URBINTEL: Automated Biking Network Planning

by Sebastian S. Szyszkowicz, Ph.D.

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]
•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;
•"Could Building Bike Lanes Become **America's Next** Big Infrastructure Project?" [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 Use this Tool?

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**, for cities up to about **2,000,000 population**. We hope to extend this to further countries and larger cities in the future.

•Implementing **USA** should be simple enough – requires finding population density files.

•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**.

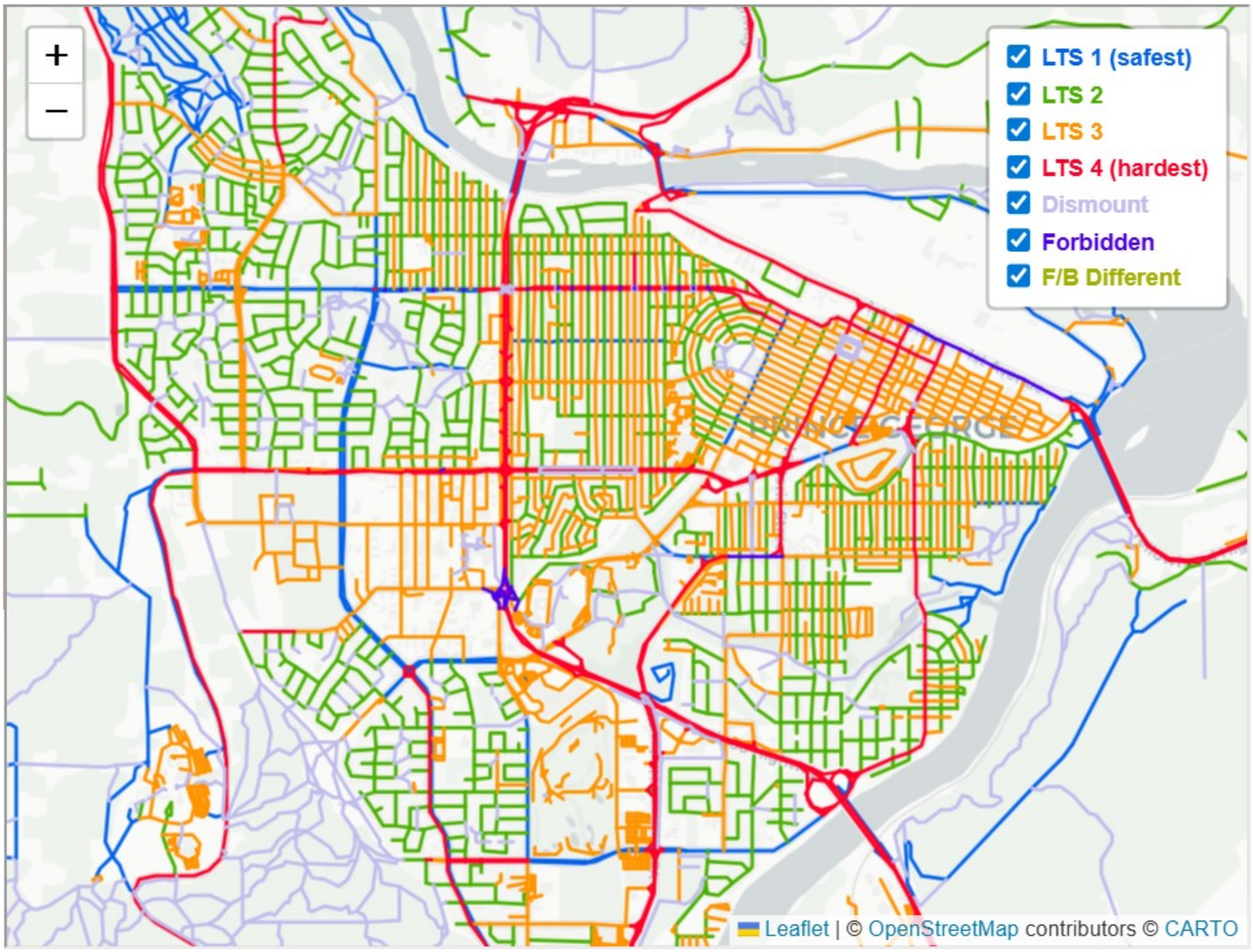
•A function of road type, posted speed limit, on-street parking, number of lanes, cycling infrastructure.

