Complexity Science Hub, Vienna

# Bicycle infrastructure data and networks: Opportunities and limitations

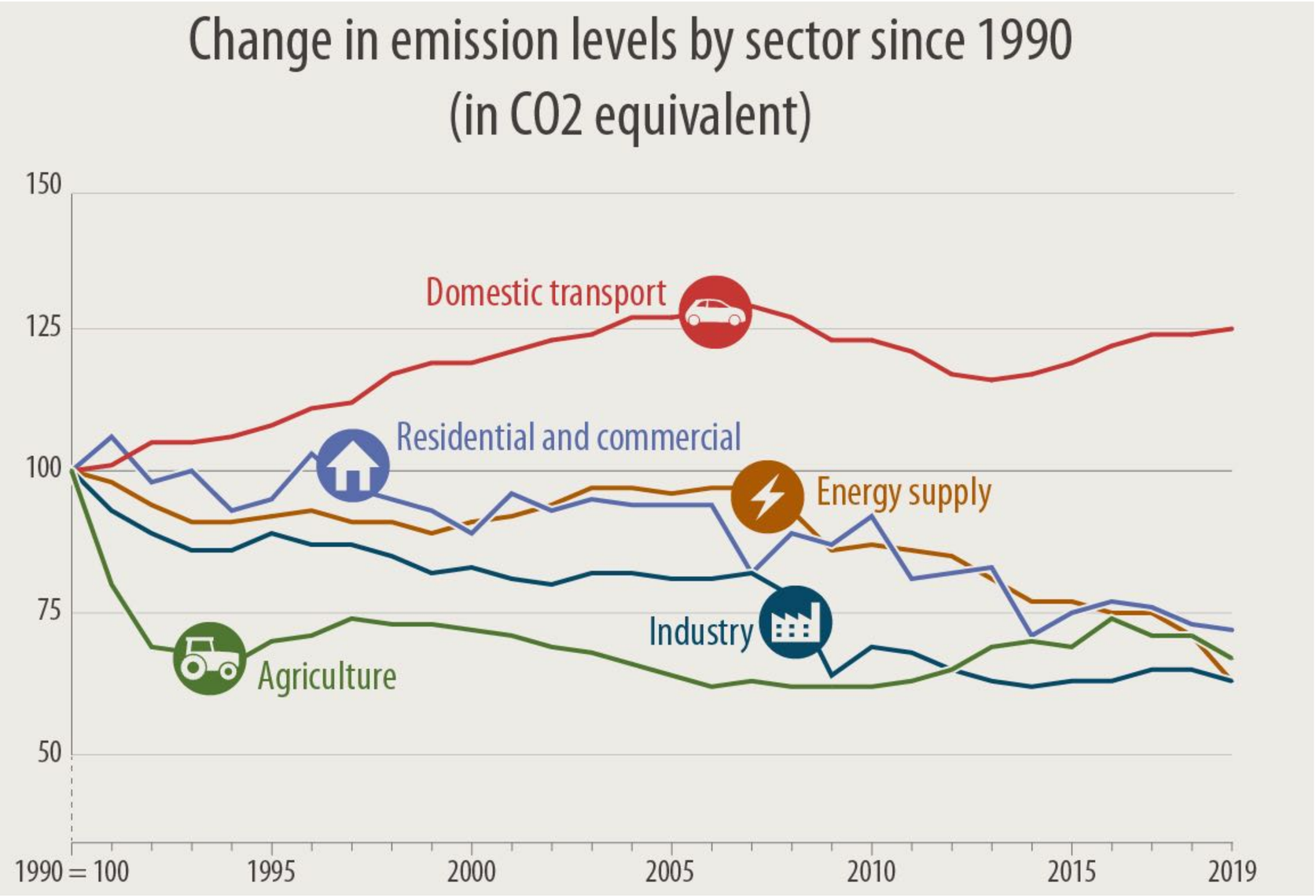
Michael Szell

NERDS (NEtwoRks, Data, and Society)
nerds.itu.dk

IT UNIVERSITY OF COPENHAGEN

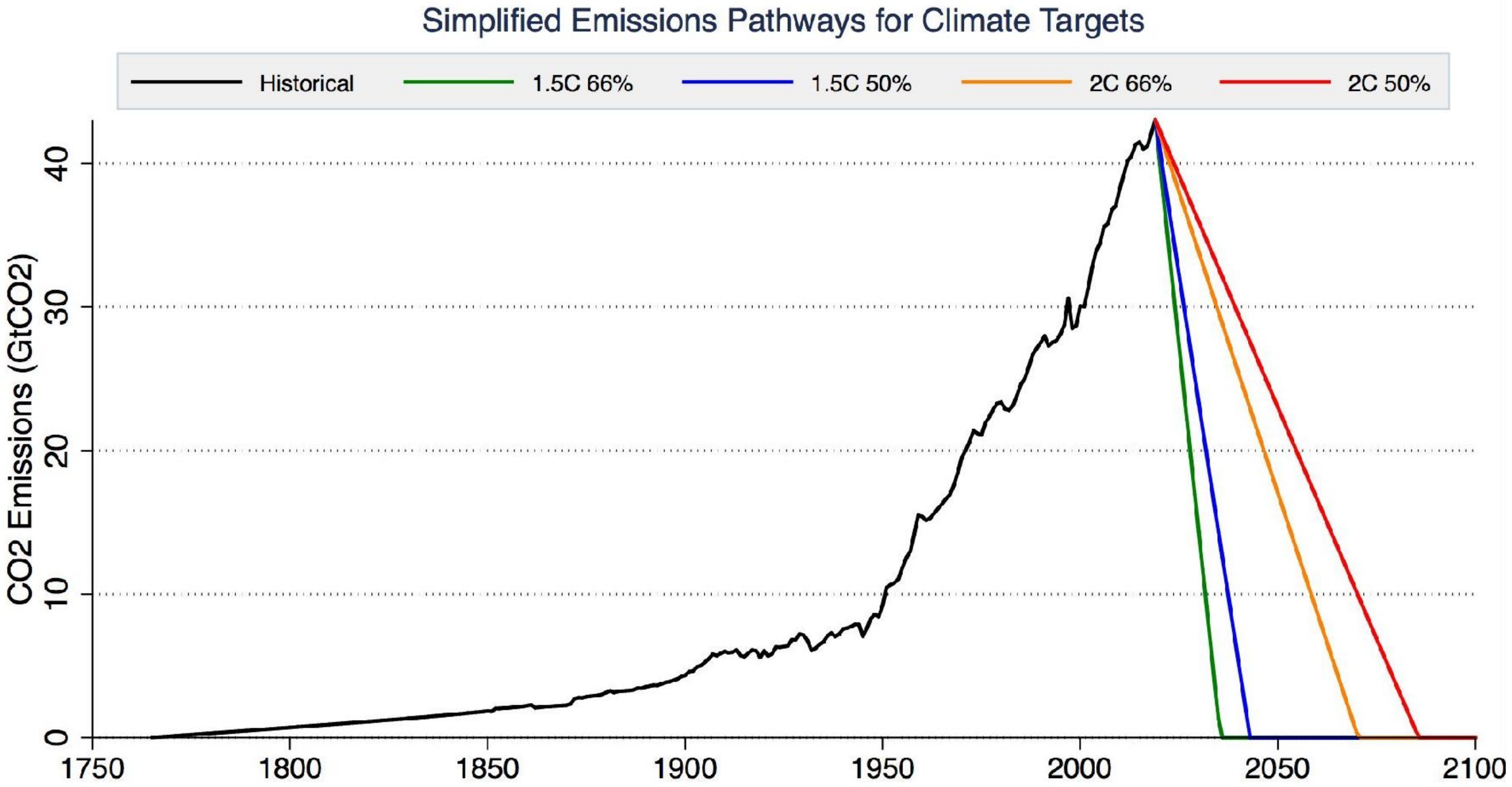
April 4, 2023

# Transport plays a key role in the climate crisis




*Transport represents almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities.*

https://ec.europa.eu/clima/policies/transport_en



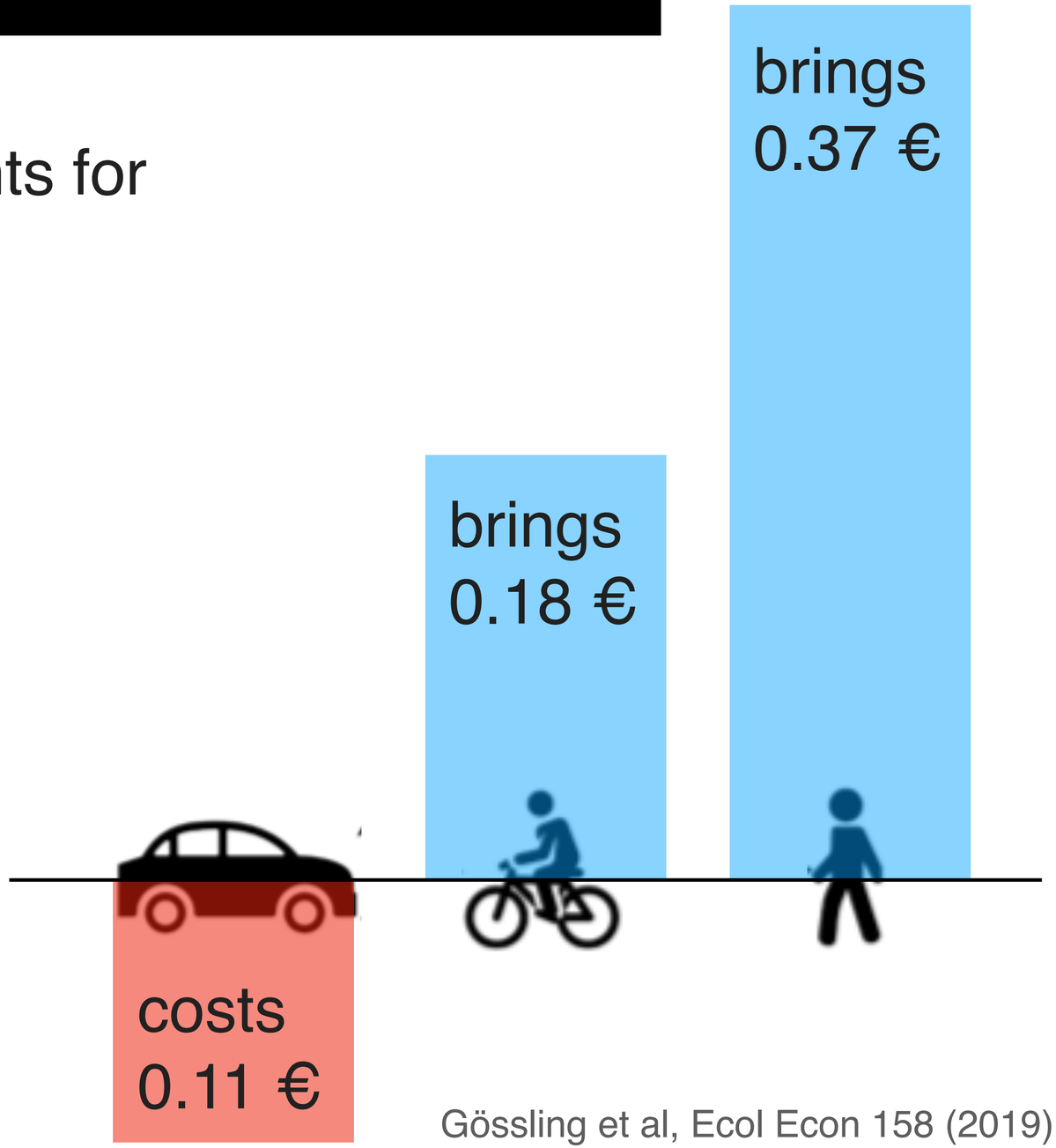

Zeke Hausfather

# More active travel is a "no-brainer"

Cost-benefit analysis in EU that accounts for

- Health
- Environment
- Travel / Congestion

shows: 1 km travelled by




Gössling et al, Ecol Econ 158 (2019)

# Data-informed planning can support a sustainability shift

# How to find the missing links in well-developed networks?

In Copenhagen, most of the network is 1 connected component.

Anastassia Vybornova

# How to find the missing links in well-developed networks?

In Copenhagen, most of the network is 1 connected component.

Still, there are a lot of "missing links".

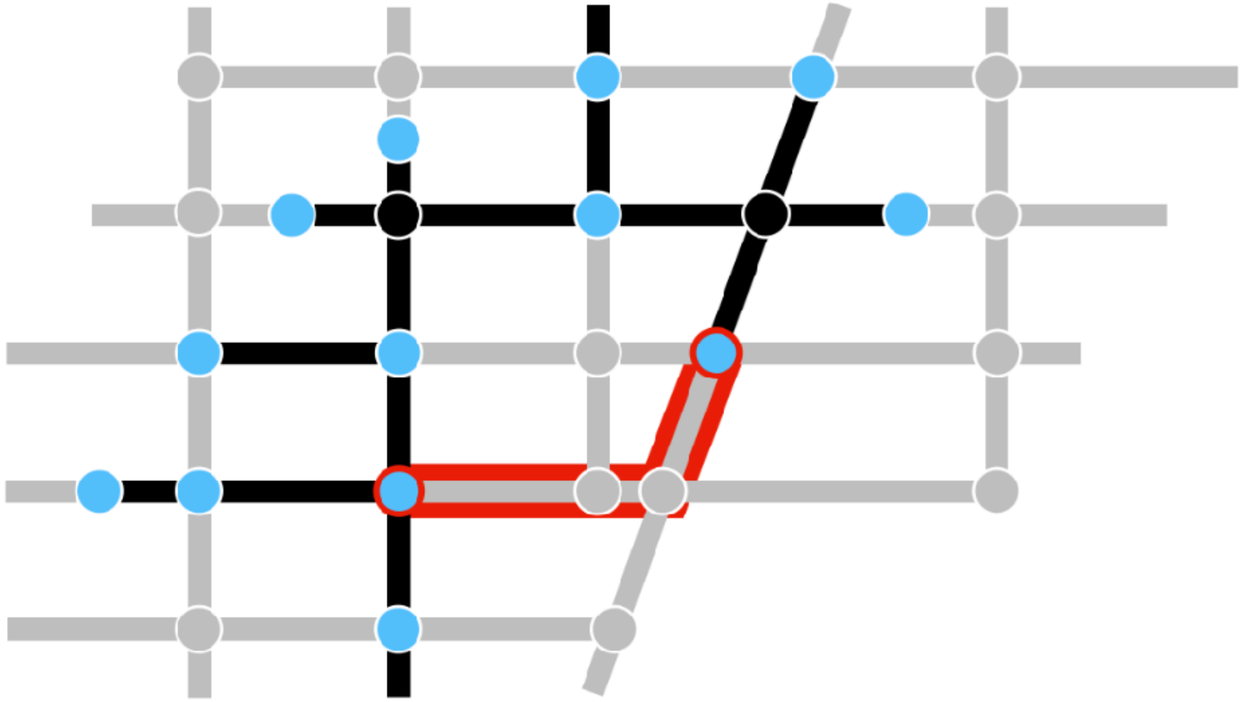
How to find them?
How to prioritize them?

# 1) Identify: We need a formal definition of “gap”

Multiplex network

Links
1) unprotected
2) protected

Nodes
1) unprotected
2) protected
3) contact



A gap is a shortest path
between two contact nodes
that consists only of unprotected links

Vybornova et al, Geographical Analysis (2022)

# 2) Prioritize

We could find millions of gaps…

We need a metric to prioritize them.

Vybornova et al, Geographical Analysis (2022)

# 2) Prioritize

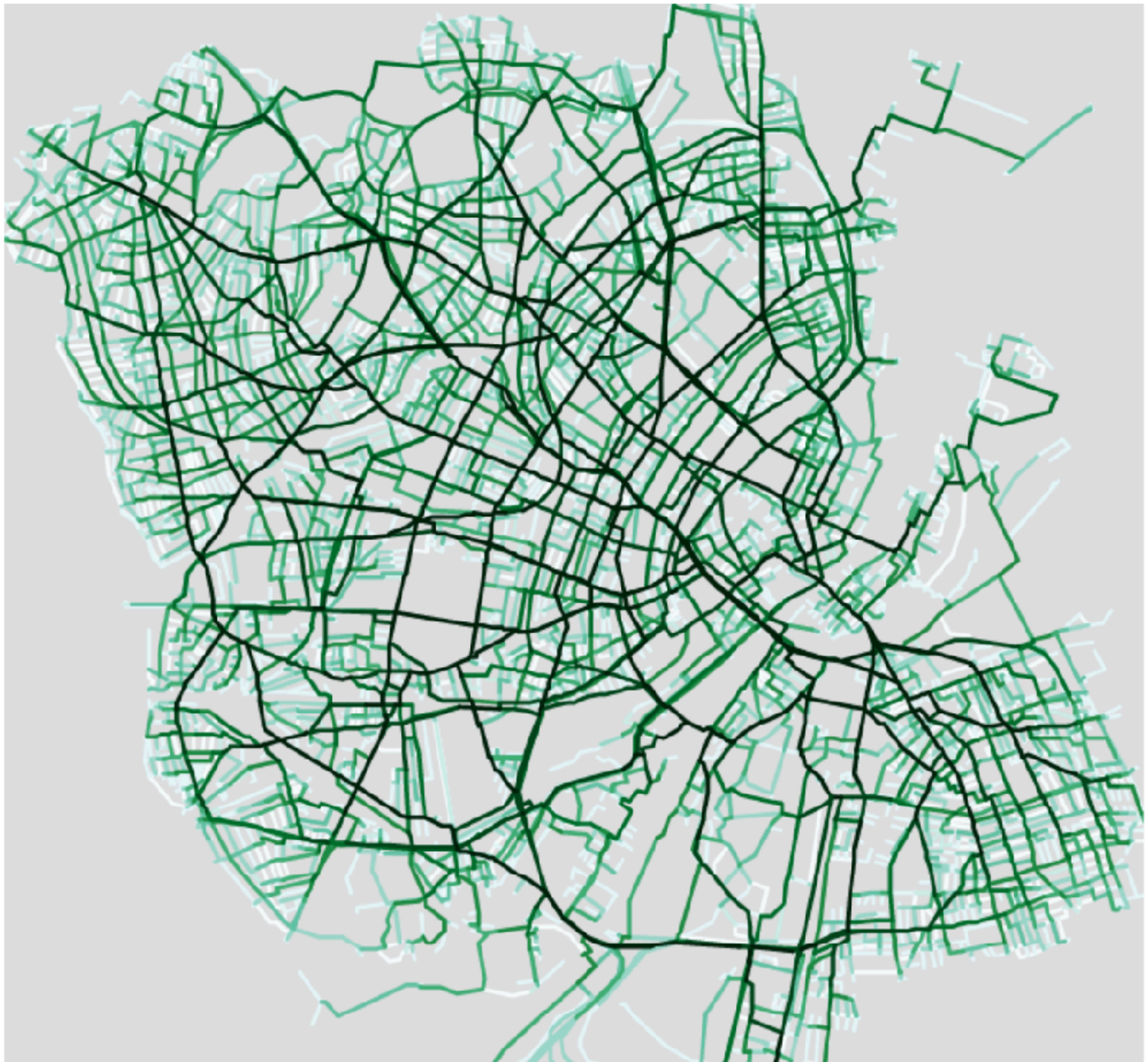
“If this gap was closed, how many meters cycled in mixed traffic would be avoided per investment unit?”

Vybornova et al, Geographical Analysis (2022)

# We can use betweenness centrality as a proxy for flow

$$C_B(i) = \sum_{i \neq j \neq k} \frac{\sigma_{jk}(i)}{\sigma_{jk}}$$

Cyclist flow data
is hard to get

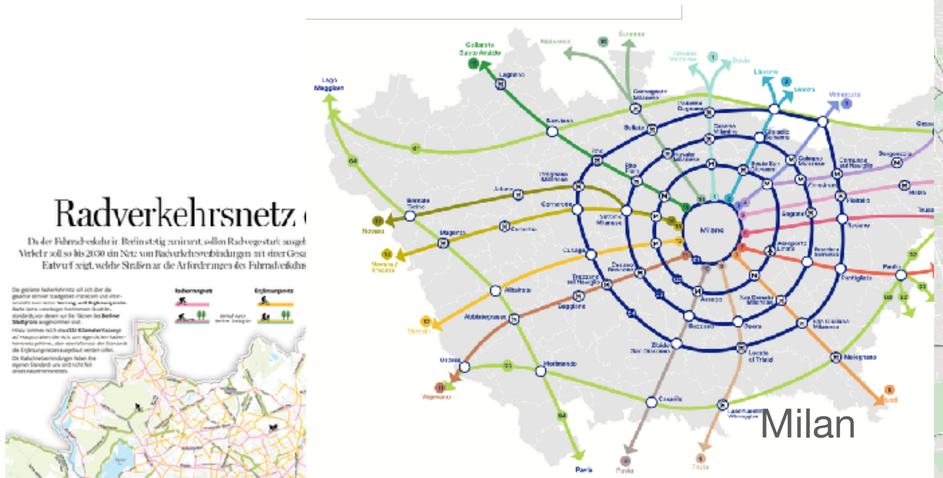


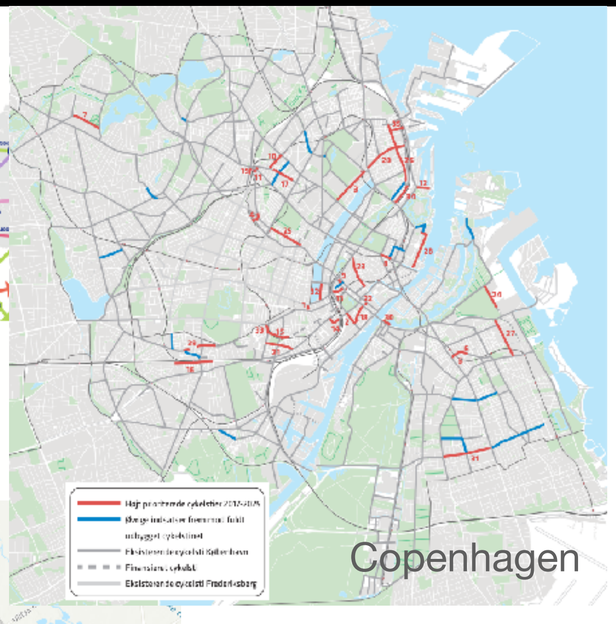
# From map to gap: **IPDC**

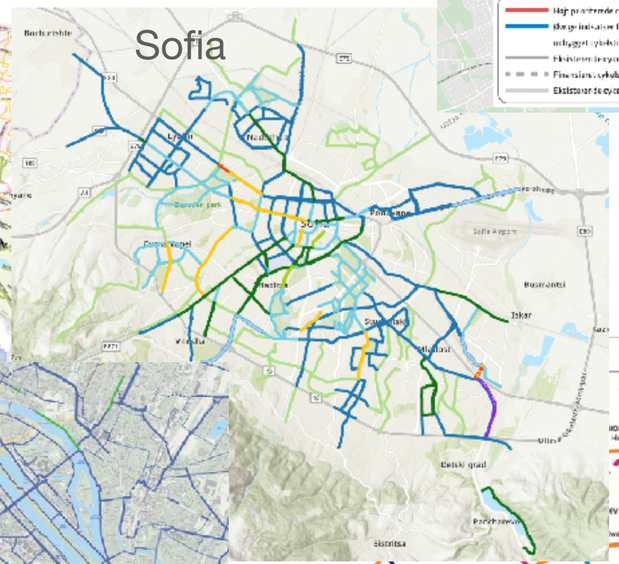
1) **I**dentify gaps
2) **P**rioritize gaps
3) **D**ecluster gaps
4) **C**lassify gaps

