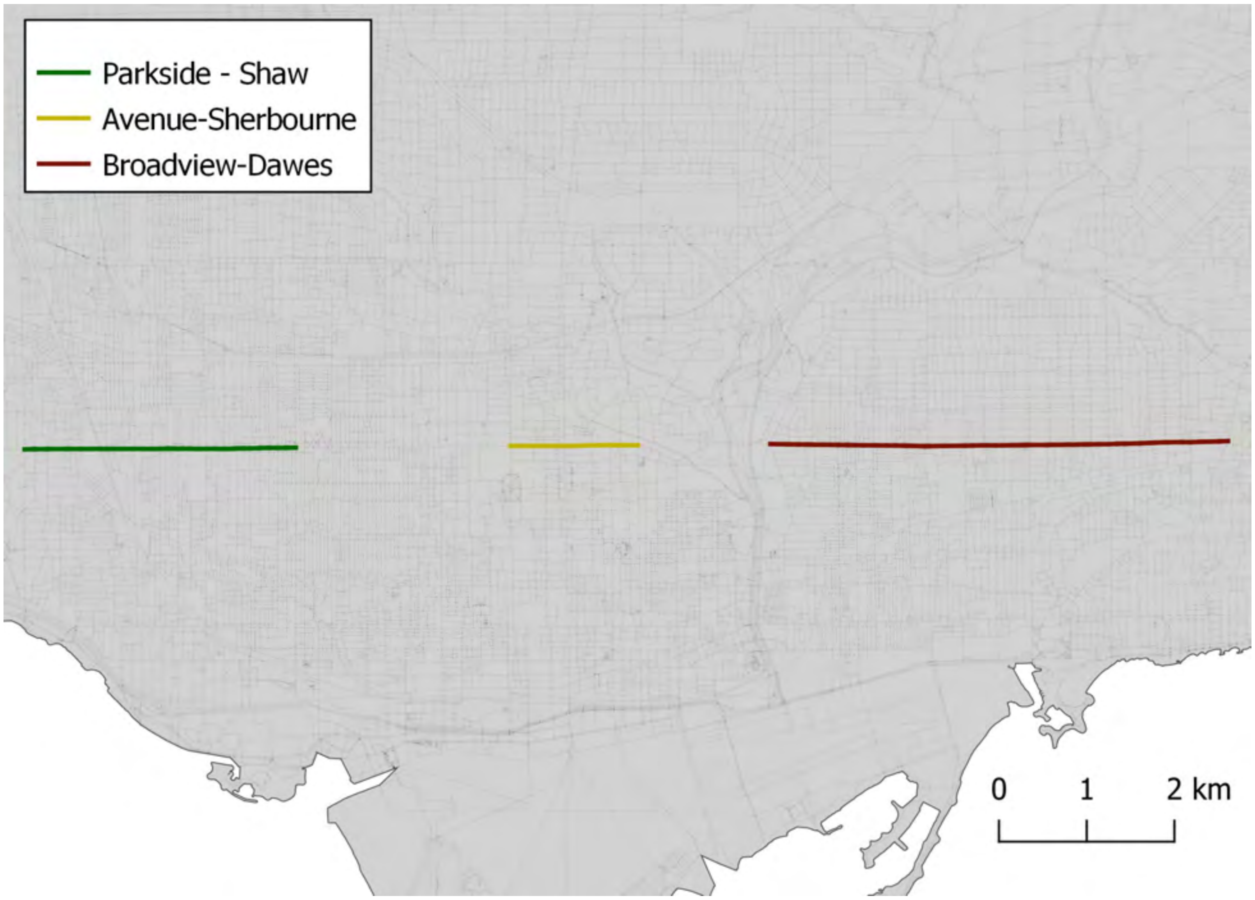

Figure 1: *Study area (Bloor-Danforth) with included street segments (Parkside-Shaw, Avenue-Sherbourne, Broadview-Dawes) highlighted. Manual counts were conducted at the endpoints of each segment. For a more detailed map, please see accompanying CBI public-facing summary report.*

