

# Automated Biking Network Planning

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## Motivation

Improving safe cycling in a city has great **benefits** in **many areas**:

- motor traffic **congestion and emissions**, amount of parking needed;
- Our plan to reduce carbon emissions in Canada by *at least 0.1%*; [see Appendix]
- "The world's 280 million **electric bikes and mopeds** are cutting demand for oil far more than electric cars." [[theconversation.com](https://theconversation.com)]
- access to **workplaces** (and commerce, community, entertainment, etc.);
- **health** benefits (cardiovascular, metabolic, mental, etc.);
- economic impact on **commerce**;
- cycling **gender** parity and access for more vulnerable individuals (**children, elderly, ...**);
- **leisure** cycling, city beautification, tourism;
- **cargo** bike access for package delivery;
- Top leaders: [[Meghan Winters et al.](#)] [[Janette Sadik-Khan](#)].
- "Could Building Bike Lanes Become **America's Next** Big Infrastructure Project?" [[usa.streetblog.org](https://usa.streetblog.org)]
- "Bike lanes and trails aren't just small, local projects; they're key components of a **national effort to end climate change**."

## Bicycle Tracks

Our technology **plans the locations** of new bicycle tracks on the existing road and path network:

- Bicycle **tracks** have a **physical barrier** (concrete blocks, bollards/pylons, etc.) protecting cyclists from motor traffic.
- On the other hand, bicycle lanes are paint-only designated cycling paths.
- Our algorithm places new bicycle tracks onto streets, either upgrading a bike lane, or as new infrastructure. It may also propose to remove the dismount constraint on certain walking paths.
- Bicycle tracks found safer than on-street cycling [[A Lusk, P Furth, P Morency, L Miranda-Moreno, W Willett, J Dennerlein](#)] [[K Teschke, C Reynolds, F Ries, B Gouge, M Winters](#)].

## Cyclist Profile

Our analysis and planning of the cycling network require a model for the behaviour of the **typical cyclist**:

- Bicycle trips are calculated from all residential locations to all non-residential locations, using a **routing engine**.
- Maximum speed: **18 km/h**; maximum trip time: **30 minutes**; minimum: 10 minutes.
- Level of Traffic Stress (LTS)** applies a speed penalty that increases with **danger** level.
- Road **surface** type speed penalty based on [OSRM:bicycle.lua].
- Slope climbing** speed penalty based on [J Broach, J Dill, J Gliebe] [M Lowry, P Furth, T Hadden-Loh] [C Cooper].
- Speed penalties are NOT cumulative: rather, the worst penalty applies.
- Routing engine finds **fastest route**, thus avoiding poor biking conditions if an alternative route is available.
- "Four Types of Cyclists" [R Geller]

## Why Partner with Us?

A turn-key solution for biking network **analysis and planning** for your city.

