

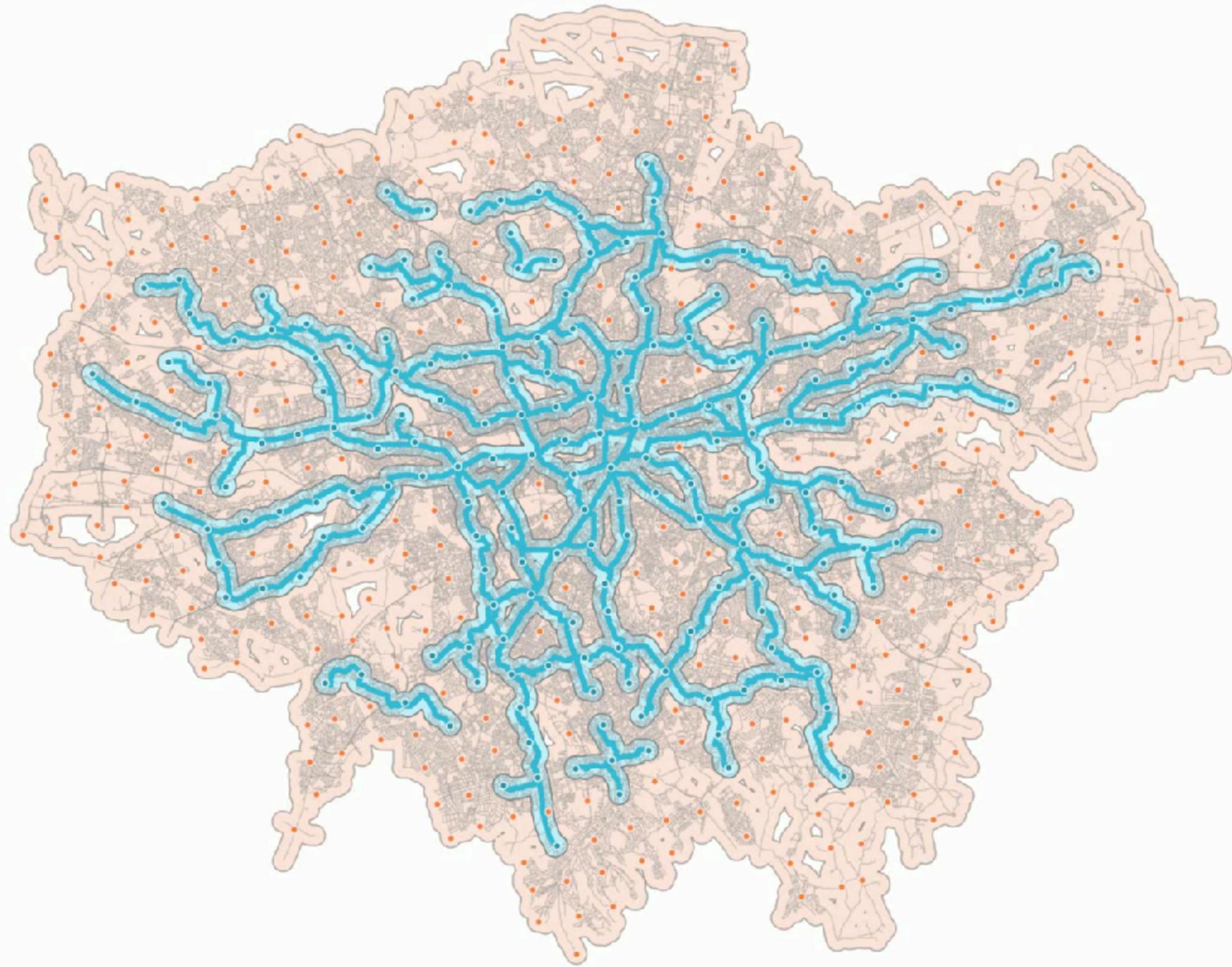
Towards a human-centric urban data science

Michael Szell

NEtwoRks, Data, and Society (NERDS)

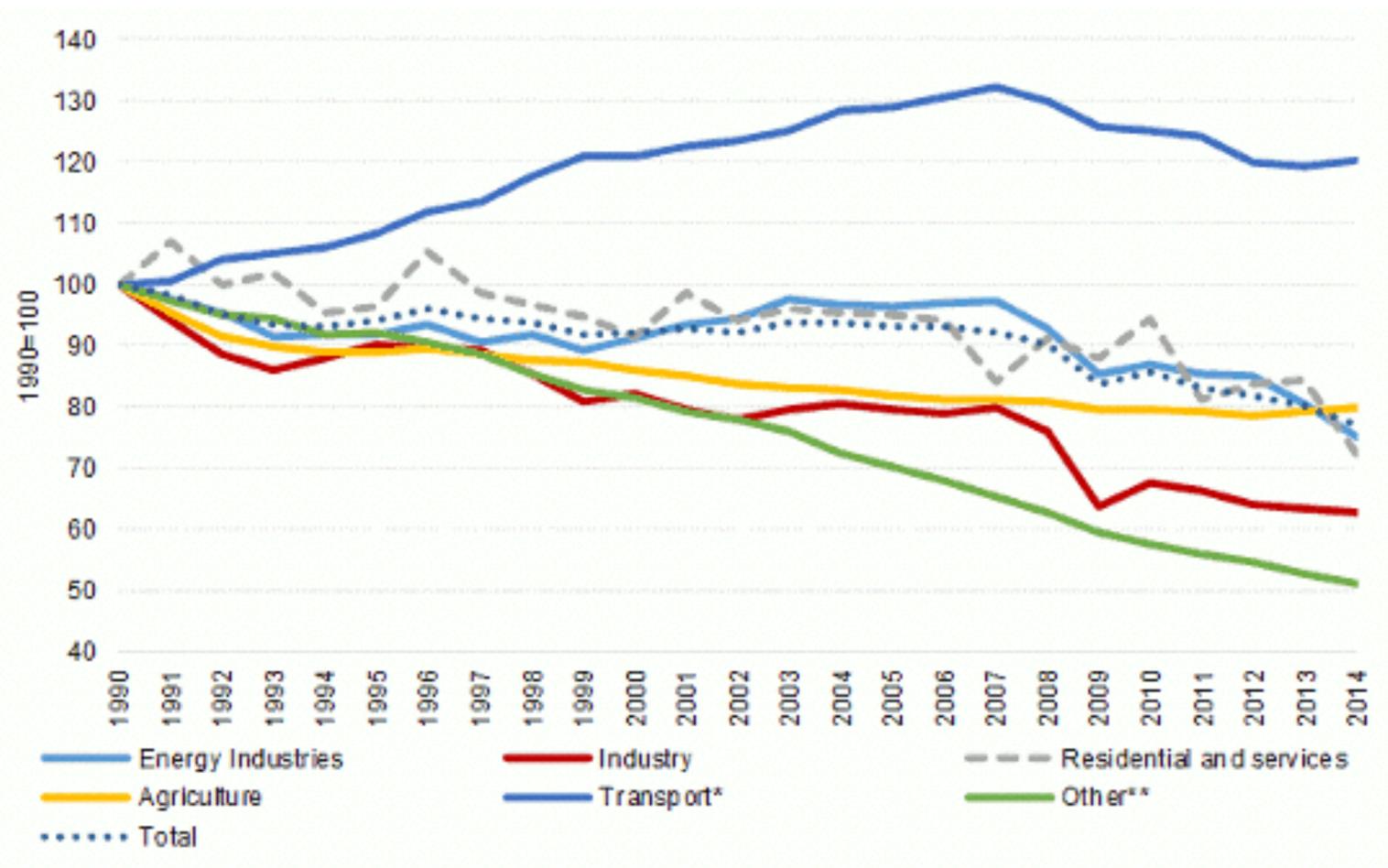
with:

S. Mimar, T. Perlman, G. Ghoshal, R. Sinatra,
A. Vybornova, T. Cunha, A. Gühnemann,
L.G. Natera Oroczo, F. Battiston, G. Iñiguez,
M. Lynghede, C.L. Kolding Andersen,
M. Klanjčić, L. Gauvin, M. Tizzoni



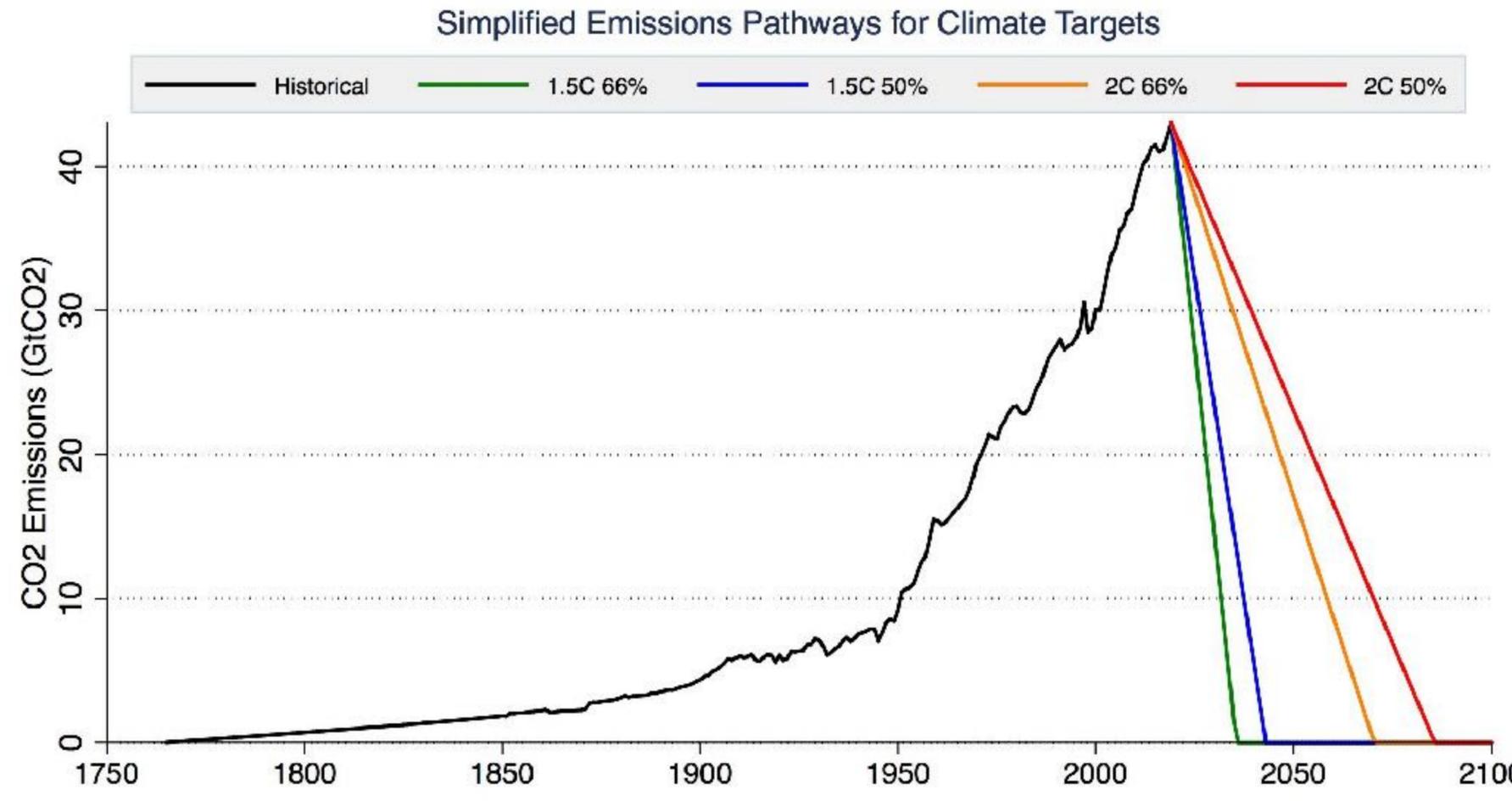
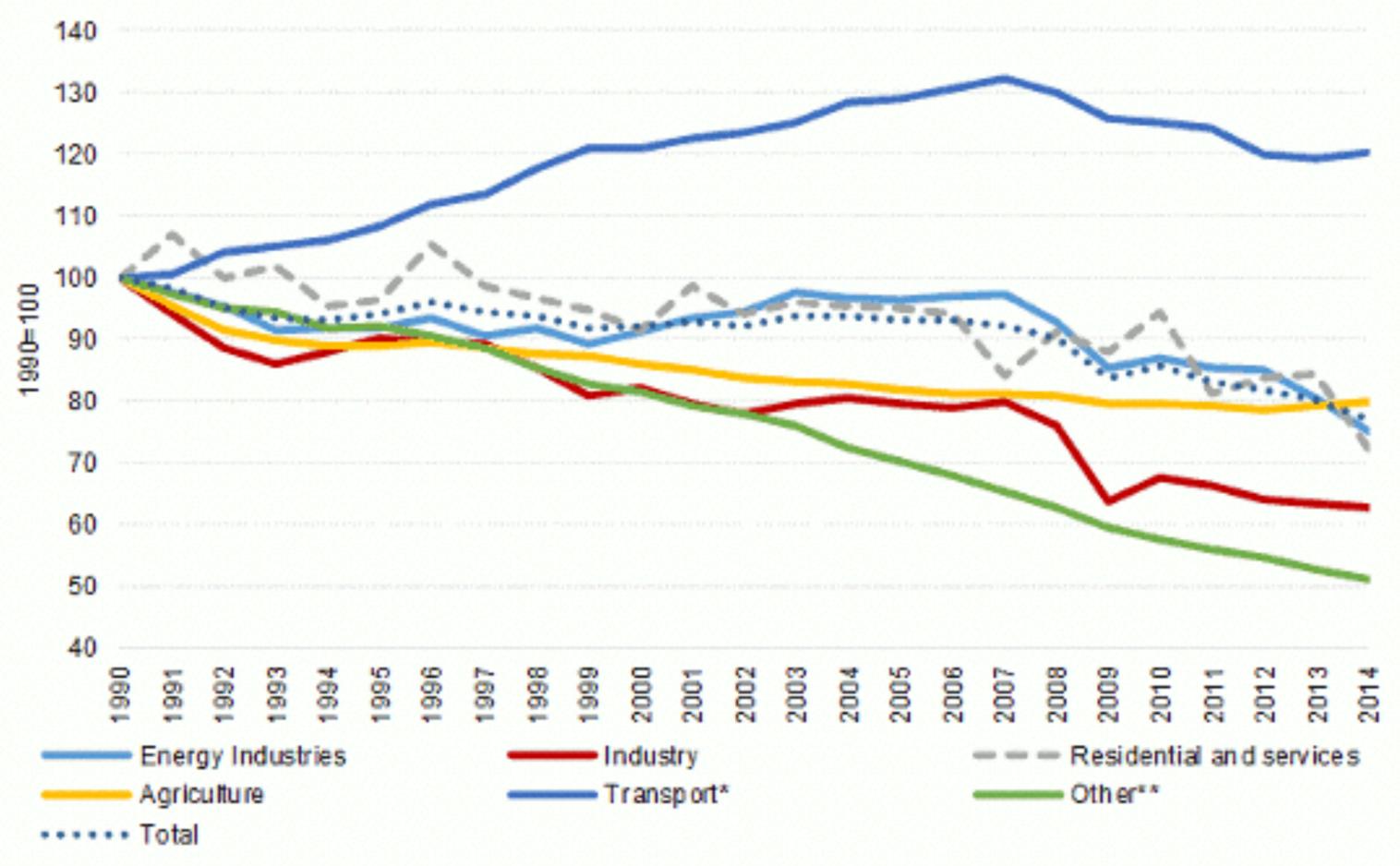
IT UNIVERSITY OF COPENHAGEN

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.

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.

But what about E-cars?