•Can also include measured traffic intensity (ADT/AADT) if available.

•[Mineta Institute, M Mekuria, P Furth, H Nixon].

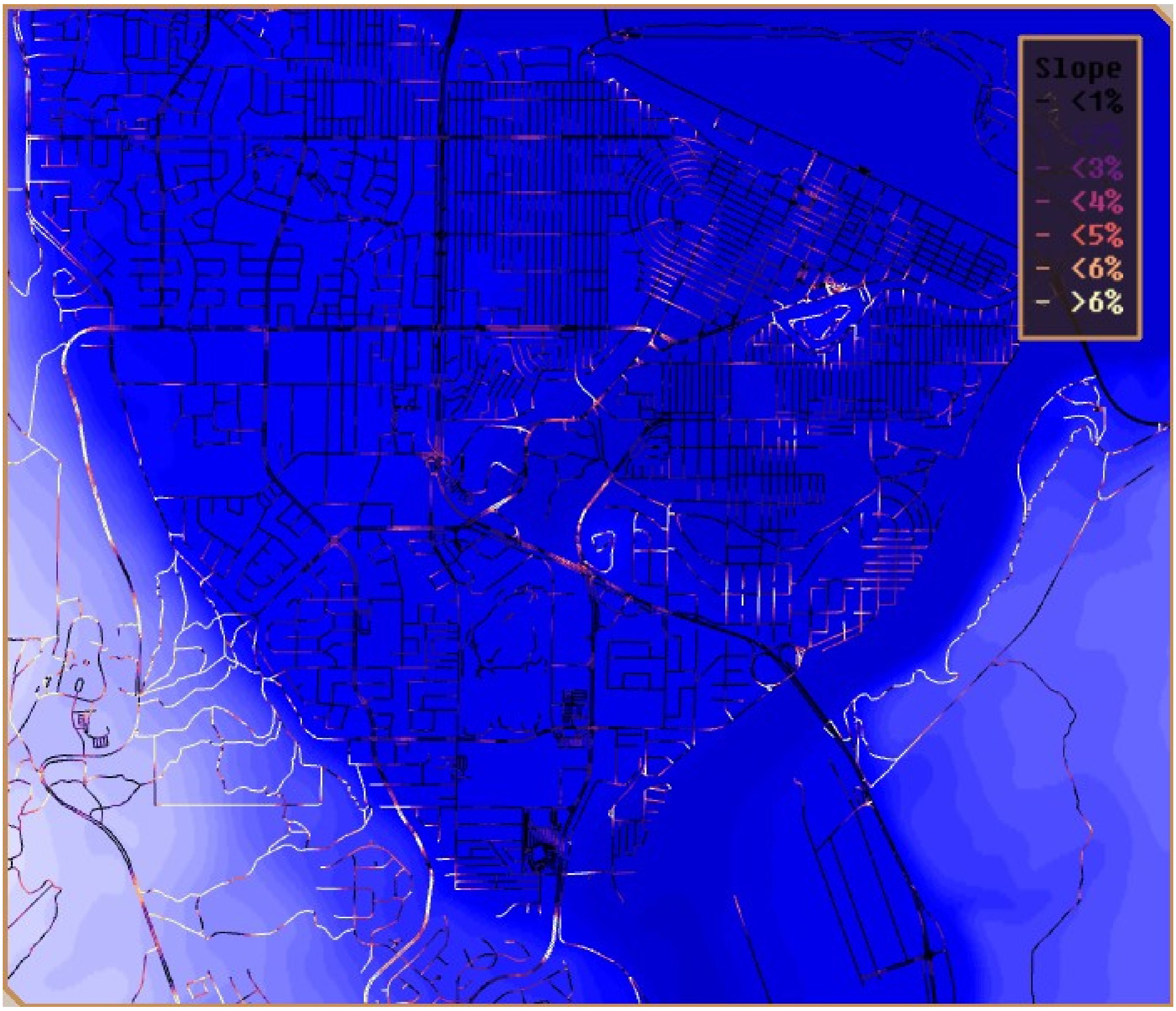
•It is rare but possible for the LTS rating to be different in both travel directions (*F/B Different*)

•LTS used in the Bicycle Network Analysis project.