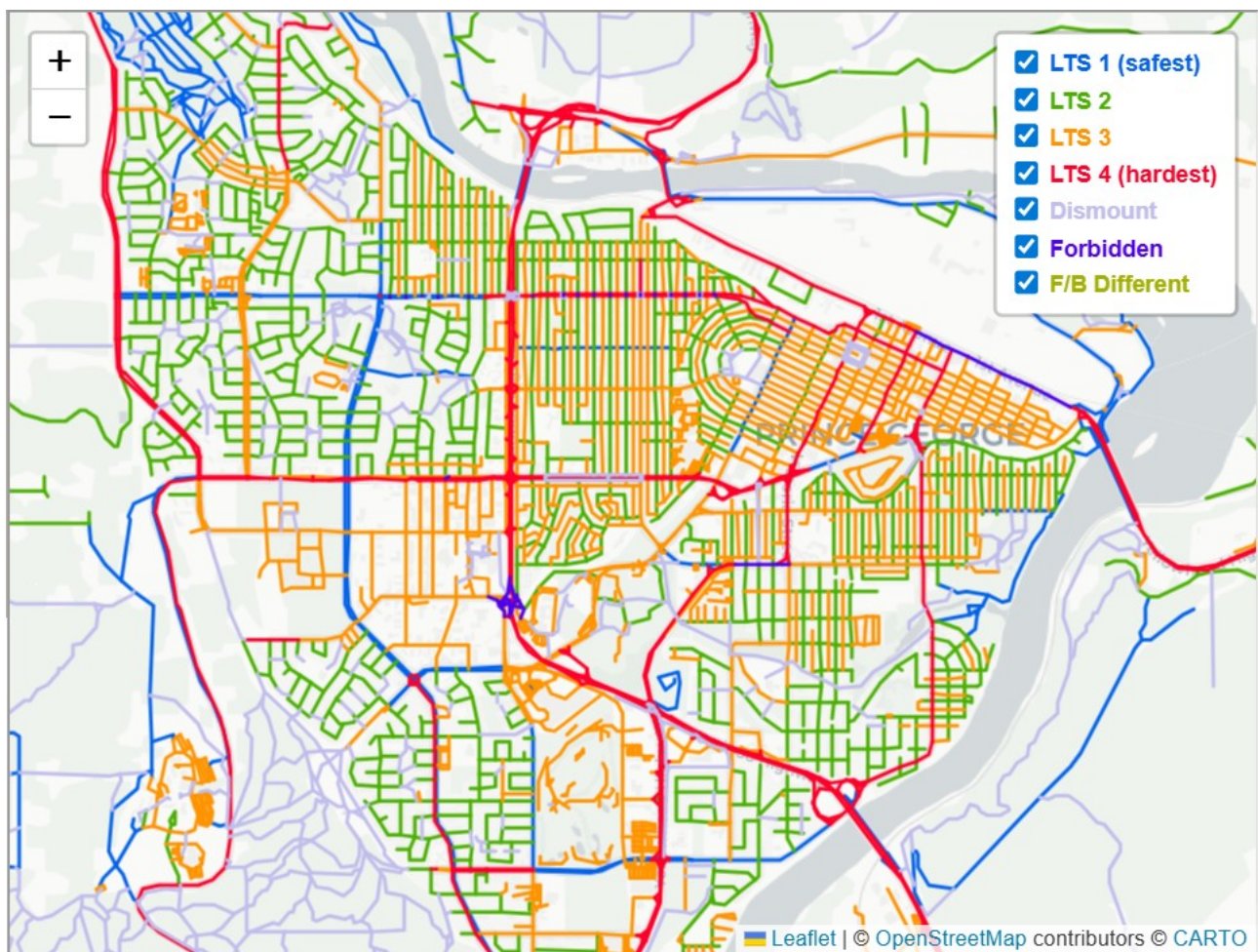
- A custom-built routing engine that is **ultra-fast**, (**20x** faster benchmark than the fastest available: OSRM), allowing for the analysis of many scenarios for your city.
- Currently works for **Canada** and the **USA**, for cities up to about **2,000,000 population**. We hope to extend this to further countries and larger cities in the future.
- We use only **open data**, so there are no data costs or privacy concerns.
- Road **conflation** technology allows combining city's open data (Shapefiles) with OpenStreetMap data.
- Results presented both as **image** and as **vector** data (Shapefile or similar).
- Research **expertise in biking GIS**. Reports for Transport Canada [Szyszkowicz 2018], Public Health Agency of Canada [Szyszkowicz 2019], Province of British Columbia [Szyszkowicz 2022].
- Previous clients (Canada): Sherbrooke QC, Peel Region ON, Hamilton ON, Nanaimo BC, Kamloops BC, Prince George BC, IKEA Corp. Vancouver BC.