E-cars are not THE solution: Replacement takes too long



[Home](#) > [News](#) > Obsessing over electric cars is impeding the race to net zero: More active travel is essential

Obsessing over electric cars is impeding the race to net zero: More active travel is essential

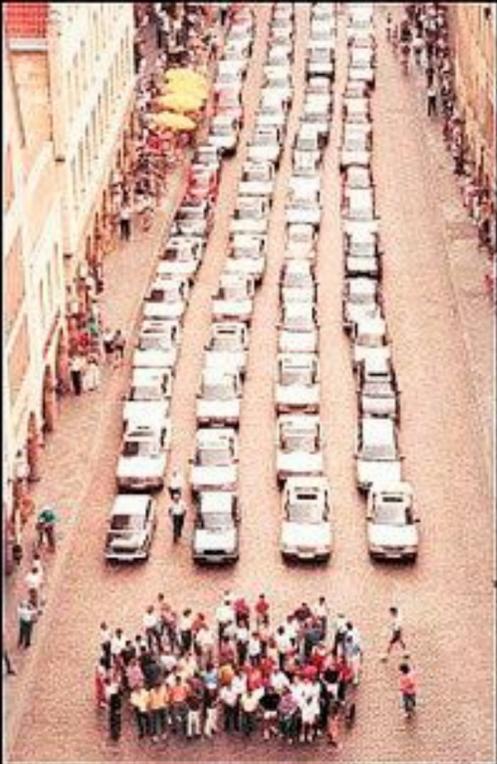


Cycling is ten times more important than electric cars for reaching net-zero cities

March 29, 2021 3.59pm BST

E-cars are not THE solution: Cars take too much space

space required
to transport 60 people



car
E-car

bus

bicycle



Life without electric cars

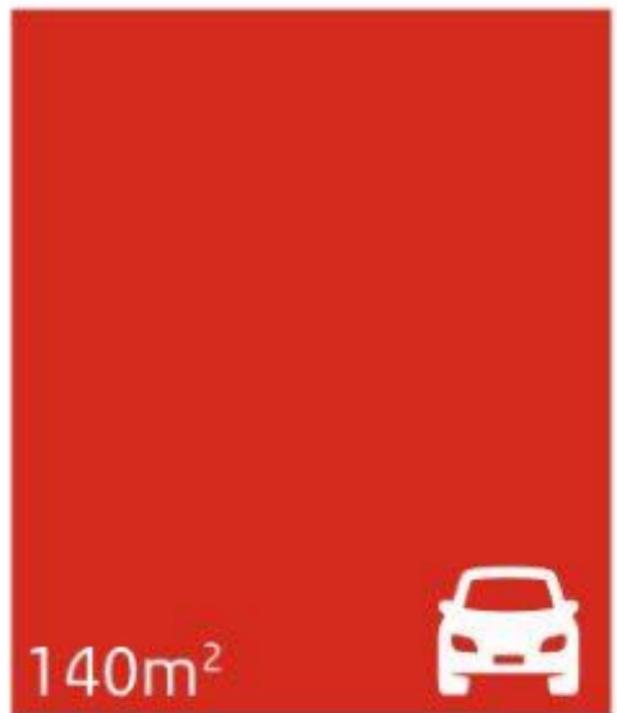


Life with electric cars

All hail the revolution!



You can't beat geometry: Cars will ALWAYS be inefficient



Car
50 kmh, 1 occupant



Car
parked



Tram
50 occupants



Pedestrian
walking



Pedestrian
standing still



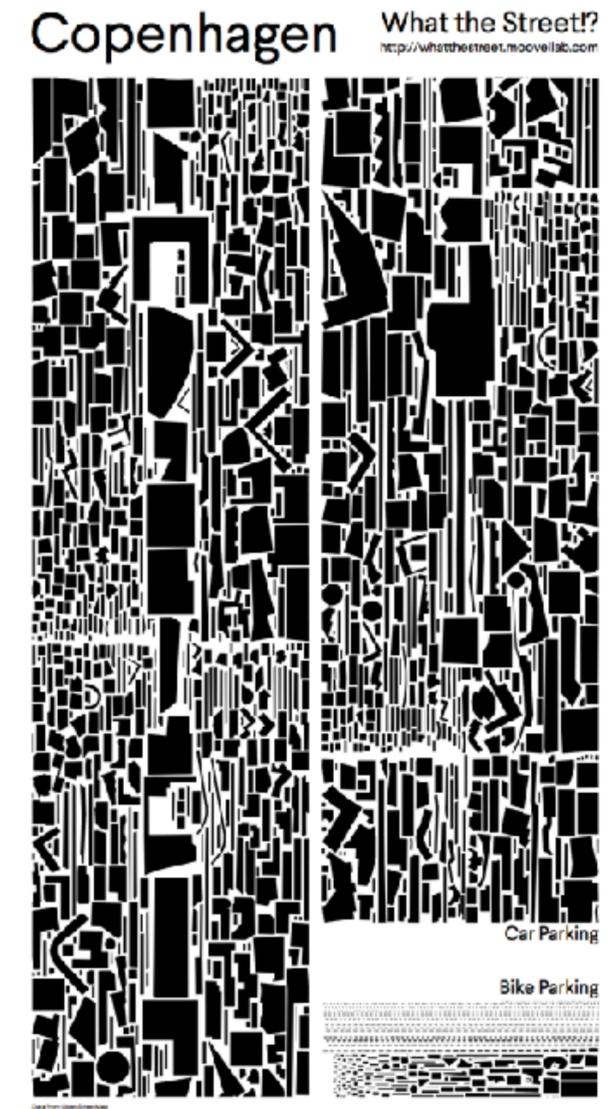
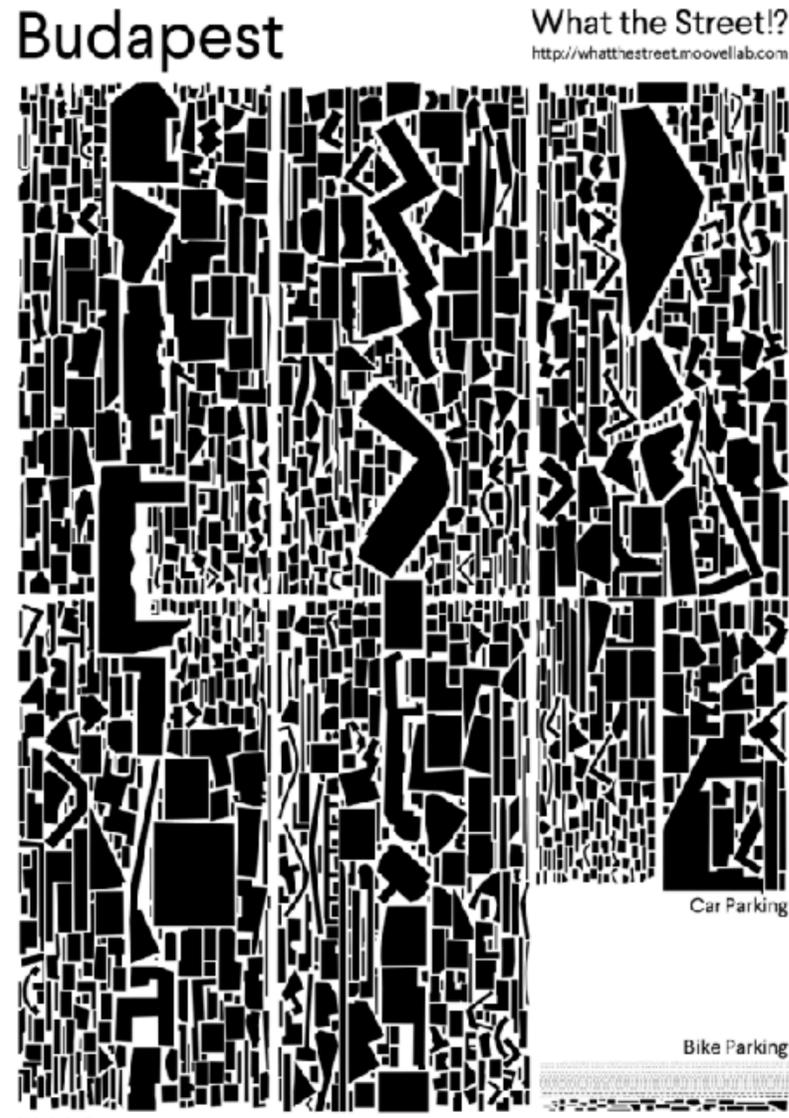
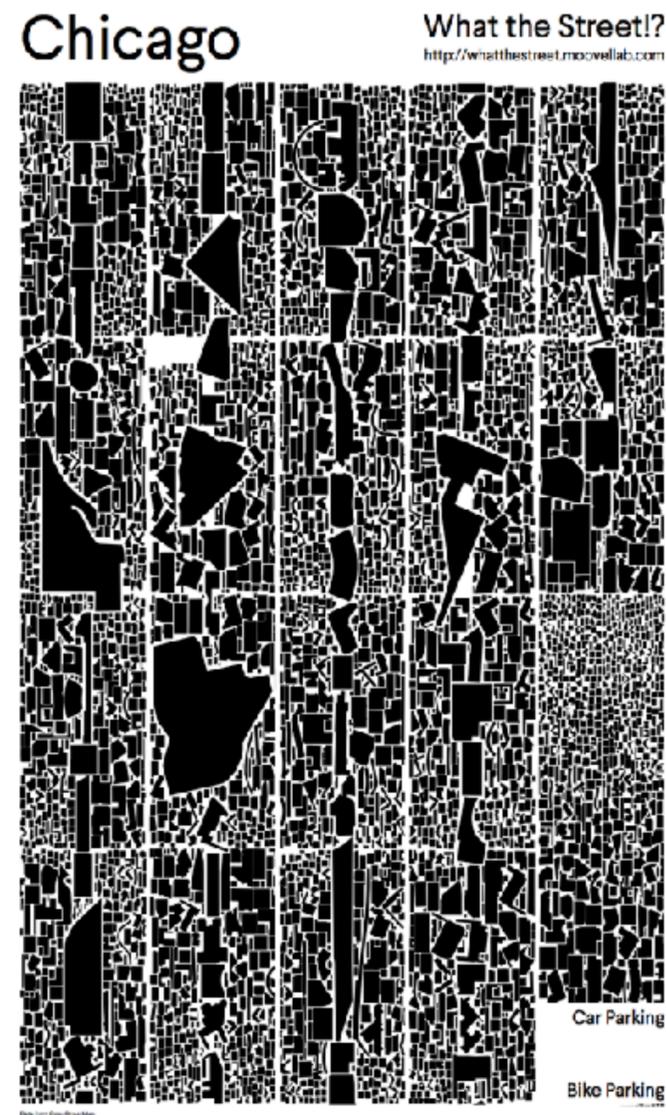
Cyclist
15 kmh



Bicycle
parked

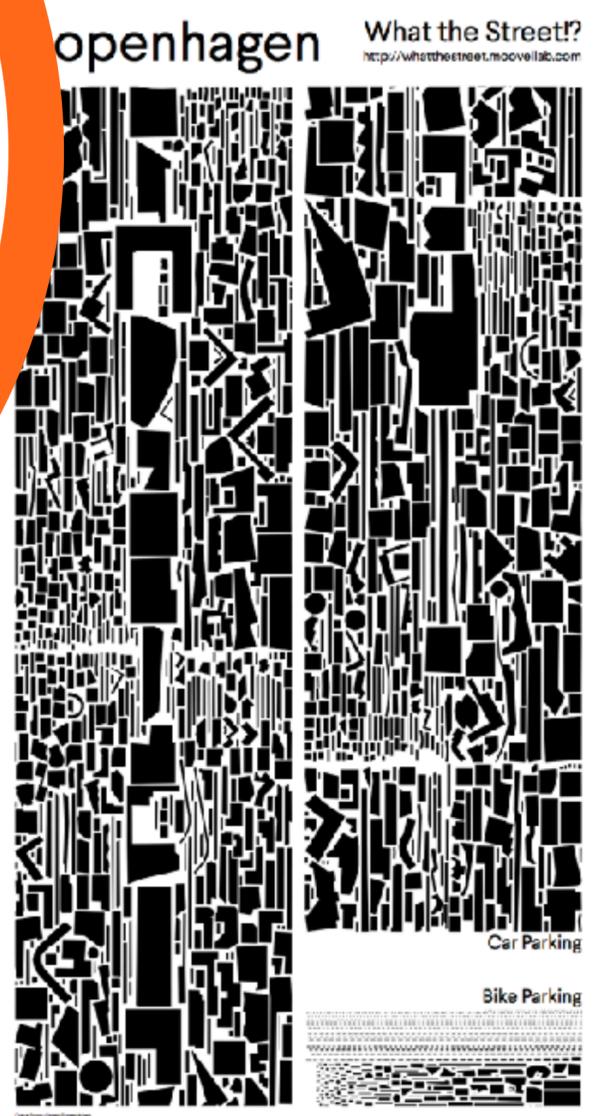
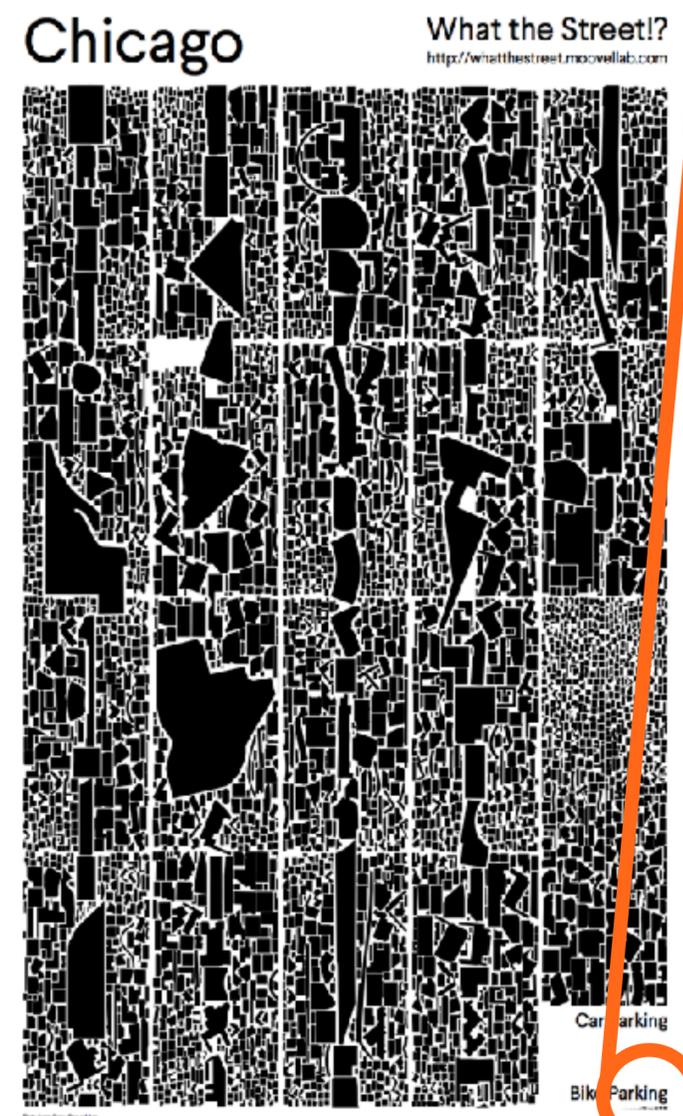
Harms and Kansen, Netherlands Institute for Transport Policy Analysis (2017)
Szell, Urb Plan 3, 1-20 (2018)