Topography and Slope

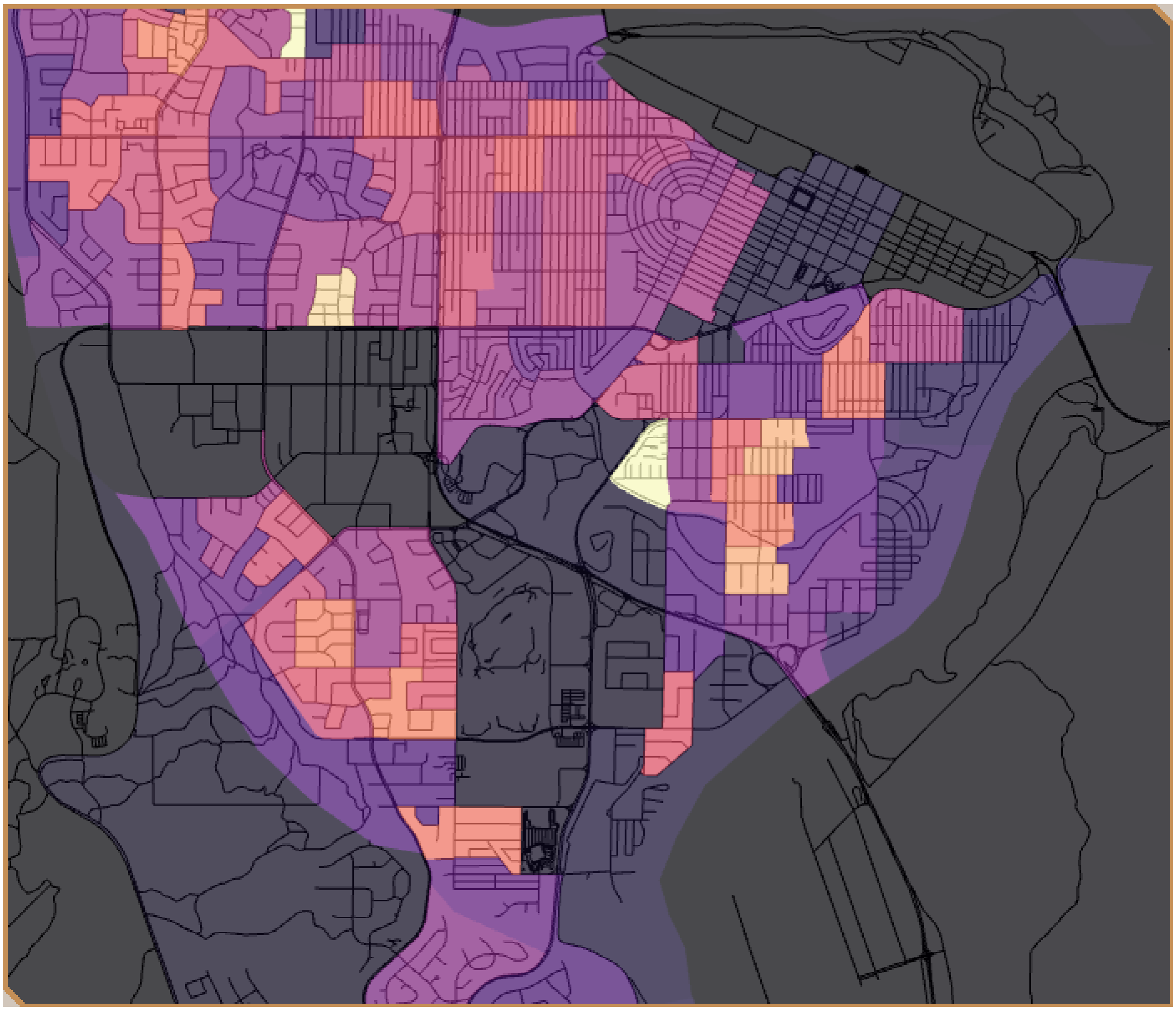
•Source: Natural Resources Canada (NRCan)



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.