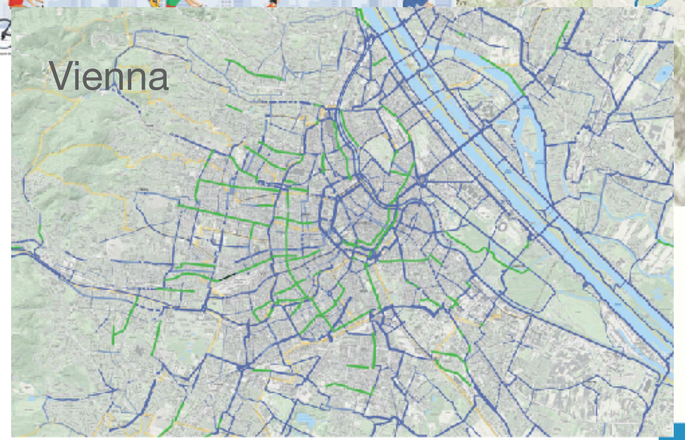
Vybornova et al, Geographical Analysis (2022)

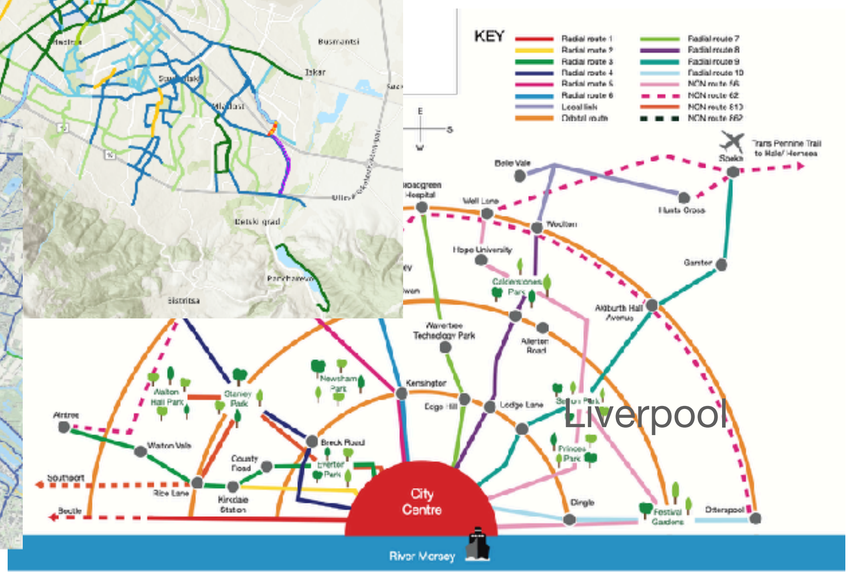
# We need data to plan more sustainable cities



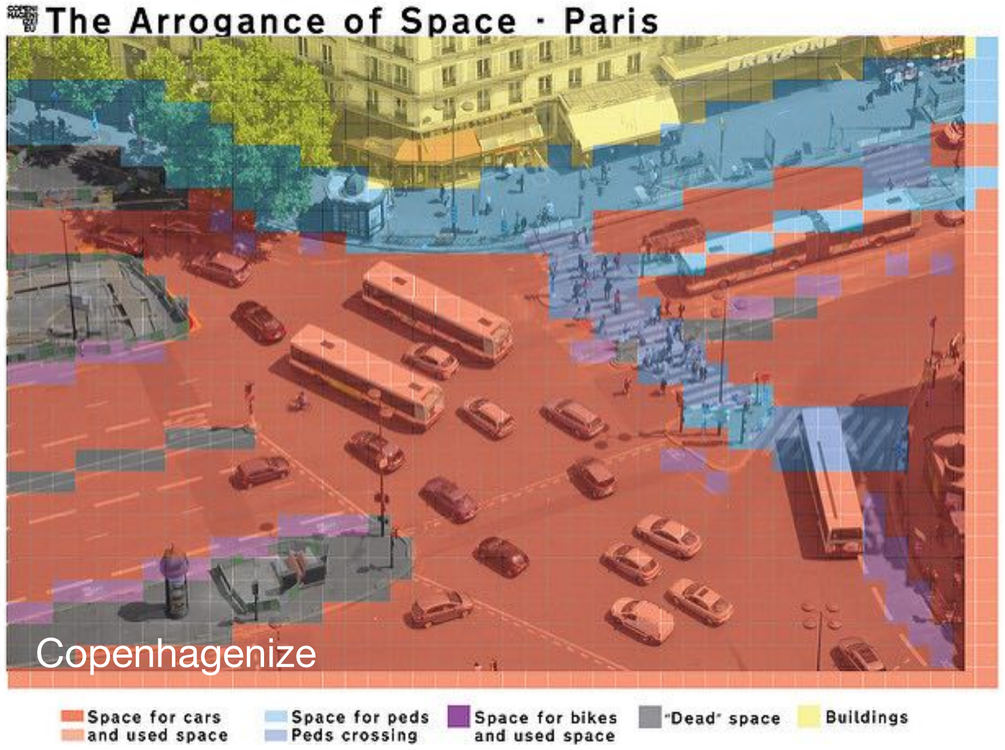





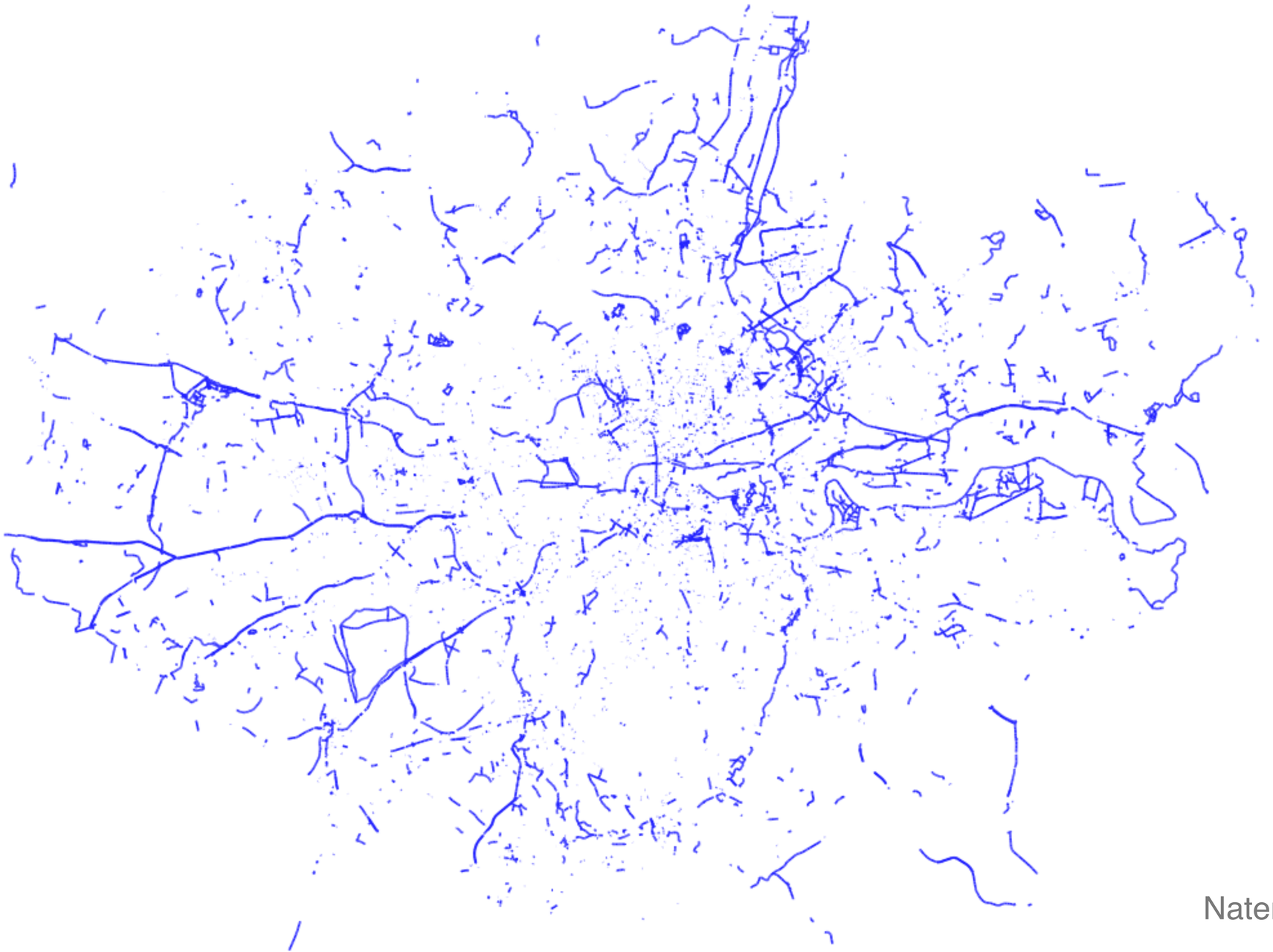
# Cycling is marginalized - BOTH in infrastructure and data



Data reflects priorities

Data influences priorities and decisions

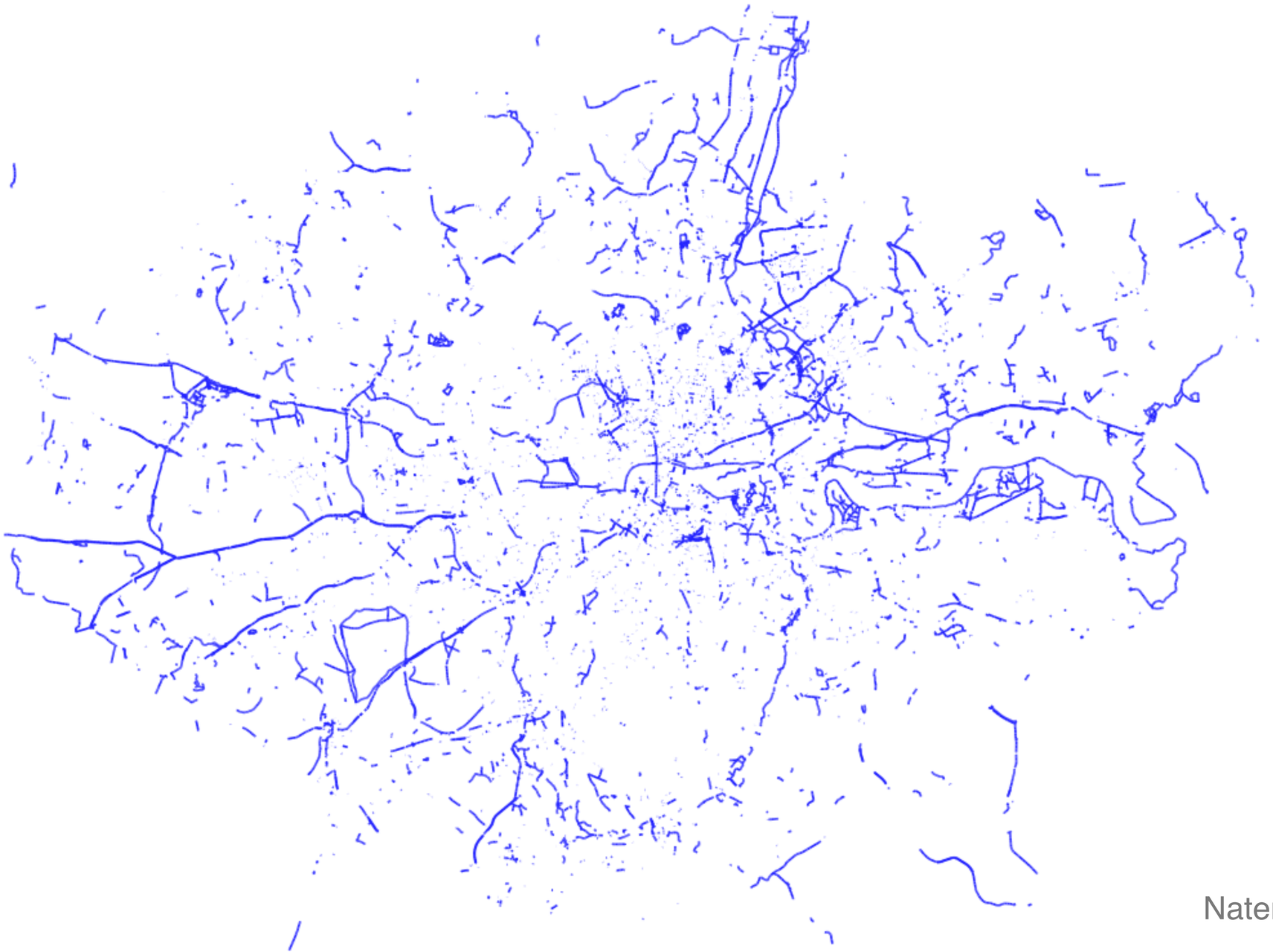
# Bicycle networks are highly fragmented



How much of this is just missing data?

Natera Oroczo et al, R Soc Open Sci 7 (2020)

# Bicycle networks are highly fragmented



How much of this is just missing data?

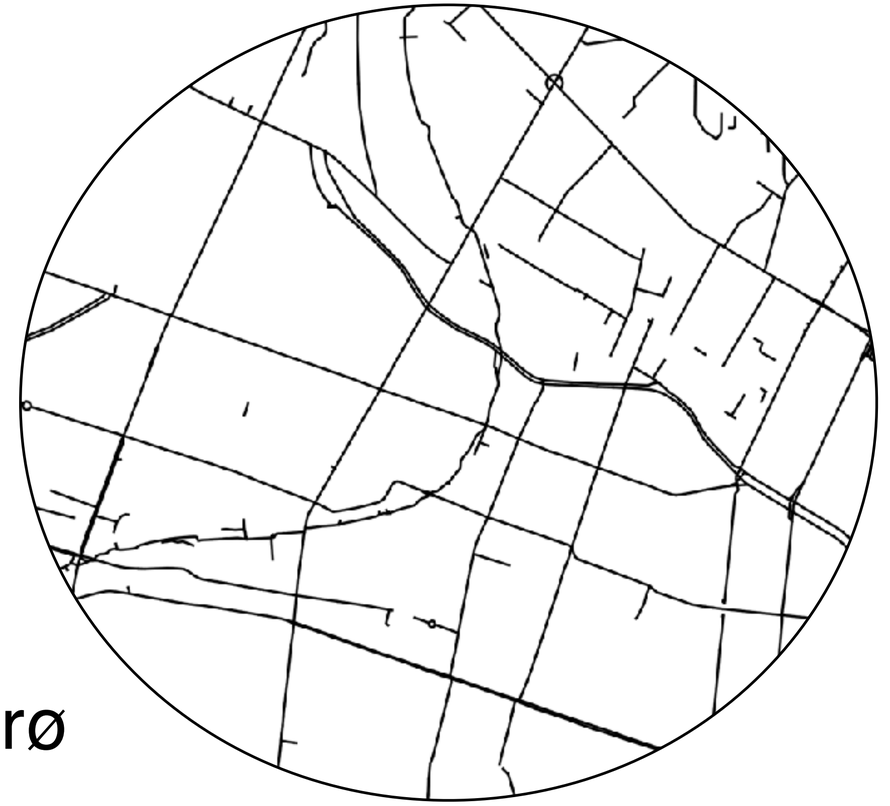
Where?

Natera Oroczo et al, R Soc Open Sci 7 (2020)

# BIKEDNA

Bicycle Infrastructure Data & Network Assessment

Ane Rahbek Vierø



+ jupyter

*Funded by The Danish Road Directorate*

# Data quality is multi-faceted

**ISO 19115**

- Completeness
- Consistency
- Positional accuracy
- Temporal accuracy
- Thematic accuracy

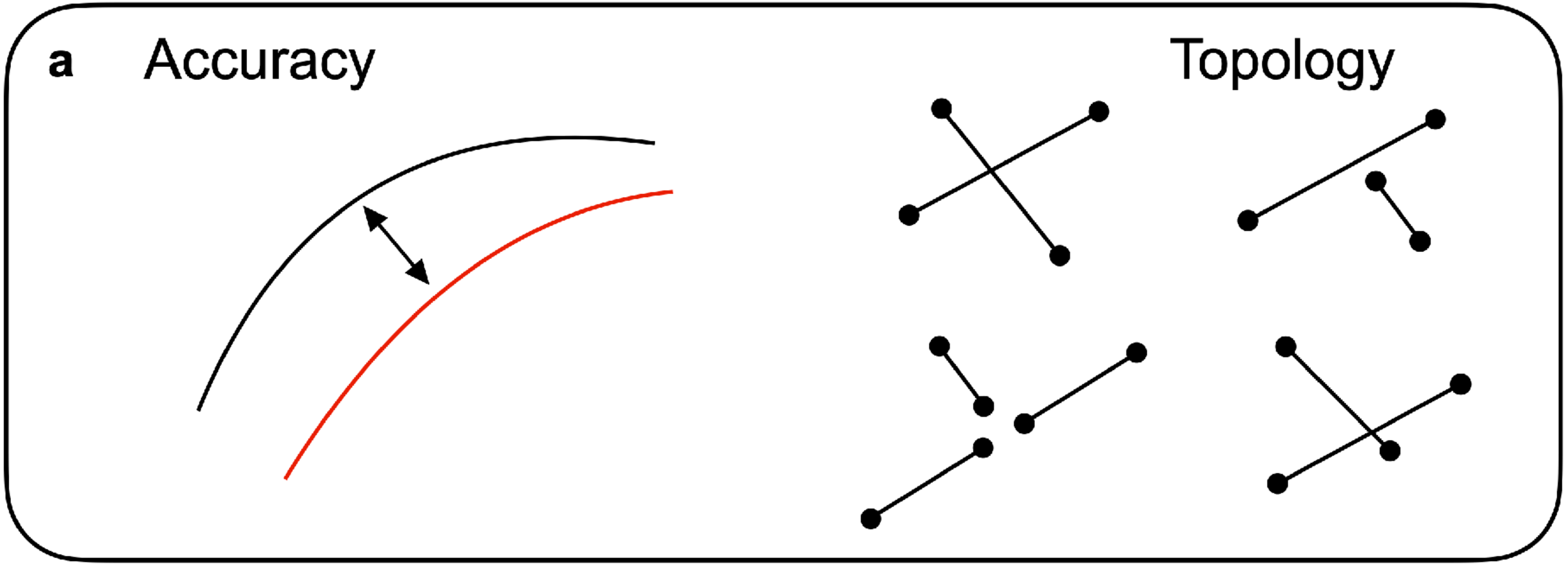
Senaratne et al., Int J GIS 31 (2017)

# We use: ‘Fitness for Purpose’

Are data good enough for my use case?