There are huge differences between car and bike parking



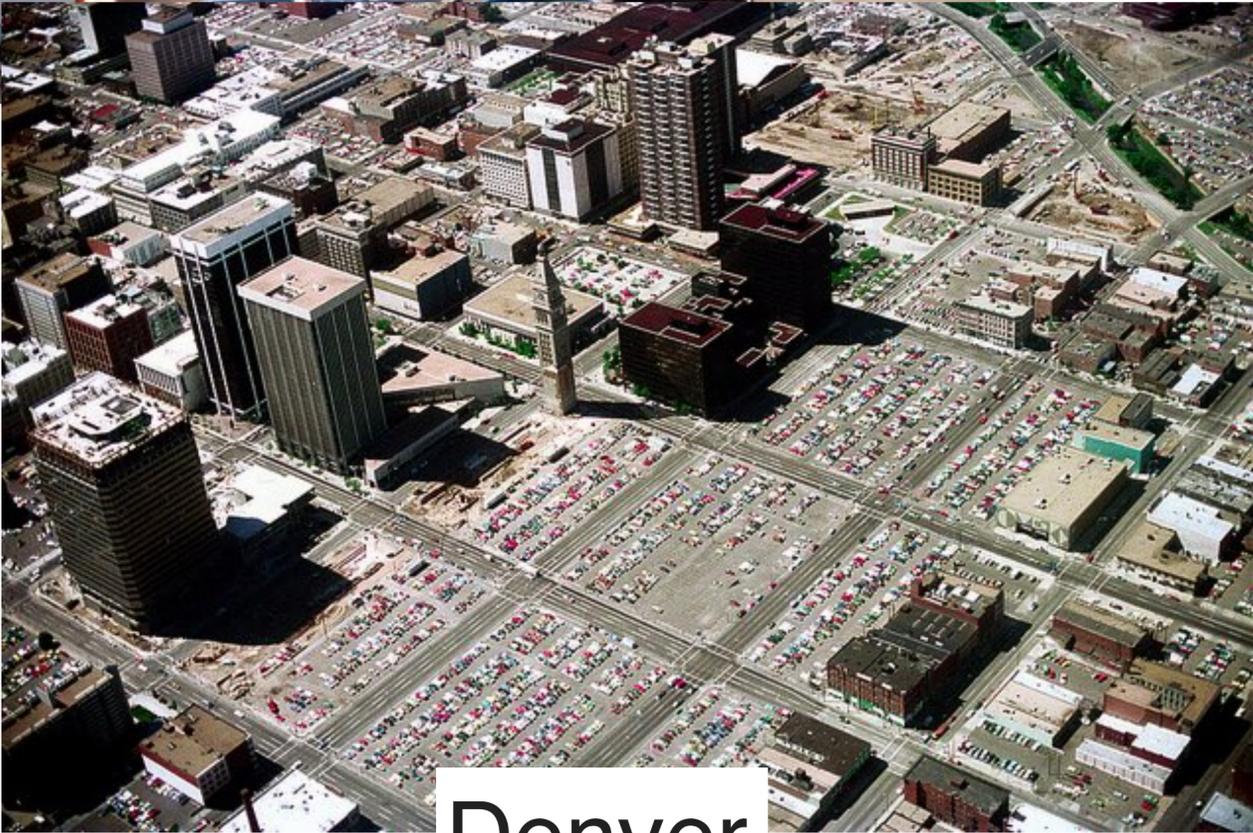
whatthestreet.com

There are huge differences between car and bike parking



whatthestreet.com

Reclaiming parking is key to the livability crisis



Denver



Groningen



E-cars are not THE solution: >50% of particles are from non-exhaust

Non-exhaust emissions

Brake pad

$\delta^{65}\text{Cu}_{\text{AE647}}$: $+0.12 \pm 0.09\text{‰}$
 $\delta^{66}\text{Zn}_{\text{IRMM3702}}$: $-0.03 \pm 0.04\text{‰}$
 $^{206}\text{Pb}/^{207}\text{Pb}$: 1.2787 ± 0.2104



Asphalt

$\delta^{65}\text{Cu}_{\text{AE647}}$: $+0.01 \pm 0.03\text{‰}$
 $\delta^{66}\text{Zn}_{\text{IRMM3702}}$: $+0.00 \pm 0.01\text{‰}$
 $^{206}\text{Pb}/^{207}\text{Pb}$: 1.1535 ± 0.0184



Tire

$\delta^{65}\text{Cu}_{\text{AE647}}$: $-0.49 \pm 0.10\text{‰}$
 $\delta^{66}\text{Zn}_{\text{IRMM3702}}$: $-0.05 \pm 0.02\text{‰}$
 $^{206}\text{Pb}/^{207}\text{Pb}$: 1.1582 ± 0.0047



Curb

$\delta^{65}\text{Cu}_{\text{AE647}}$: $+0.04 \pm 0.03\text{‰}$
 $\delta^{66}\text{Zn}_{\text{IRMM3702}}$: $+0.16 \pm 0.02\text{‰}$
 $^{206}\text{Pb}/^{207}\text{Pb}$: 1.1829 ± 0.0002



Road paint

$\delta^{65}\text{Cu}_{\text{AE647}}$: $+0.13 \pm 0.18\text{‰}$
 $\delta^{66}\text{Zn}_{\text{IRMM3702}}$: $-0.24 \pm 0.31\text{‰}$
 $^{206}\text{Pb}/^{207}\text{Pb}$: 1.2963 ± 0.0827

Cycling is a time-tested solution that delivers on 11 SDGs



CYCLING DELIVERS ON THE GLOBAL GOALS

Shifting towards a better economy, society, and planet for all

<https://unric.org/en/sustainable-development-goals-cycling/>

More active travel is also an *economic* "no-brainer"

Cost-benefit analysis in EU that accounts for

- Health
- Environment
- Travel / Congestion

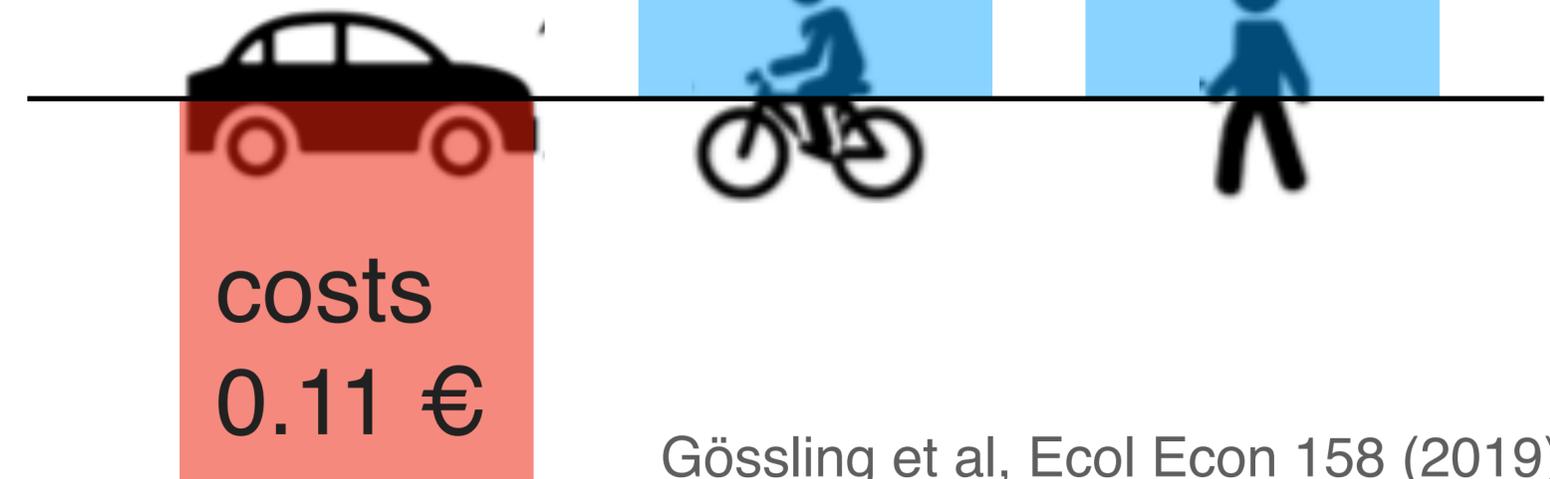
shows:

More active travel is also an *economic* "no-brainer"

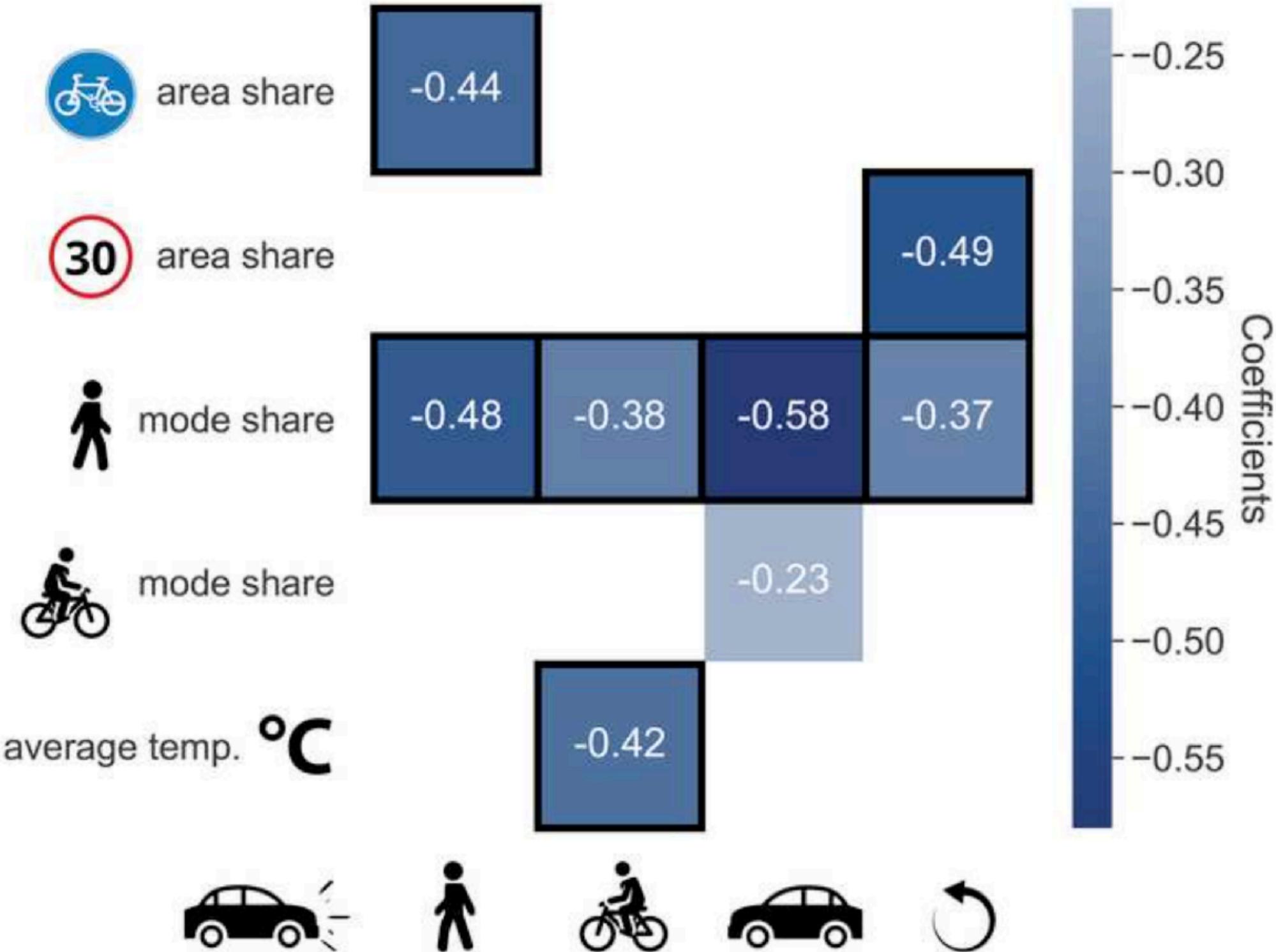
Cost-benefit analysis in EU that accounts for

- Health
- Environment
- Travel / Congestion

shows: 1 km travelled by



More active travel is associated with fewer road deaths



More active travel is crucial to
make cities better.

How to build bicycle infrastructure?

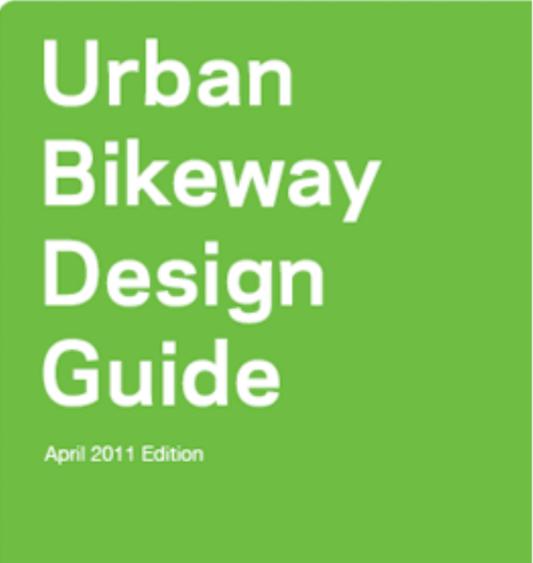
How to build bicycle infrastructure?



We have great planning guides.



NACTO



How to build bicycle infrastructure?



We have great
planning guides.



NACTO



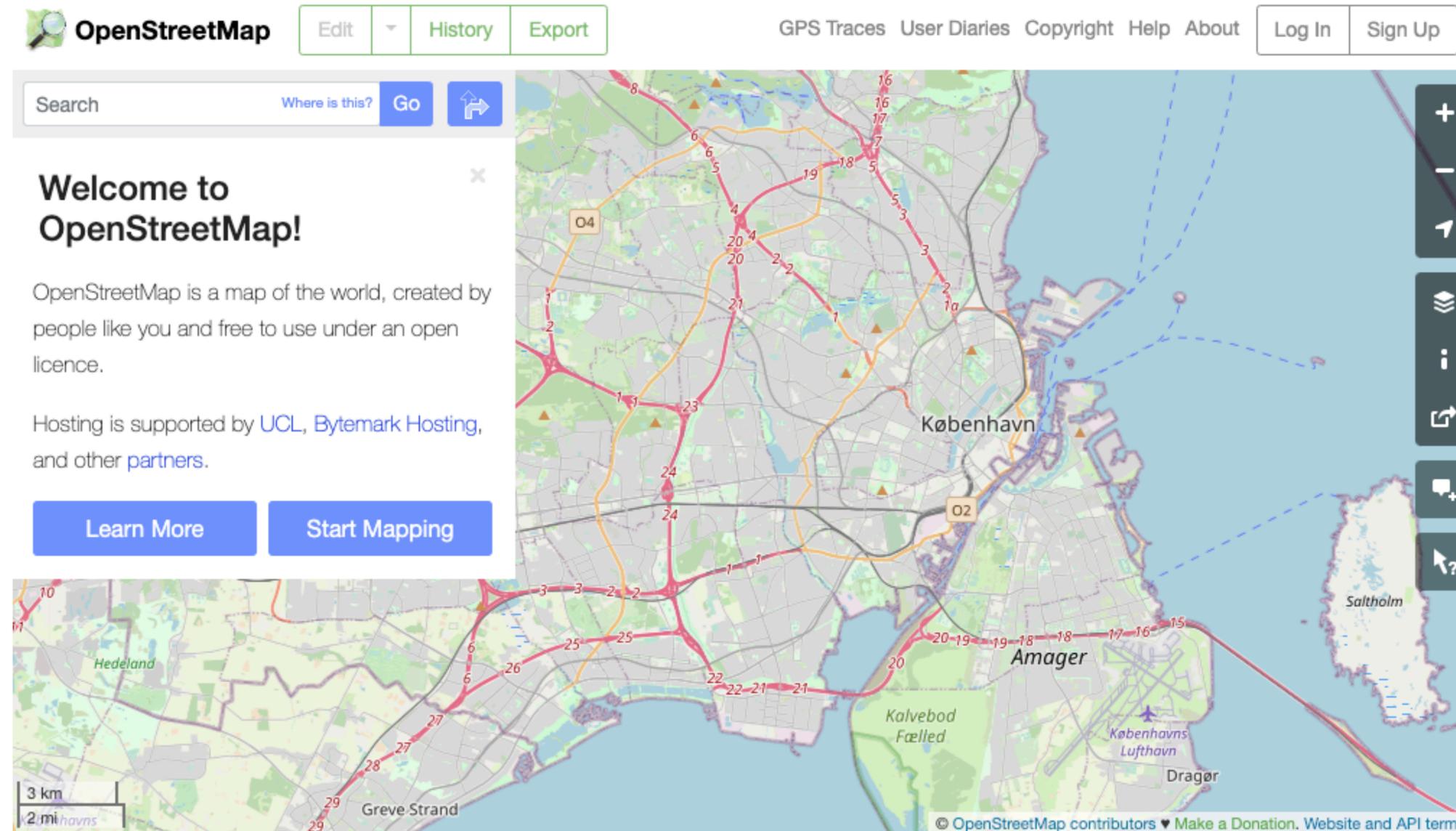
**Urban
Bikeway
Design
Guide**

April 2011 Edition

But no knowledge:

- on the fundamental topological limitations of network growth
- or on how hard/easy it is to fix existing networks

All our research builds on OpenStreetMap (OSM)



OSM data are quite reliable in western countries

Haklay et al, Cart J 47 (2010)

Barrington-Leigh & Millard-Ball, PLOS ONE 12, (2017)

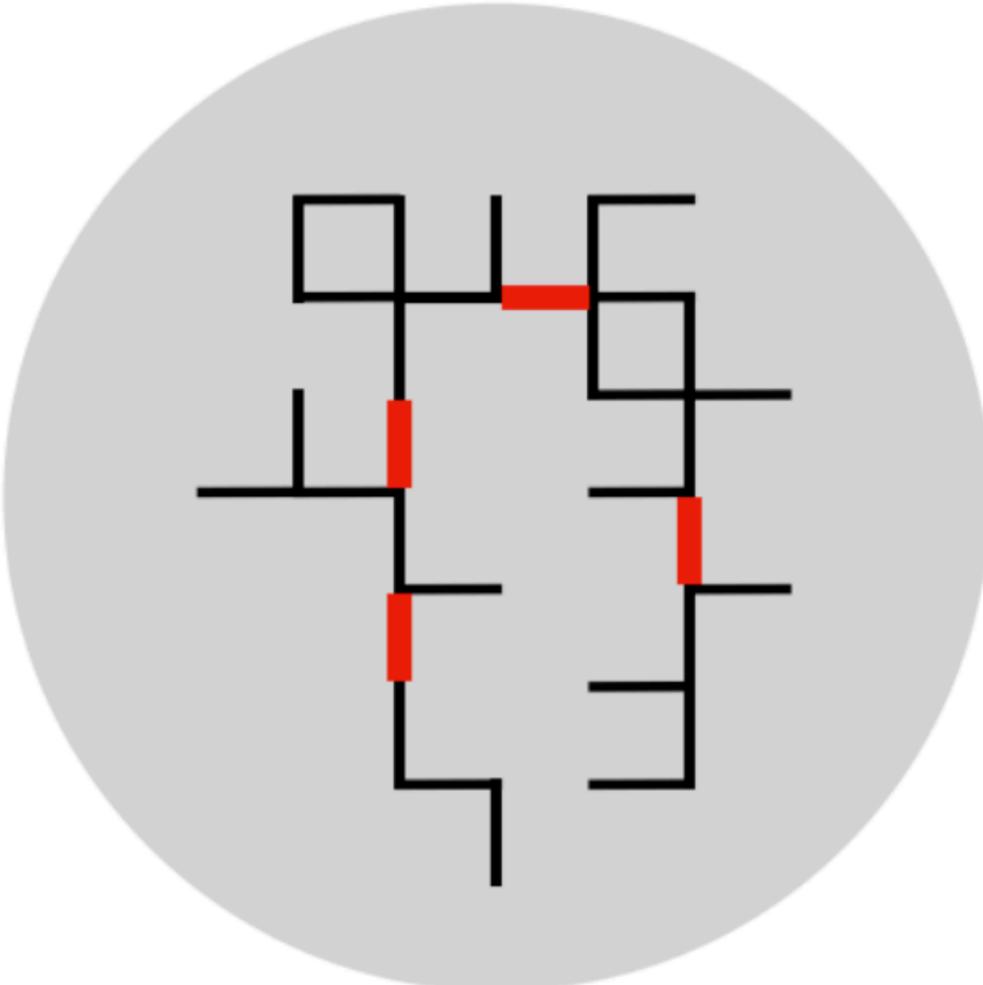
Different cities need different strategies

Most cities
Not developed



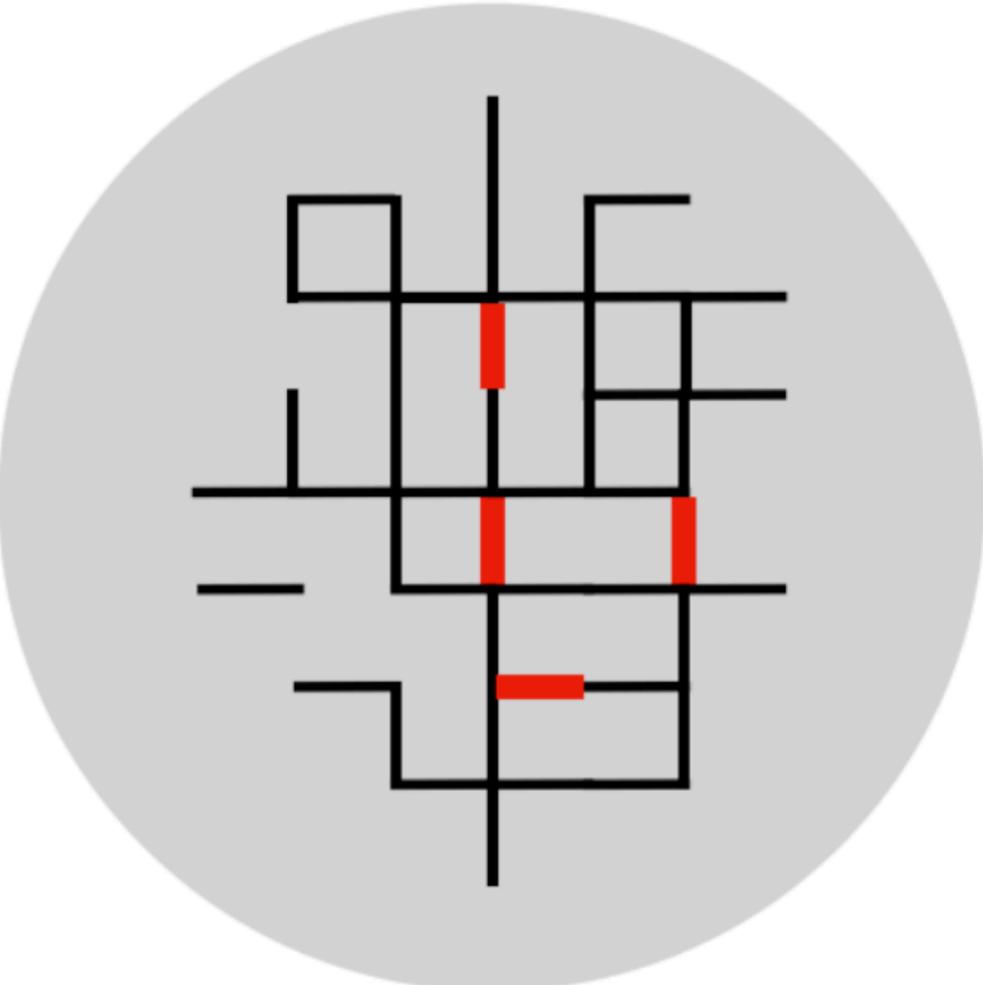
Grow from scratch
GrowBike.Net

Some cities
Developed but
disconnected



Connect components
LinkBike.Net

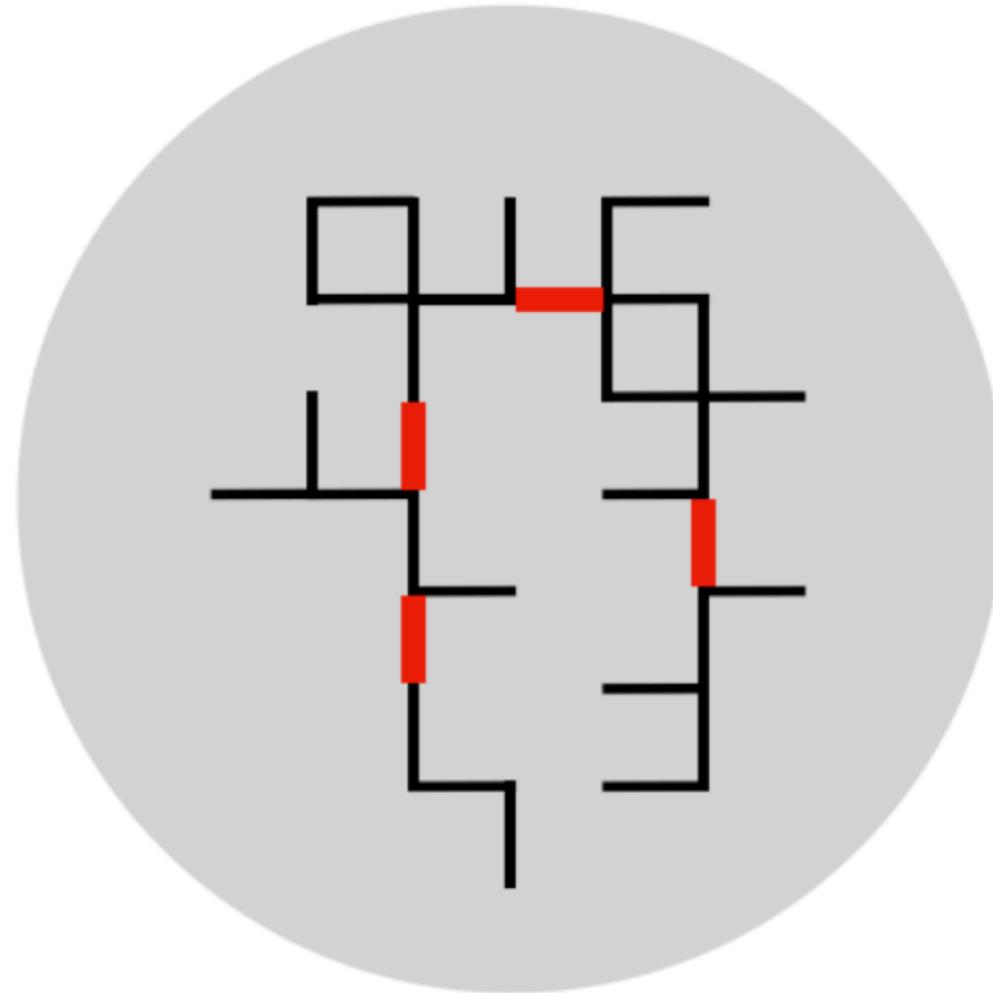
Few cities
Developed and
mostly connected