# Methodology

## Level of Traffic Stress (LTS)

**Well-established** rating system for biking safety on a road:

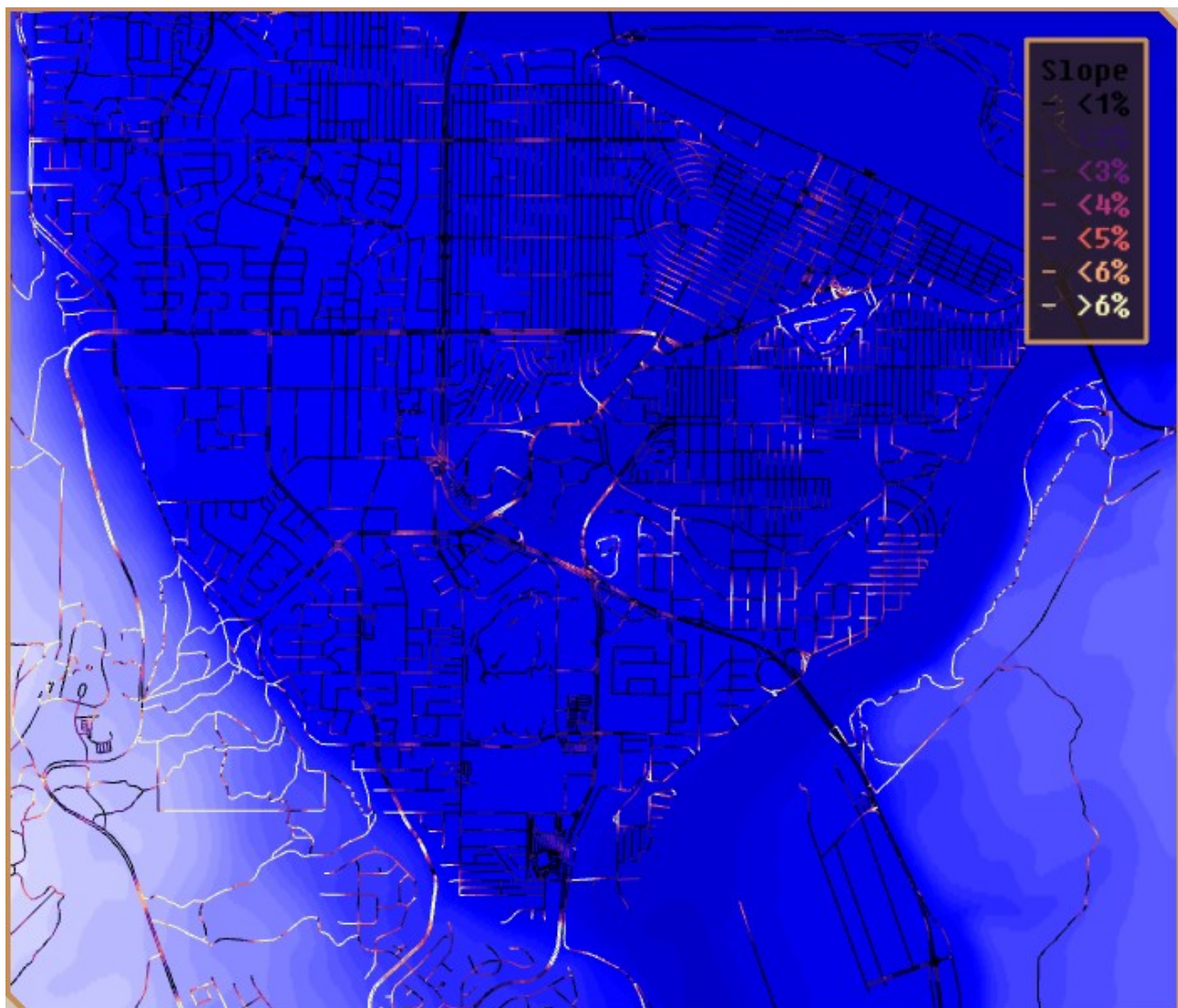
- Rating can be derived from road properties found in typical **open data**.
- A function of road type, posted speed limit, on-street parking, number of lanes, cycling infrastructure.
- Can also include measured traffic intensity (ADT/AADT) if available.
- [Mineta Institute, M Mekuria, P Furth, H Nixon].
- It is rare but possible for the LTS rating to be different in both travel directions (*F/B Different*)
- LTS used in the [Bicycle Network Analysis](#) project.