Figure 2

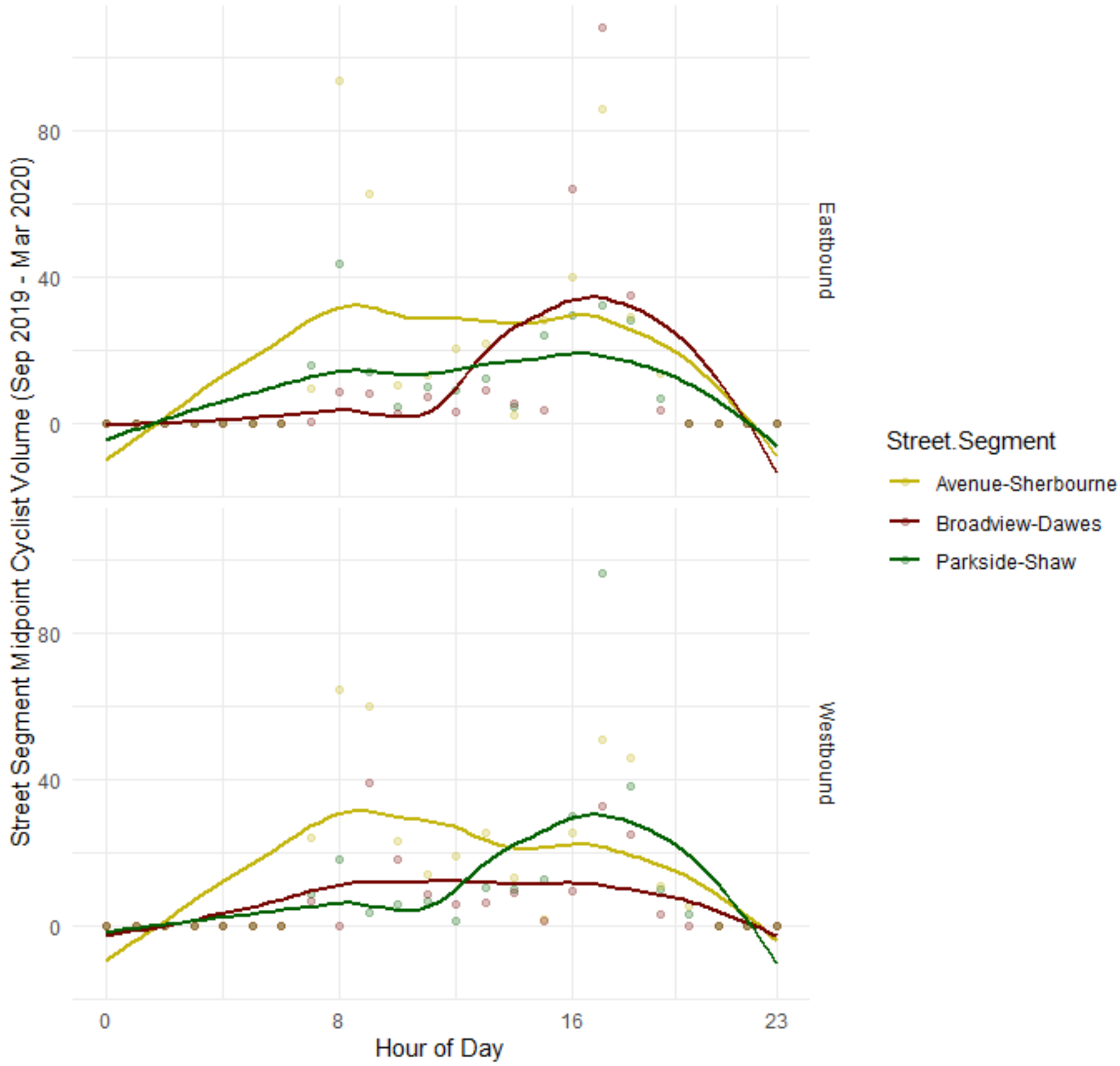

Figure 2: *RA observed bicycle count (points) by cross-streets along our study area of interest over 24-hours. A regression line has been fitted to estimate bicyclist traffic over a 24-hour period. Bicyclist volume was collected between September 2019 and March 2020.*

Figure 3

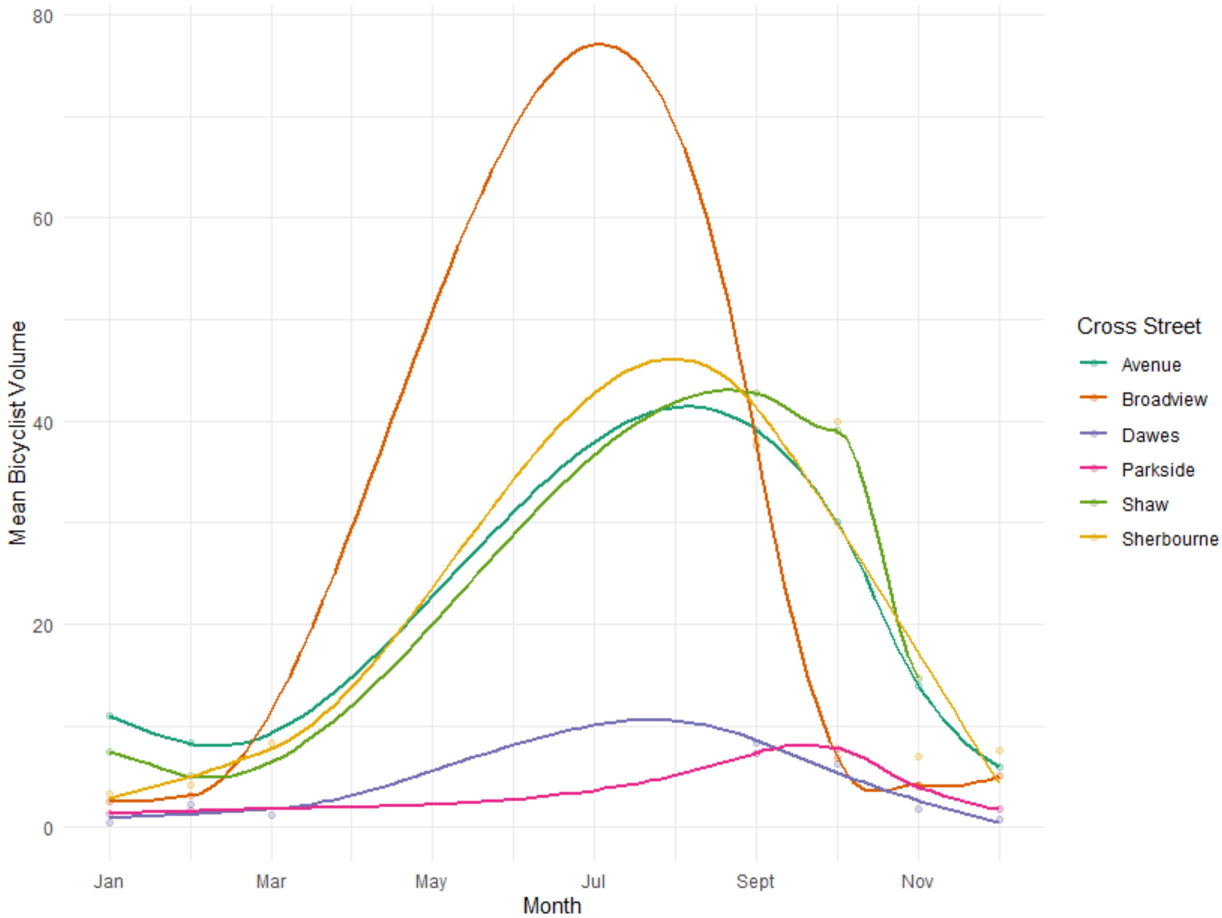

Figure 3: *RA observed mean bicyclist count by cross-street from September 2019 to March 2020. Data has been fitted with a LOESS smoother to show bicyclist volume over one year. Data after March 13, 2020 was predicted by the smoother to account for missing data from the COVID-19 pandemic. Mean bicyclist volume is derived from the total number of bicyclists divided by the number of observations in each month.*