Find missing links
FixBike.Net

1) Connecting bicycle networks

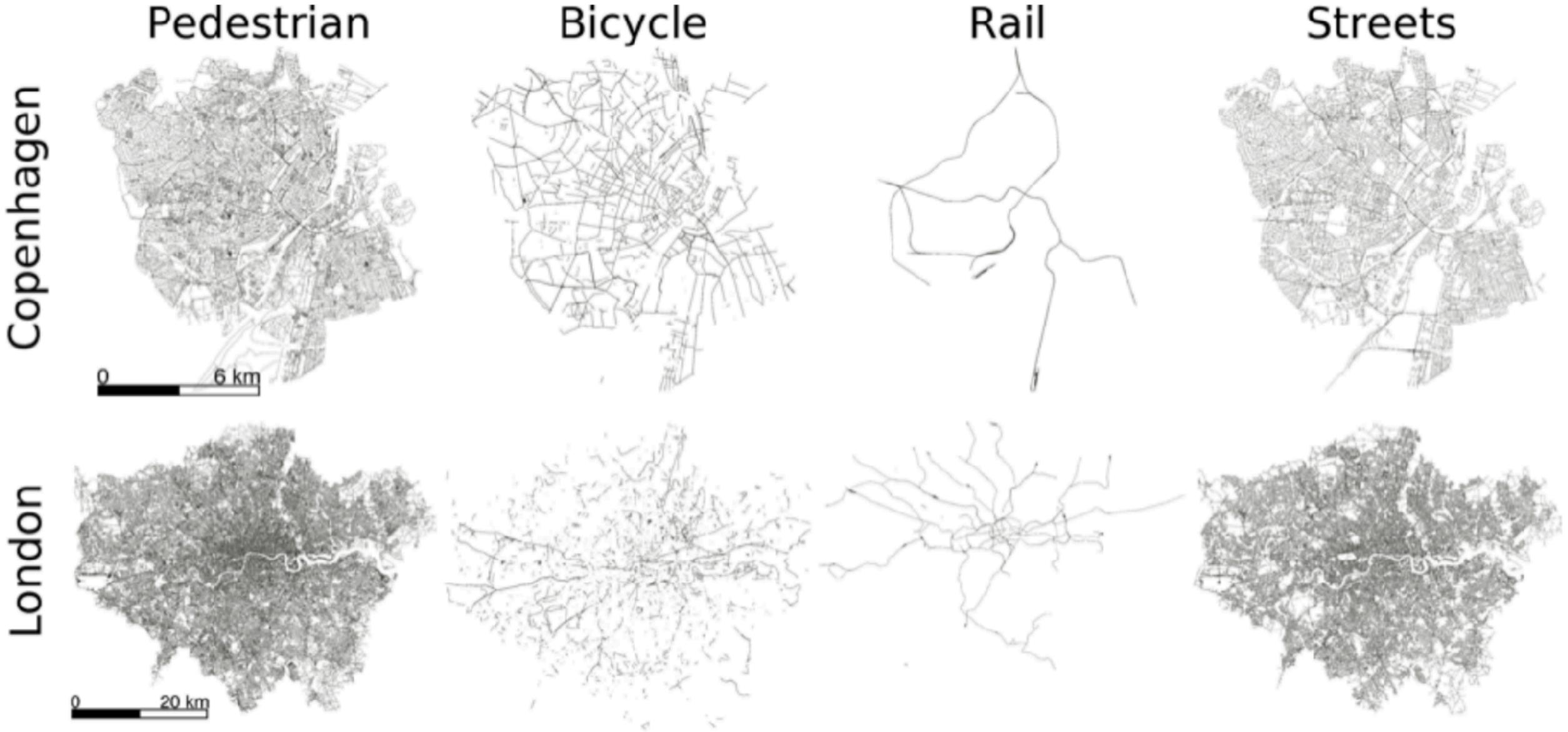
Some cities
Developed but
disconnected



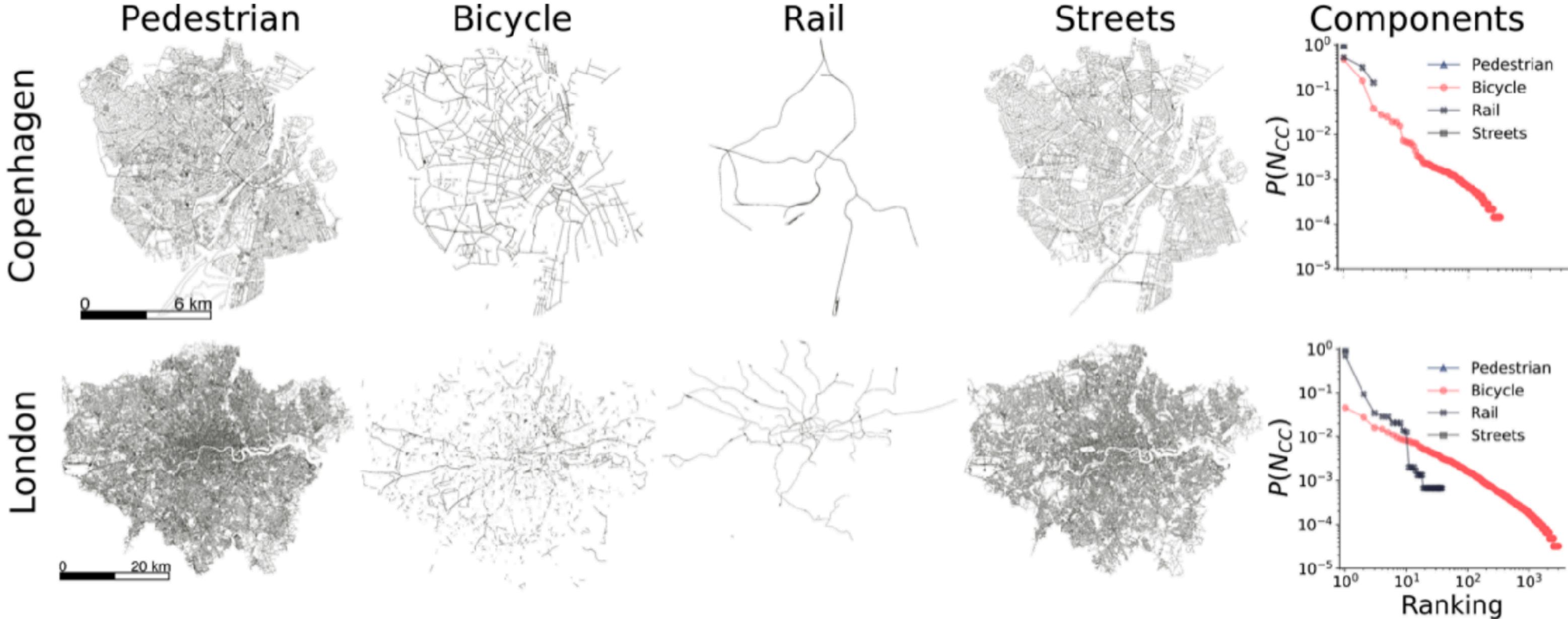
Connect components

LinkBike.Net

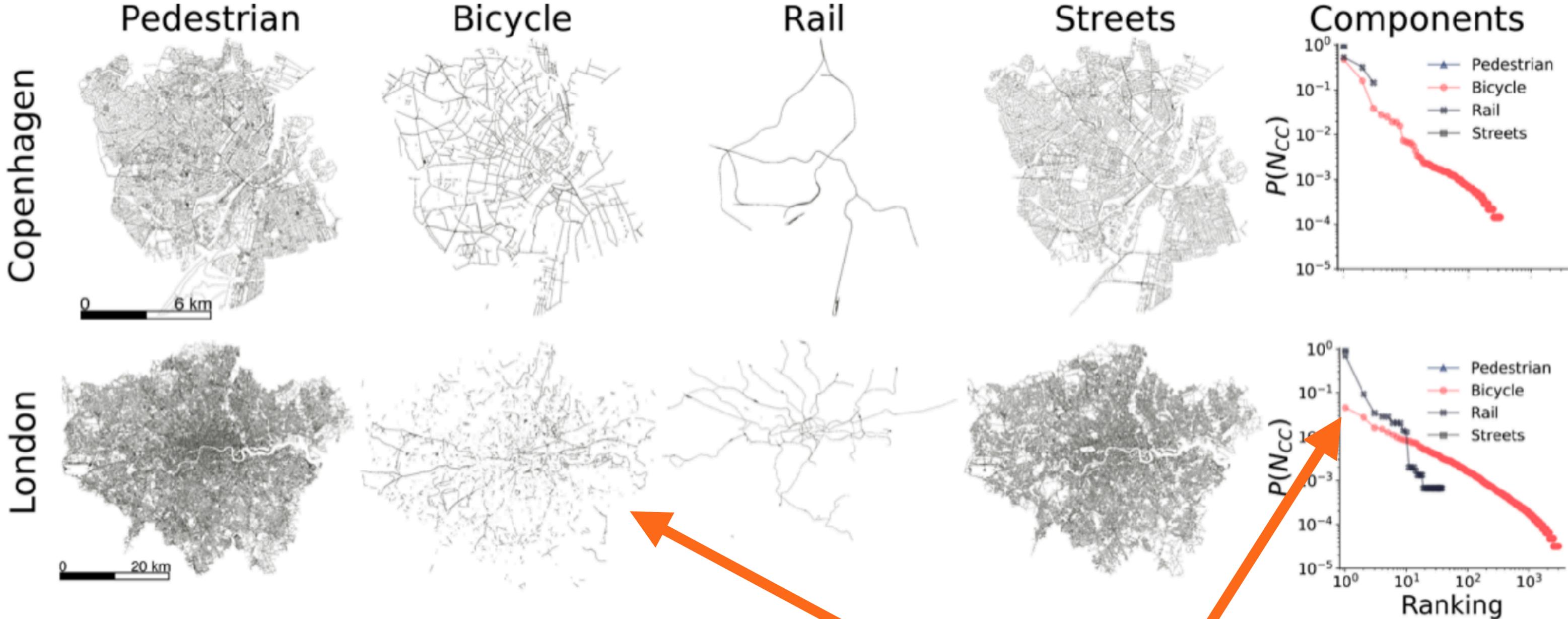
Cities have different transport network layers



Bicycle networks are highly fragmented

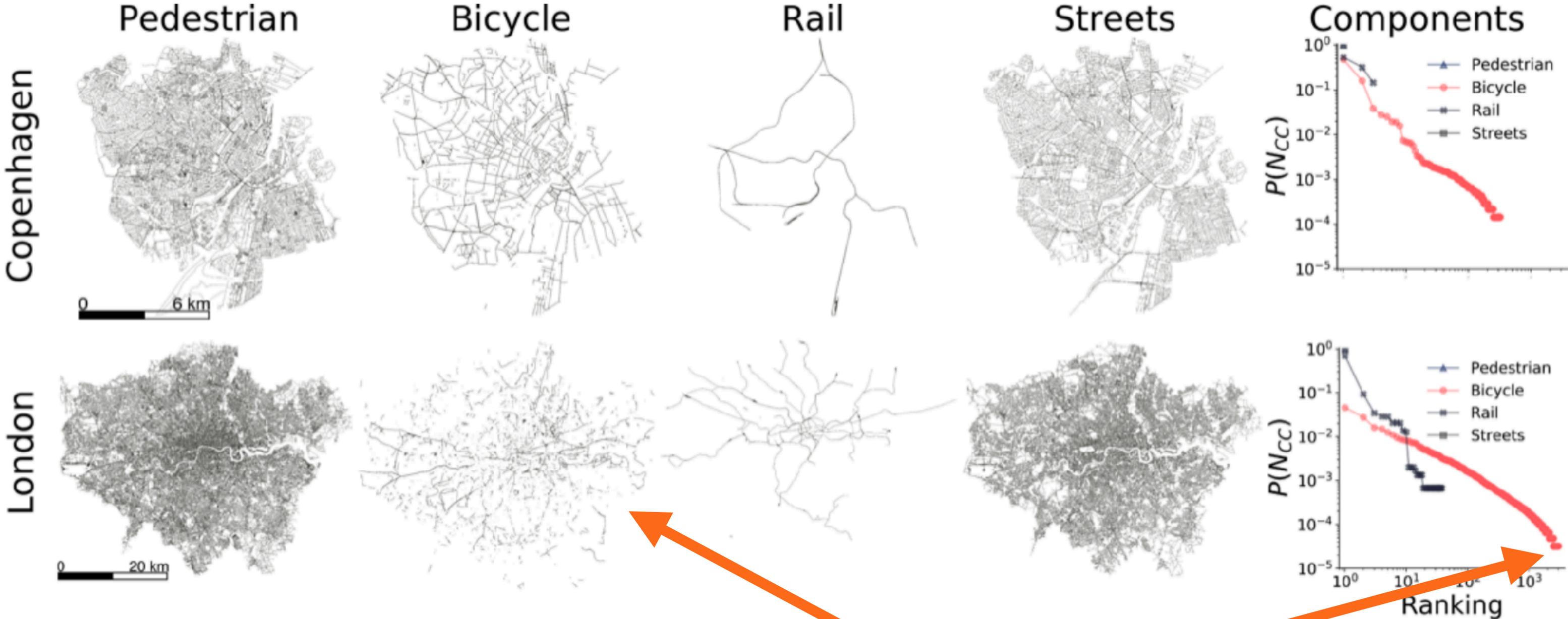


Bicycle networks are highly fragmented



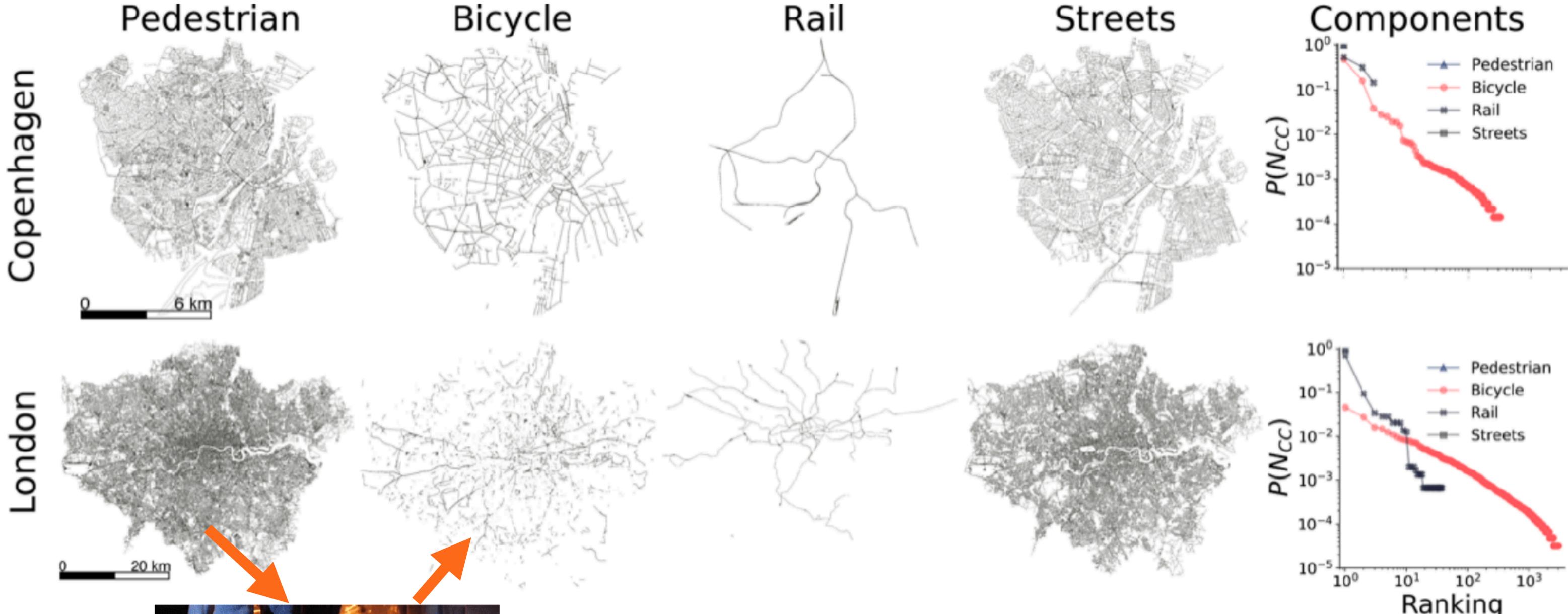
1) In London, the largest connected bicycle component covers only 5% of nodes

Bicycle networks are highly fragmented



2) In London, the bicycle network has >3000 disconnected components

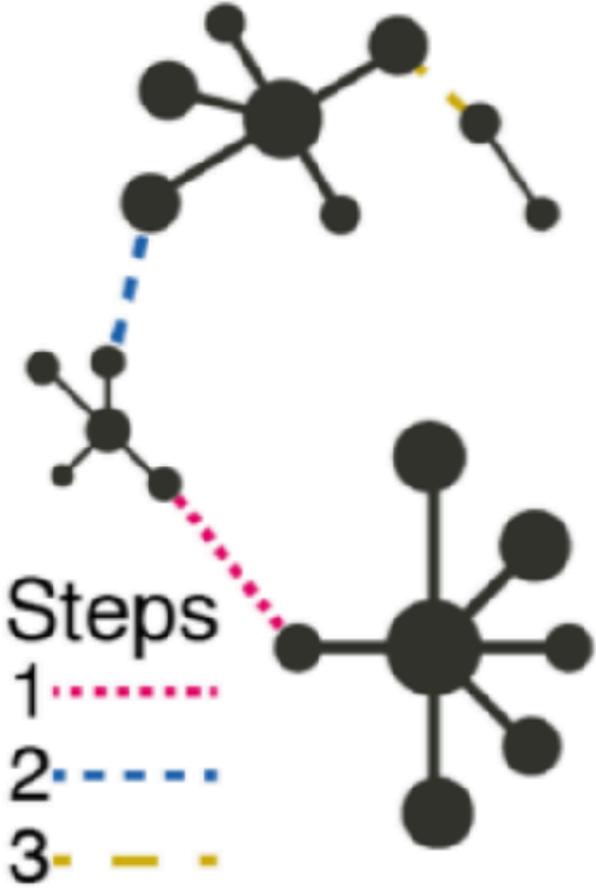
Bicycle networks are highly fragmented



How should we connect the components?

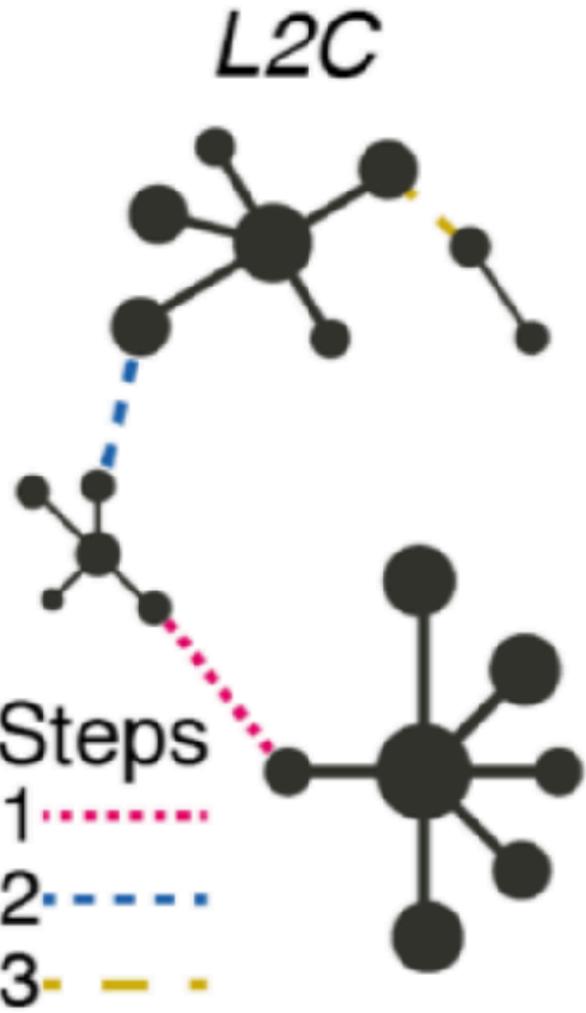
Largest to
closest

L2C

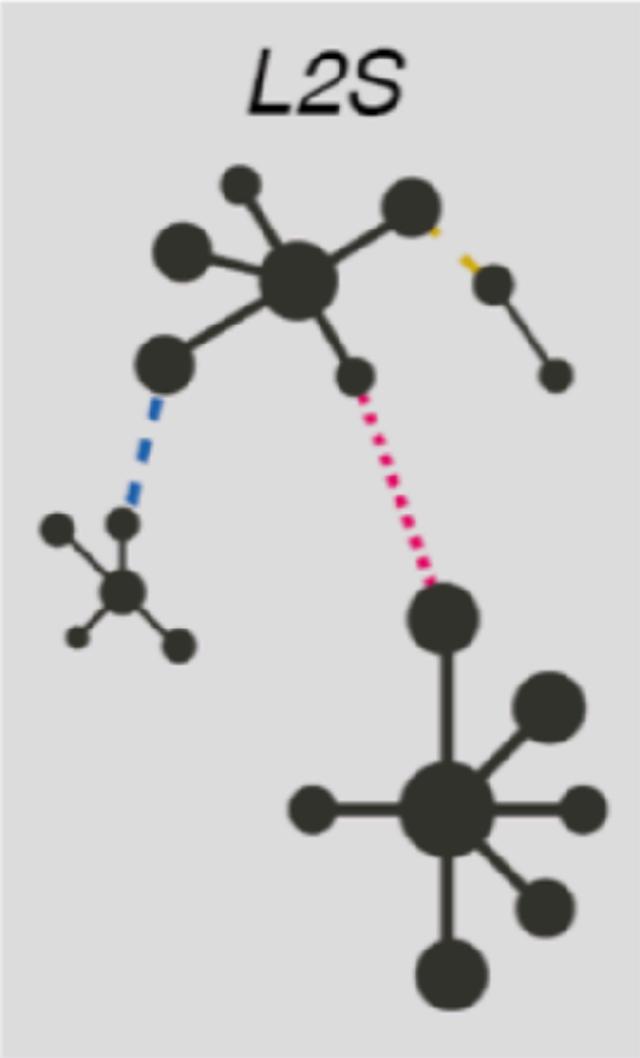


How should we connect the components?