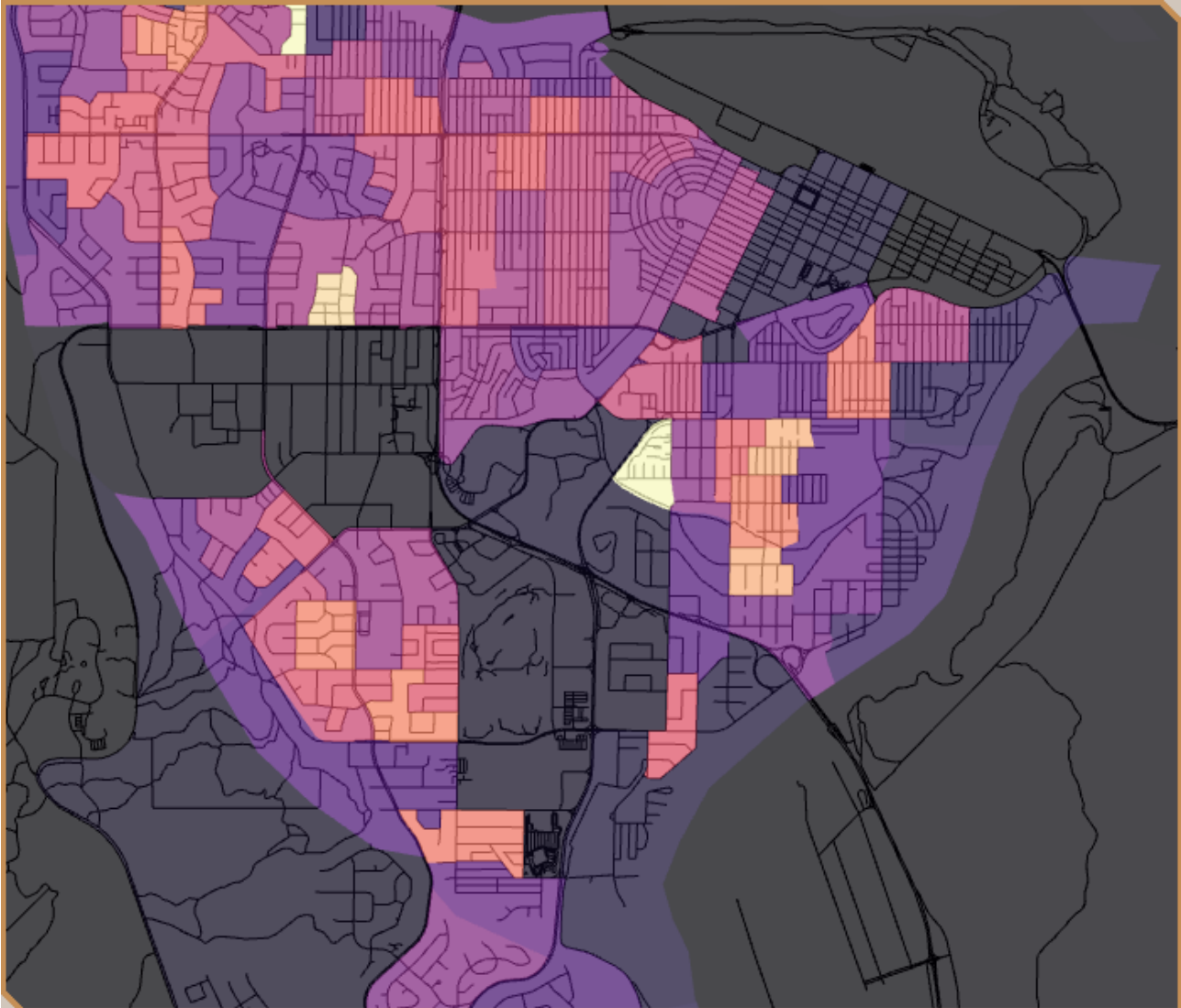
# Topography and Slope

•Source: Natural Resources Canada (NRCan)