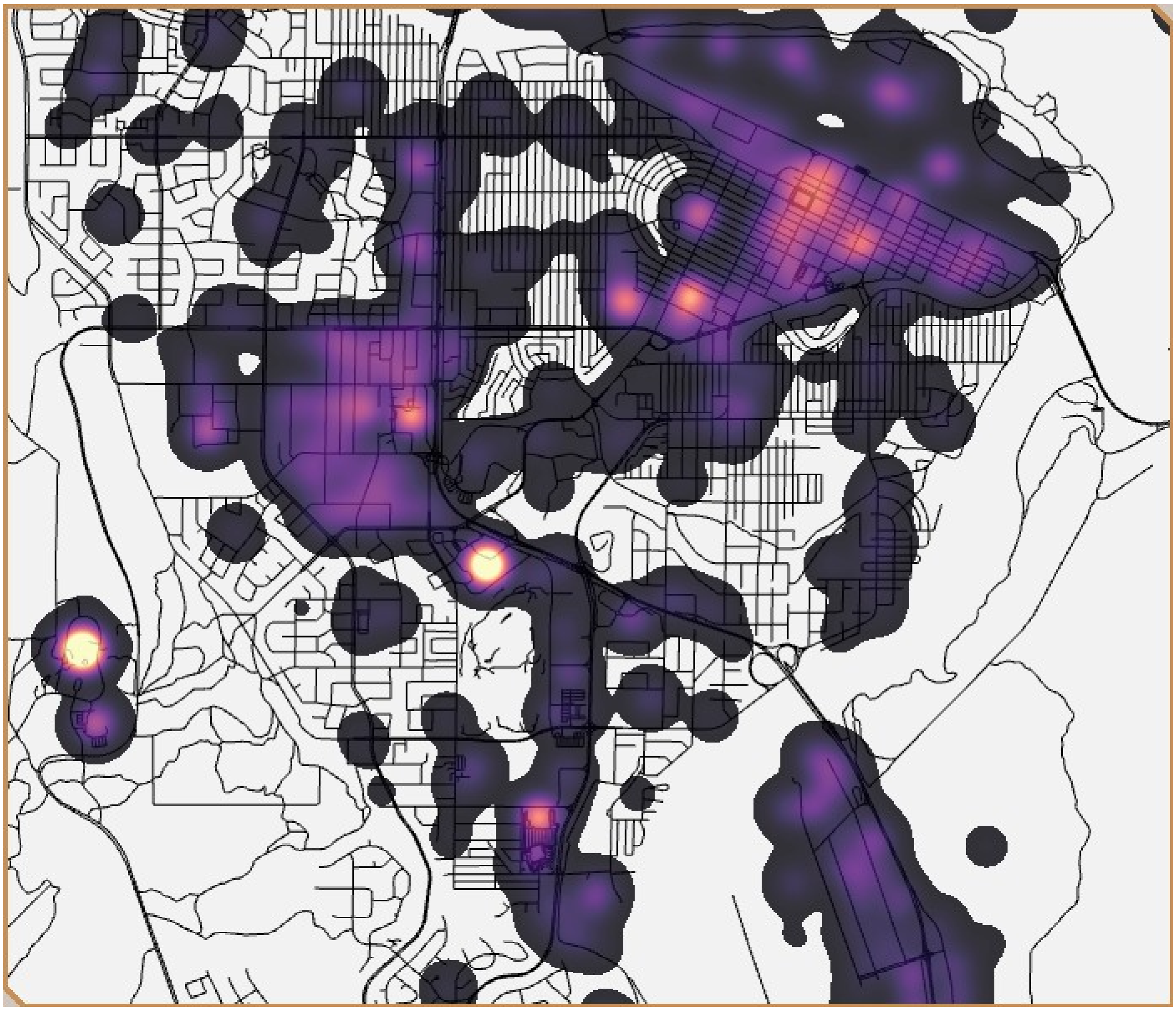


Workplace Density

•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