Figure 4

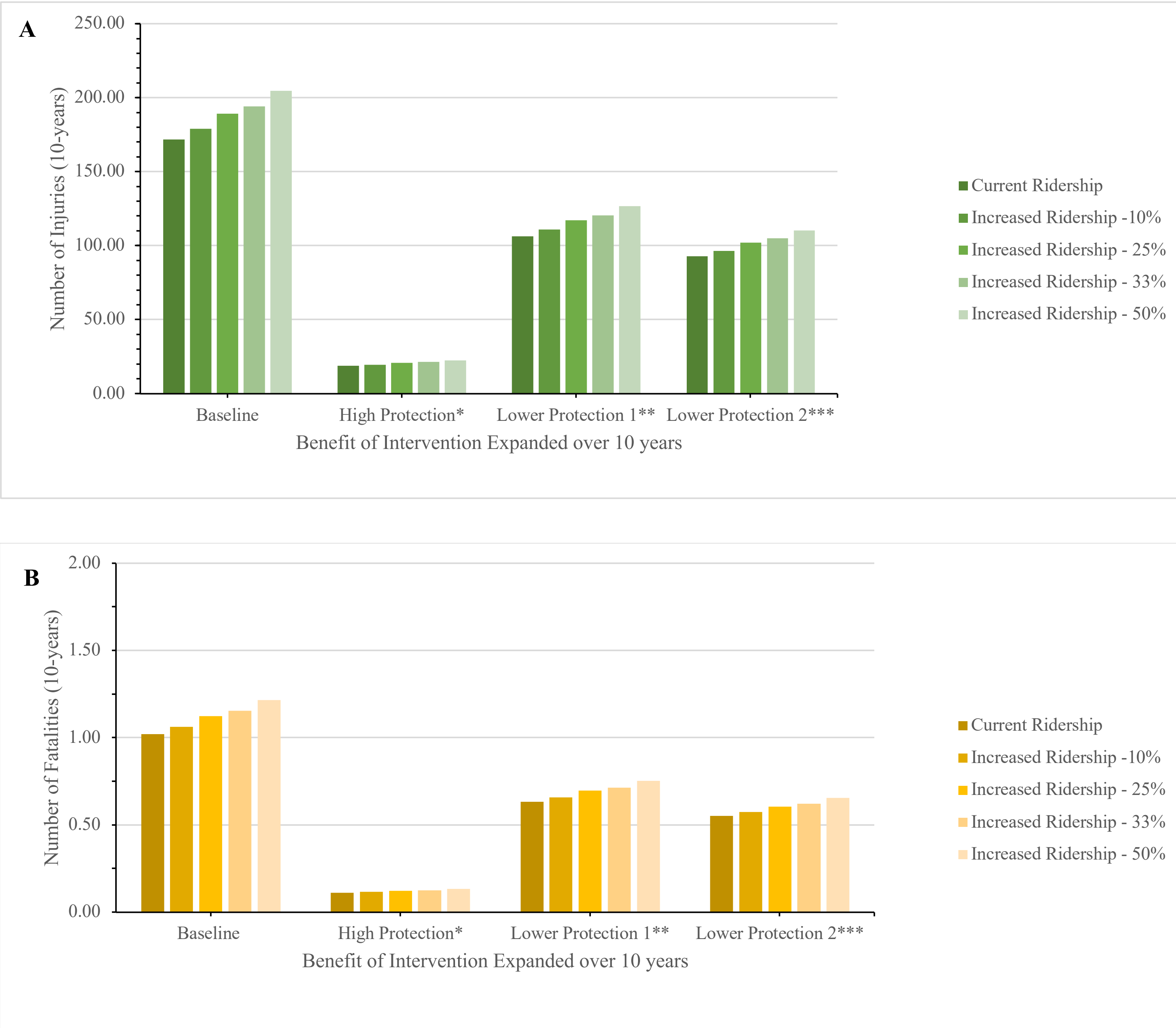

Figure 4: *A) Injury burden along Bloor-Danforth with and without ("baseline") the effect of safer bicycling infrastructure. B) Fatality burden along Bloor-Danforth with and without ("baseline") the effect of safer bicycling infrastructure. Results are summarized over 10 years to show the effect of permanently installed infrastructure on injury or fatality burden.*

*Cycle tracks taken from Teschke et al.
**Cycle tracks taken from Ling et al.
*** Bike lanes taken from Teschke et al.