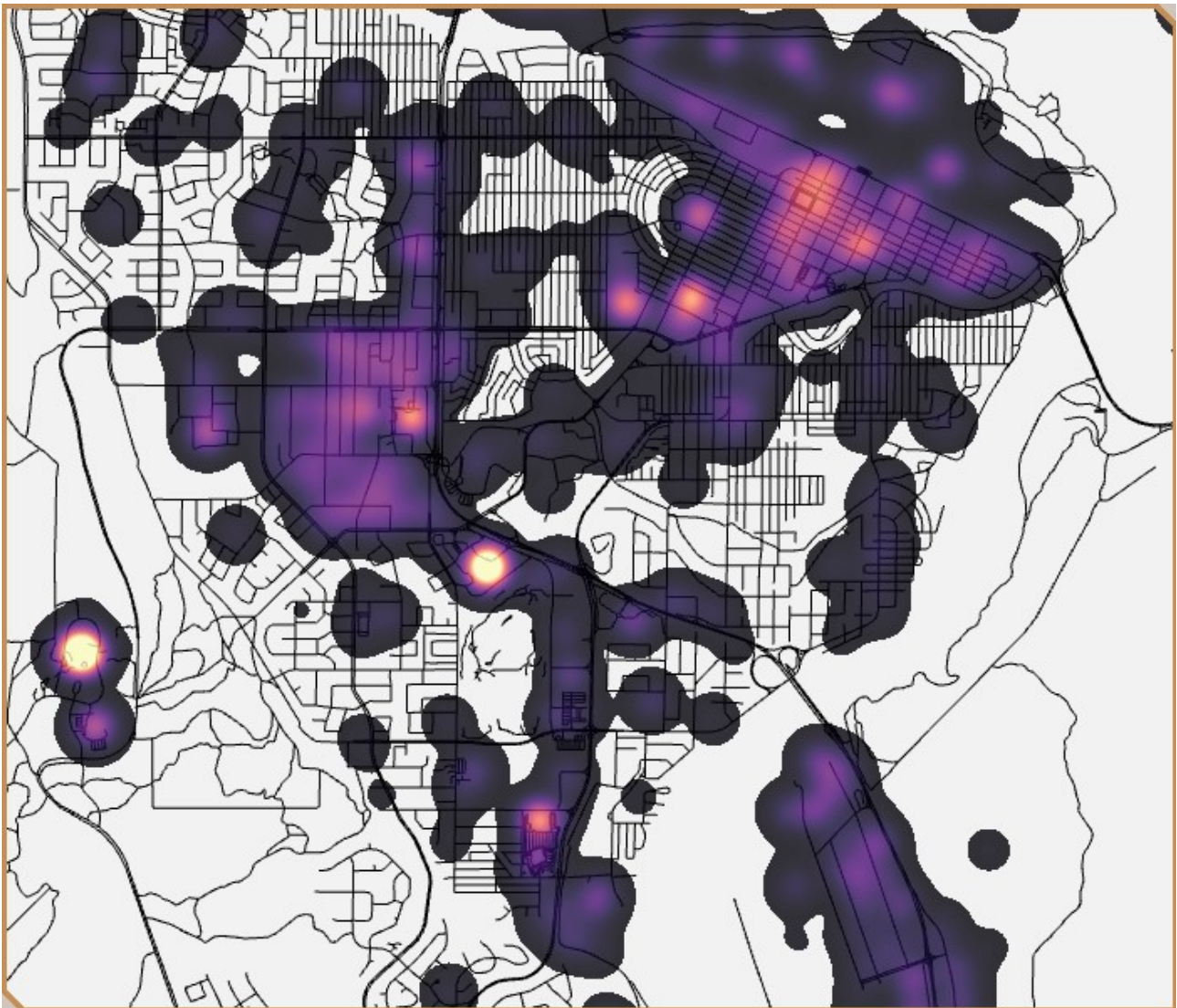
# Population Density

- Source: Canadian census [[visualization](#)] [[US census](#)]
- Within each census parcel ("dissemination area" in Canada), the population is distributed **uniformly on the residential streets** for simulation purposes.



## Workplace Density

- Based on building volume and type.
- Buildings taken from [OpenStreetMap](#) or city open data.
- Alternatively, can be based on business listing with locations and number of employees, if available.