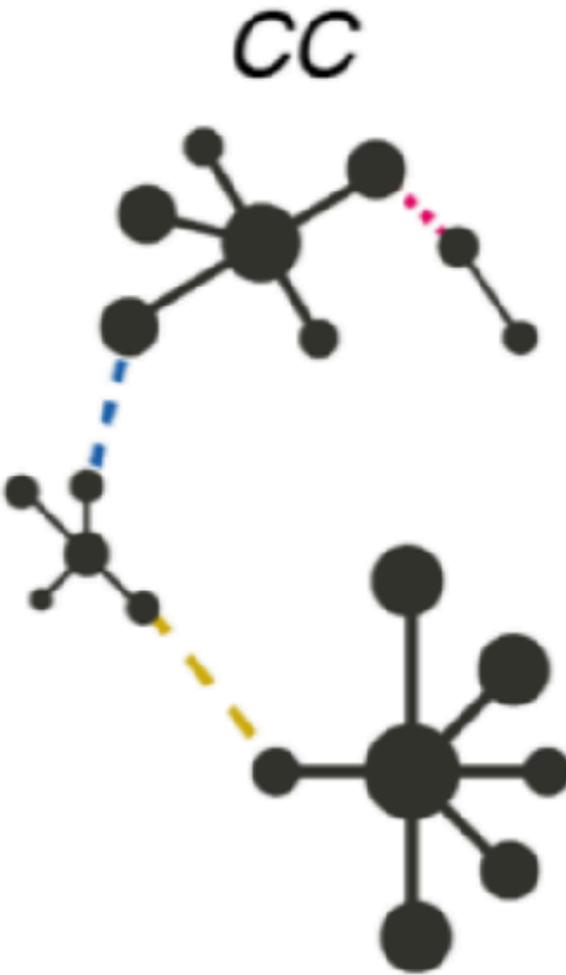
Largest to closest



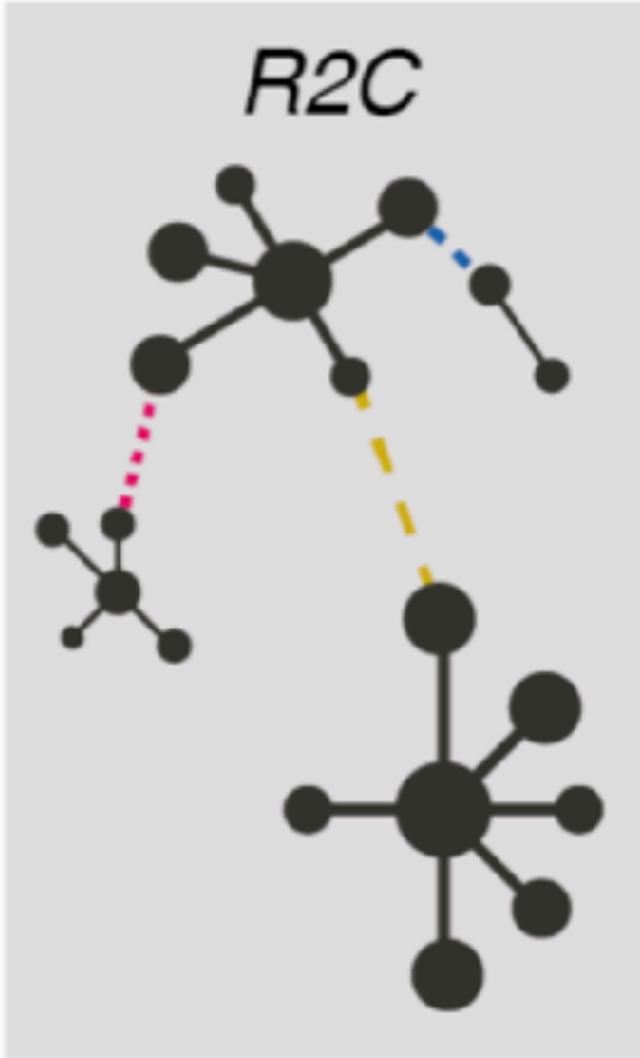
Largest to second largest



Closest components



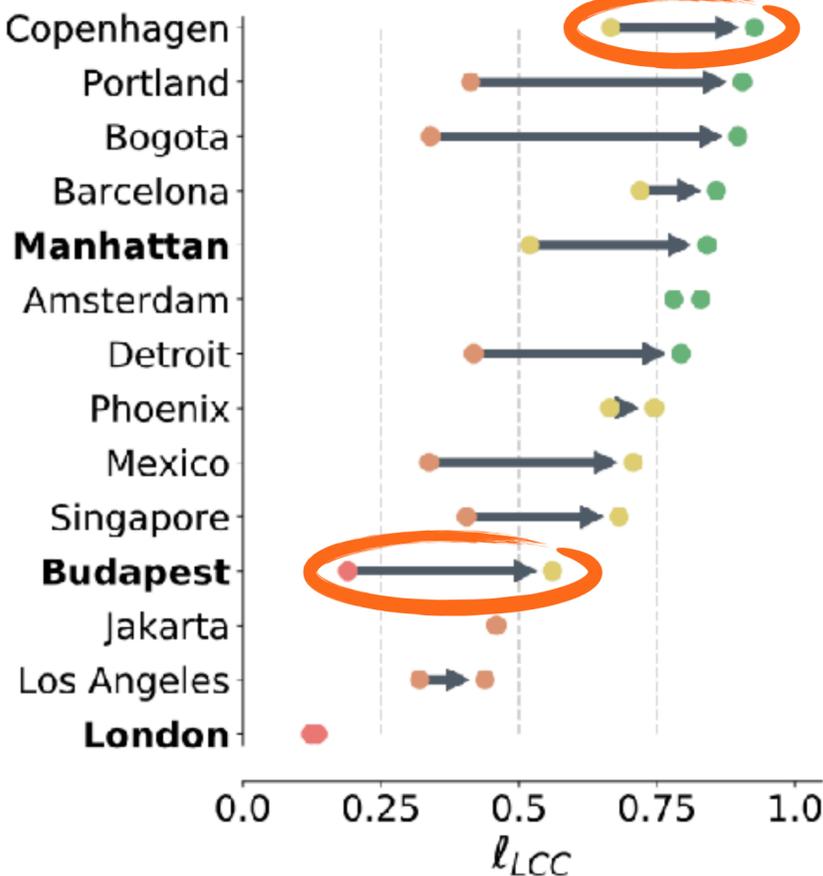
Random to closest



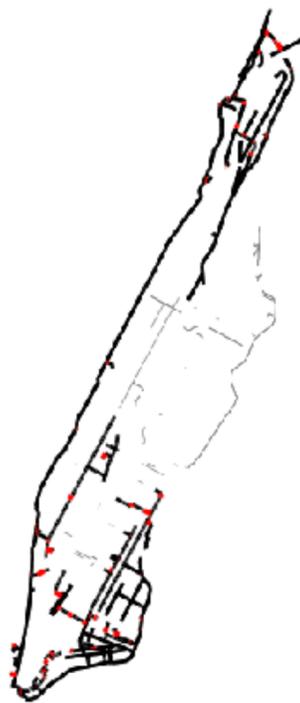
Effective connectivity improvements are possible