Figure 5

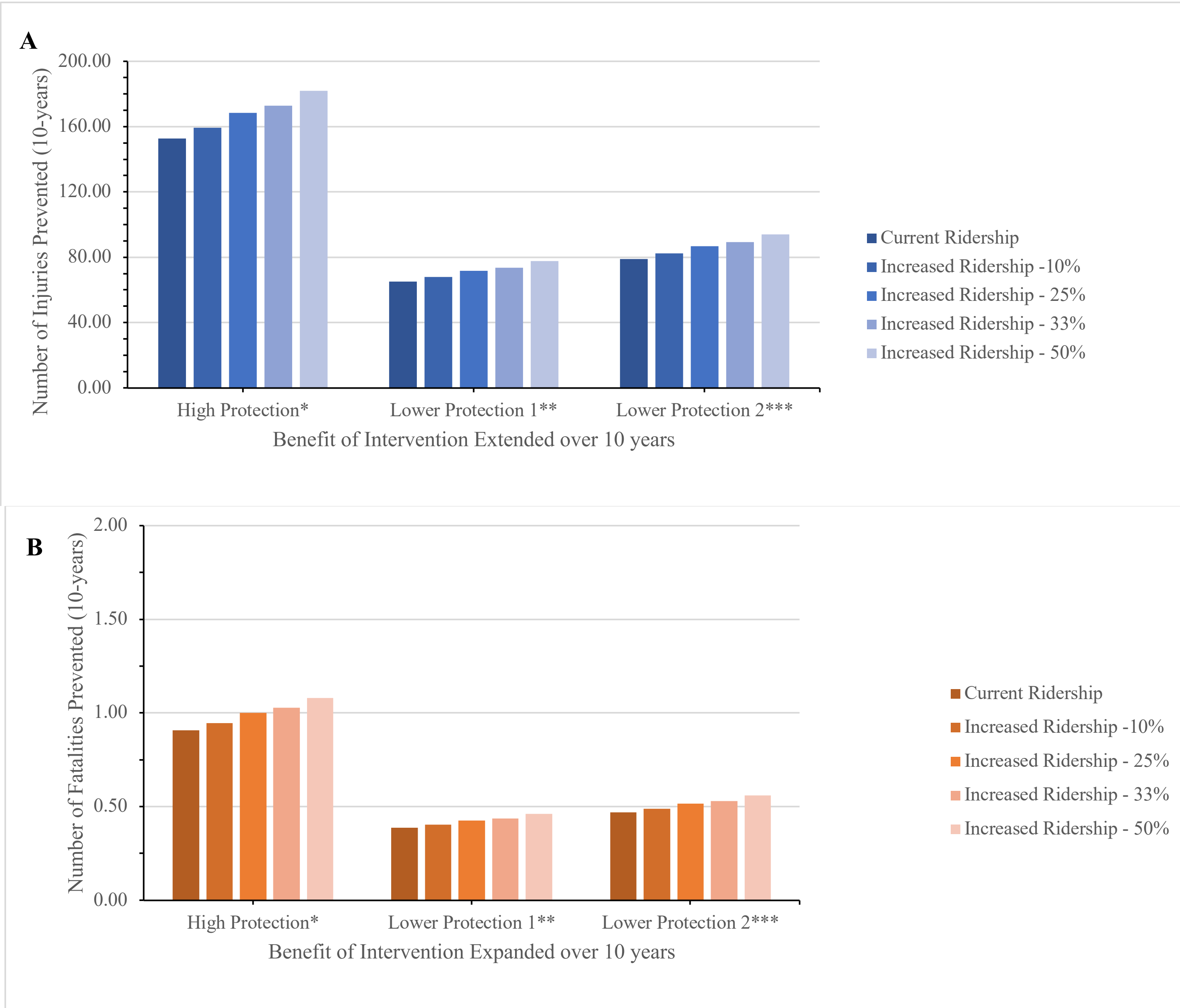

Figure 5: *A) Injuries prevented over 10 years by installing safer bicycling infrastructure across Bloor-Danforth. B) prevented over 10 years by installing safer bicycling infrastructure across Bloor-Danforth.*

*Cycle tracks taken from Teschke et al.
**Cycle tracks taken from Ling et al.
*** Bike lanes taken from Teschke et al.

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11.0 Supplemental appendices

Appendix 1

Appendix 1: *Summary of reviewed literature study characteristics.*

Author	Title/Year/Country	Population/Exposure	Outcome	Study Design	Method Details	Results
Bhatia et al.	Examining the impact of cycle lanes on bicyclist-motor vehicle collisions in the city of Toronto/2016/Canada	Bicyclist motor vehicle collisions (N = 23,959) reported between January 1, 1991 and December 31, 2010. Exposed to bicycling pre- and post-implementation of painted cycle lanes in Toronto.	Injury severity and collisions frequency.	Before-After	Before-After analysis to compare observed changes in collision frequency, and injury frequency stratified by severity. Lane segments were defined as those where a cycle lane was painted on the road between 1991 and 2010. Collisions and injury severity data were taken from Toronto Police Service dataset. Analyses were conducted using a zero-inflated Poisson model. Results are reported for incidence rate ratios (IRR) for each segment-month. No further adjustments were made for bicyclist volume pre- or post-implementation.	Aggregated results showed a statistically insignificant reduction in collision frequency (IRR = 0.82, 95%CI = 0.65, 1.03). Similar non-significant reductions were noted for minimal/minor injuries (IRR = 0.84, 95%CI = 0.58, 1.20) and major/fatal injuries (IRR = 0.72, 95%CI = 0.51, 1.01). However, an increase was noted in collisions without injury (IRR = 5, 95%CI = 1.44, 17.28).
Cicchino et al.	Not all protected bike lanes are the same: Infrastructure and risk of bicyclist collisions and falls leading to emergency department visits in three U.S. cities/2020/USA	604 emergency department patients who had crashed or fallen while bicycling. Exposure was riding along routes with bicycle facilities (cycle lanes, cycle tracks, sharrows), or other route types (e.g. sidewalk, local road with traffic calming).	Crash or fall	Case-crossover	Case-crossover analysis means each participant acts as their own control. Crash sites are considered the case and are matched to a randomly selected control location along the same route. Participants were recruited between 2015-2017 from emergency department visits in Washington D.C., New York City, and Portland. Site characteristics were described by participants and confirmed by Google Street View and city data. Results were adjusted for confounders (route type, grade, temporary features, streetcar/train tracks). Cycle tracks were stratified by lane size (one-way or two-way) and degree of separation (light or heavy).	After adjustment for covariates, cycle lanes (OR = 0.53, 95%CI = 0.33, 0.86) and sharrows (OR = 0.57, 95%CI = 0.23, 1.43) were found to decrease probability of a crash or fall. However, sharrows were not found to reduce the odds of a collision or fall at a statistically significant level. Only one-way cycle tracks with heavy separation from the street were found to reduce the odds of crashing (OR = 0.10, 95%CI = 0.01, 0.95). One-way cycle tracks with light separation (OR = 1.19, 95%CI = 0.46, 3.10) and two-way cycle tracks with light separation (OR = 11.38, 95%CI = 1.40, 92.57) were both found to increase odds of fall or crash. Though only two-way cycle tracks were associated with statistically significant rise in odds.
Ling et al. [*]	**Bicyclist-motor vehicle collisions before and after implementation of cycle tracks in Toronto, Canada/2020/Canada**	**Collisions were taken from the Toronto Police Service Killed or Seriously Injured dataset between 2000 and 2016. Exposure was bicycling volumes on**	**Collisions.**	**Before-After**	**Before-after comparisons were conducted by examining collisions 2-years pre- and 2-years post-cycle track implementation. Zero-Inflated Poisson regression was used to model incidence rates. Bicyclist volume was accounted for in adjusted results.**	**Analyses were presented for crude results and adjusted results. Adjusted results considered bicyclist volume. While crude results indicated non-statistically significant rise in collisions (IRR = 2.06, 95%CI = 0.51, 2.81), adjusted results taking into account volume, showed the**