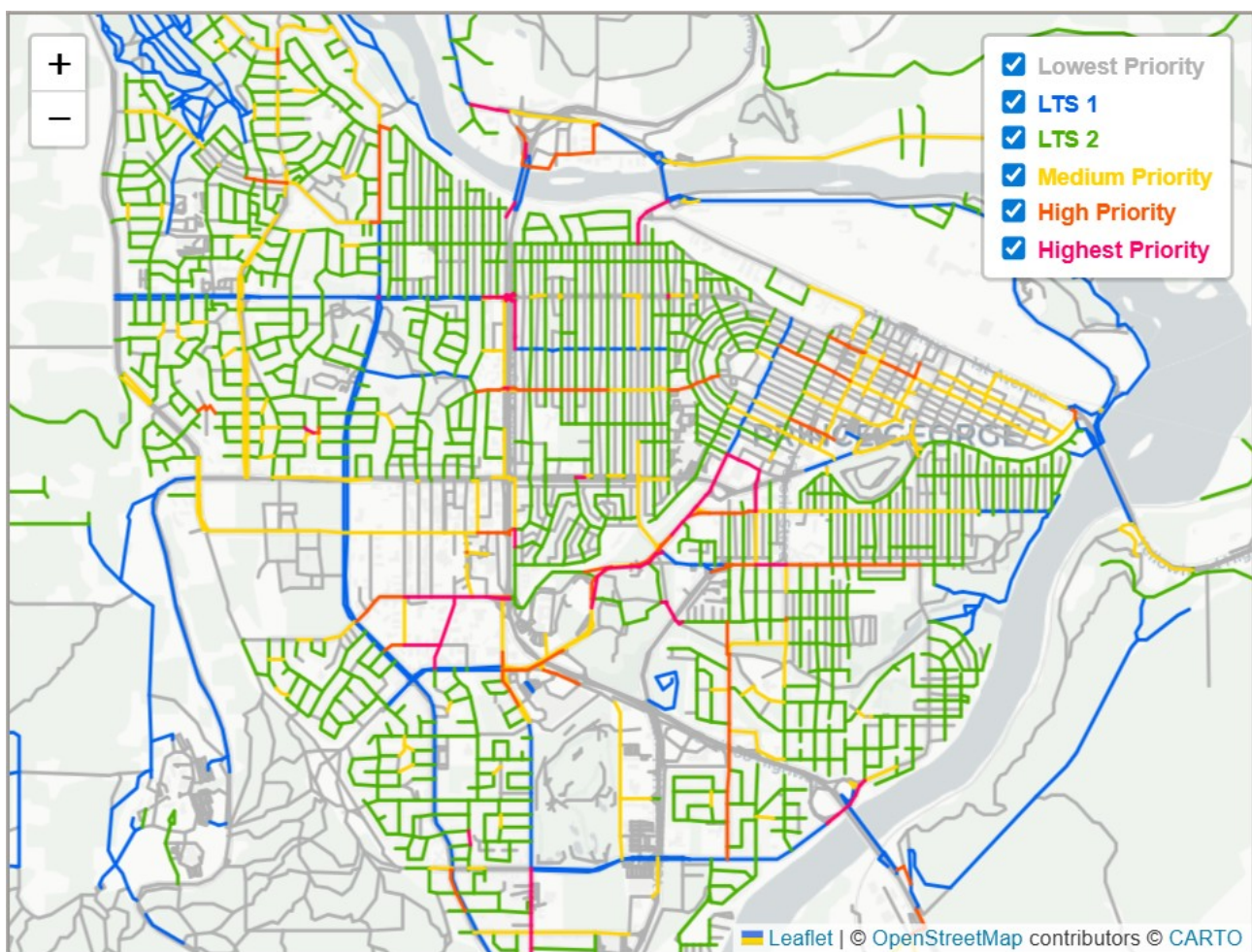




# Priority Biking Network Interventions

Output of algorithm: where to place protected bike tracks.

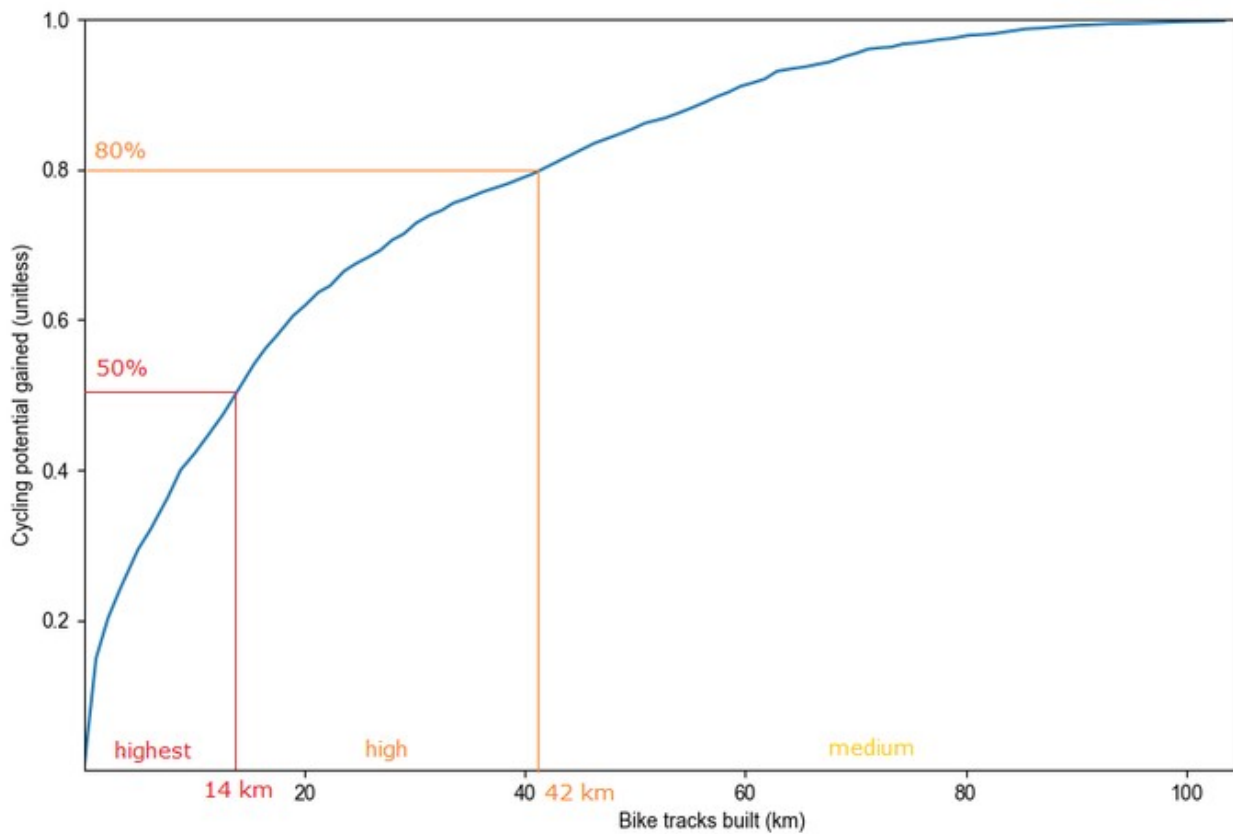
- Based on street segment **betweenness centrality** (BC) and proprietary optimization algorithm.
- BC in bicycle network planning [M Lowry, P Furth, T Hadden-Loh] [M Lowry: YouTube].
- BC in transportation and urban planning [A Sevtšuk et al.] [B Hillier, T Yang, A Turner] [Y Kaoru, K Yusuke, Y Yuji]
- [Y Shen] [M Goremyko, V Makarov, A Hramov, D Kirsanov, V Maksimenko, A Ivanov, A Yashkov, S Boccaletti] [P Crucitti, V Latora, S Porta] [S Lämmer, B Gehlsen, D Helbing] .



