ARE WE CONNECTED?

Geneviève Boisjoly
Ahmed M. El-Geneidy
School of Urban Planning, McGill University

TRAM
Transportation Research at McGill

Assessing bicycle network performance through directness and connectivity measures: A Montreal, Canada case study

CONTEXT

Over the last two decades, cycling has seen a rise in popularity in North American cities. In this context, many cities are continuously **expanding their bicycle networks** to promote bicycle use.

While a good network should provide **direct bicycle routes** for cyclists to reach their desired destination, most network assessments simply measure the **length of bicycle facilities** in a region.

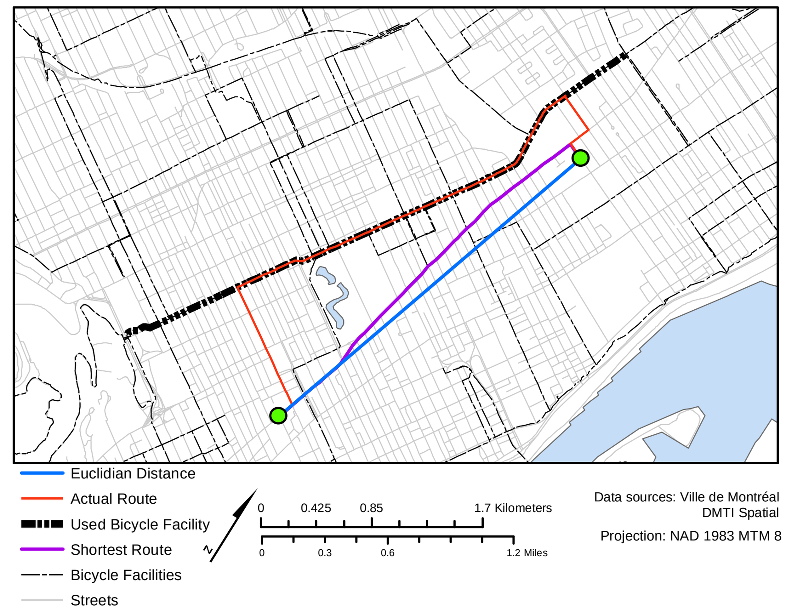
Building on a set of complementary indicators to account for the **directness** of bicycle facilities, this study assesses the performance of the bicycle network in Montreal, Canada.

PERFORMANCE INDICATORS

A good network should provide **direct bicycle routes** for cyclists to reach their desired destination.

To account for the **directness** of the bicycle network, two indicators are developed at the route level.

- Bicycle route **diversion** compared to the shortest street network distance
- Presence of bicycle facilities, measured as the **proportion of the route on bicycle facilities**



Shortest Route, Actual Route and Euclidian Distance (Example from the 2009 Survey)

PERFORMANCE INDICATORS

Network connectivity

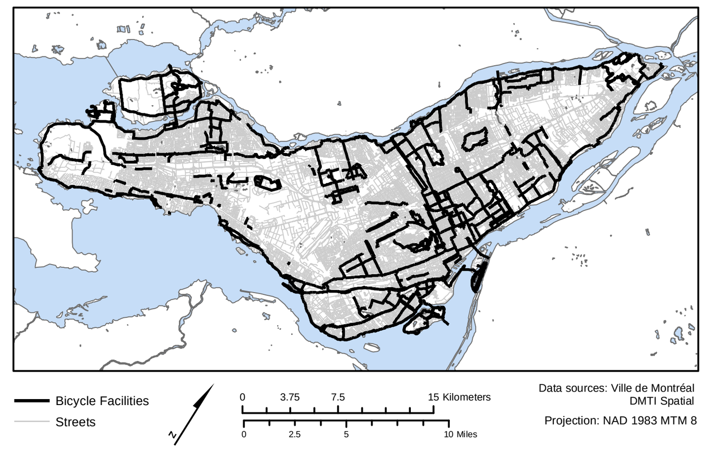
A **connectivity measure** is developed to measure the network performance based on the two indicators **simultaneously**.

$$C = \frac{\sum_{i=1}^{n} C_i}{n} \qquad C_i = \begin{cases} 1 \text{ if } D_i \leq t_D \text{ } AND \text{ } P_i \geq t_P \\ 0 \text{ if } D_i > t_D \text{ } OR \text{ } P_i < t_P \end{cases}$$

C: Network connectivity
n: Number of routes
C_i: Route connectivity
D_i: Route diversion
t_D: Threshold for route diversion
P_i: Proportion of the route on bicycle facilities
t_D: Threshold for proportion of the route on bicycle facilities

Network generation

Since most cyclists do part of their trip on the street network, we generated a network combining the **bicycle facility network** and the **street network** while assigning a **preference for bicycle facilities**.



Montreal Bicycle and Street Network (2013)

Actual trip origins and destinations

To assess to which extent the bicycle network allows individuals to **reach their desired destinations**, actual origins and destinations are used.

Description of the Data Sources

	Cycling Survey (2009)	Cycling Survey (2013)	Origin-Destination Survey (2008)
Mode	Cycling	Cycling	Cycling and driving
Sample size	2,917	2,644	826 and 10,759
Data used	Home location Work/school location Route details	Home location Work/school location	Home location Work/school location
Purpose	Cyclists' preferences	Network assessment	Mode comparison

NETWORK PERFORMANCE

1 Montreal cyclists' route preferences

Based on the **2009 cycling survey**, the characterstics of the routes actually taken by cyclicsts in Montreal are calculated.