Barron, Neis & Zipf, Transaction in GIS 18,6 (2014)

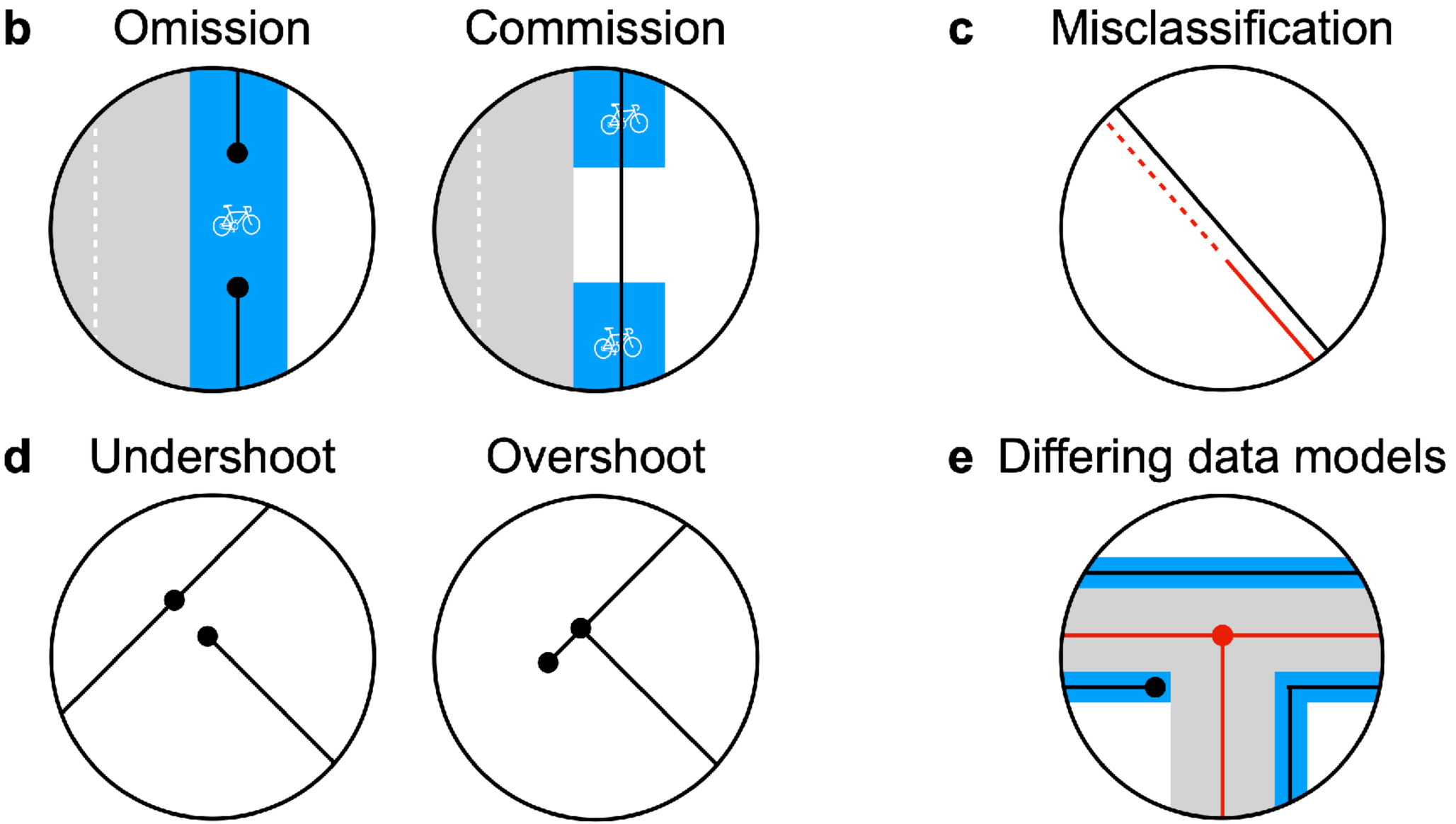
# We care less about accuracy, more about topology




Haklay et al., The Cart J 47:4 (2010)

Neis, Zielstra & Zipf, Fut Int 4,1 (2012)

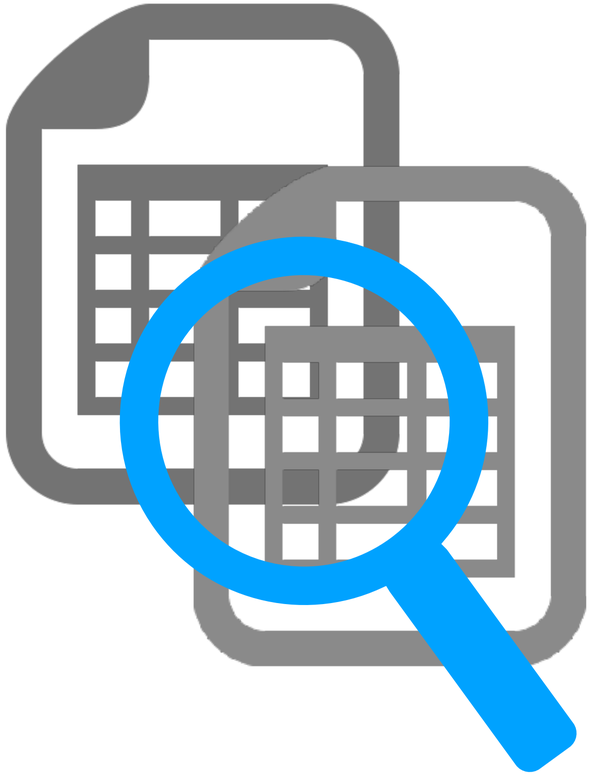
# Some common (topo)logical issues in bike infra data

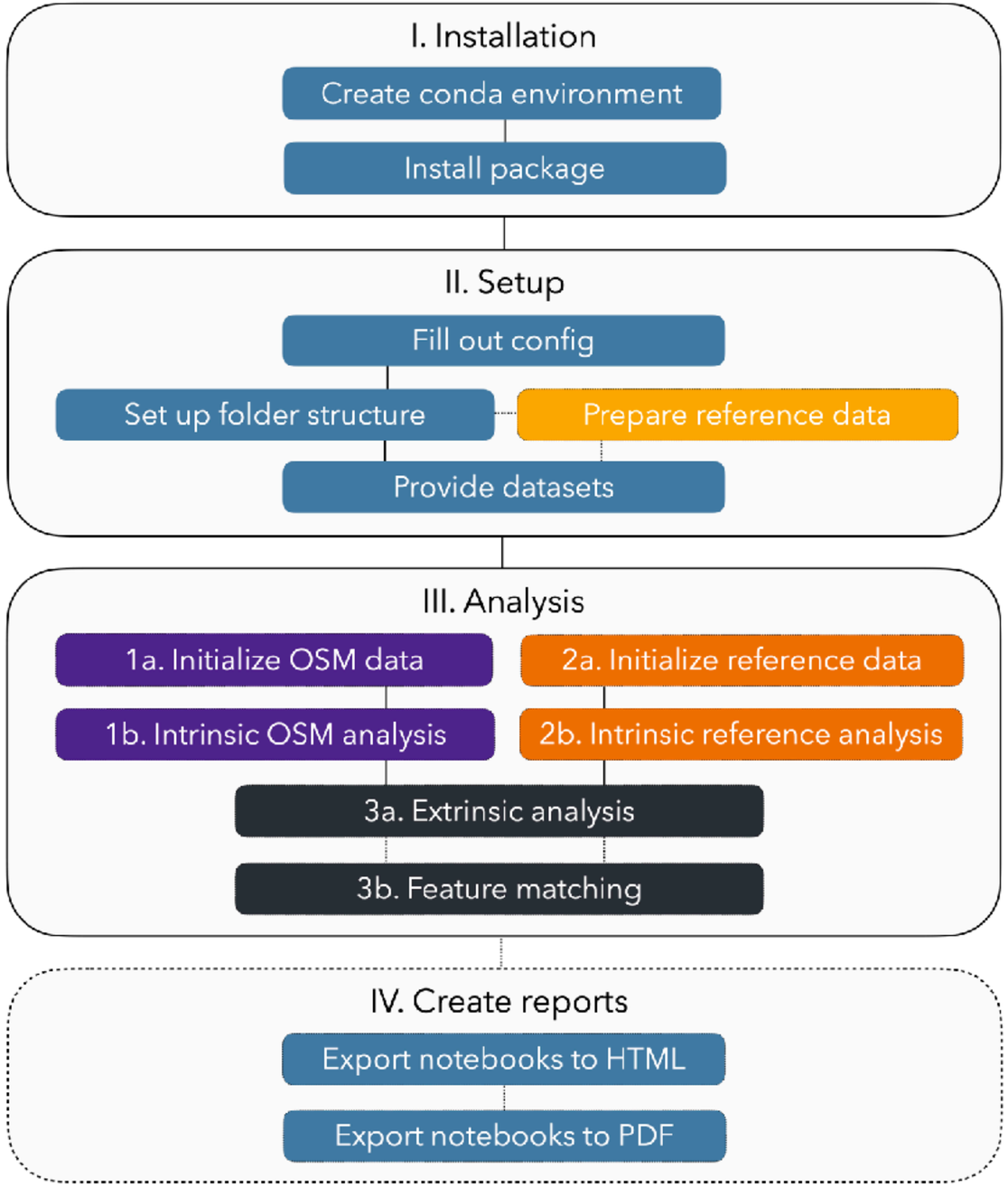


# You can analyze one data set or compare two

Intrinsic

Extrinsic






README.md

BIKEDNA

# BikeDNA: Bicycle Infrastructure Data & Network Assessment

This is the repository of BikeDNA, a tool for assessing the quality of OpenStreetMap (OSM) and other bicycle infrastructure data sets in a reproducible way. It provides planners, researchers, data maintainers, cycling advocates, and others who work with bicycle networks a detailed, informed overview of data quality in a given area.

▶ Background

## Workflow

BikeDNA consists of Jupyter notebooks that analyze bicycle infrastructure data sets. It therefore requires an installation of Python, including tools for Jupyter notebook.

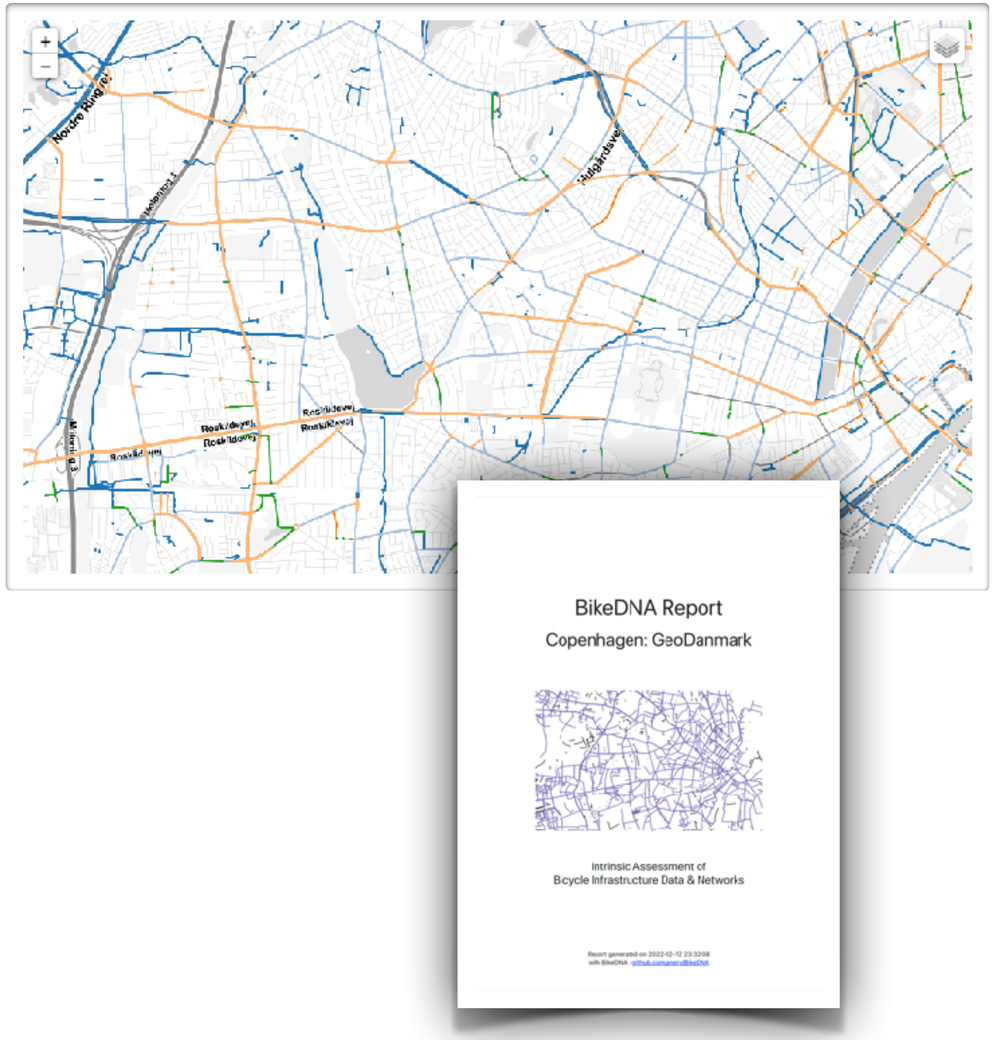
https://github.com/anerv/BikeDNA

# Features of BikeDNA

Data + network quality (completeness, consistency, accuracy)

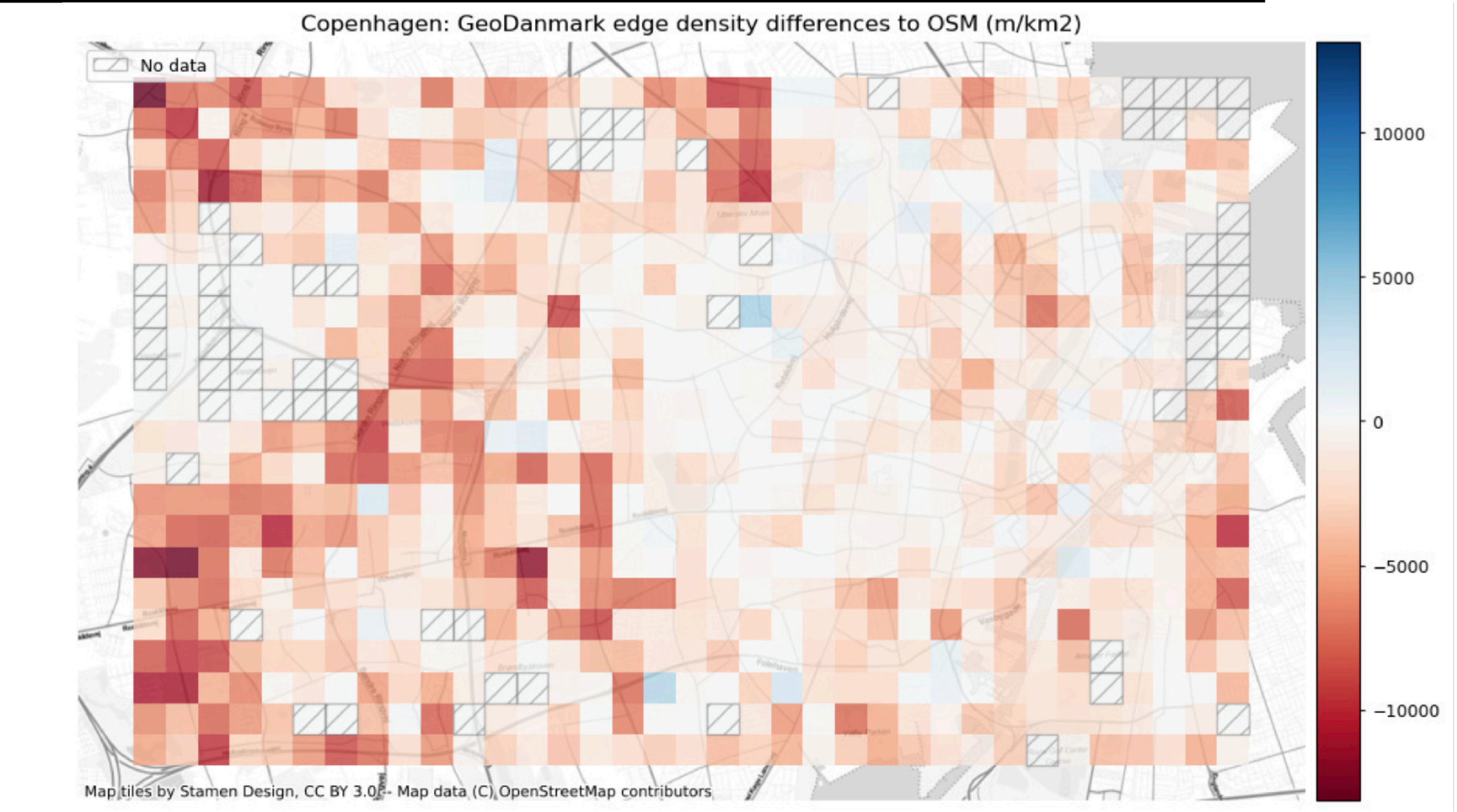
Both intrinsic and extrinsic, comparing reference data to OSM

Export reports: HTML (interactive), PDF

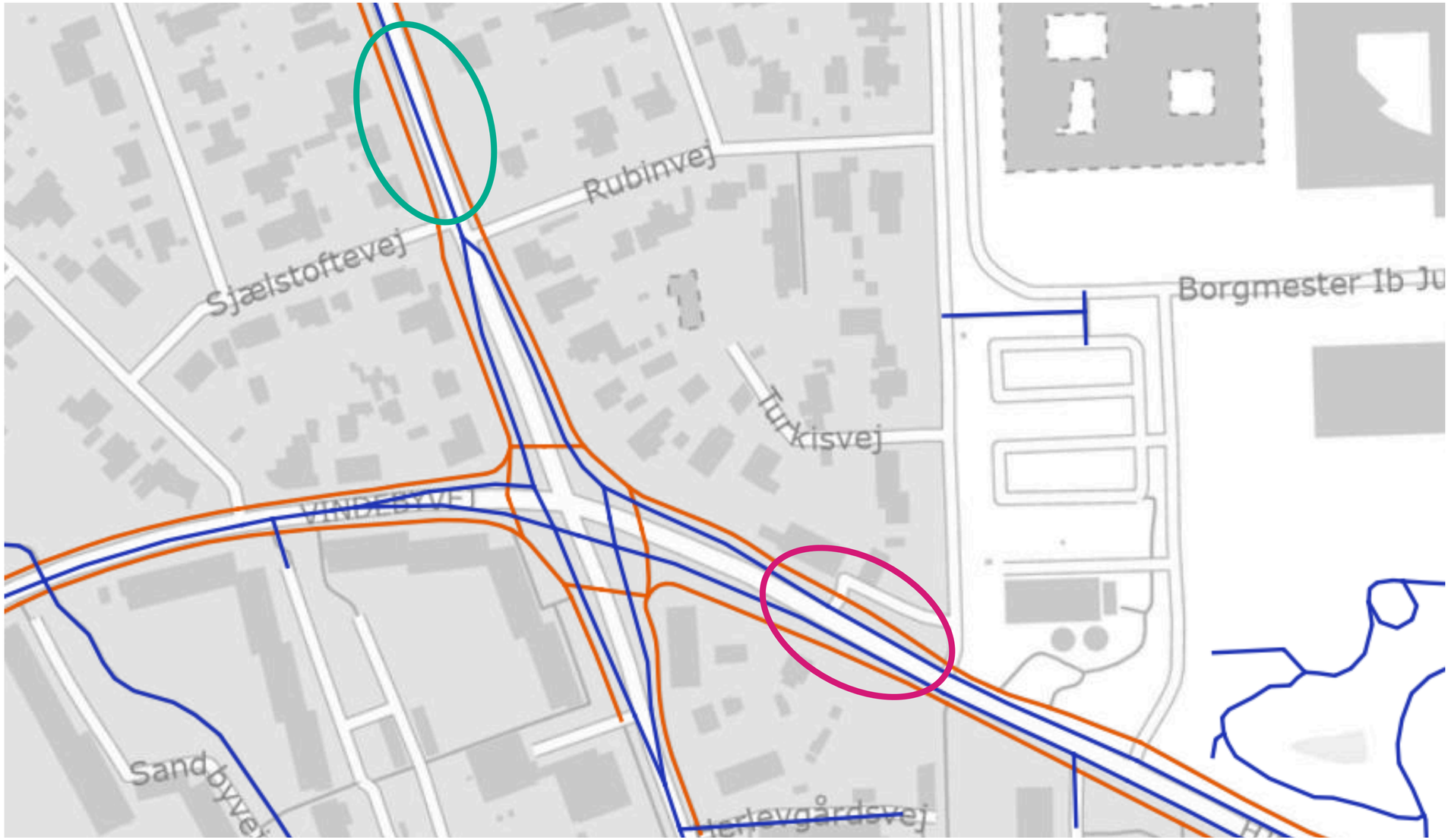



Soft-released Feb 2023

# Data completeness is the first step

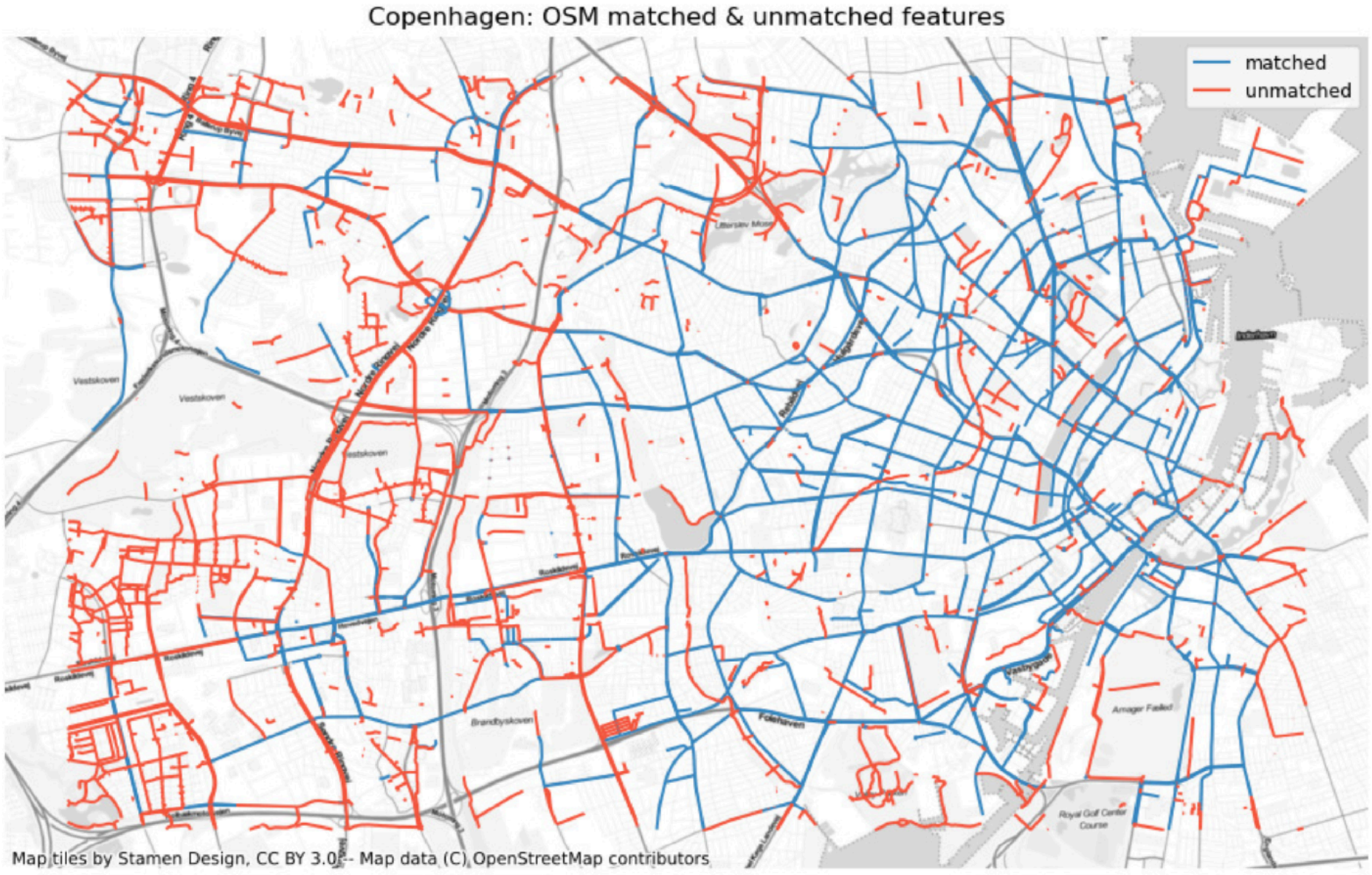


# …but comparing data completeness is tricky




© OpenStreetMap contributors, © GeoDanmark

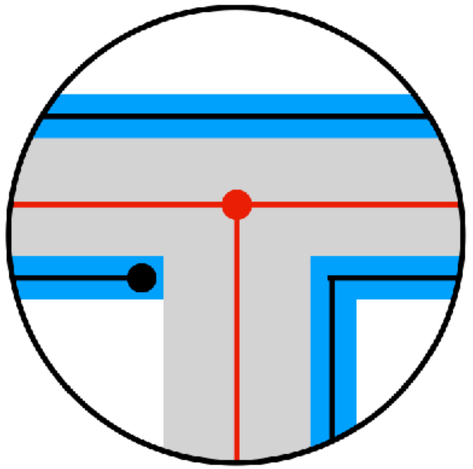
# Feature matching reveals inaccuracies & missing data