# Cycling Potential Curve

Second output of algorithm: **tradeoff** curve between making the **most urgent infrastructure improvements** and amount of biking trips improved.

- In this example, building only the most urgent 13% (14 km) of the bike network length results in 50% of the potential gains.

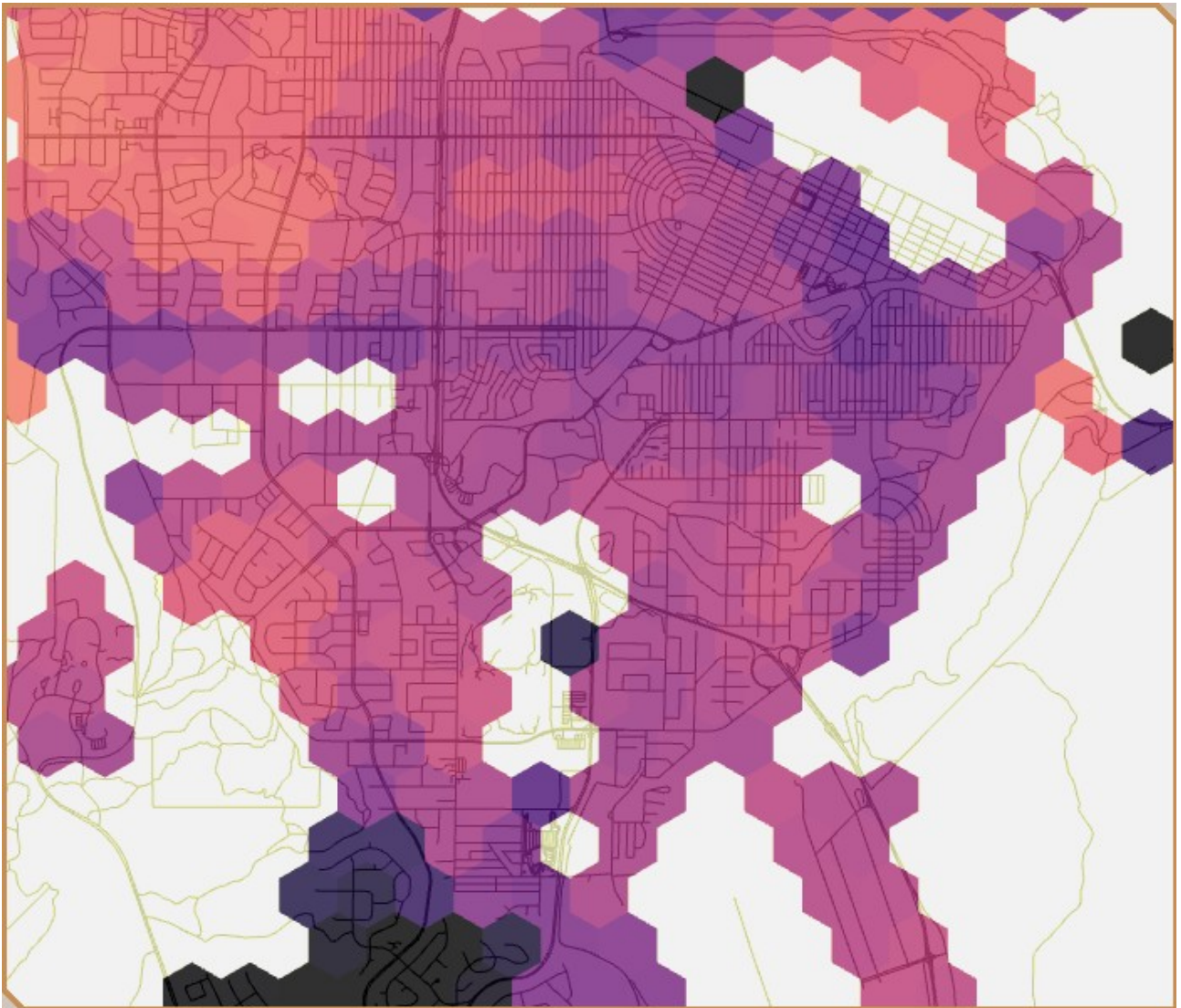




## Residential Neighbourhood Accessibility

Third output of algorithm: **accessibility** of neighbourhoods to **workplaces** (lighter colours represent better access).