Small but **focused** investments connect the bicycle network effectively

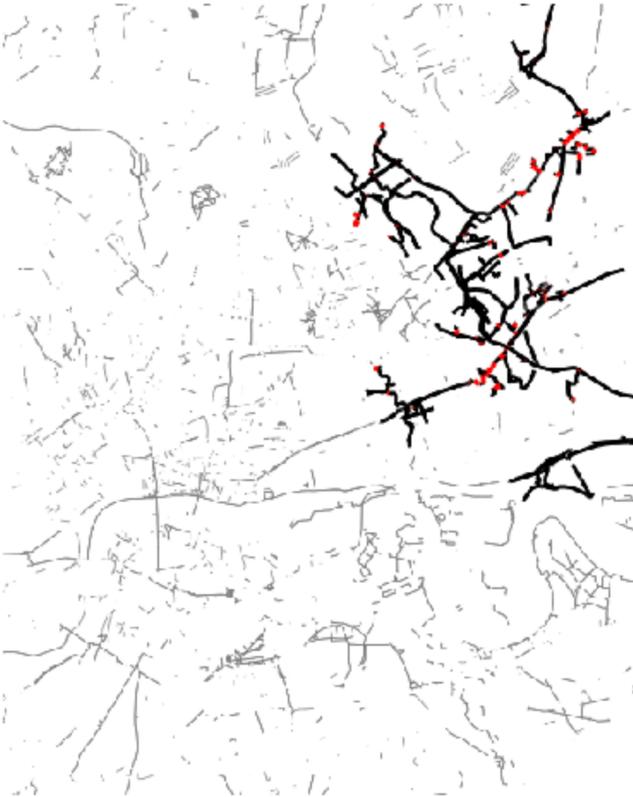
(a) 5 km investment



Manhattan



London



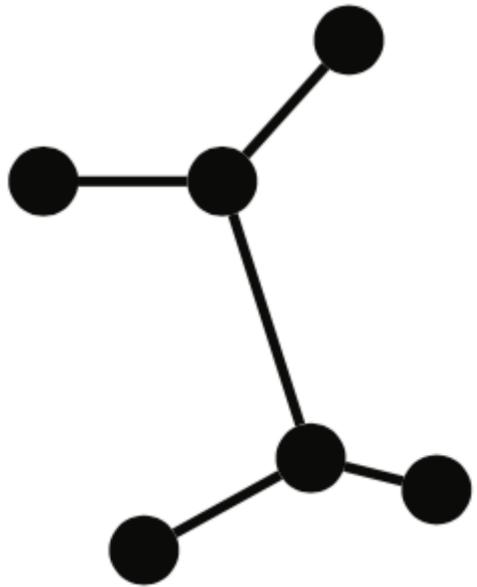
Budapest



Just connecting components comes with 3 issues

1) No resilience

Minimum spanning tree



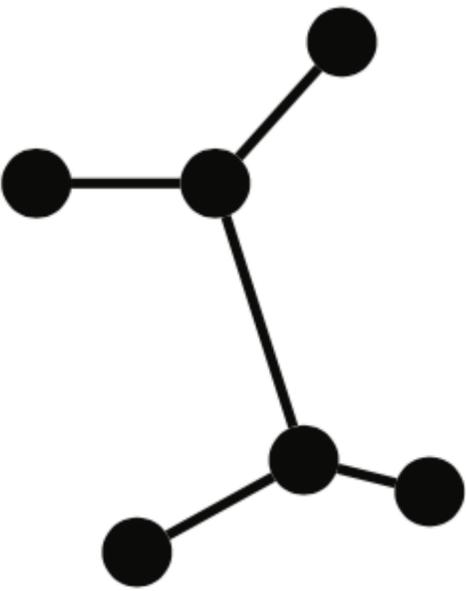
Investor's
optimum

Just connecting components comes with 3 issues

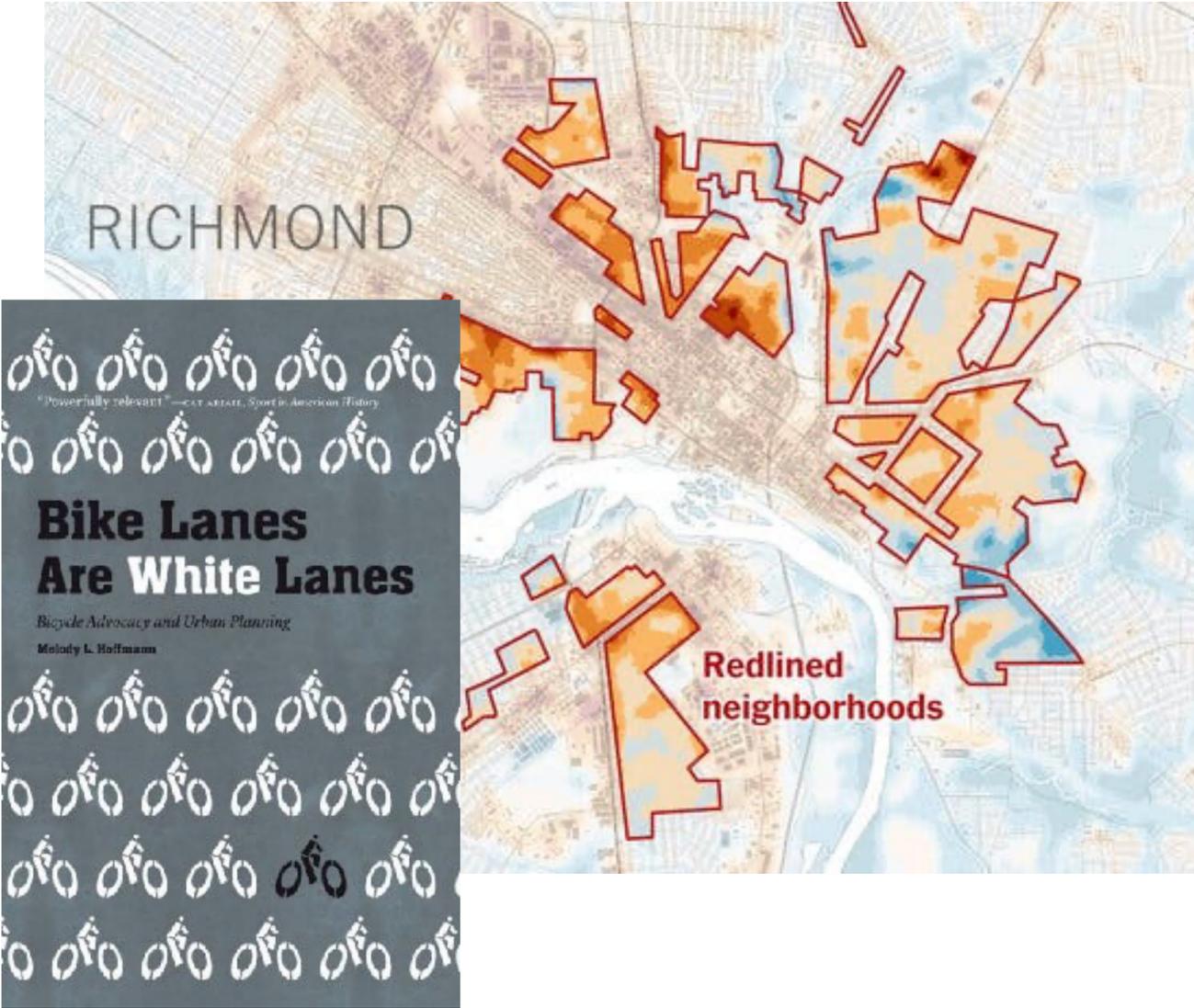
1) No resilience

2) Develops only developed areas

Minimum spanning tree



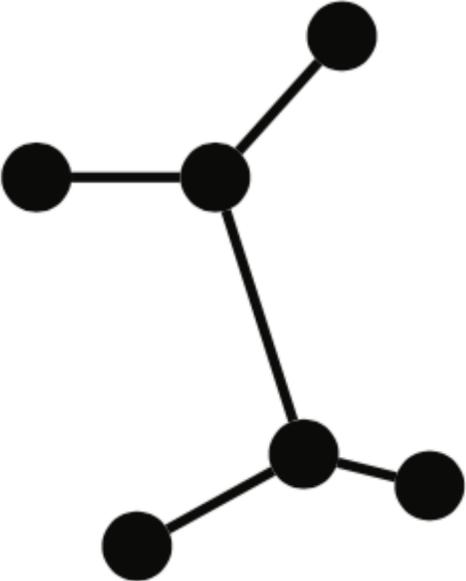
Investor's optimum



Just connecting components comes with 3 issues

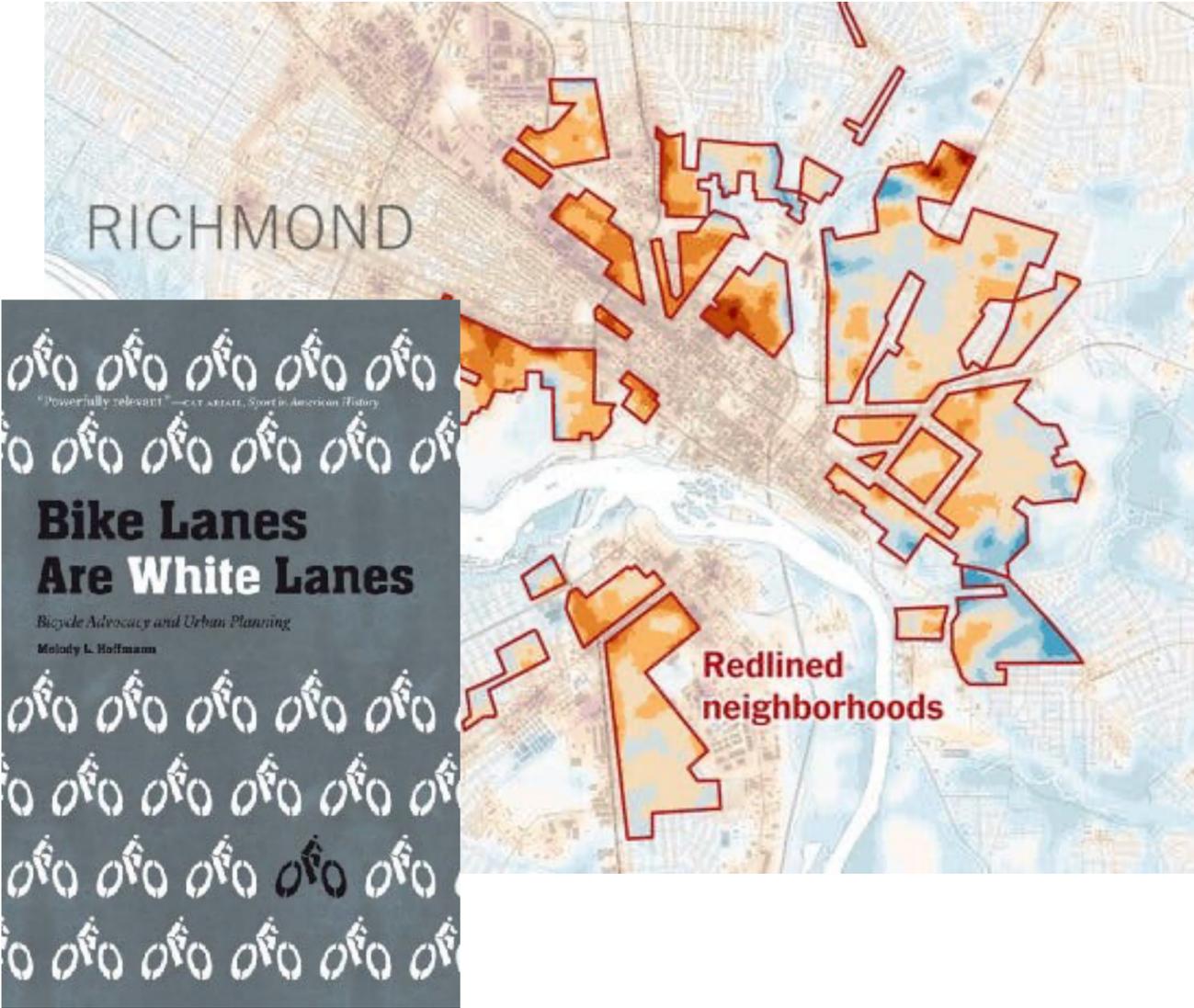
1) No resilience

Minimum spanning tree

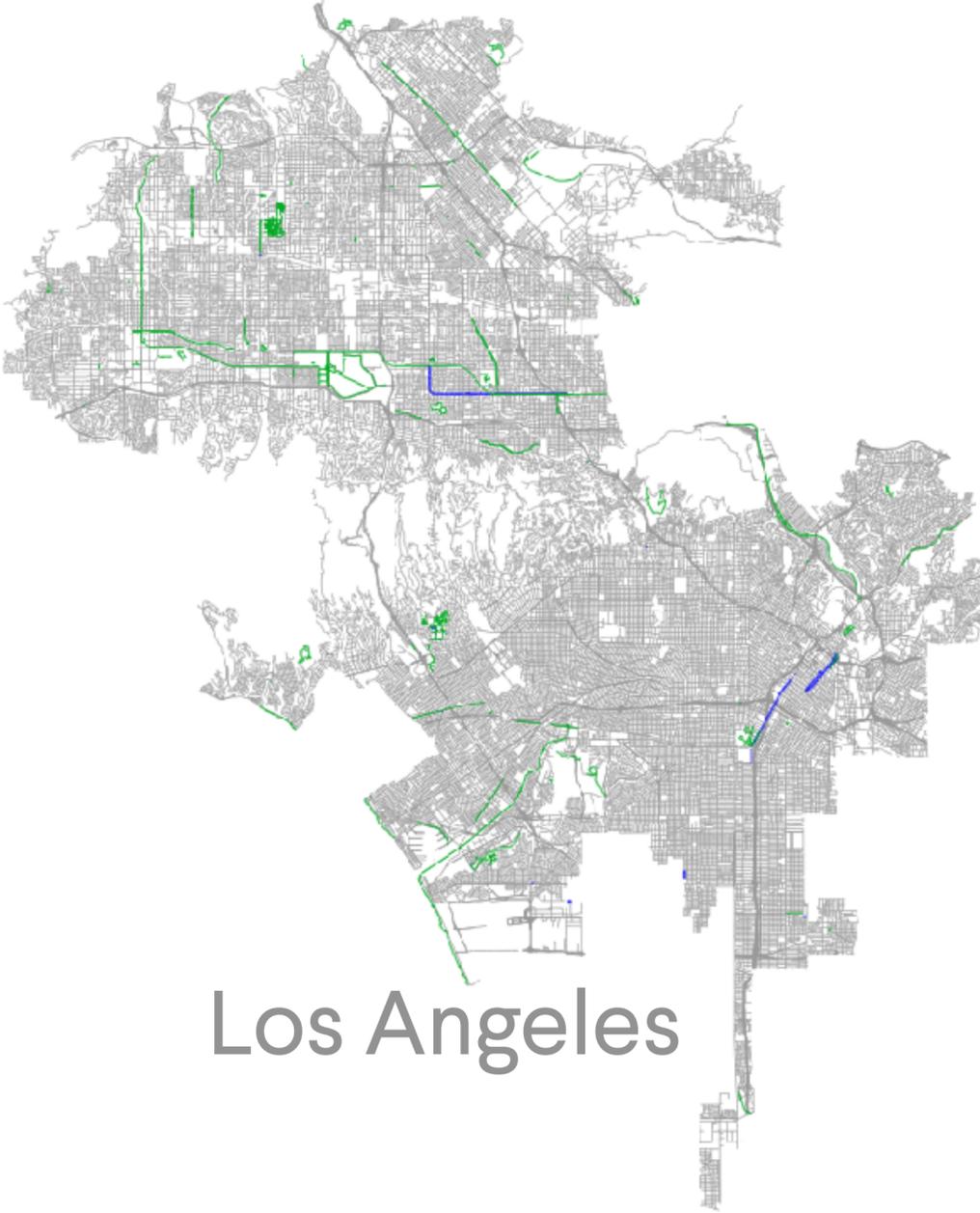


Investor's optimum

2) Develops only developed areas



3) Irrelevant for >99% of cities on the planet

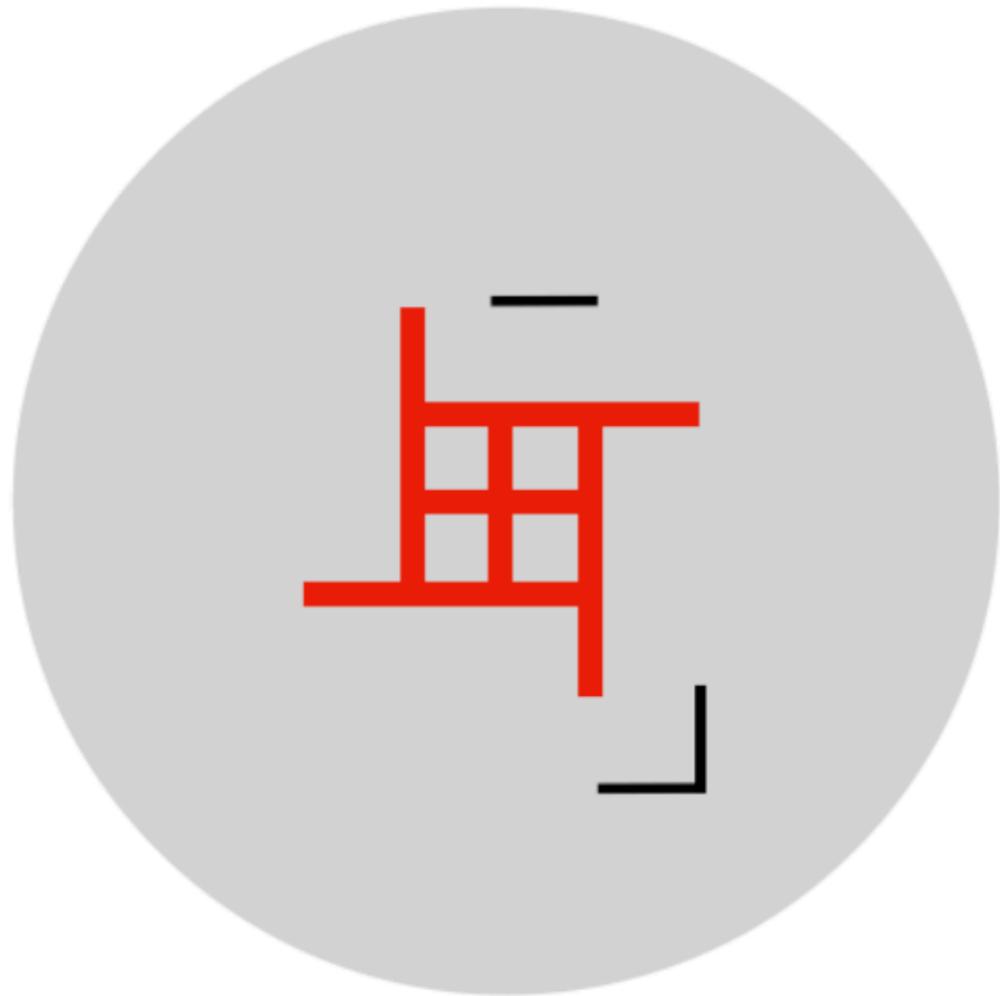


Los Angeles

Let's grow networks
from scratch

2) Growing bicycle networks

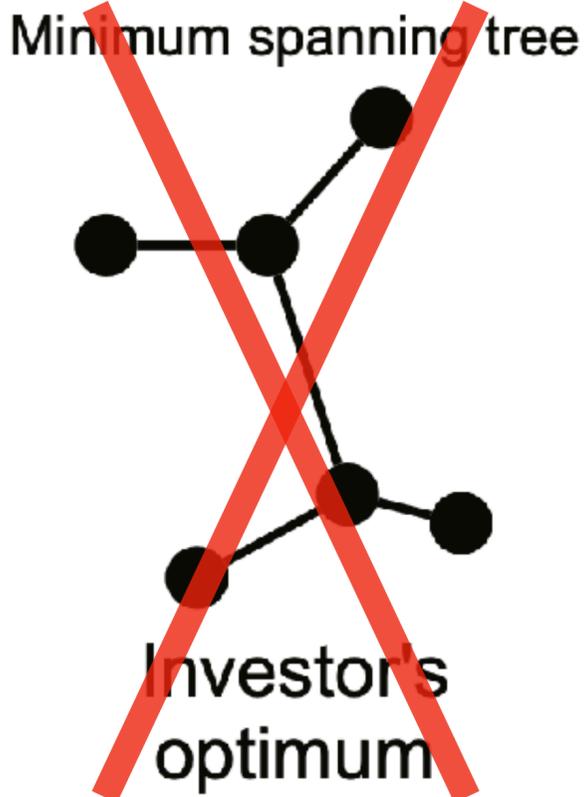
Most cities
Not developed



Grow from scratch
GrowBike.Net