		streets with cycle tracks and routes without.				**opposite relationship (aIRR = 0.62, 95%CI = 0.44, 0.89).**
Lusk et al.	Risk of injury for bicycling on cycle tracks versus in the street/2011/Canada	Injuries and crashes recorded from emergency medical response database and police recorded vehicle-bicycle crashes. Exposure was bicycling volume along routes with and without cycle tracks.	Injury risk.	Case-control	Relative risk was determined from the Poisson distribution of incidents. Injury and crash rates were obtained from hospital data and police recorded data. Bicycle counts were conducted from 24-hour bicycle count stations between May and September. Average daily use was converted to annual by multiplying daily counts by 200 bicycling days, as cycle tracks are open April – November. Reference streets bicyclist volume was estimated by taking a ratio of 2-hour bicyclist counts on reference streets to cycle track streets. Linear interpolation was used to determine average daily volume.	Overall results found a significant reduction in injury risk for cycle tracks compared to similar on-street routes (RR = 0.72, 95%CI = 0.60, 0.85).
Romanow et al.	Environmental determinants of bicycling injuries in Alberta, Canada/2012/Canada	Cases were bicyclists struck by a motor vehicle or with severe injuries requiring hospitalization (N = 76). Controls were selected from the same emergency departments and matched for each case (N = 240). Exposure was to a variety of environmental characteristics.	Motor vehicle crash or severe injury.	Case-control	Conditional logistic regression was used to examine the effect of exposure on risk of crash or injury severity. Cases and controls were matched individually based on time of day and day of the week. These were determined two weeks prior to or following the case event. Each case was matched to 3 controls; however, motor vehicle cases with severe injuries were matched with 6 controls. These were 3 motor vehicle controls, and 3 minor injury cases.	Cycle lanes were not associated with a statistically significant reduction in bicyclist motor vehicle collisions (OR = 0.64, 95%CI = 0.10, 4.19).
Schepers et al.	Road factors and bicycle-motor vehicle crashes at unsignalized priority intersections/2011/Netherlands	540 unsignalized intersections were observed with 339 bicycle-motor vehicle crashes. Exposure was the various forms of infrastructure and route conditions.	Crash risk.	Correlational: Infrastructure	This study used a negative binomial regression model to compare the effect of road design on number of crashes. Two models were created, one for crashes where the bicyclist has the right-of-way and one where motorists have the right-of-way.	Results presented are from the two most relevant outcomes. First, two-way cycle tracks were compared to one-way cycle tracks. The authors found a statistically significant increase in odds of crashing on two-way cycle tracks (OR = 1.75, 95%CI = 1.01, 3.03). Second, cycle tracks were compared to cycle lanes. Cycle tracks were found to reduce the odds of crashing (OR = 0.65, 95%CI = 0.28, 1.51) but this was not a statistically significant result.
Teschke et al. *	**Route infrastructure and the risk of injuries to bicyclists: a case-crossover study/2012/Canada**	**690 bicyclists who were admitted to one of five hospital emergency departments in Toronto/Vancouver.**	**Collisions.**	**Case-crossover**	**Logistic regression was used for this study. Cases where adult bicyclists who were injured during a bicycle ride and treated within 24-hours at hospitals in Toronto/Vancouver between May 2008**	**Results are broken down into three strata: major street with parked cars, major street without parked cars, and off-street routes. For a major street route, with parked cars, cycle lanes (aOR = 0.69, 95%CI = 0.32, 1.48) and**

		Exposure was route types and infrastructure type.			**and November 2009. Control sites were along the crash route but were randomly selected by multiplying a randomly generated proportion of the trip distance and then tracing the distance along the route.**	**sharrows (aOR = 0.71, 95%CI = 0.21, 2.45) were associated with a non-significant decrease in crash probability. Similar results were noted for cycle lanes (aOR = 0.54, 95%CI = 0.29, 1.01) and sharrows (aOR = 0.60, 95%CI = 0.21, 1.72) on major street routes without parked cars. Cycle tracks were only noted for off-street routes, as they are physically separated from the actual street route. Cycle tracks were noted to have a statistically significant decrease in risk of collision (aOR = 0.11, 95%CI = 0.02, 0.54).**
Wall et al.	The effect of sharrows, painted bicycle lanes and physically protected paths on the severity of bicycle injuries caused by motor vehicles/2016/USA	839 injured bicyclists involved in a bicycle-motor vehicle collision. Annual daily traffic and infrastructure were considered exposures.	Injury severity.	Cross-sectional	This study used multivariable logistic regression. Participants were enrolled from the Bellevue Hospital in NYC between December 2008 and August 2014. Crash data was obtained using patient interviews, interviews with EMS, police and witnesses to corroborate. Injury severity was measured using the Injury Severity Score (ISS). The ISS was dichotomized into none or mild injuries (score 0-8) versus moderate, severe or critical injuries (score >8). Bicyclist volume was estimated using pedestrian foot traffic.	Results are reported from the adjusted logistic regression model. Wall et al. found sharrows (aOR = 1.94, 95%CI = 0.91, 4.15), cycle lanes (aOR = 1.52, 95%CI = 0.85, 2.71), and cycle tracks (aOR = 1.66, 95%CI = 0.85, 3.22) were all associated with a statistically insignificant increase in collision risk.
Williams et al.	Spatial characteristics of bicycle–motor vehicle crashes in Christchurch, New Zealand: A case-control approach/2014/New Zealand	785 reported crashes between 2003 and 2009 in New Zealand's Crash Analysis System. Matched to 3140 controls, which were randomly placed along the bicycling routes. Exposed to bicycling and a variety of route characteristics and infrastructure.	Crash	Case-control	Logistic regression was used to model crash risk. Four models were created. The first used routes with highest bicyclist fatalities; the second used streets with <10,000 vehicles/day; the third used the most direct routes; and the fourth model used the quickest routes.	Cycle lanes were noted with a significant decrease in risk of collision in model 1 (OR = 0.57, 95%CI = 0.43, 0.75), in model 2 (OR = 0.44, 95%CI = 0.33, 0.59), in model 3 (OR = 0.33, 95%CI = 0.26, 0.43), and in model 4 (OR = 0.29, 95%CI = 0.22, 0.39). While cycle tracks were included in each model analysis results were not reported due to non-significant findings.

*Bolded studies were used to estimate relative risk of infrastructure.