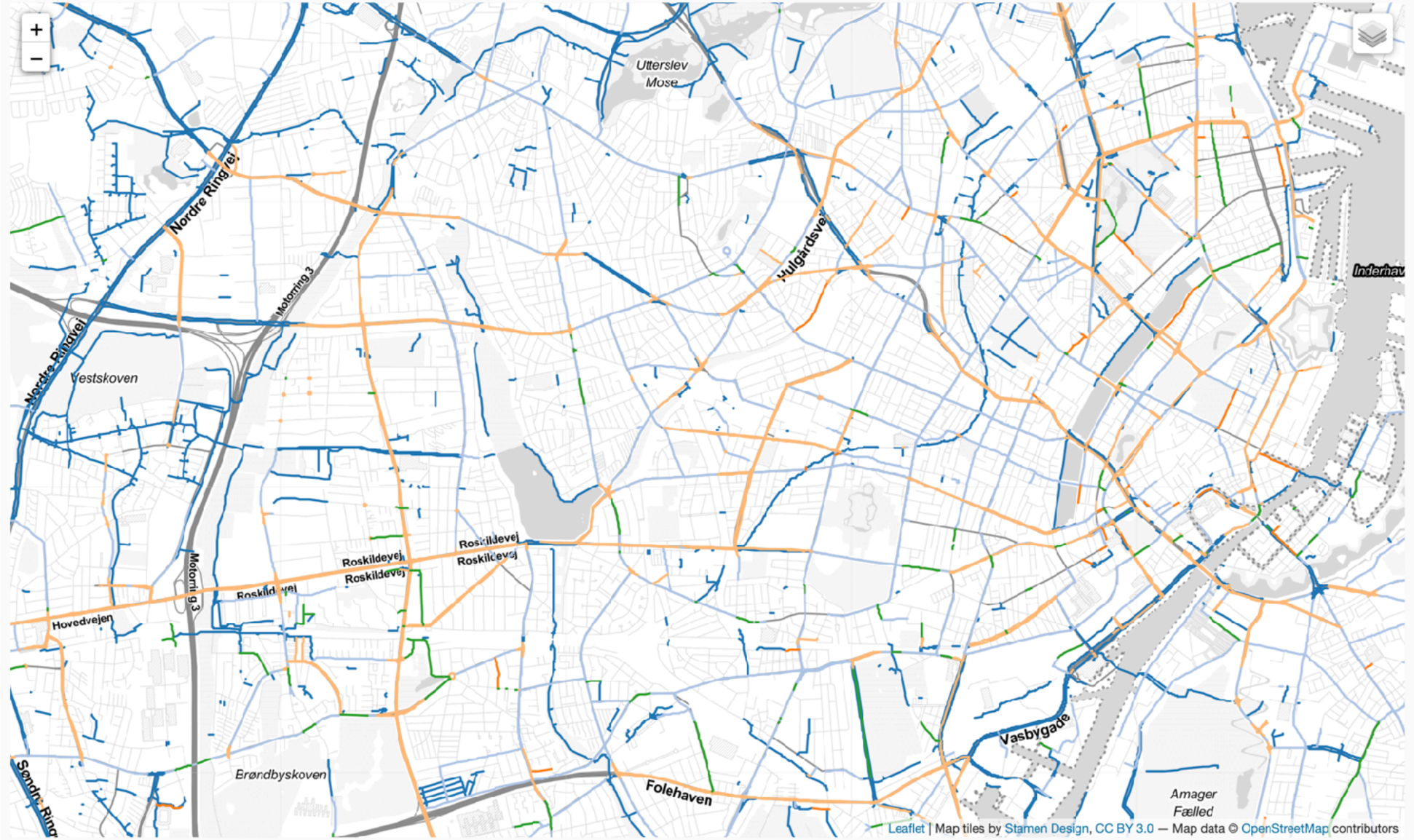



*See also Koukoletsos et al. 2012*

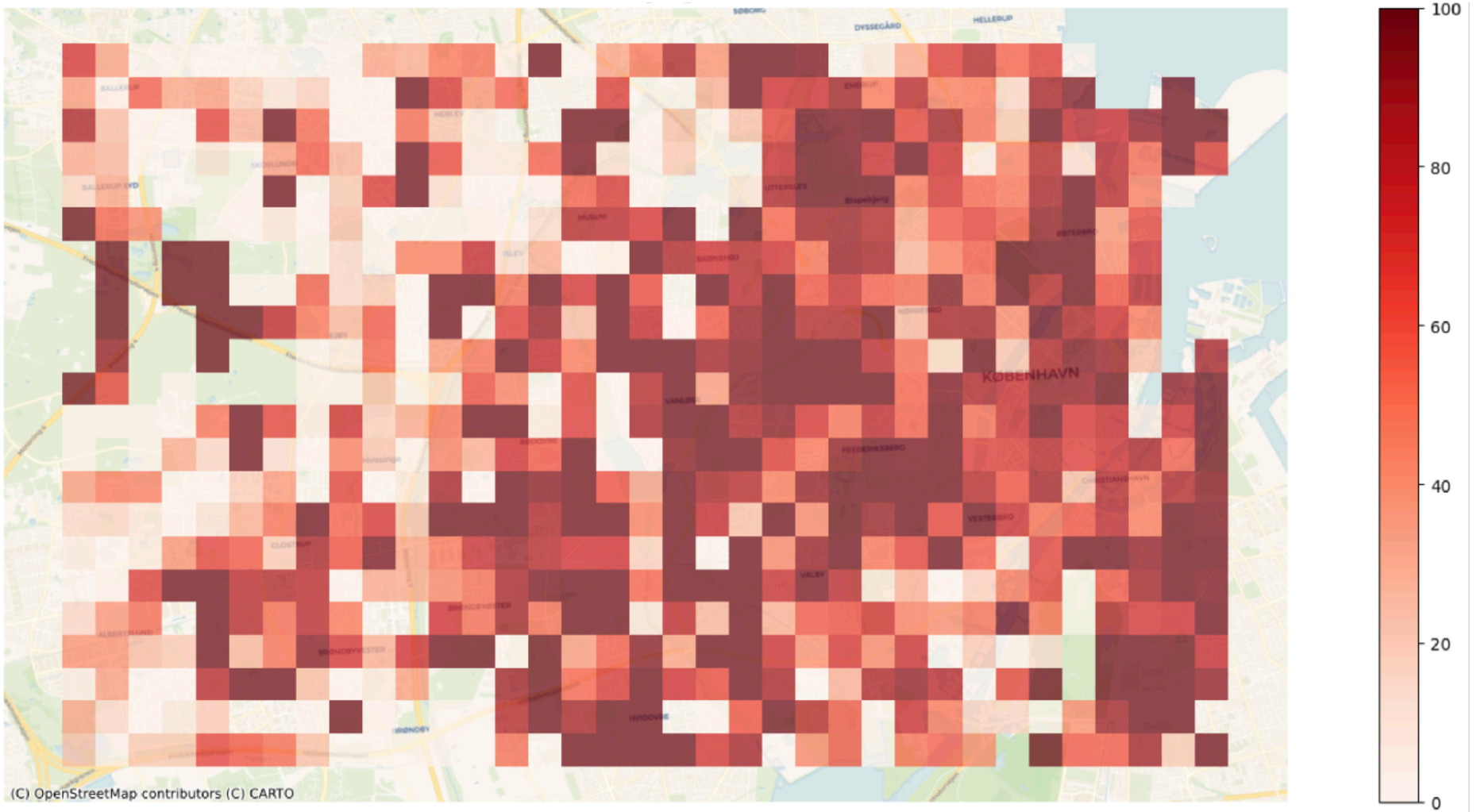
*© OpenStreetMap contributors, © GeoDanmark*

# We map the tagging patterns to help new users understand OSM practices





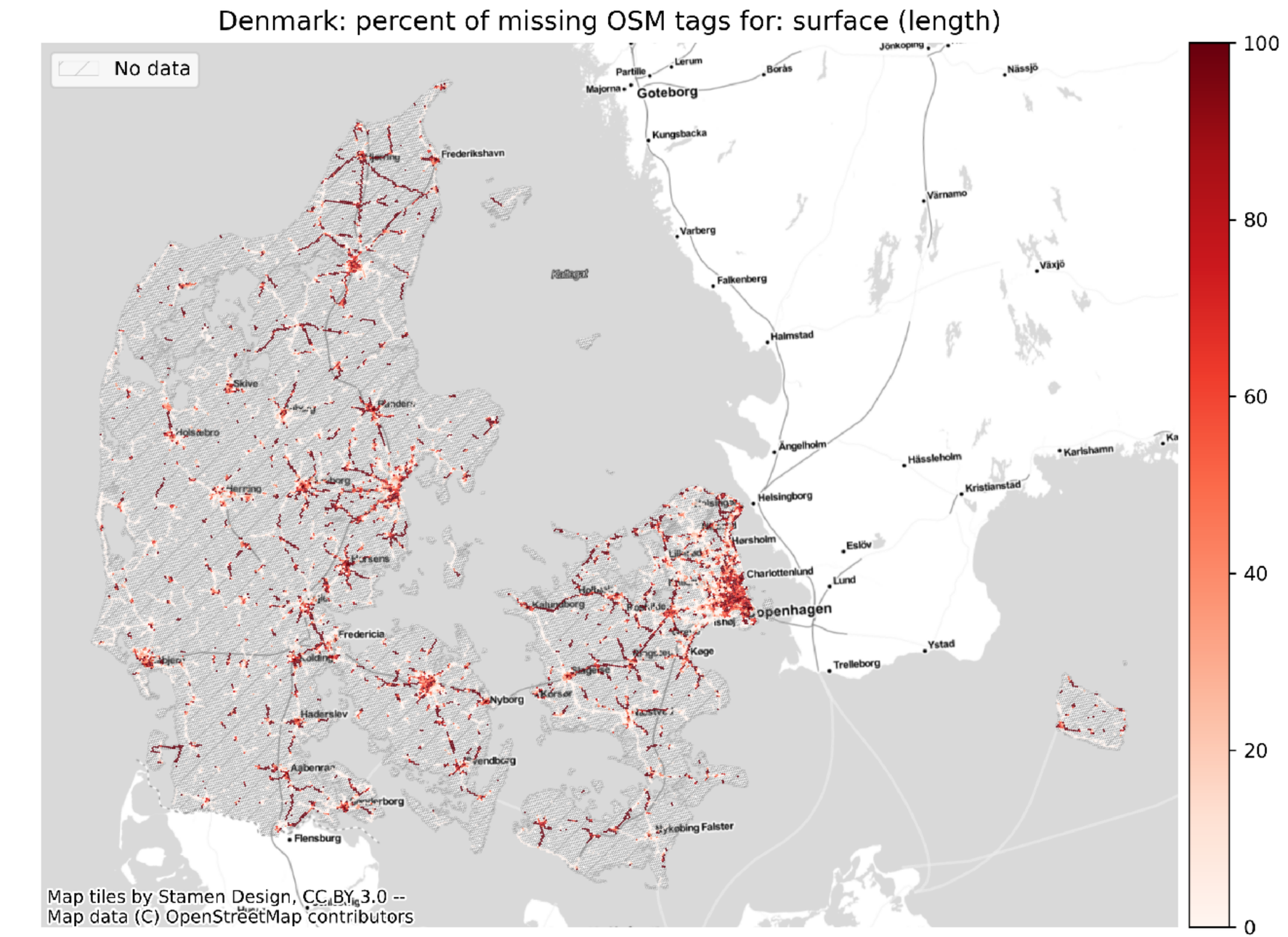
# OSM tags are added inconsistently




% edges without ‘surface’ tag

© OpenStreetMap contributors

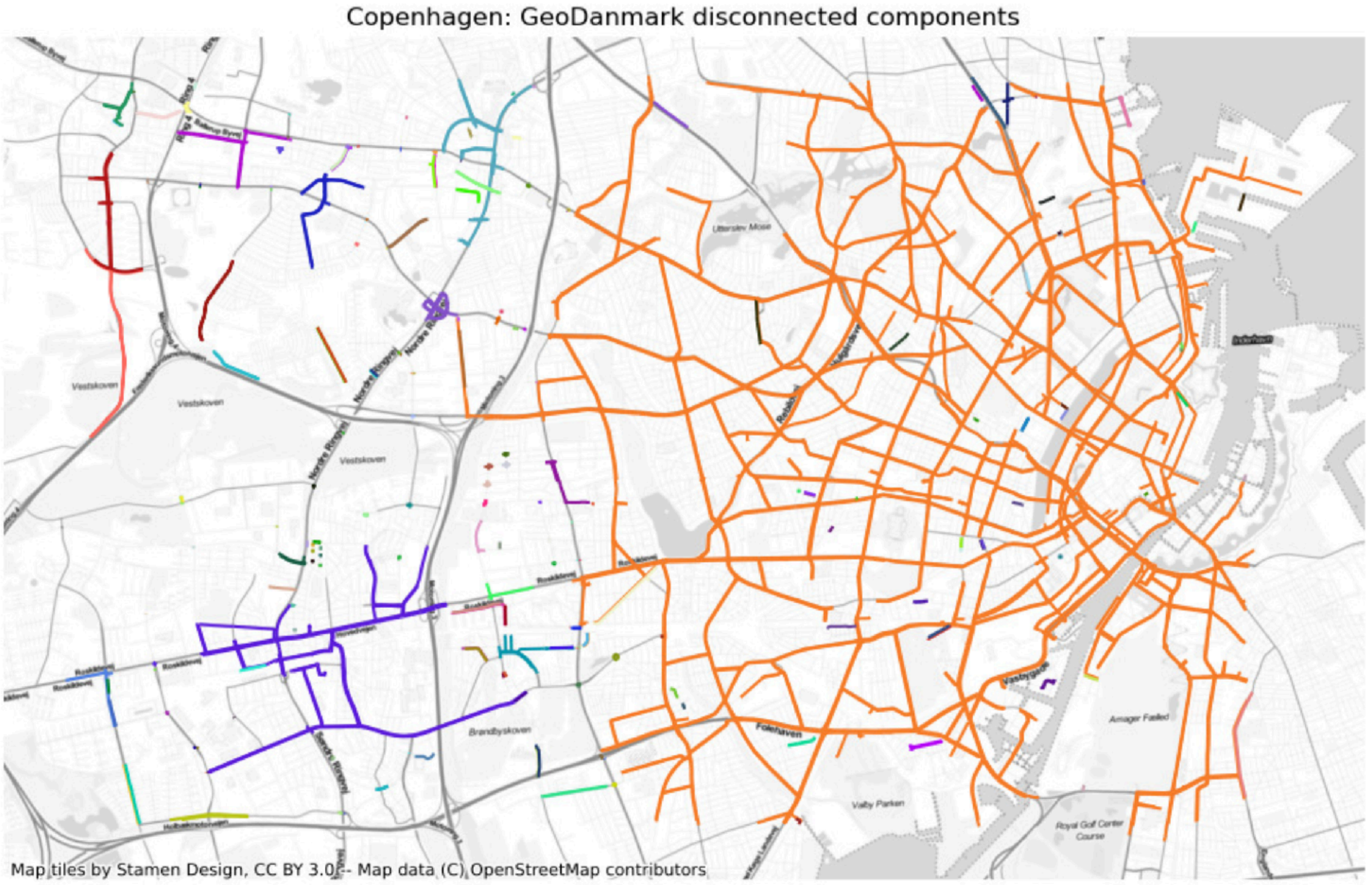
# OSM tags are added inconsistently




© OpenStreetMap contributors

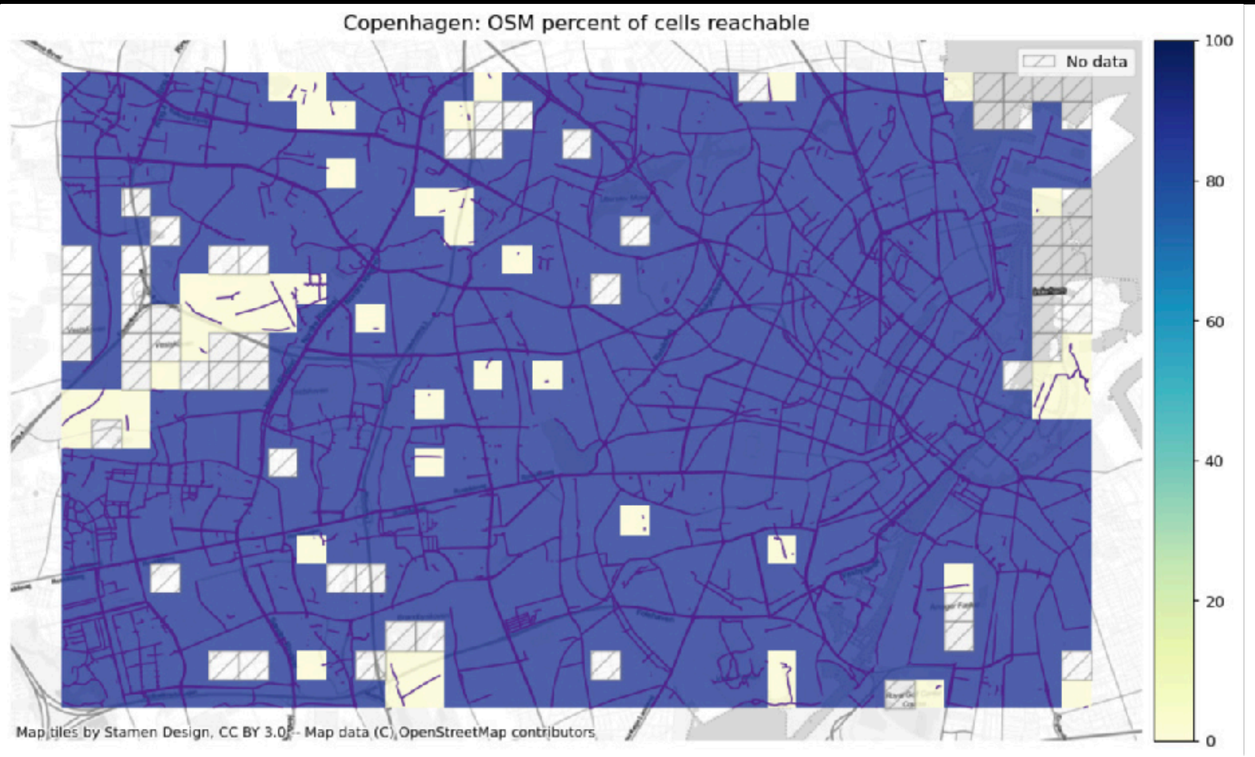
# Actual bicycle networks are often not connected…

# …even less so when mapped

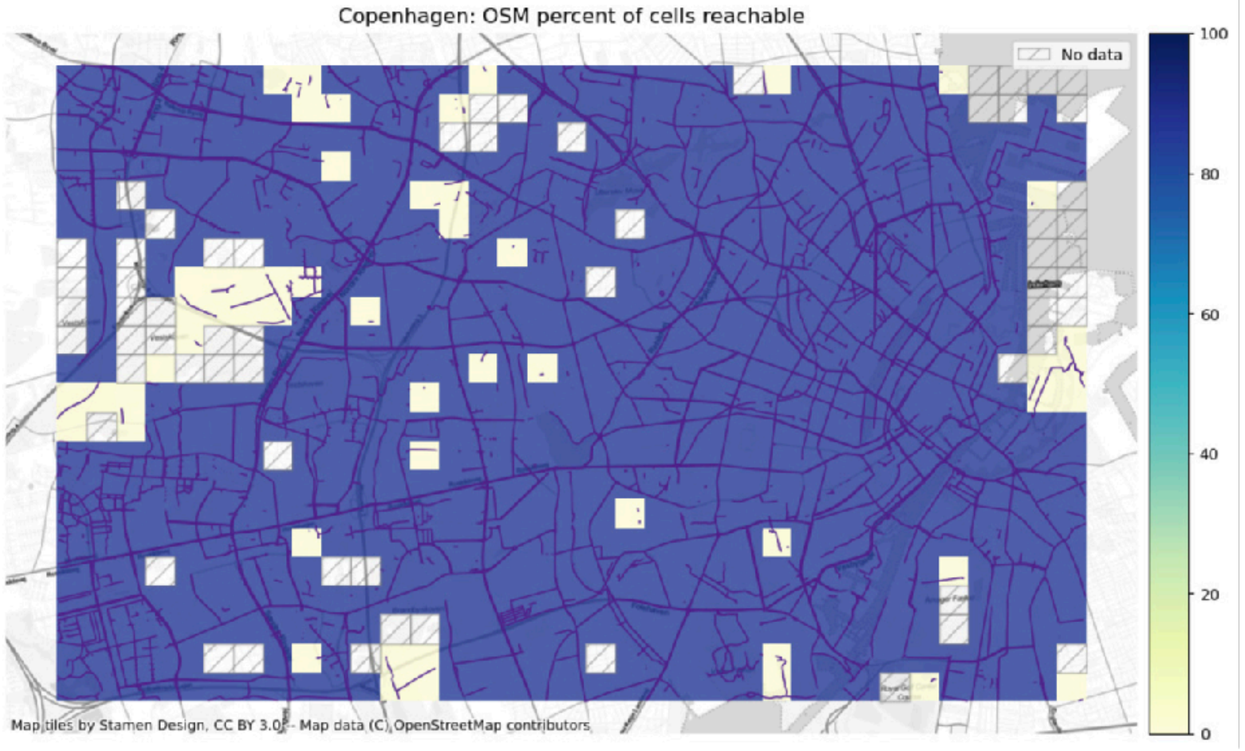


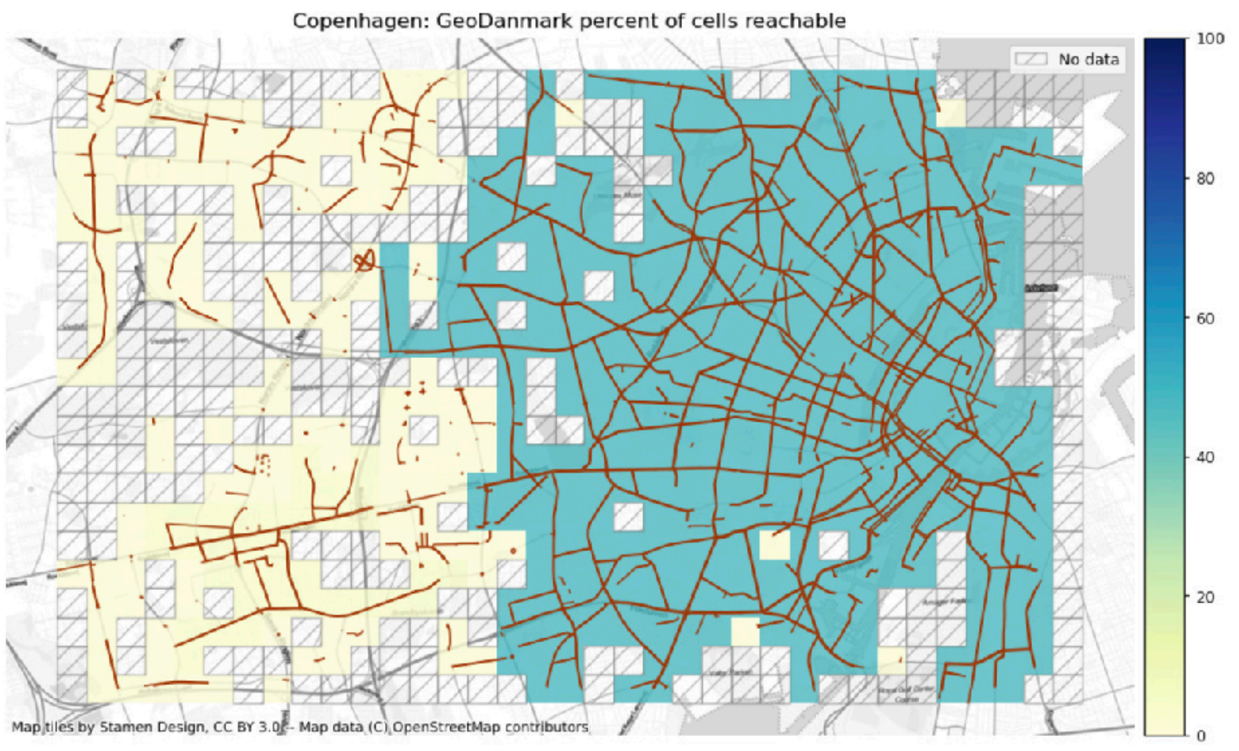
# Inconsistent mapping methods results in data gaps