- Metric similar to the one used in the [Propensity to Cycle Tool](#).



# External Resources

## Other Significant Projects Related to Biking Networks

- [Propensity to Cycle Tool](#) (United Kingdom)
- [Bicycle Network Analysis](#) (United States)
- [BikeDNA](#): Bicycle Infrastructure Data & Network Assessment
- [BikeScore®](#)
- [BikeMaps.org](#) (crowdsourced cycling accident reports)
- [BikeOttawa.org](#) (Ottawa, Canada)
- [OpenStreetMap](#); cycling infrastructure can be viewed as [OpenCycleMap](#) or [CyclOSM](#).
- [\[M Winters, M Brauer, E Setton, K Teschke\]](#)
- [\[M Lowry, P Furth, T Hadden-Loh\]](#) [\[M Lowry: YouTube\]](#)
- [\[R Lovelace\]](#) paper on open-source GIS tools.

## Routing Engines with Biking Profiles

- [OpenSourceRoutingMachine](#) (OSRM)
- Mapzen's [Valhalla](#)
- [GraphHopper](#)
- [OpenTripPlanner](#), [OTP Analyst](#)
- [Conveyal R5](#)
- [CycleStreets](#)
- [Cyclopath](#)
- [Openroute Service](#)
- **Comparisons** of some routing engines [\[F Ramm: YouTube, in German\]](#) [\[Y Akhadi: YouTube\]](#).

## Some Cycling Plans

- [New Zealand cycling plan](#)
- [Cycling and walking plan for England](#)
- [Vancouver cycling plan](#)
- [Vélo Canada Bikes cycling strategy](#)
- [New York City bike sharing live map](#)

# Appendix

Our low-ball **estimate of total yearly CO<sub>2</sub> emissions reduction for Canada** is 274,000 tonnes. Our optimistic estimate is twice that: 547,000 tonnes. Canada emits about [550M tonnes](#) of CO<sub>2</sub> per year. Thus, we are aiming to save **0.1%** in carbon emissions.

Below is a detailed calculation:

We are looking to replace 3-to-9km-long commutes with bicycle trips. This is an average distance of **6.5 km per trip**, or 65 km weekly. Assuming 3 weeks vacation, that's  $49 \times 65 = 3185$  km yearly per commuter.

Most Canadian cities have about a 2% bike commute participation rate, except Vancouver, which has 6%. A conservative goal would be to bring the participation rate of all other major cities **up to 6%** - in the summer months. In the winter months, we assume half the participation (based on bike commute rates from Finland: 20%/10%). So we wish to increase average participation by  $4\% \times (7/12) + 2\% \times (5/12)$  given 5 winter months, that is 3.17%.

We are targeting all **62 Canadian cities** above 50,000 population except the Greater Vancouver Area. That is 22,300,000 citizens. [\[2021 Census\]](#)

Out of these, we will take as workers those aged 20 to 64, that is [59% of the population](#).

Typical Canadian cars emit CO<sub>2</sub> at an average rate of **206g/km**.

The final yearly CO<sub>2</sub> saved is  $3185\text{km} \times 3.17\% \times 22,300,000 \times 59\% \times 206\text{g/km} = 274,000$  tonnes.

This is a low-ball estimate. A few important factors that could increase this estimate are:

- The benefits of reducing traffic are **superlinear** because during rush hour cars block and slow down other cars and there is lots of idling. Thus, removing X% of cars from the road during rush hour may reduce emissions by much more than X%, because the other cars have a smoother resulting trip.
- This calculation only included daily commutes, but bike lanes can also be used for **shopping, community, social, and entertainment** trips, all of which help reduce emissions.
- Vancouver** may also benefit from more bike lanes and increase its bike commute participation rate even more, as it already has a strong biking culture.
- The 9km travel range is assumed for average-ability cyclists. However, more performant cyclists may replace much **longer trips** with cycling. Also, the advent of **e-bikes** may extend the cycling range for many people.

- A well-connected biking network may bring participation higher than 6% in many cities, up to **European** levels (at least outside winter) of **7% or more**, even into the double-digits.