Appendix 2

Appendix 2: *Standardized form provided to Research Assistant to count bicyclist volume at cross-streets (Parkside Dr., Shaw St., Avenue Rd., Sherbourne St., Broadview Ave., Dawes Rd.) along Bloor-Danforth corridor.*

Ryerson University

2019-20 Bicyclist Counts PI:
Dr. Anne Harris E:
anne.harris@ryerson.ca

OBSERVER NAME:

Date (YYYY-MM-DD): Photo from perspective of observation point • YES	**OBSERVATION START TIME:** **OBSERVATION END TIME:**
Location: (Street, cross-street) Direction of travel observed: ☐ Westbound ☐ Northbound ☐ Eastbound ☐ Southbound	Weather conditions ☐ Sunny, clear ☐ Cloudy, road dry ☐ Cloudy, road wet ☐ Rain ☐ Snow ☐ Fog TEMP (CELSIUS):
Sun rise/sunset *(can look up before or afterwards):* Sunrise time for date: Sunset time for date:	**Observed light conditions:** ☐ Dawn ☐ Daylight ☐ Dusk/twilight ☐ Dark

BICYCLIST TALLY

Men	Women	Unsure	Child Passengers

Post observation
Did you witness any of the following during this observation period?
Please check all that apply

- ☐ Obstruction of route, construction
- ☐ Bicyclist travelling opposite to traffic direction on that side (“salmoning”)
- ☐ Bicyclist on sidewalk
- ☐ Sudden braking of mv to avoid bicyclist
- ☐ Sudden braking of bicyclist to avoid mv
- ☐ Sudden braking of bicyclist to avoid ped
- ☐ Sudden stopping of ped to avoid bicyclist
- ☐ Near collision
- ☐ Near dooring
- ☐ Dooring
- ☐ Bicyclist Shouting
- ☐ MV driver shouting
- ☐ Pedestrian shouting
- ☐ Close pass (motor vehicle closely passes bicyclist)
- ☐ Sudden acceleration (e.g. squealing tires) in maneuvering around bicyclist
- ☐ Observed injury incident: bicyclist injured, continued on
  Observed injury incident: bicyclist injured, EMS/police contacted

Appendix 3, Figure 1

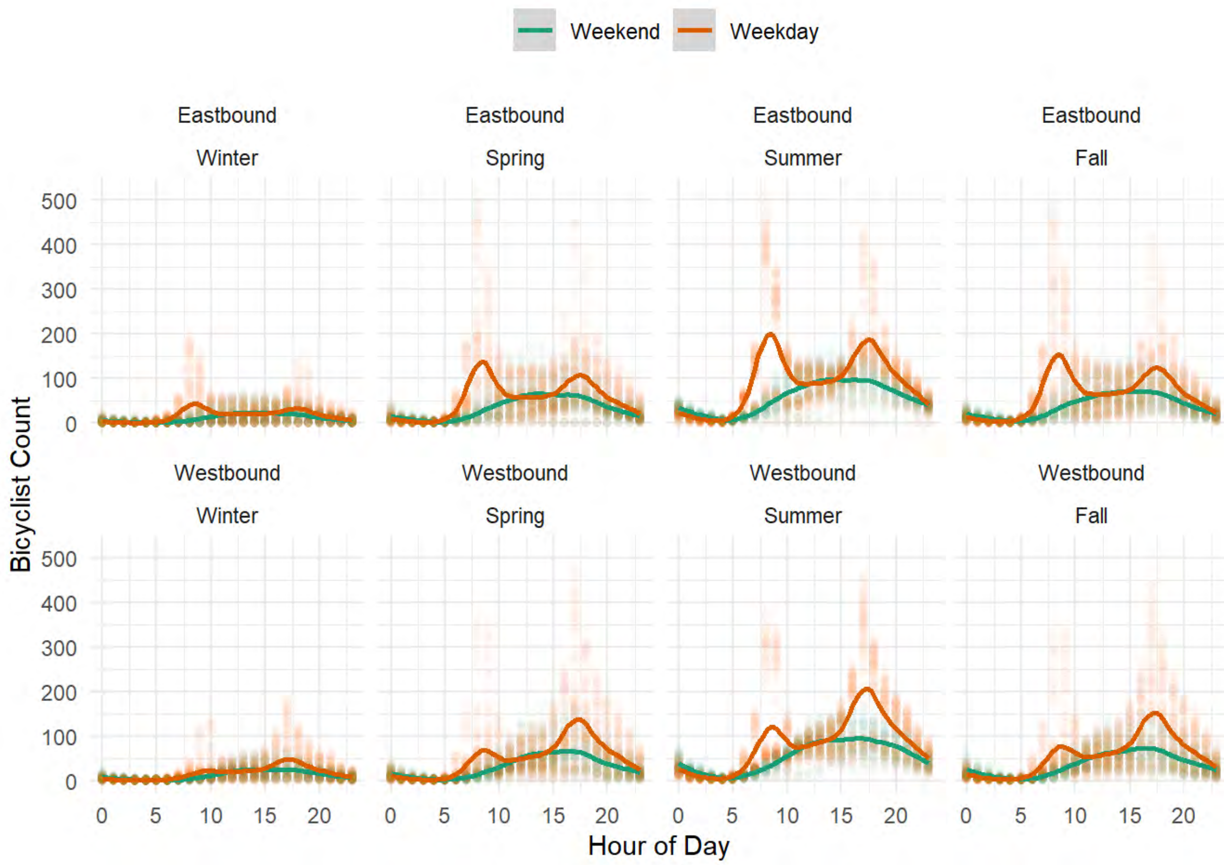

Figure 1: *Patterns in hourly bicycling volume on Bloor-Danforth by season, direction of travel and weekday. Data are from City of Toronto automatic counters between March 1, 2018 to February 28, 2019. Each smoothed line represents an "hourly curve" and were fitted with a LOESS smoother.*