# Errors and omissions have real network effects

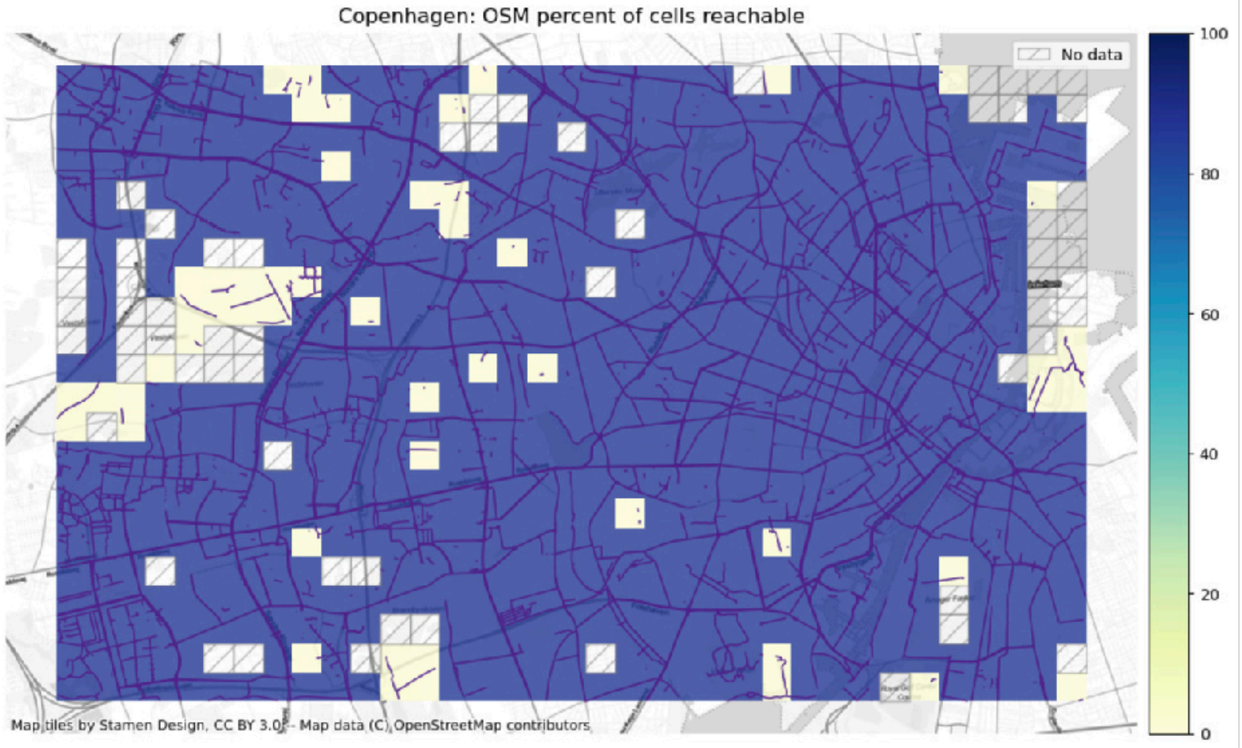


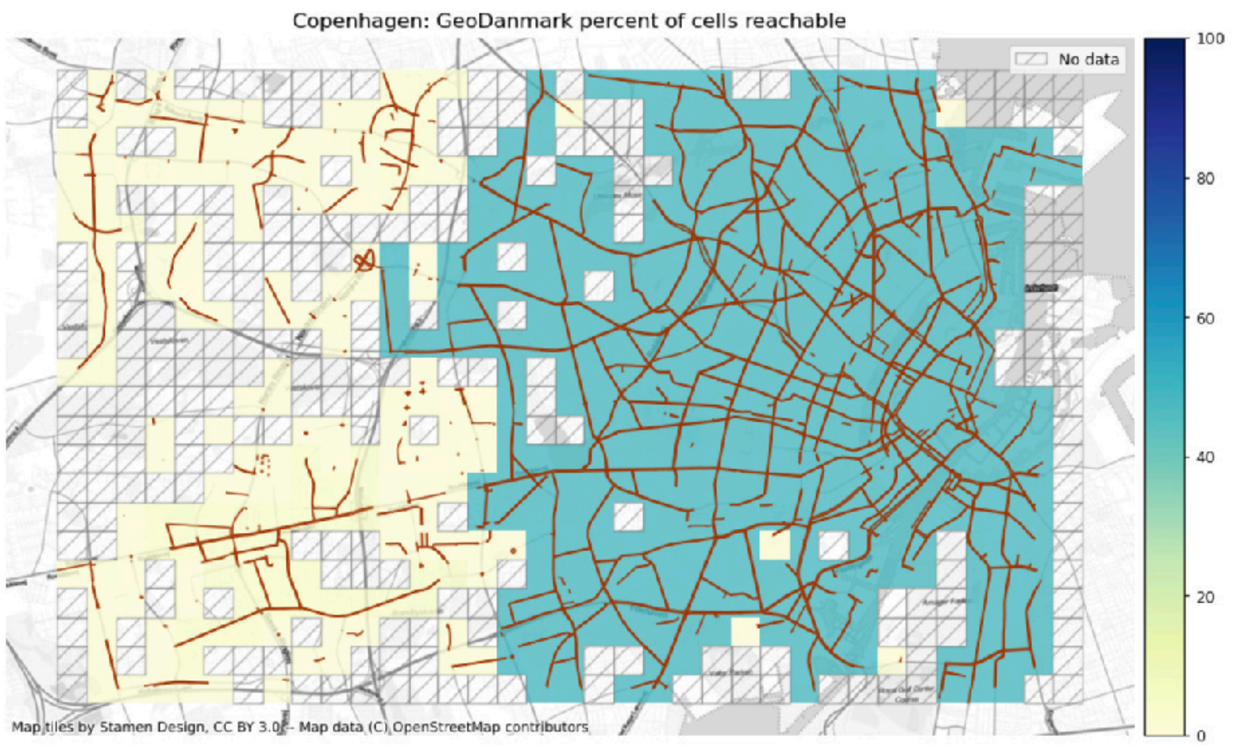
# Errors and omissions have real network effects

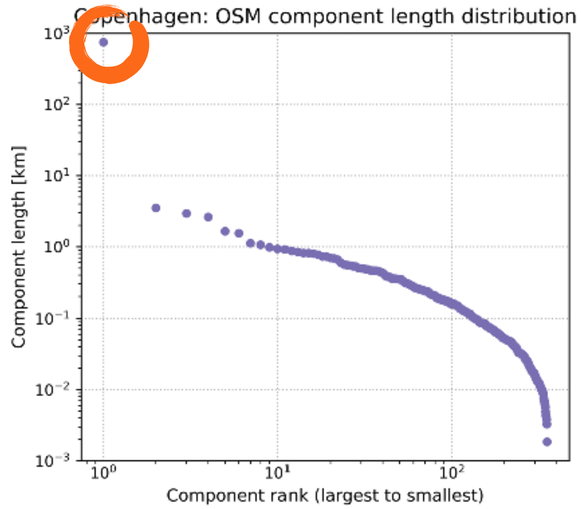


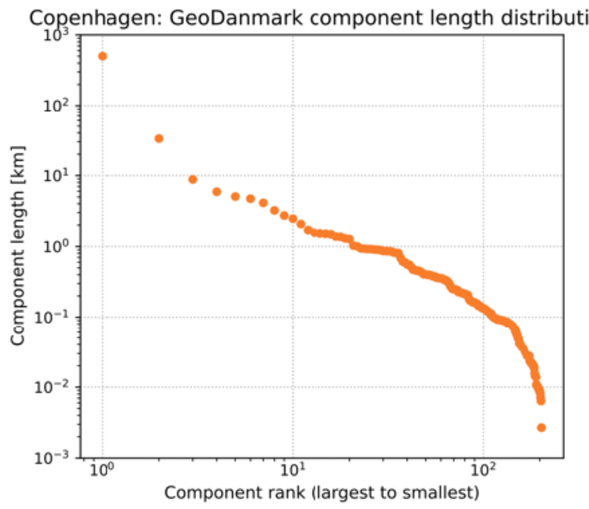



# Errors and omissions have real network effects

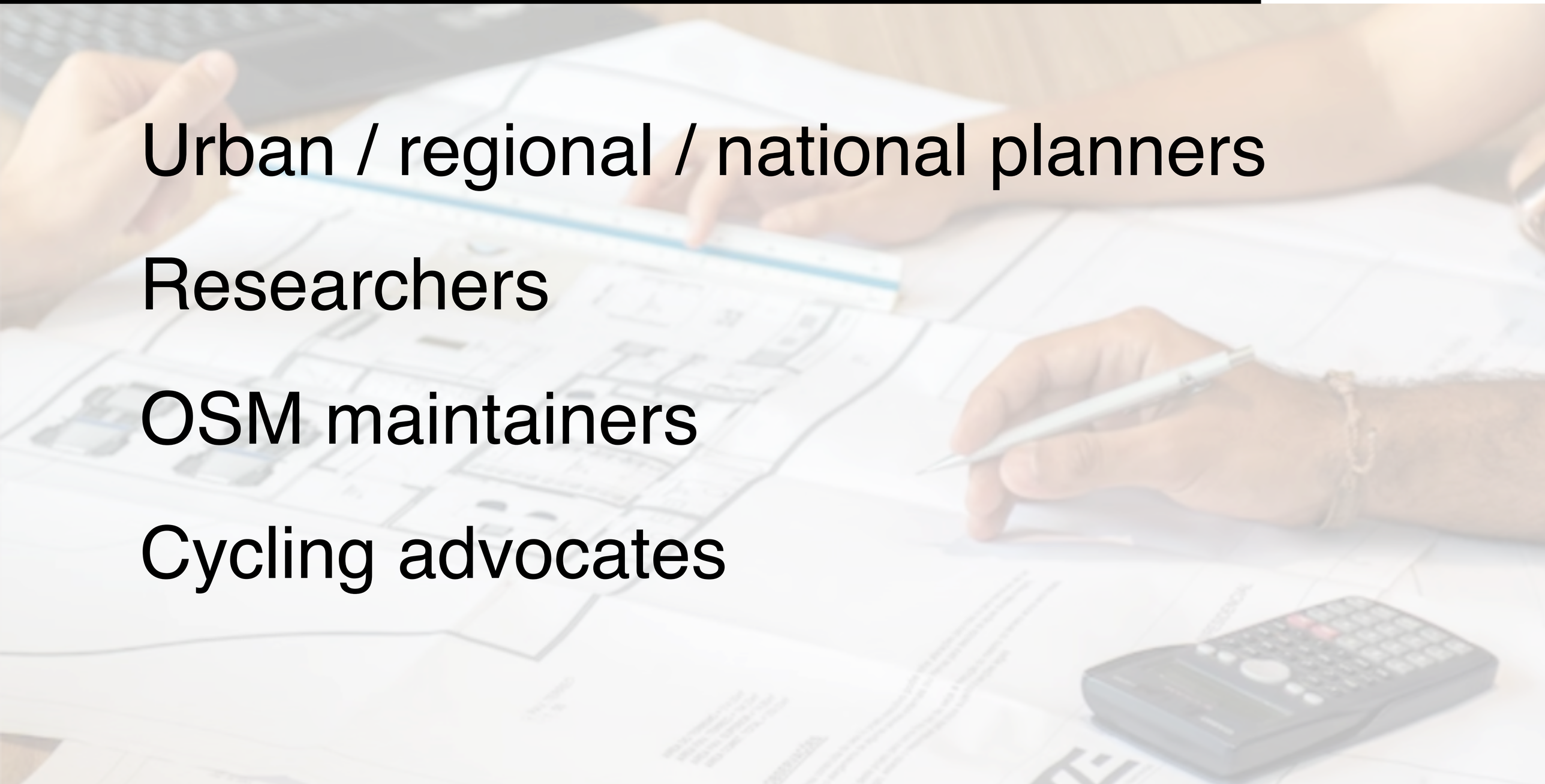


# Use cases of BikeDNA



Urban / regional / national planners

Researchers

OSM maintainers

Cycling advocates

# There are still unsolved challenges

No ground truth

# Key take aways

Data quality matters

# Key take aways

Data quality matters

Quality data not a given

# Key take aways

Data quality matters

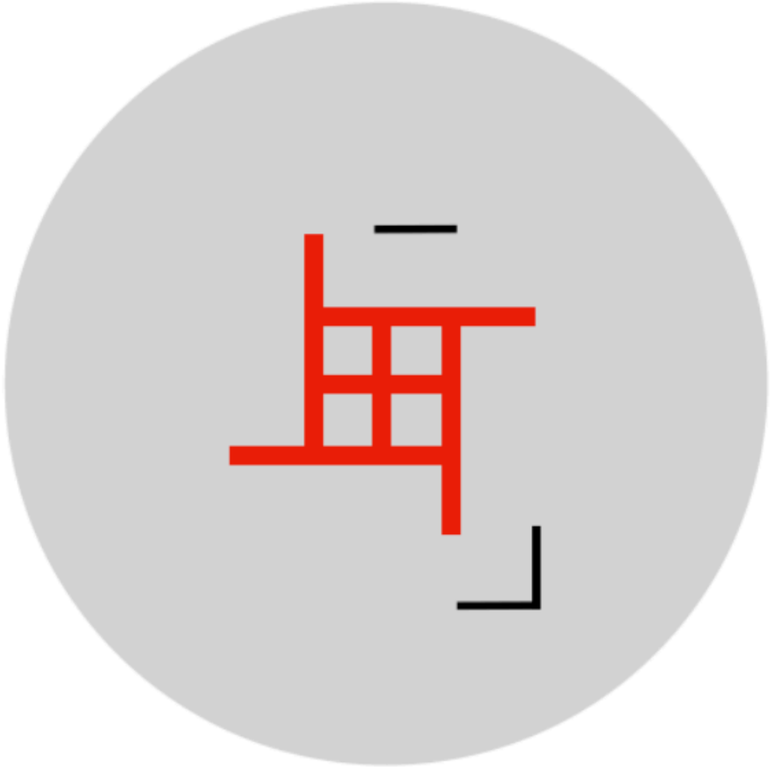
Quality data not a given

Data (quality) is political

?

# Different cities need different strategies

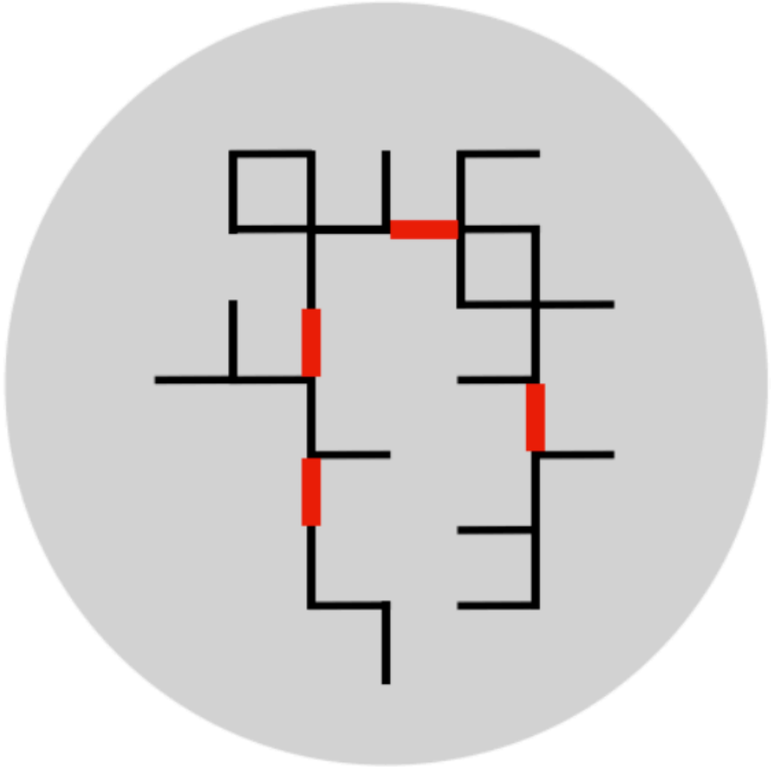
Most cities
Not developed



Grow from scratch

GrowBike.Net

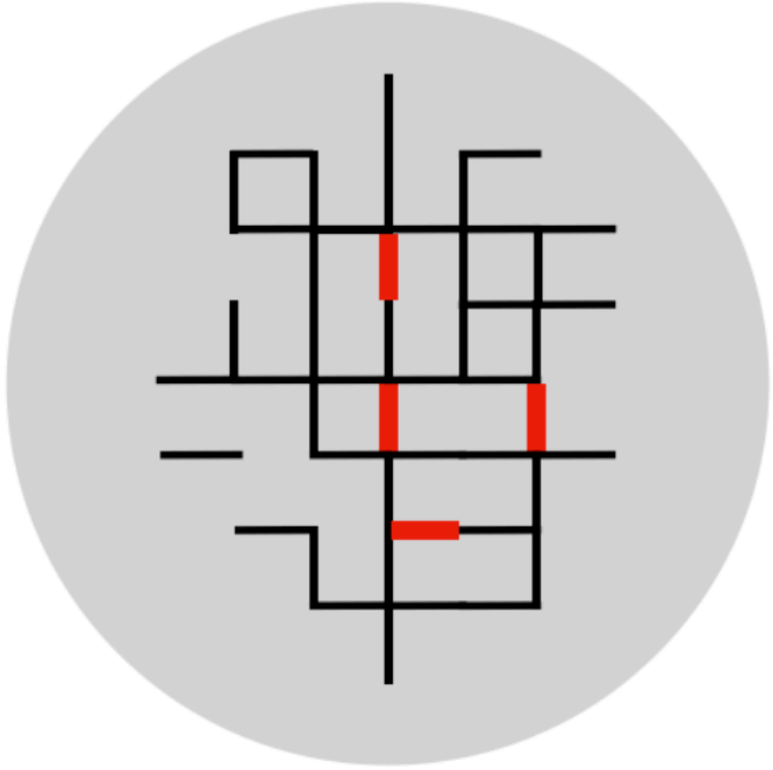
Some cities
Developed but disconnected



Connect components

LinkBike.Net

Few cities
Developed and mostly connected

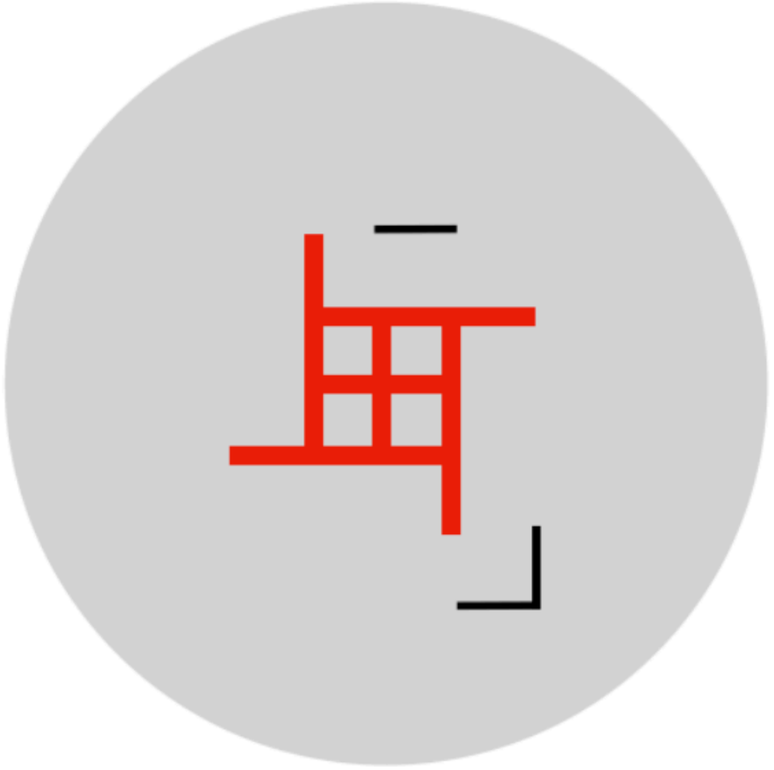


Find missing links

FixBike.Net

Most cities

Not developed



Grow from scratch

GrowBike.Net

Let's grow networks
from scratch

# How to build bicycle infrastructure?

fietsberaad CROW

## Design Manual for Bicycle Traffic

We have great planning guides.

NACTO

## Urban Bikeway Design Guide

April 2011 Edition

# How to build bicycle infrastructure?

We have great planning guides.

NACTO

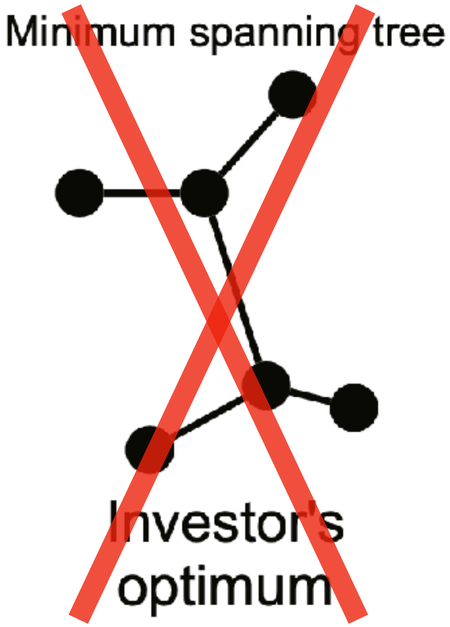
Urban Bikeway Design Guide

April 2011 Edition

But no knowledge on the fundamental topological limitations of network growth.