Average Route Characteristics for Facility- and Non Facility-Users

Route Characterstic	Facility-Users	Non Facility-Users
Euclidian Distance (km)	4.91	4.23
Length – Shortest Route (km)	6.46	5.02
Length – Actual Route (km)	5.76	5.02
Detour (m)	695	0
Detour (%)	12	0
Portion of Trip on Facilities (%)	50	0

The trip characteristics of the facility-users are used to set the **minimum thresholds** for calculating the connectivity of the network:

- 12% maximum diversion
- 50% minimal proportion of the route on bicycle facilities

2 Network performance

Based on four levels of preference for using bicycle facilities, routes are generated for each pair of home-work/school locations from the **2013 cycling survey** and the following indicators are calculated:

- Average **diversion** of all routes
- Average **proportion on facilities** of all routes
- **Connectivity** of the nework

Performance Indicators for each Level of Preference

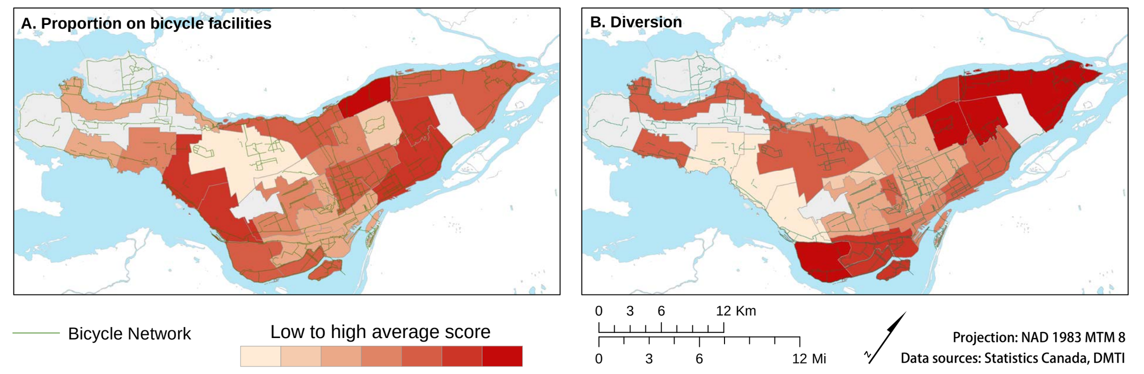
Route Characteristic	No	Low	Med.	High
Diversion (%)	0	4.3	12	24
Proportion of Route on Facilities (%)	19	32	82	89
Connectivity (% of all routes)	20	36	51	51

The **medium preference level** aligns best with the 2009 facility-user preferences with an average diversion of 12% and is accordingly used to conduct the spatial analysis.

SPATIAL ANALYSIS

Presence of bicycle facilities and diversion

- Most boroughs located on the periphery of the Island have a **high proportion** on bicycle facilities and **high diversion**. This is due to the presence of a major recreational cycling facility around the Island, but few other bicycle facilities in these areas.
- Some boroughs located in the centre of the Island are characterized by a relatively **low diversion** score and a **low proportion** on bicycle facilities, given the very low presence of bicycle facilities.



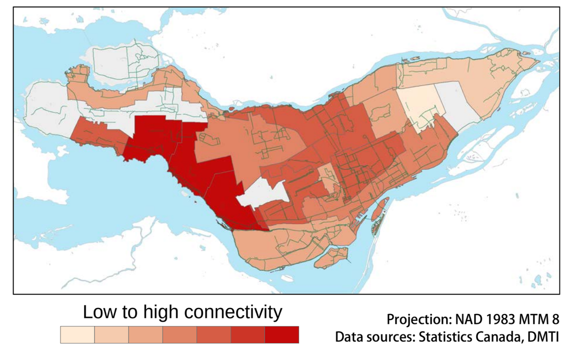
Average Proportion on Bicycle Facilities and Diversion at the Borough Level

The **trade-off** between route directness and proportion of route along bicycle facilities illustrates the need to **include multiple indicators** when assessing network performance.

Connectivity

Central boroughs north of downtown have a **high connectivity** given the presence of bicycle facilities on both north-south and east-west axes.

Boroughs located in the southwest have the highest connectivity, due to the fact that all trips originate near the major bicycle facility.



Connectivity of the Bicycle Network

The **connectivity measure** provides an overview of the **quality of the bicycle network** in each area.

COMPARISON ACROSS MODES

A measure of **circuity**, defined as the **ratio between the network and Euclidian distances**, is used to compare network efficiency across modes. Circuity measures are calculated for all origin-destination pairs corresponding to trips made by bicycle or by car for work and school purposes, using the **2008 Origin-Destination Survey**.

Average Circuity for Bicycle and Car Trips

	Cyclists O-D	Drivers O-D
Bicycle network (medium preference)	1.35	
Street network		1.22

The results suggests that the street network provides car drivers with more direct routes than the bicycle network does for cyclists.

CONCLUSION

Bicycle Network Assessment:

Multiple, **complementary indicators** should be used to evaluate the directness of bicycle networks.

Bicycle Network Planning:

To **promote bicycle use**, bicycle facilities should be designed as a **cohesive network** allowing cyclists to directly reach their desired destinations.

ACKNOWLEDGMENTS

The authors would like to thank Gabriel Damant-Sirois and Jacob Larsen for their work on previous cycling surveys in Montreal. Additionally, thanks to David Verbich for his critical comments on the paper. Finally, we gratefully acknowledge the financial support received from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Fonds de recherche du Québec–Nature et technologies (FRQNT).

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