Appendix 3, Figure 2

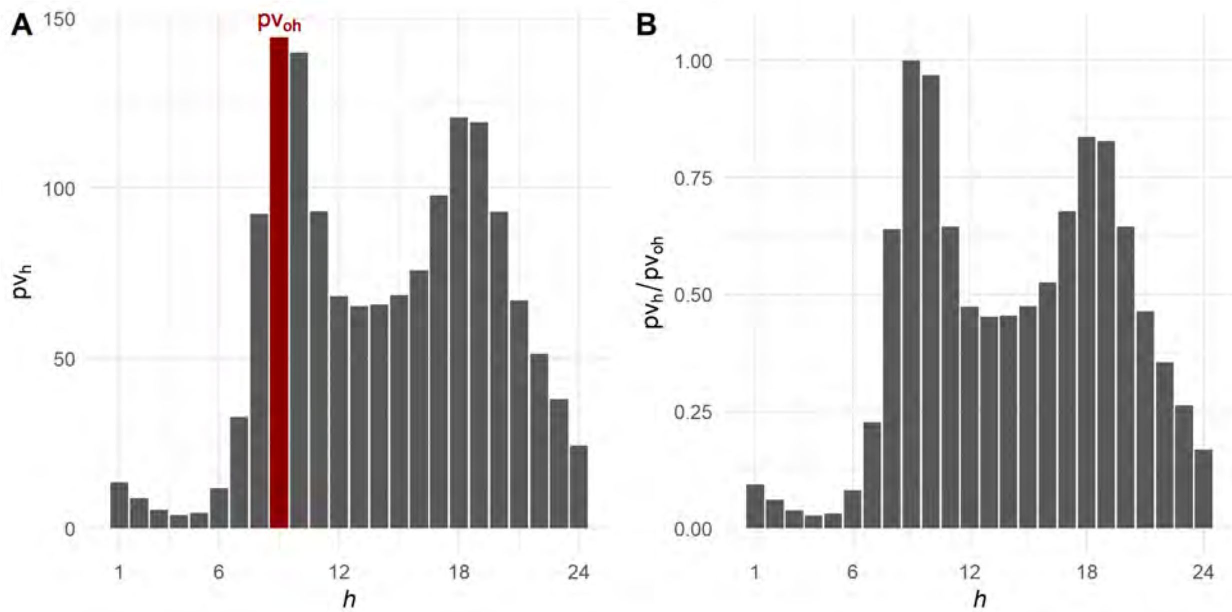

Figure 2: *A) Predicted volume of bicyclists at each hour (pv_h) for eastbound travel on a weekday in the Fall derived from the City of Toronto automatic counts over the course of one year. Here the red column represents the predicted volume of bicyclists during the hour in which we had observed manual counts (pv_{oh}). In this example we had observed counts between 8:00 and 9:00 AM B) Converting the predicted volume of bicyclist at each hour to change in hourly counts relative to the value of pv_{oh}. To obtain the expansion factor by which we can multiply our observed counts to estimate a total daily count, we sum the value of each column.*

Appendix 3, Figure 3

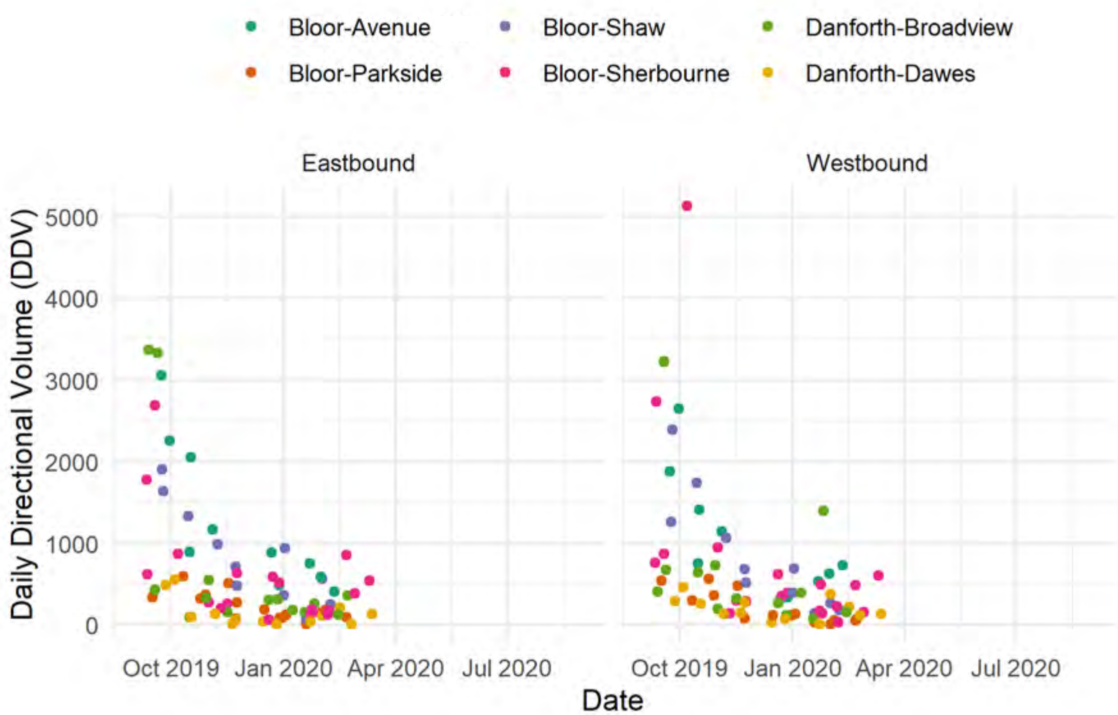

Figure 3: *Estimates of daily directional volume (DDV) for each location and date where field observations were made. These represent the estimated counts after manual counts during 20-minute observation windows were expanded to a daily count.*