# Inspired by CROW, we want a cohesive network

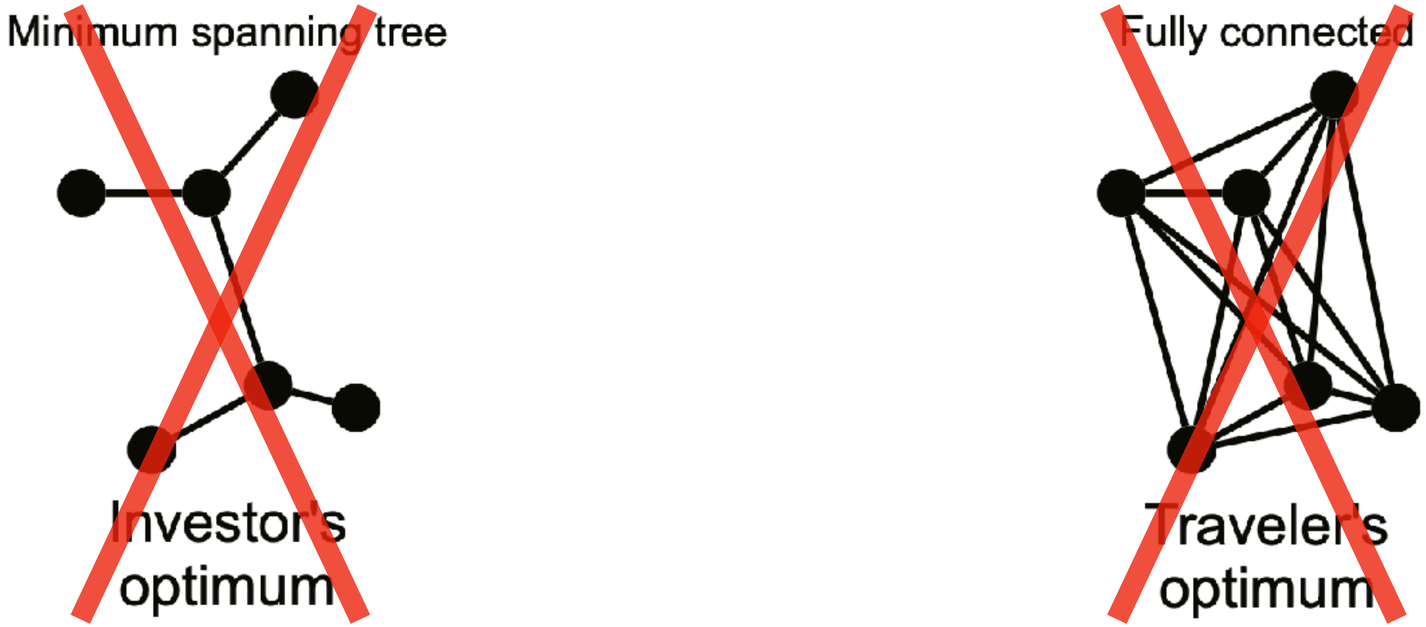
Connectedness & Resilience




Szell et al., Sci Rep 12, 6765 (2022)

# Inspired by CROW, we want a cohesive network

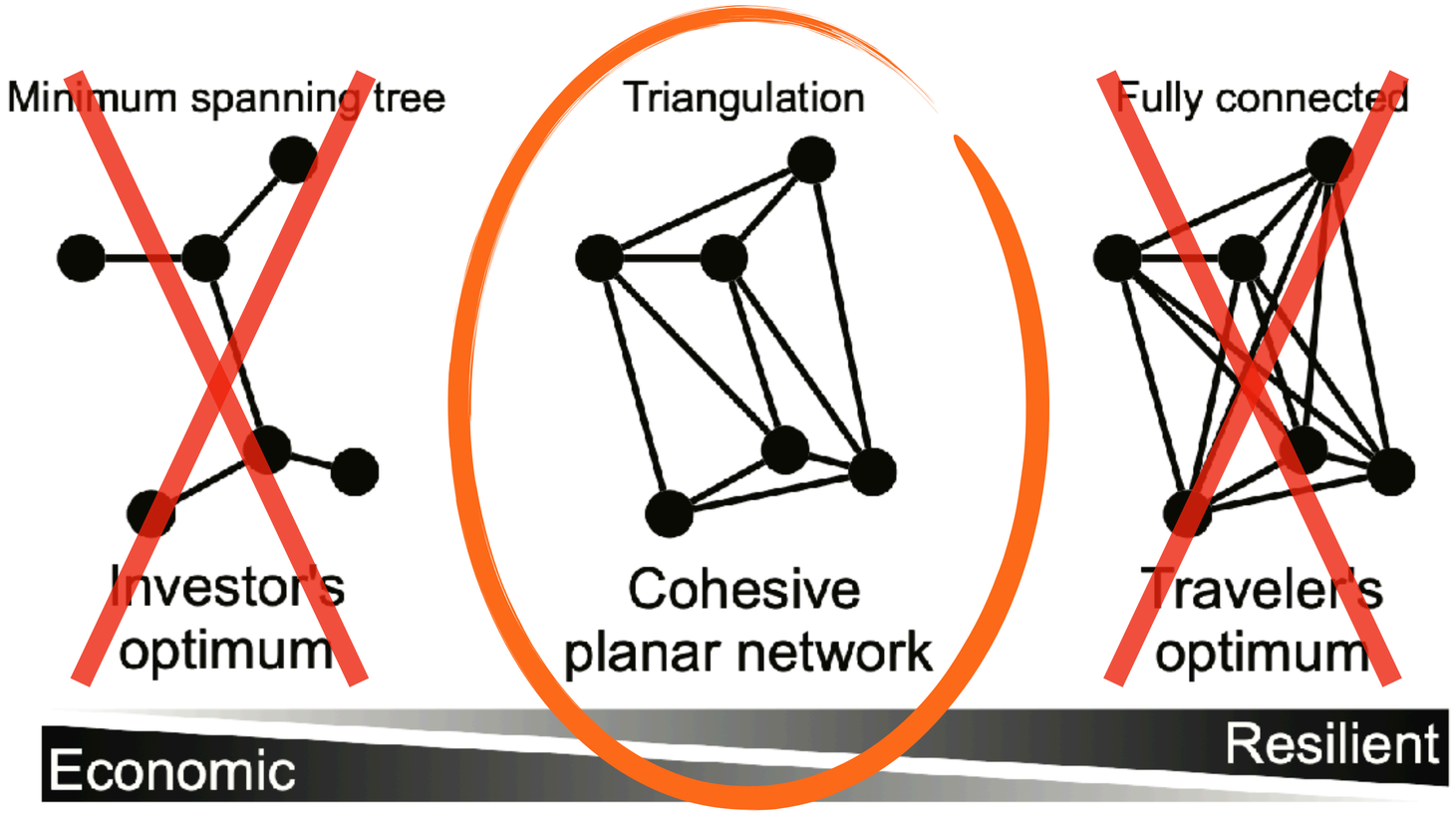
Connectedness & Resilience




Szell et al., Sci Rep 12, 6765 (2022)

# Inspired by CROW, we want a cohesive network

Connectedness & Resilience

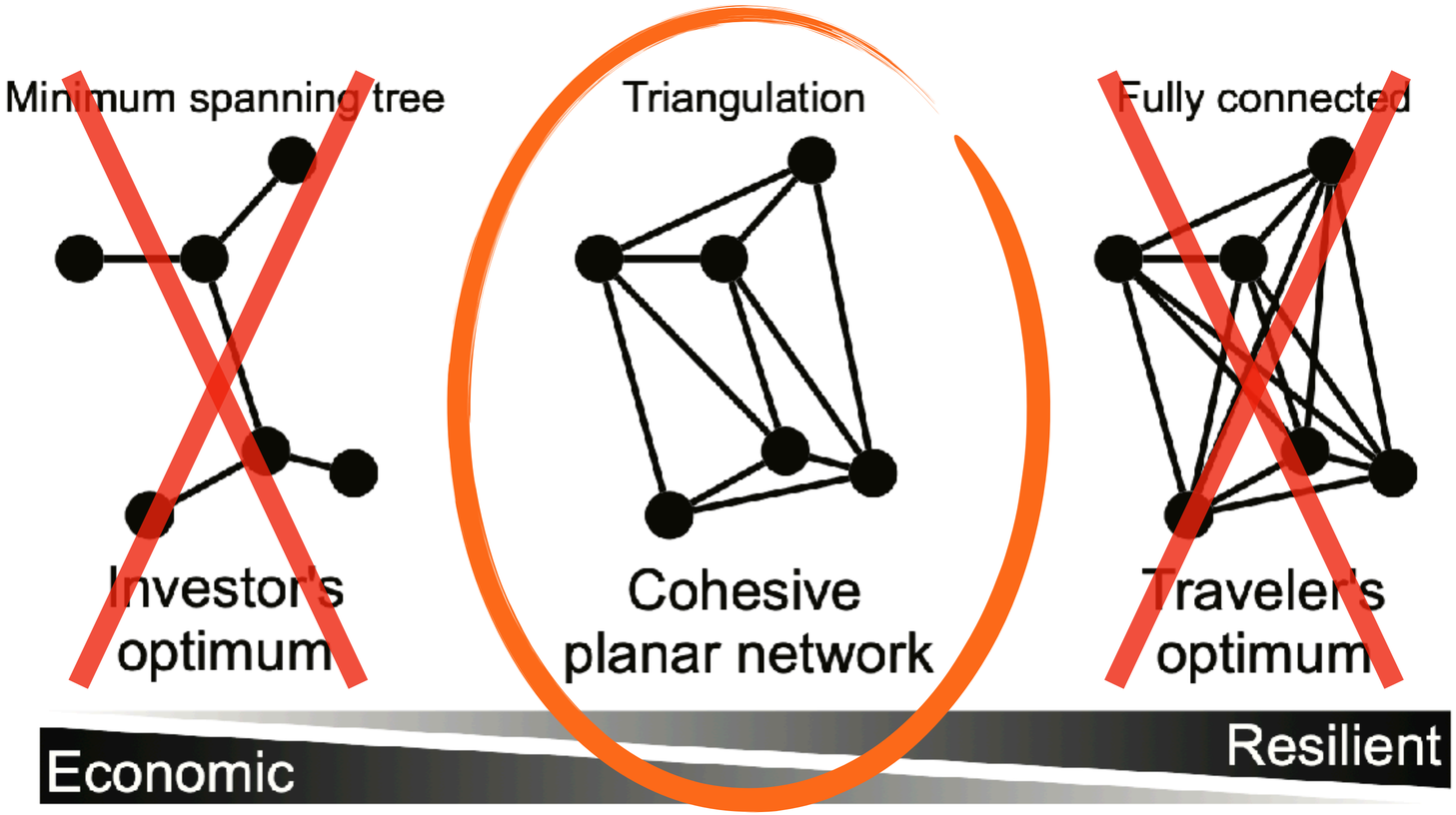


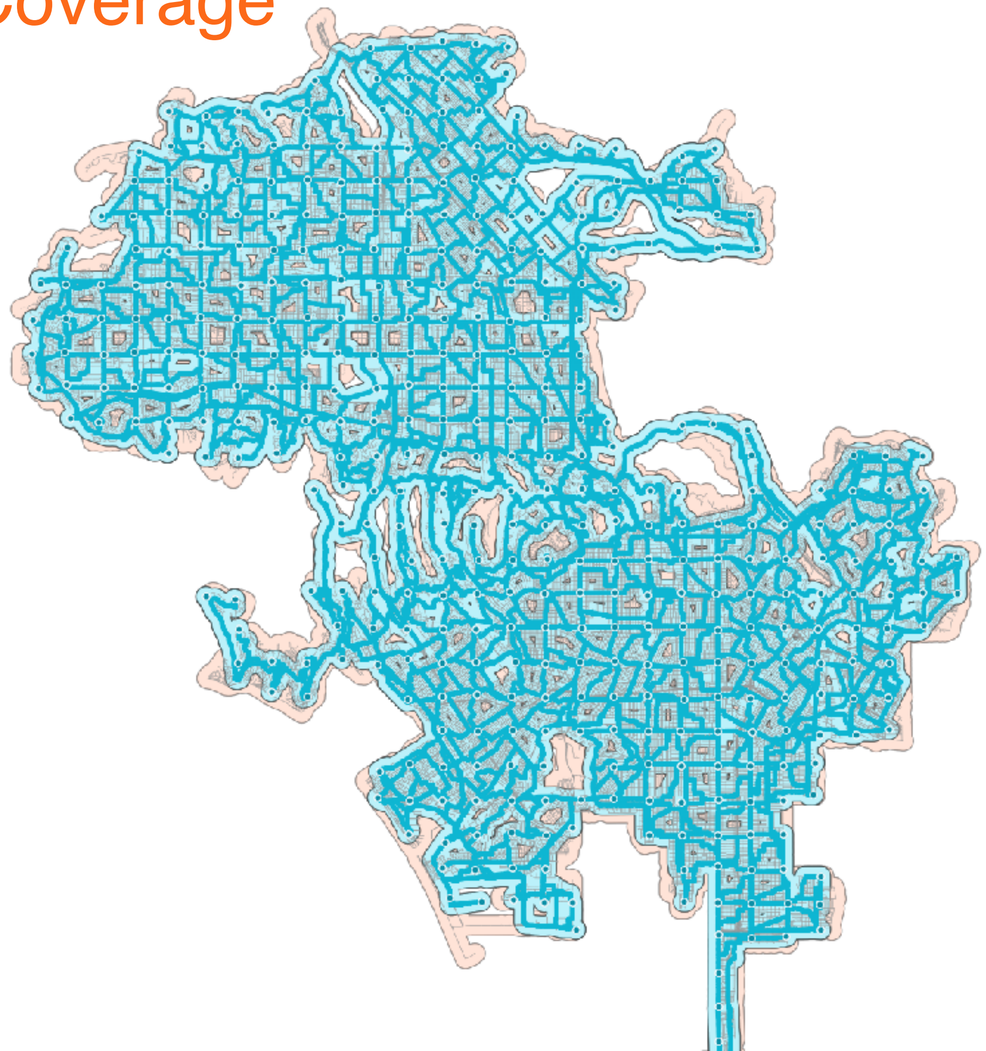

Szell et al., Sci Rep 12, 6765 (2022)

# Inspired by CROW, we want a cohesive network

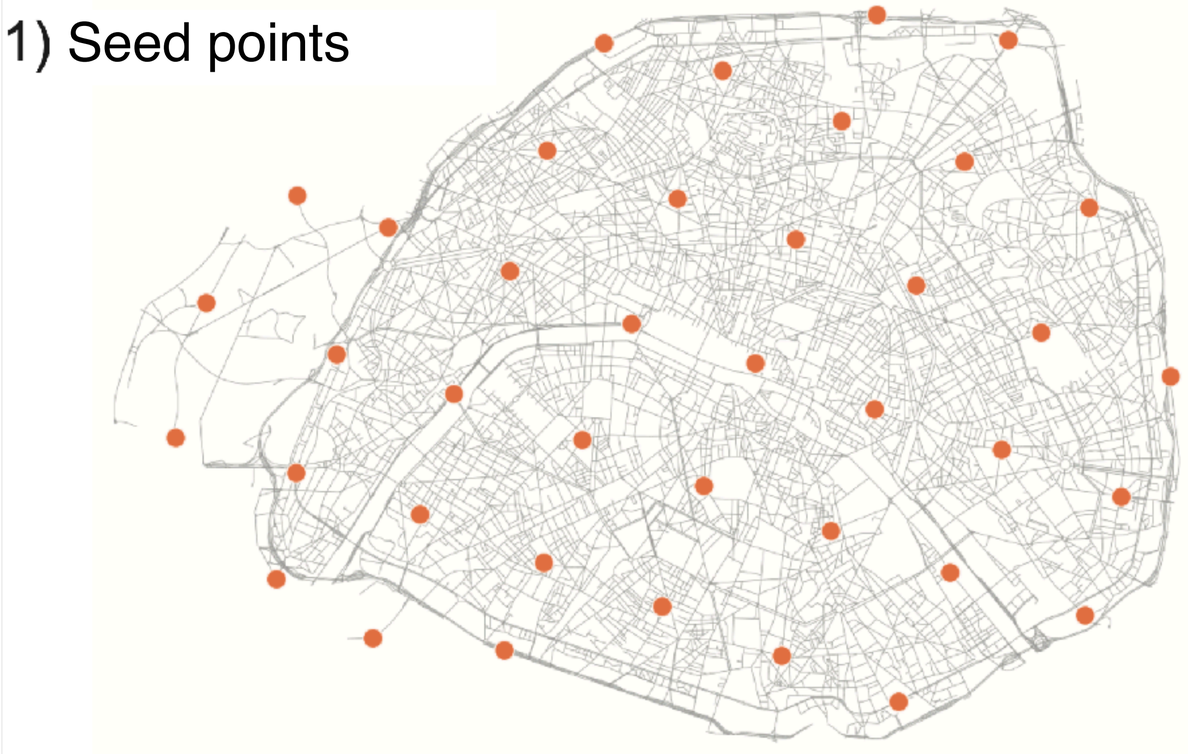
Connectedness & Resilience

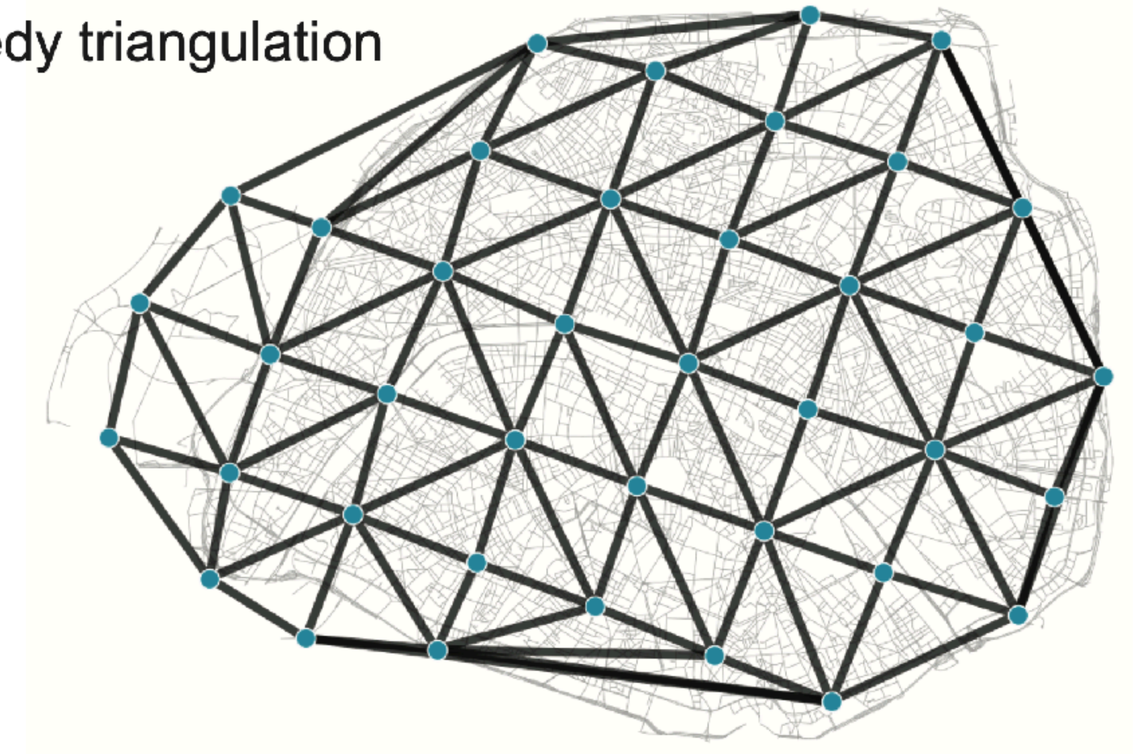
& Coverage



# We build a greedy triangulation between points of interest



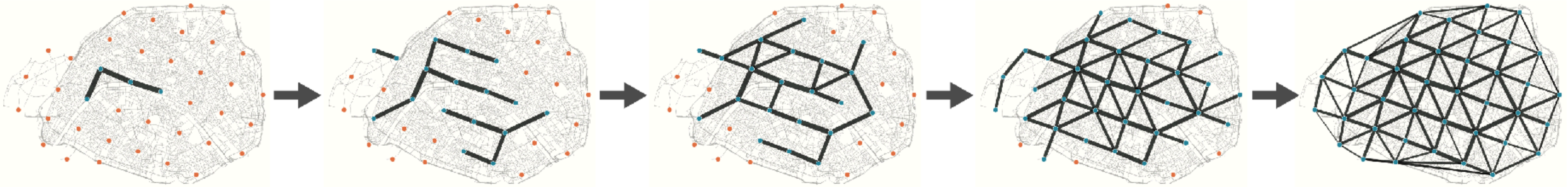




Szell et al., Sci Rep 12, 6765 (2022)

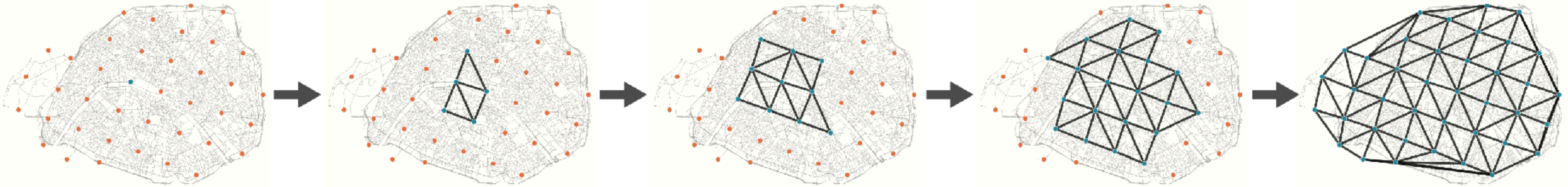
# We build a greedy triangulation between points of interest