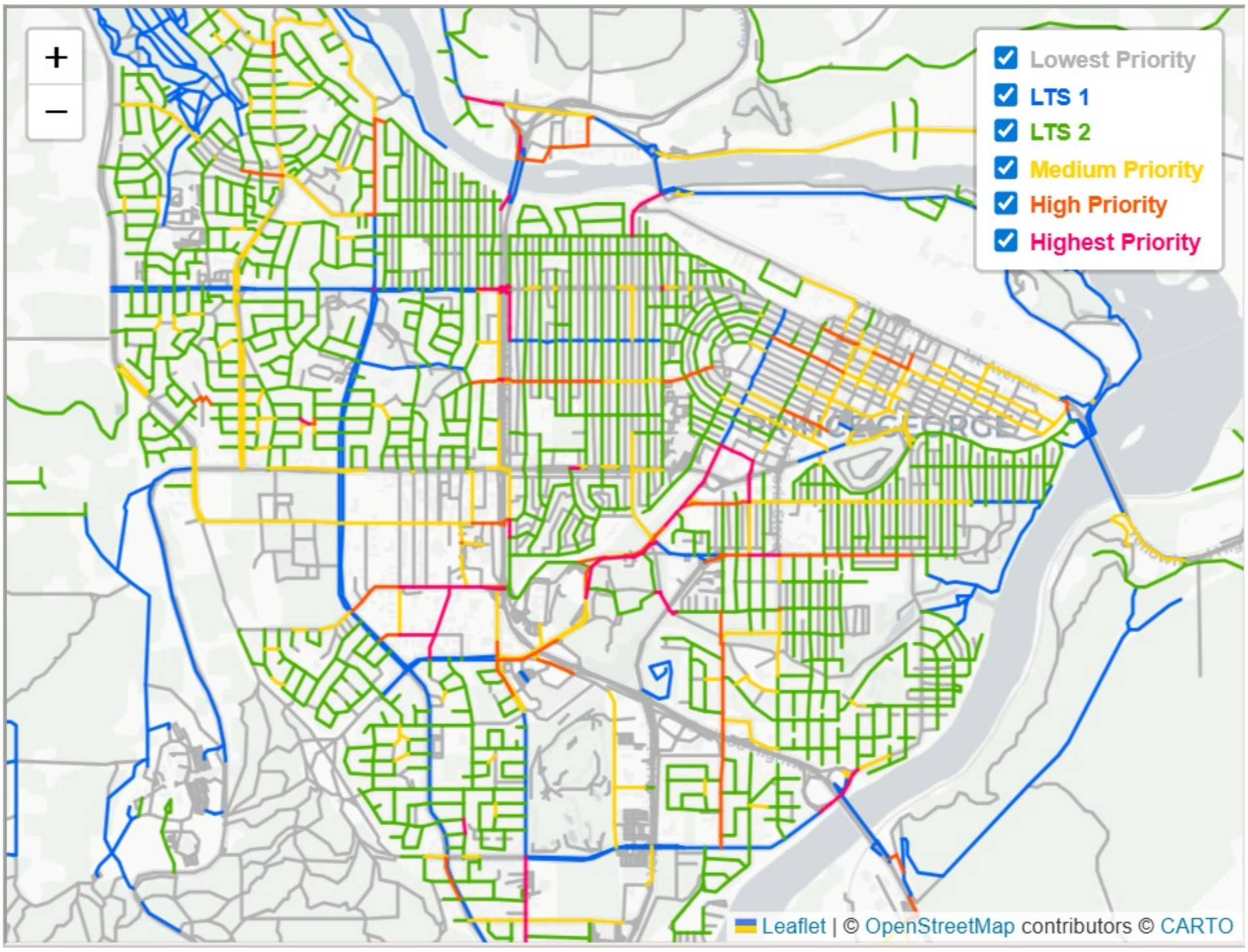
Output of algorithm: where to place protected bike tracks.