Appendix 3, Figure 4

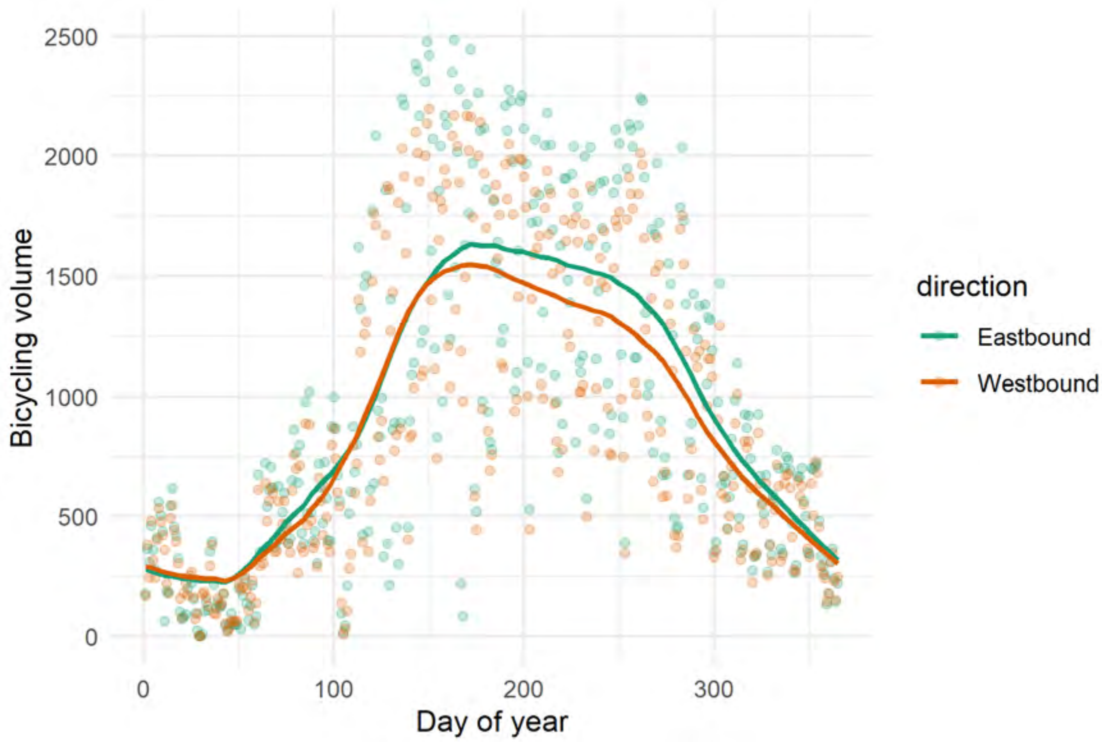

Figure 4: *Annual pattern in daily bicycling volumes (number of bicyclists) by direction of travel from City of Toronto automatic counter data between March 1, 2018 and March 1, 2019.*

Appendix 3, Figure 5

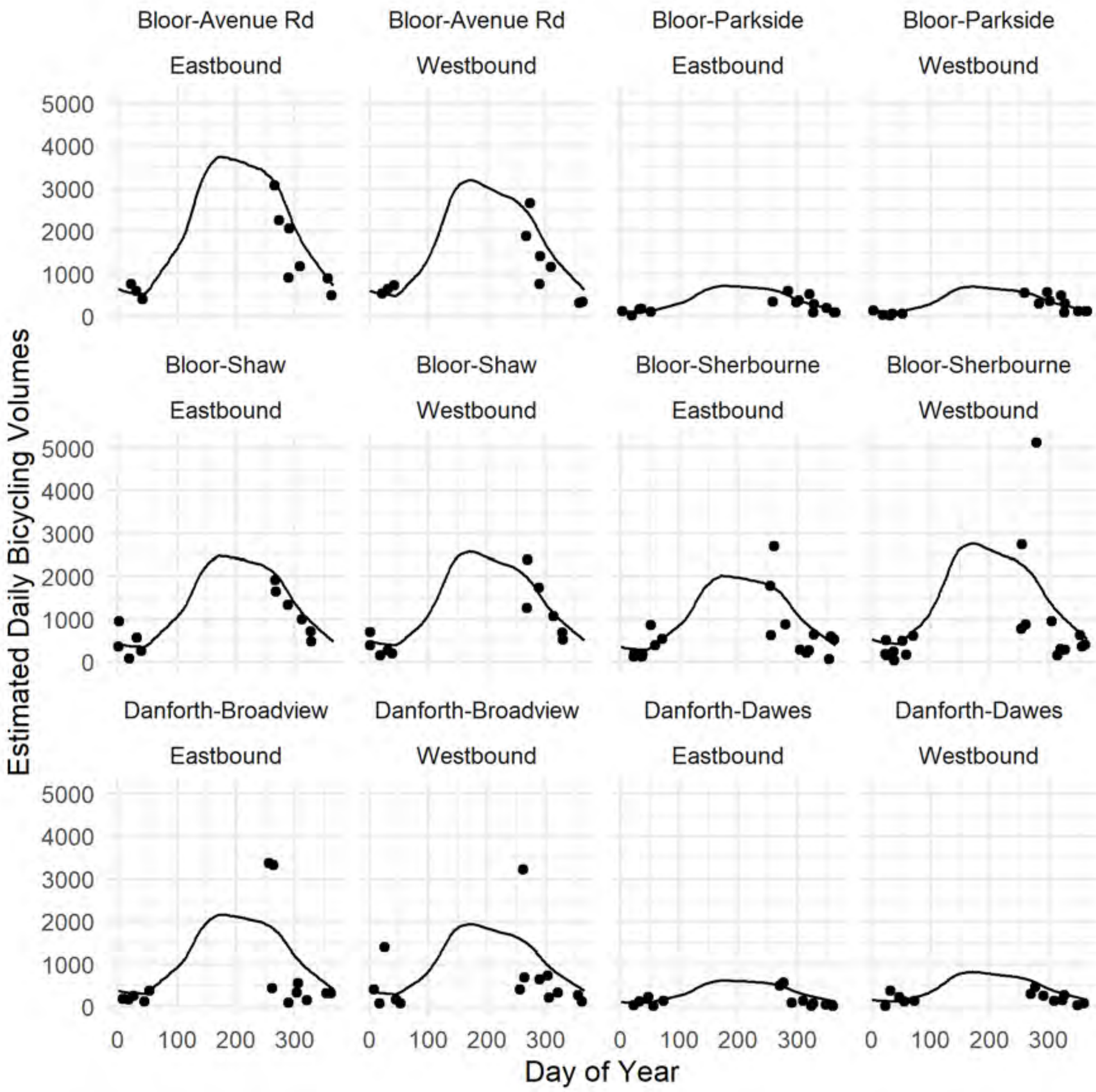

Figure 5: *Estimated daily bicycling volumes by day of year for each location and direction of travel. Points represent the estimated daily directional volume derived from observed data, while the line represents the estimated volume based on annual patterns in daily bicycling from City of Toronto counters.*

Appendix 4

See attached Excel spreadsheet "Appendix 4 Injury Burden Estimate.xlsx" to walk through the calculation steps. This implements the formula shown in 4.0 and enables manipulation of components. Spreadsheet can be downloaded from CBI webpage accompanying report.