## 3) Order by growth strategy

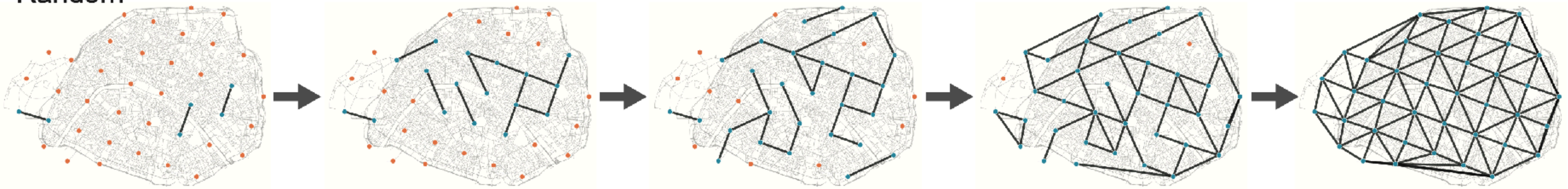
Betweenness



Closeness

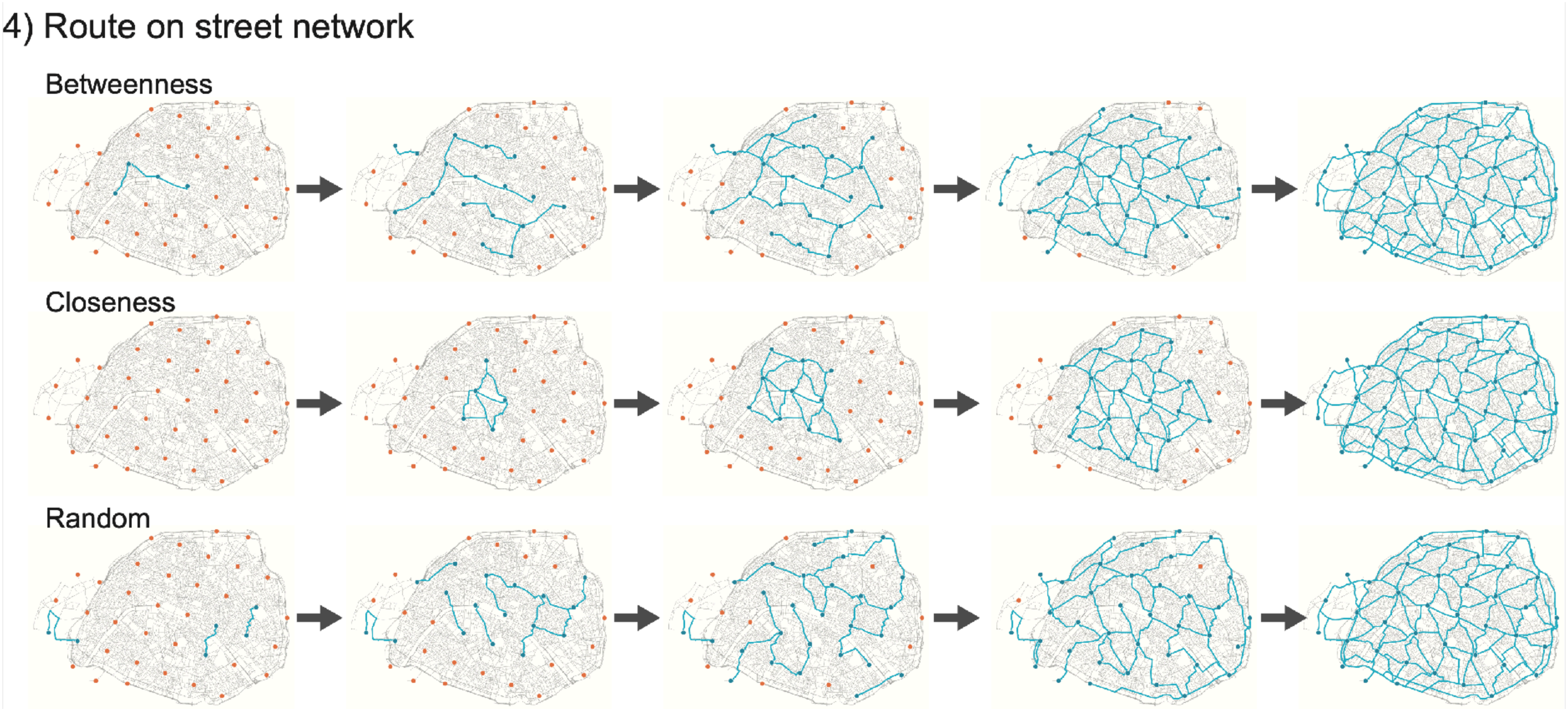


Random



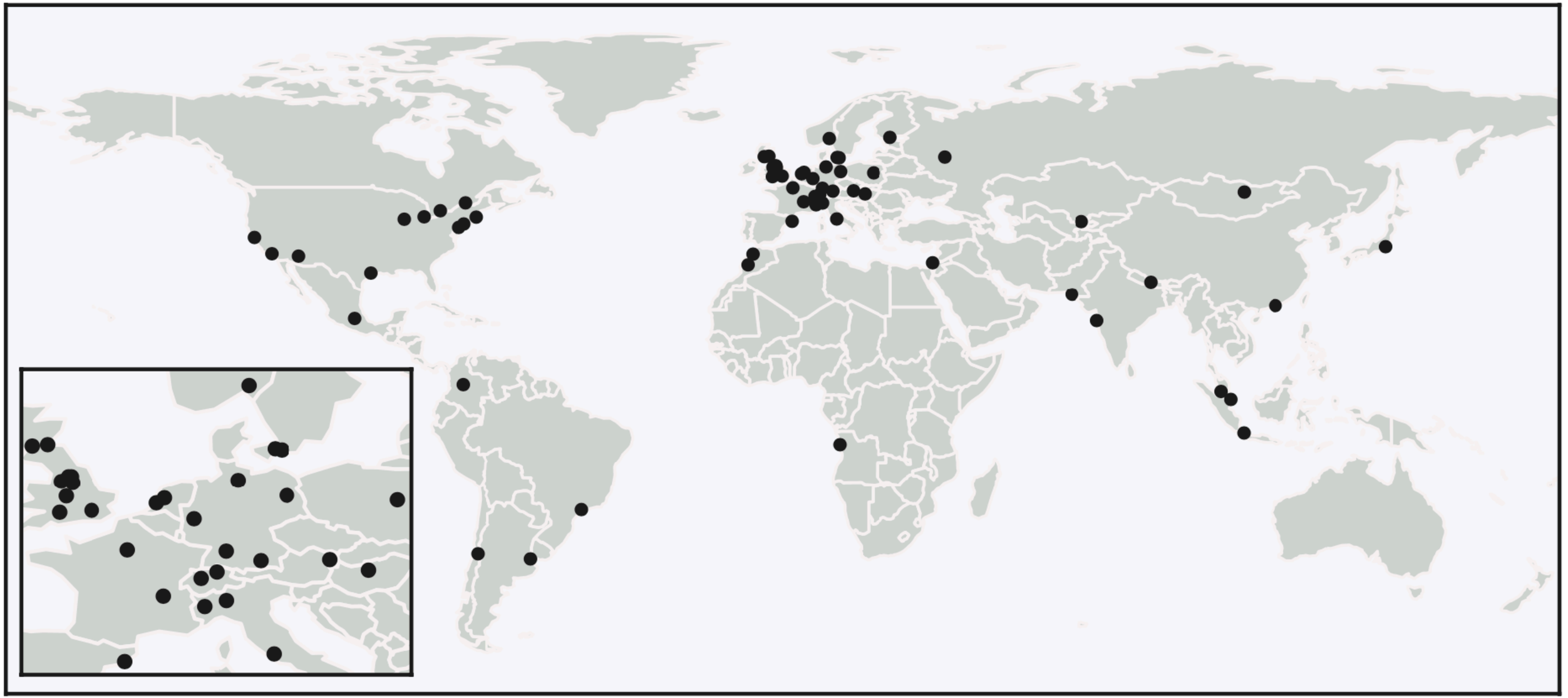
Szell et al., Sci Rep 12, 6765 (2022)

# We build a greedy triangulation between points of interest



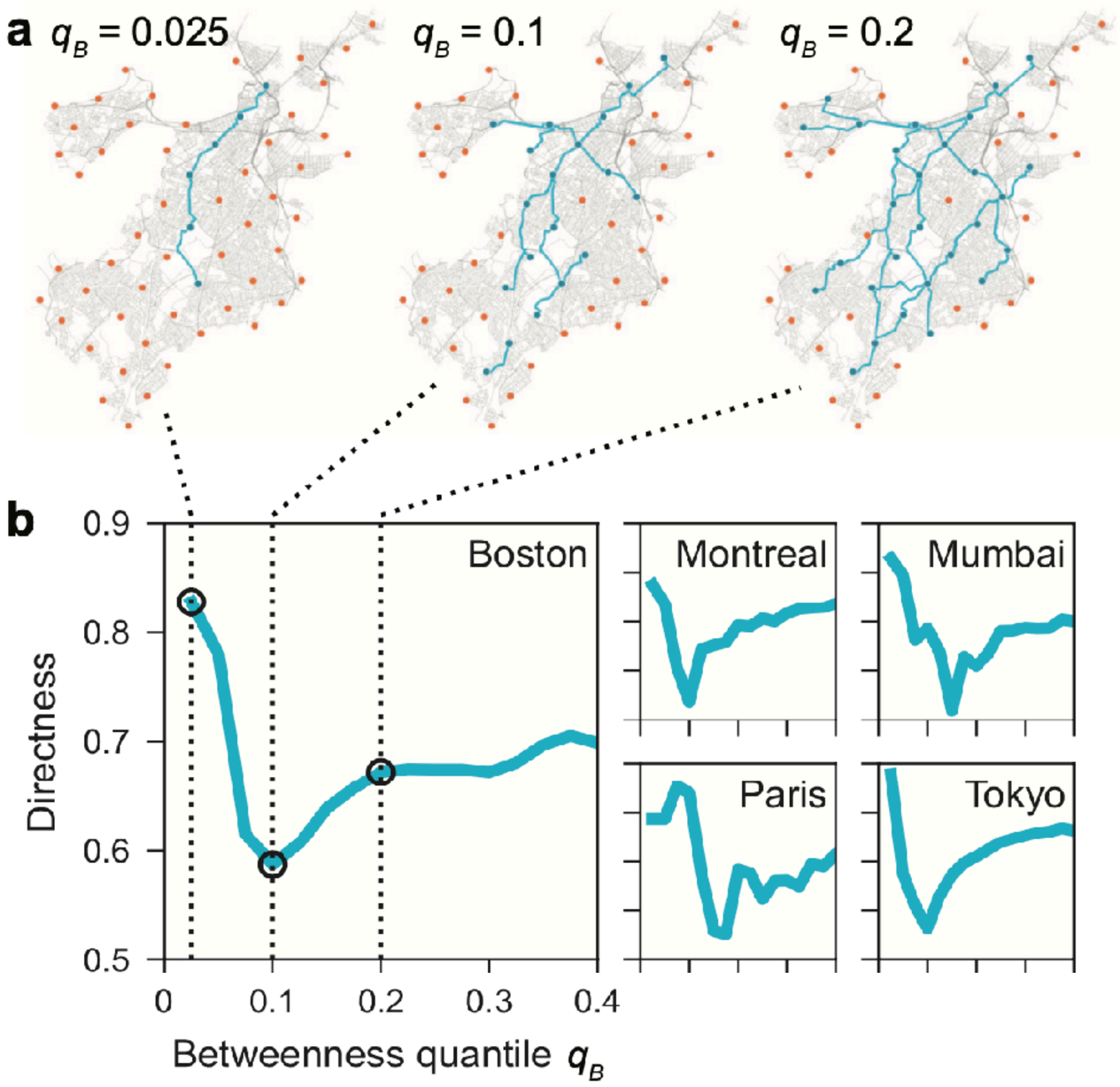

Szell et al., Sci Rep 12, 6765 (2022)

# We explore 62 cities



Szell et al., Sci Rep 12, 6765 (2022)

# Result 1: Investments need to surpass a critical threshold




The pieces need to connect and to form cycles

Szell et al., Sci Rep 12, 6765 (2022)

# Policy implication 1: Invest persistently!

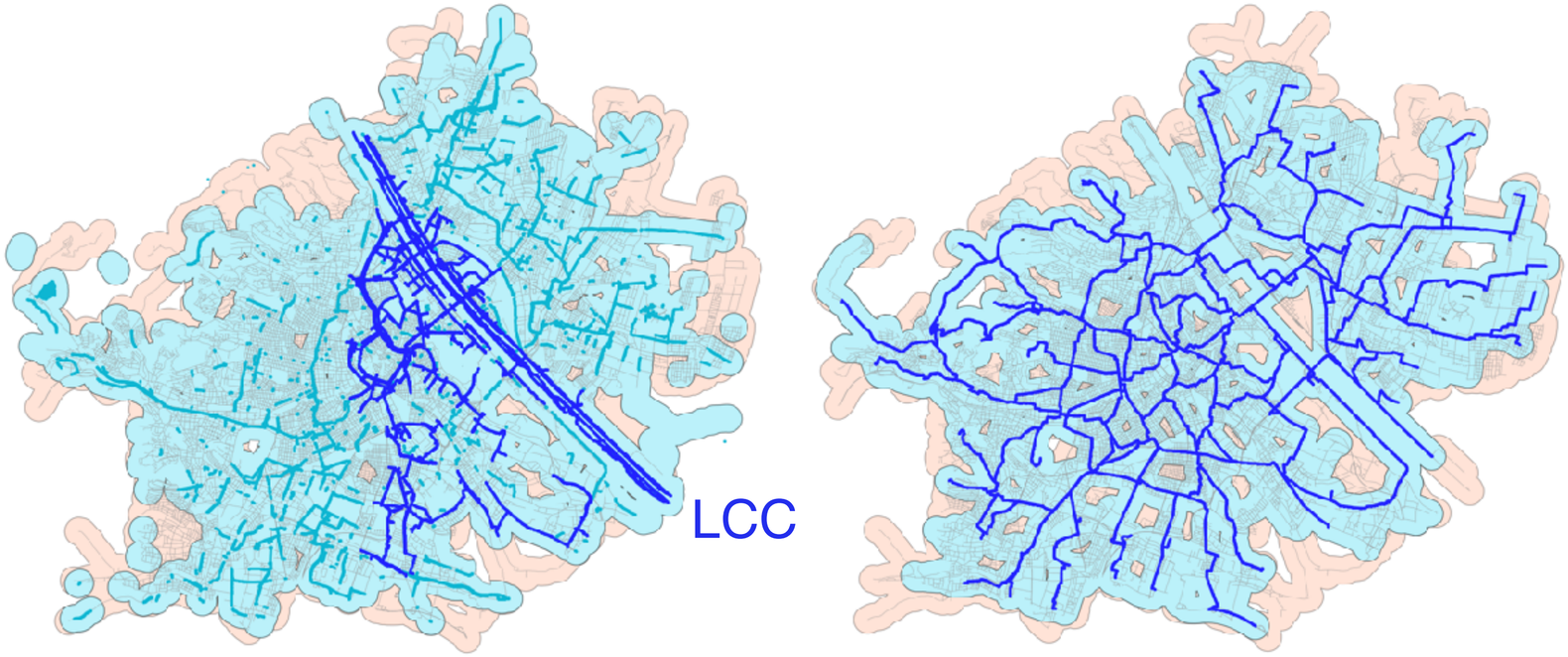
**Brent Toderian** @BrentToderian · Jul 30

My real advice for ambitious municipal elected leaders on building a safe, connected network of REAL (not painted lines or sharrows) bike infrastructure — direct your staff to do ALL of the work that you're currently planning to build over the next 5-10 years, ALL IN ONE YEAR.

https://twitter.com/BrentToderian/status/1420907319982915587?s=20

# Result 2: It's not a network's length that matters but how you grow it

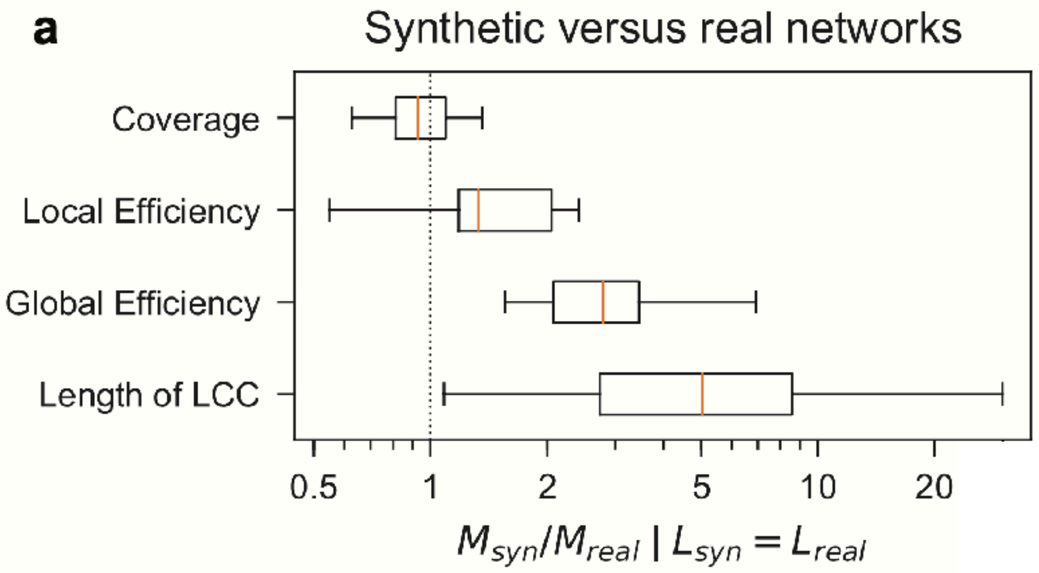
## At same length, we could do much better



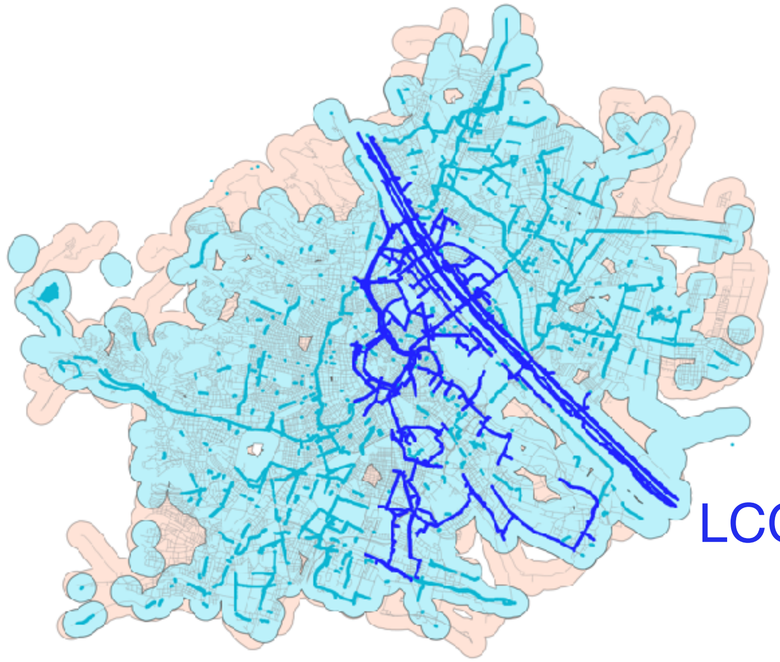

Real Vienna

Synthetic Vienna

# Result 2: It's not a network's length that matters but how you grow it

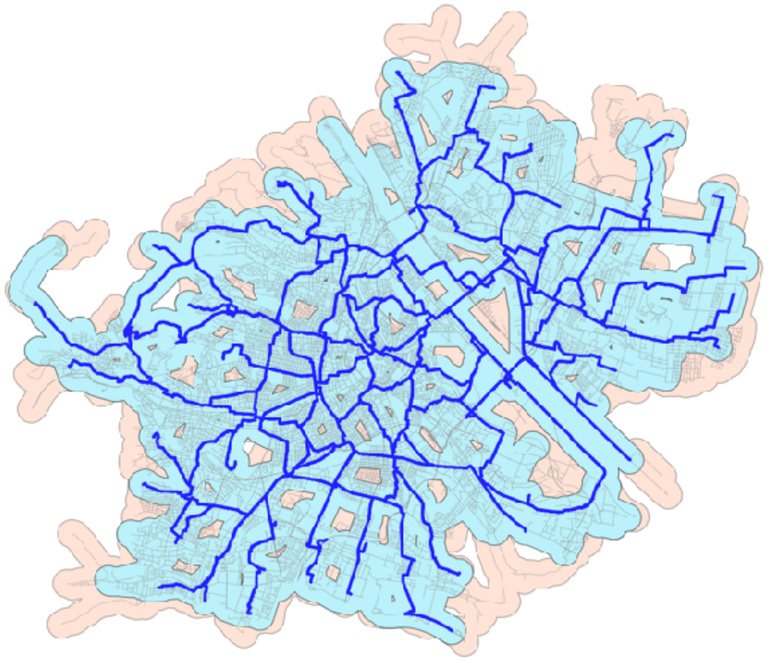



At same length, we could do much better



LCC

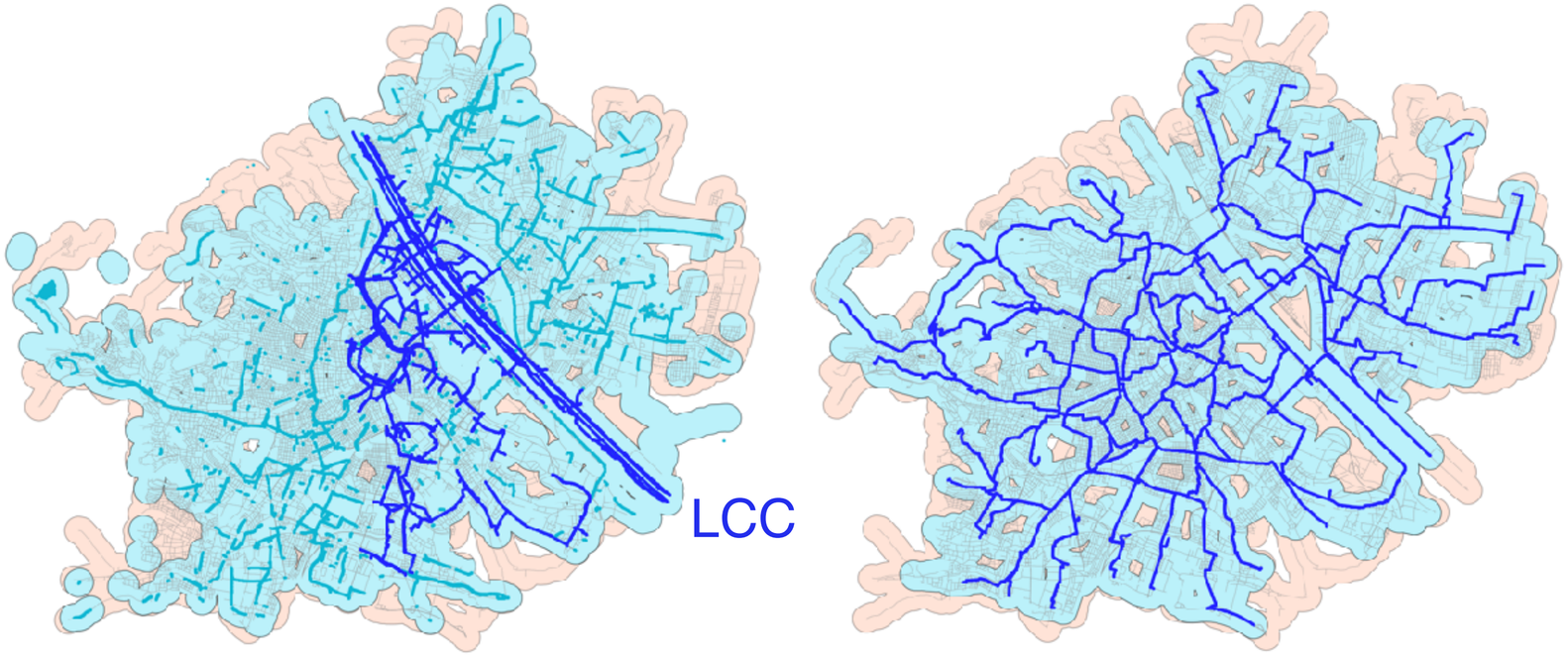
Real Vienna



Synthetic Vienna

# Policy implication 2: Strategy matters: Build for the whole city

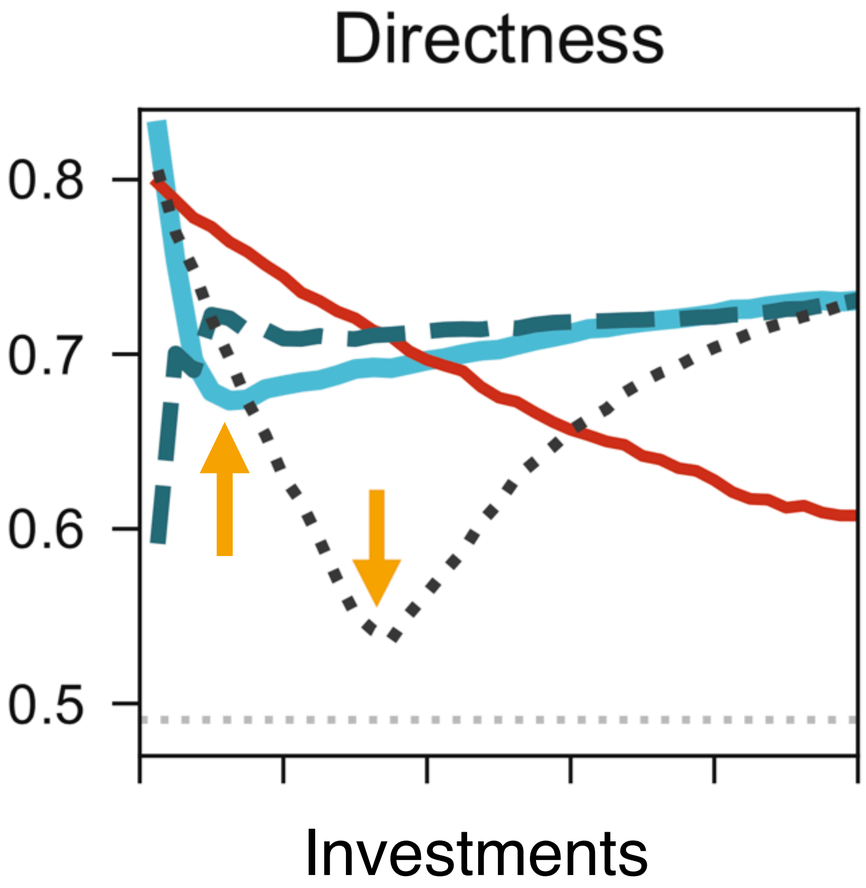
## Avoid "random-like", piecewise growth