•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]

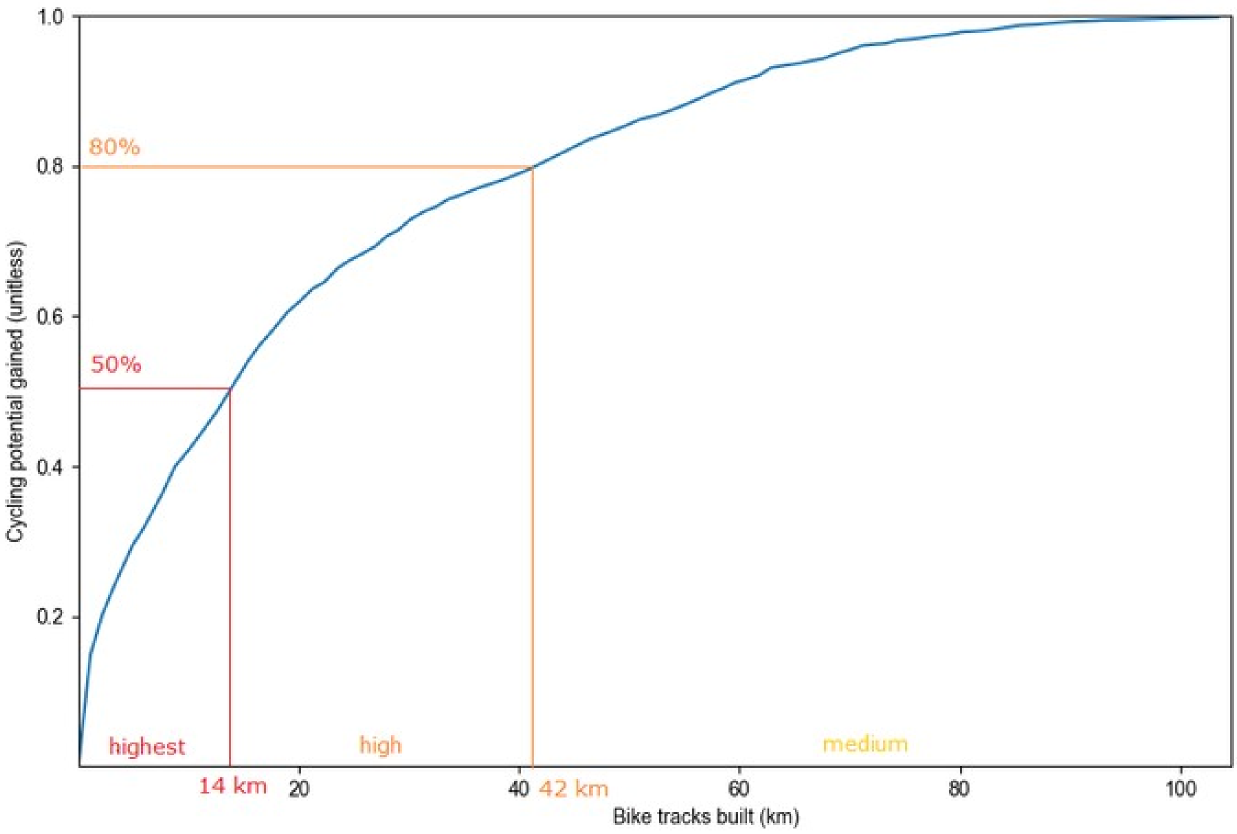
[Y Shen] [M Goremyko, V Makarov, A Hramov, D Kirsanov, V Maksimenko, A Ivanov, A Yashkov, S Boccaletti] [P Crucitti, V Latora, S Porta] [S Lämmer, B Gehlsen, D Helbing] .



Cycling Potential Curve

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

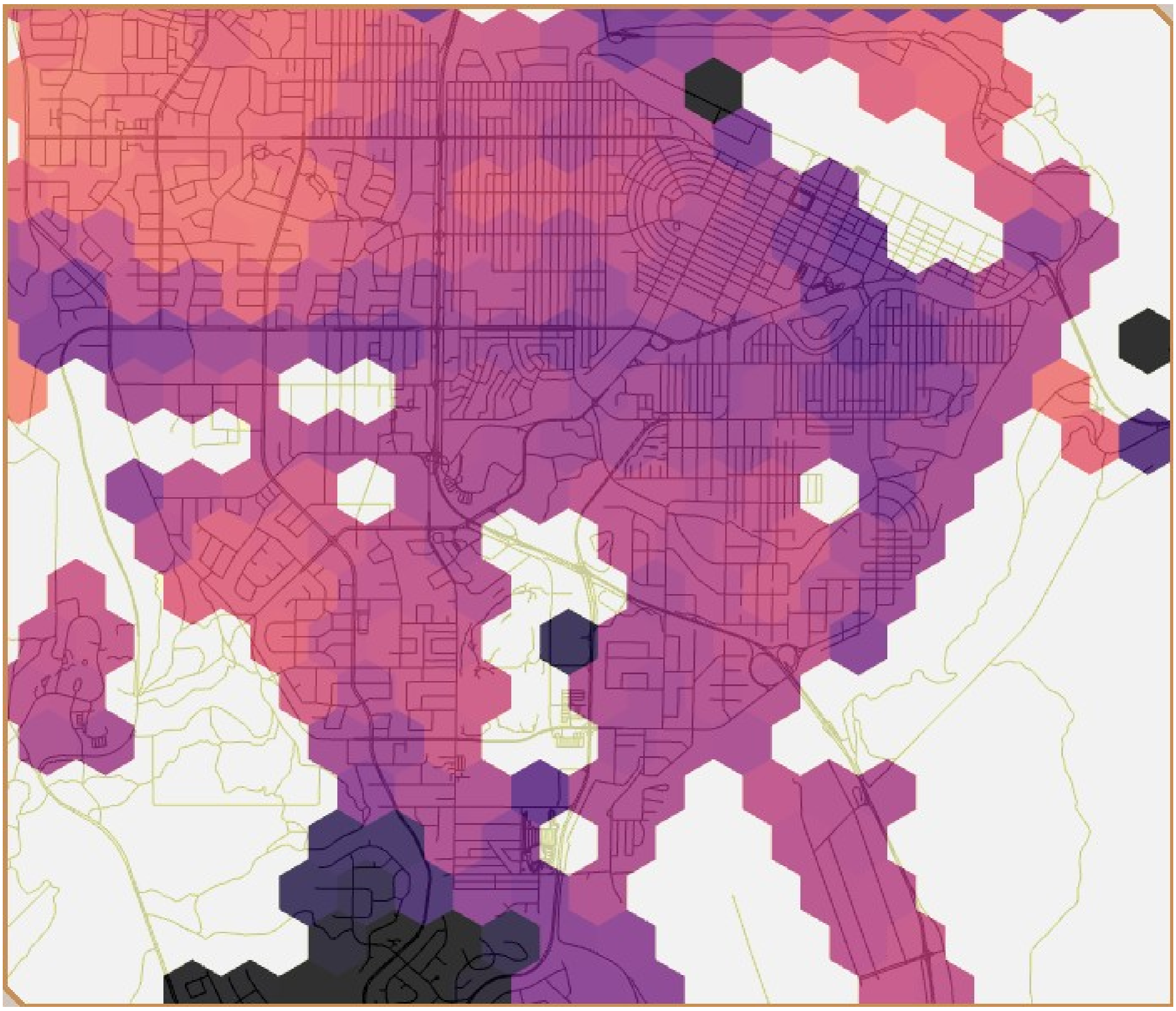
•In this example, building only the most urgent 13% (14 km) of the bike network length results in 50% of the potential gains.



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_2 emissions reduction for Canada** is 274,000 tonnes. Our optimistic estimate is twice that: 547,000 tonnes. Canada emits about 550M tonnes of CO_2 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 49x65 = 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 increase average participation by 4%*(7/12)+2%*(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_2 at an average rate of **206g/km**.

The final yearly CO_2 saved is 3185km * 3.17% * 22,300,000 * 59% * 206g/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.