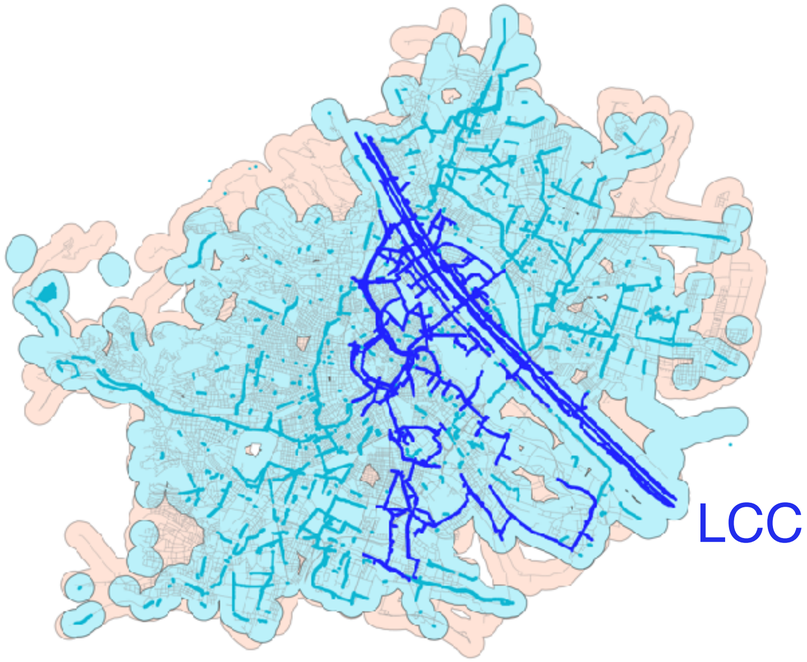

Real Vienna

Synthetic Vienna

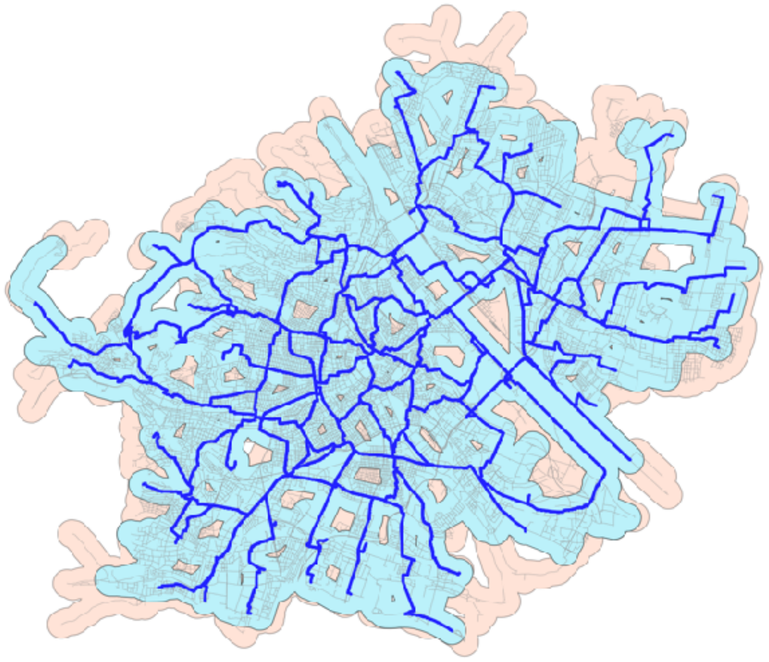
# Policy implication 2: Strategy matters: Build for the whole city




Random growth needs 3x the investments than a global strategy



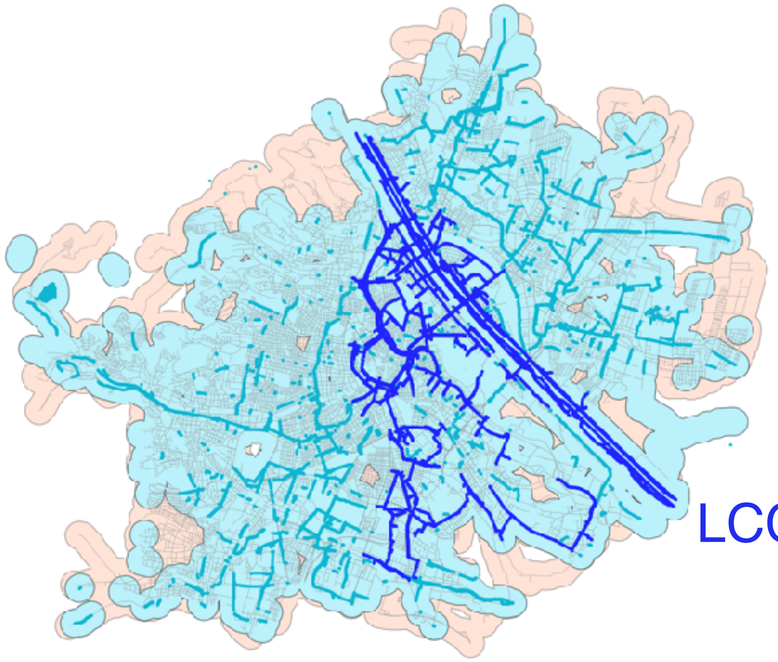
LCC



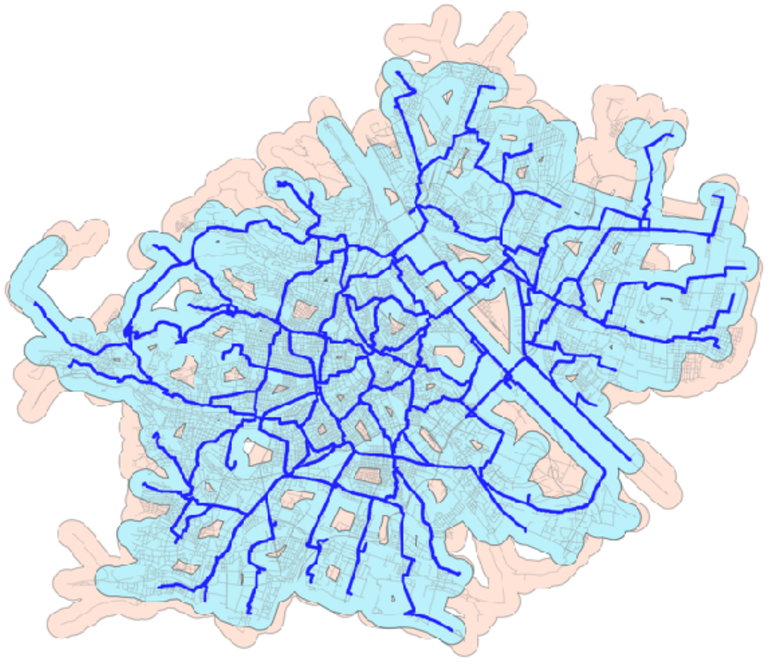
Real Vienna

Synthetic Vienna

# *Easier said than done - Isn't this unrealistic??*



LCC

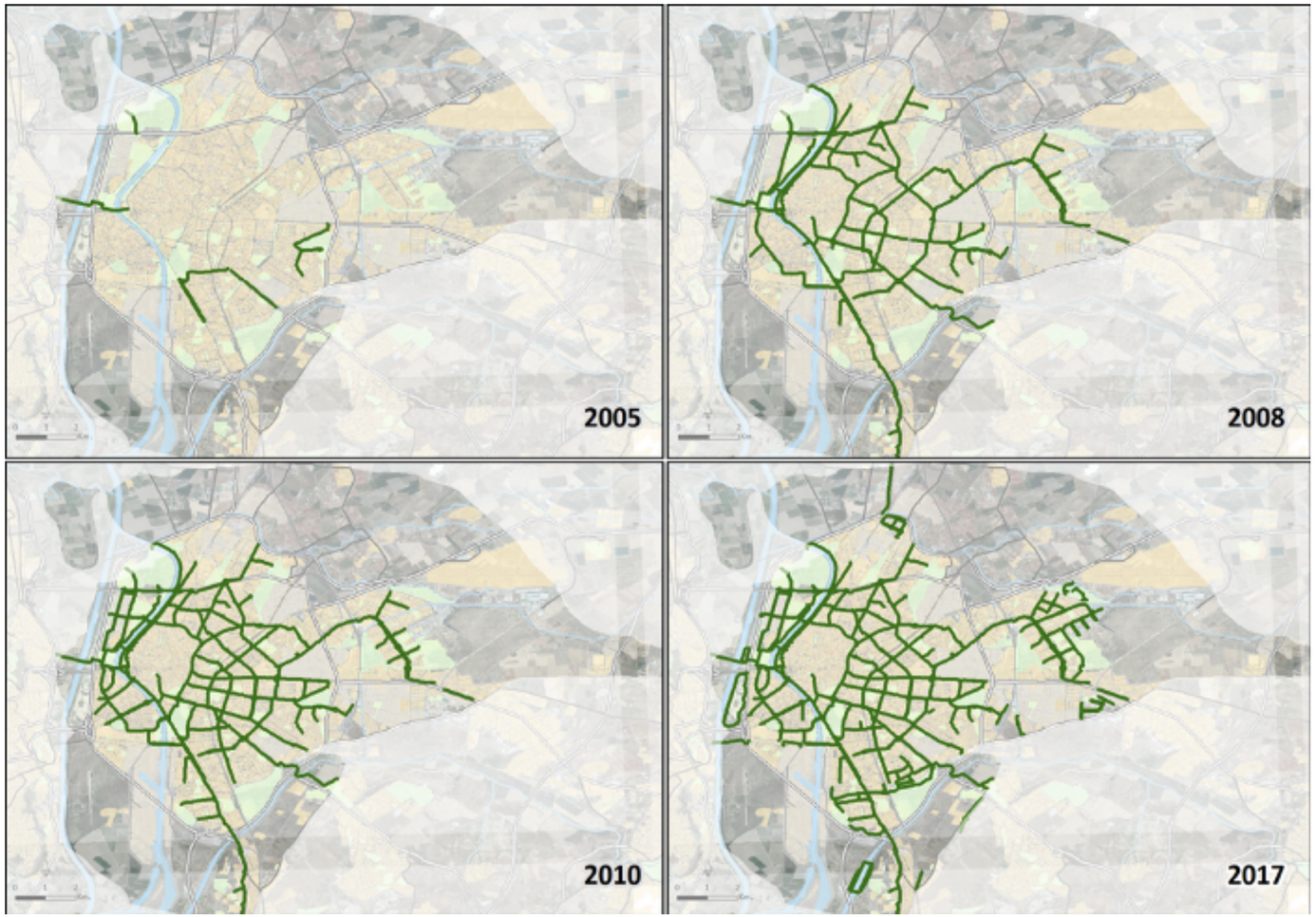


Real Vienna

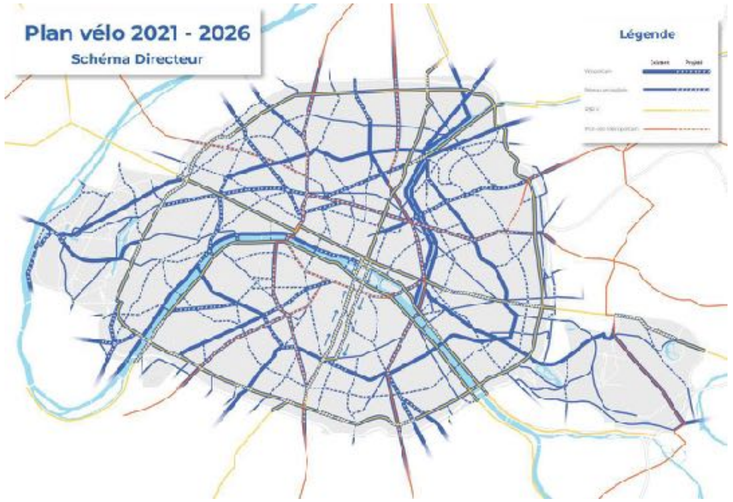
Synthetic Vienna

# *Easier said than done - Isn't this unrealistic??*

## Nope: See Seville



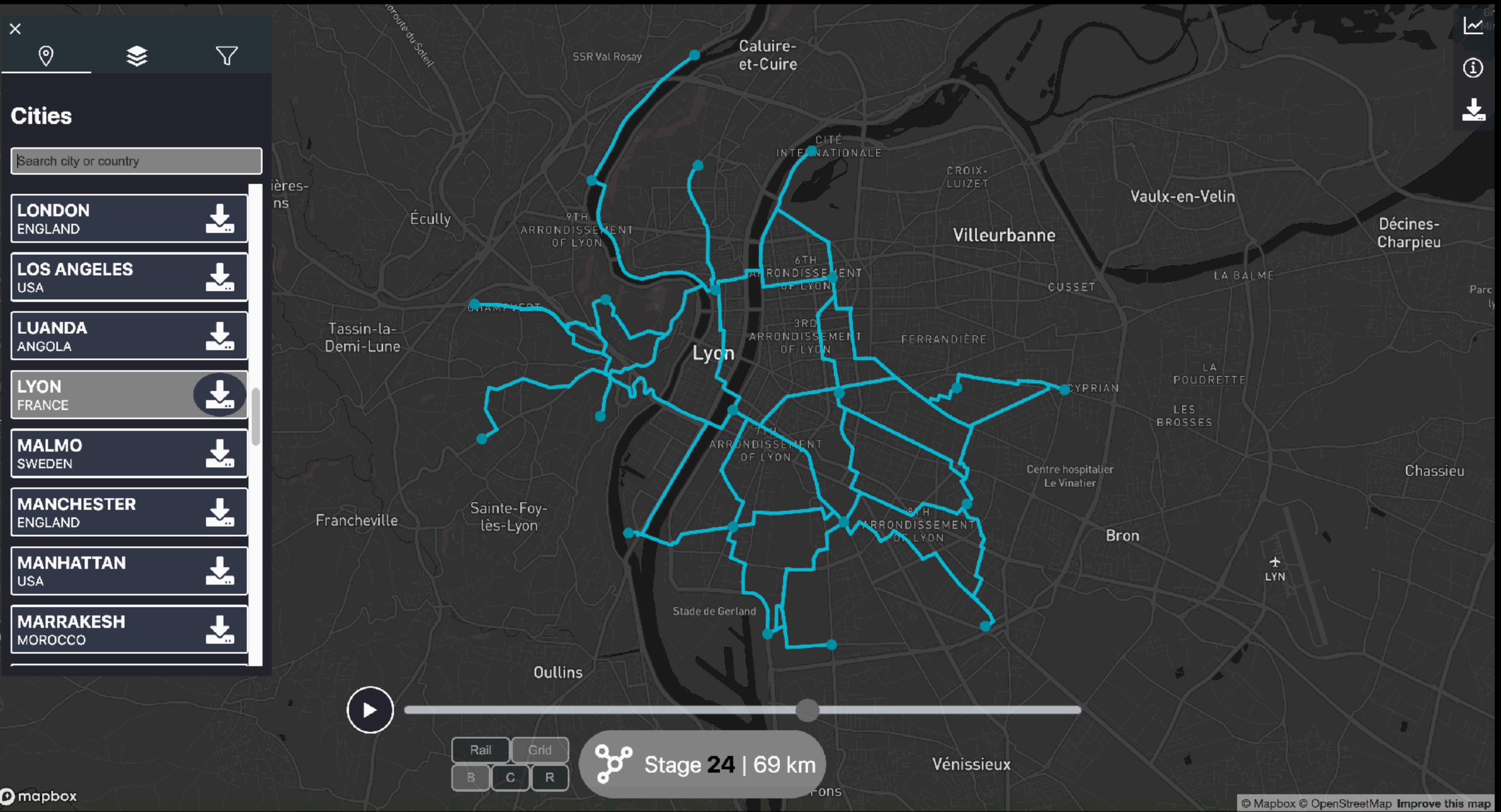

## Also: Paris, Oslo, ...




There is no excuse

https://usa.streetsblog.org/2020/10/13/best-practices-how-seville-became-a-city-of-cyclists/

# Explore your city at GrowBike.Net



# We lack data+research on

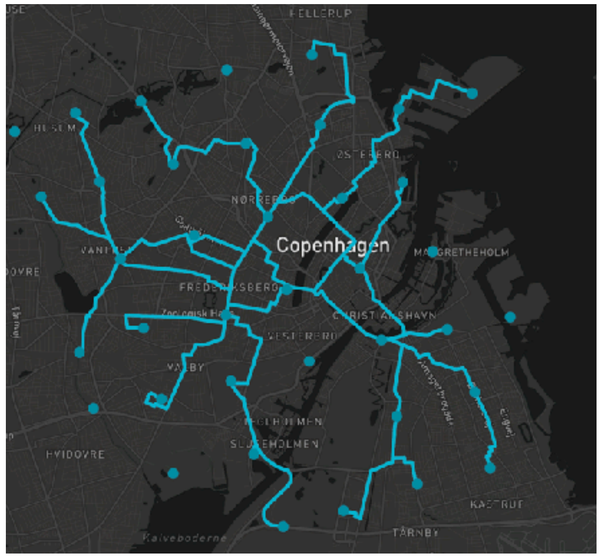
- Cyclist traffic behavior
- Cyclist flows
- Bicycle networks
- ...

but..

..Building sustainable cities is a political, not a technical question

You cannot optimize yourself out of an unsustainable political system

# Our work: Data-driven tools to help sustainable urban planning




Grow bicycle networks

Geospatial Data Science

BikeDNA

Missing Links

# Our work: Data-driven tools to help sustainable urban planning

ROYAL SOCIETY OPEN SCIENCE

royalsocietypublishing.org/journal/rsos

## Data-driven strategies for optimal bicycle network growth

Research

Cite this article: Natera Orozco LG, Battiston F,

Luis Guillermo Natera Orozco[1], Federico Battiston[1], Gerardo Iñiguez[1,2,3] and Michael Szell[4,5,6]

www.nature.com/scientificreports

scientific reports

OPEN

## Growing urban bicycle networks

Michael Szell[1,4,5✉], Sayat Mimar[4], Tyler Perlman[4], Gourab Ghoshal[4] & Roberta Sinatra[2,4,5]

Breum, Simon Martin, Bojan Kostic, and Michael Szell. 2022. "Computational Desire Line Analysis of Cyclists on the Dybbølsbro Intersection in Copenhagen." Findings, December.

TRANSPORT FINDINGS

## Computational Desire Line Analysis of Cyclists on the Dybbølsbro Intersection in Copenhagen

Simon Martin Breum[1], Bojan Kostic[1], Michael Szell[1,2,3]

[1] Computer Science, IT University of Copenhagen, [2] ISI Foundation, [3] Complexity Science Hub Vienna

Keywords: urban data science, cycling, traffic behavior, intersection design, human-centric planning

https://doi.org/10.32866/001c.56683

geographical analysis

*Geographical Analysis* (2022) 0, 1–29

## Automated Detection of Missing Links in Bicycle Networks

Anastassia Vybornova[1], Tiago Cunha[1], Astrid Gühnemann[2], Michael Szell[1,3,4]

Journal Title
XX(X):2–22
©The Author(s) 2022
Reprints and permission:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/ToBeAssigned
www.sagepub.com/

SAGE

## BikeDNA: A Tool for Bicycle Infrastructure Data & Network Assessment

Ane Rahbek Vierø[1], Anastassia Vybornova[1], Michael Szell[1,2,3]

https://arxiv.org/abs/2303.01223

Vejdirektoratet

growbike.net

fixbike.net

whatthestreet.com

nerds.itu.dk