Inspired by CROW, we want a **cohesive** network

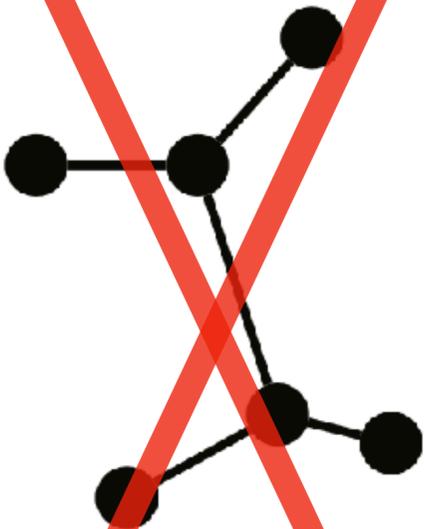
Connectedness & Resilience



Inspired by CROW, we want a **cohesive** network

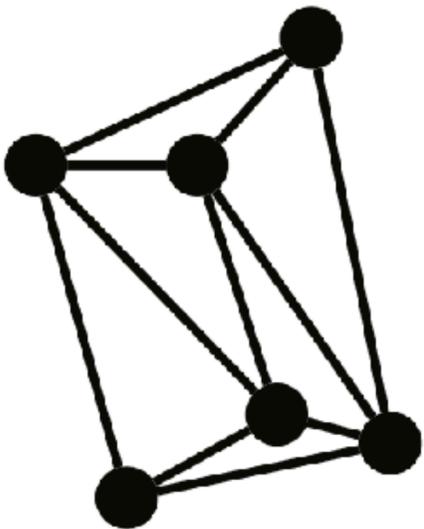
Connectedness & Resilience

~~Minimum spanning tree~~



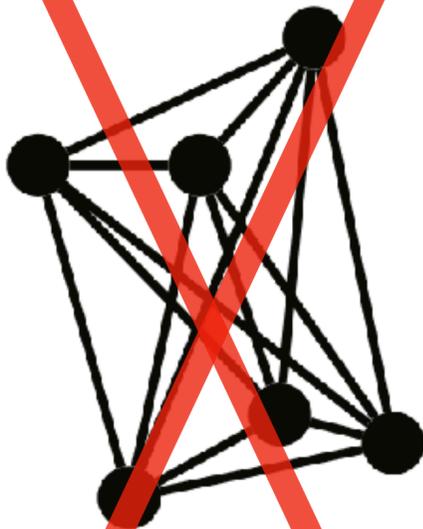
~~Investor's optimum~~

Triangulation



Cohesive planar network

~~Fully connected~~



~~Traveler's optimum~~

Economic

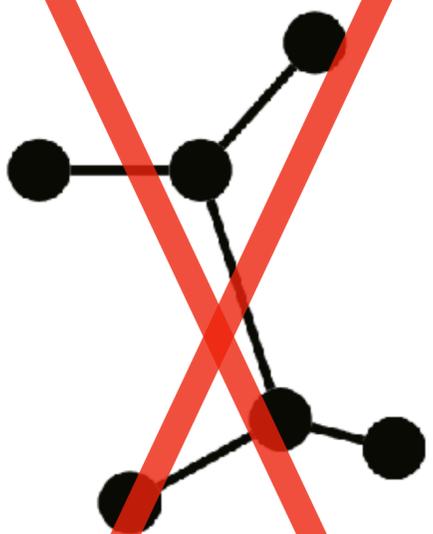
Resilient

Inspired by CROW, we want a **cohesive** network

Connectedness & Resilience

& Coverage

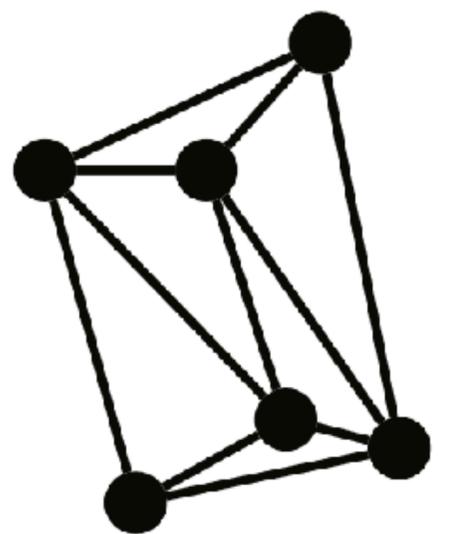
~~Minimum spanning tree~~



~~Investor's optimum~~

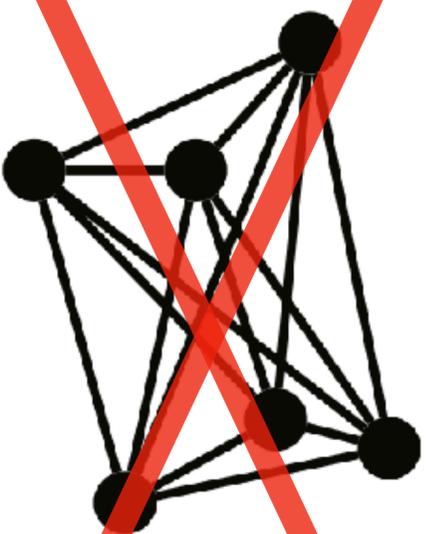
Economic

Triangulation



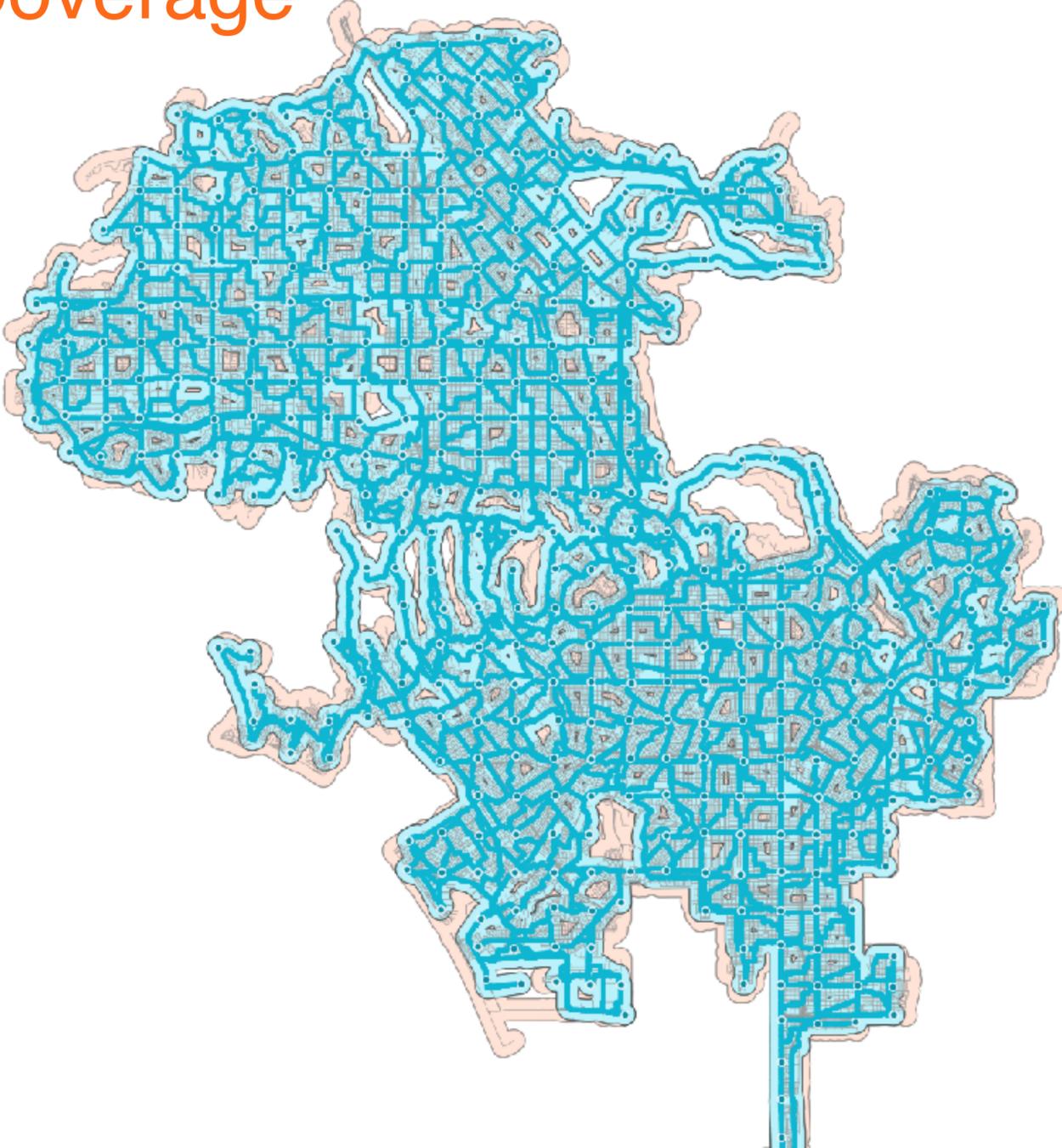
Cohesive planar network

~~Fully connected~~



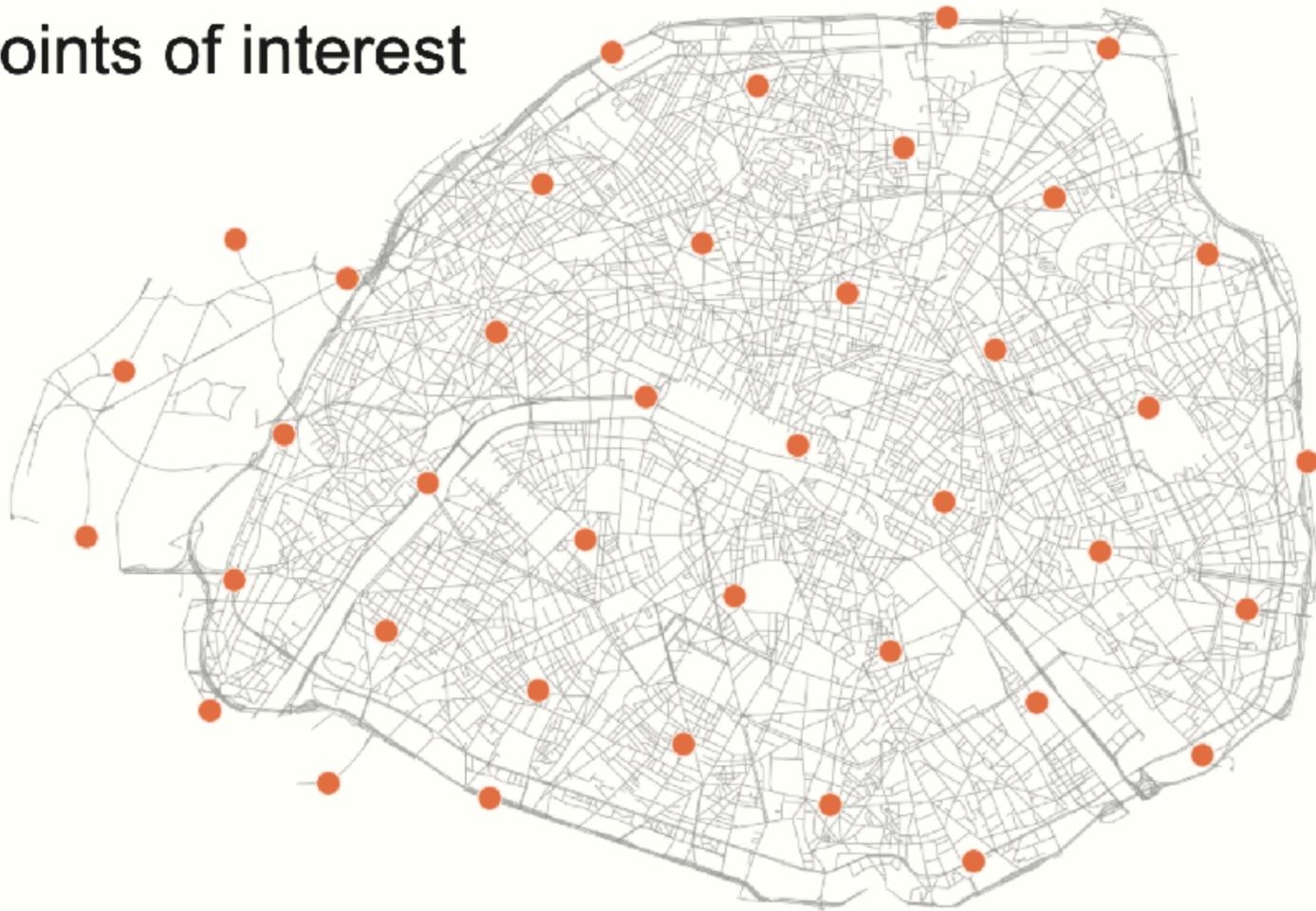
~~Traveler's optimum~~

Resilient

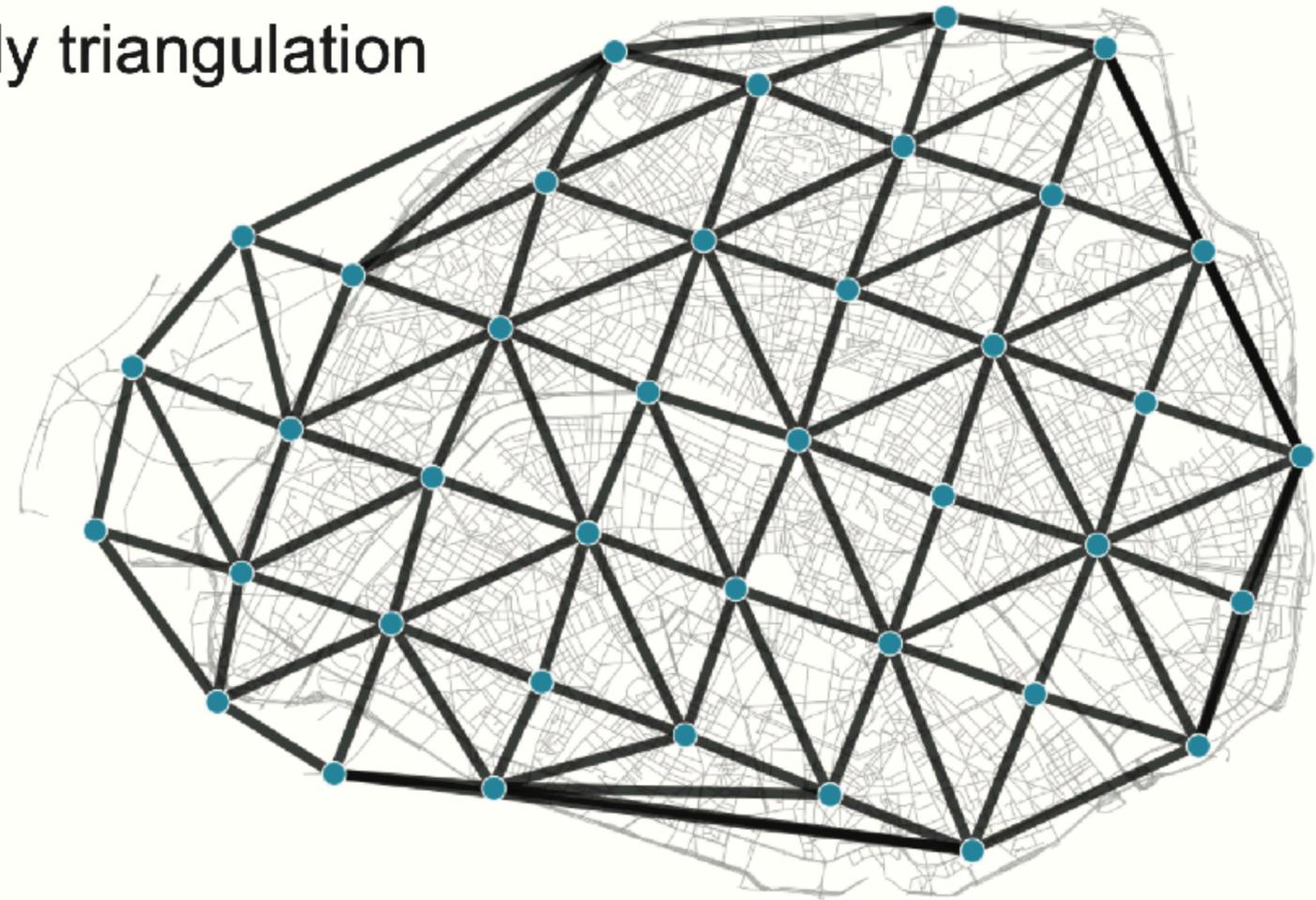


We build a greedy triangulation between points of interest

1) Points of interest



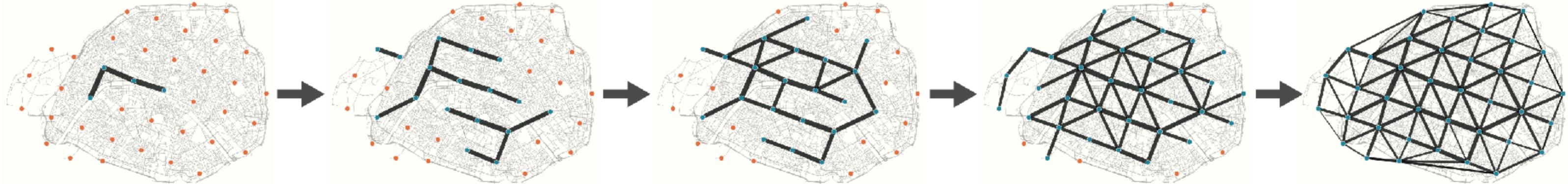
2) Greedy triangulation



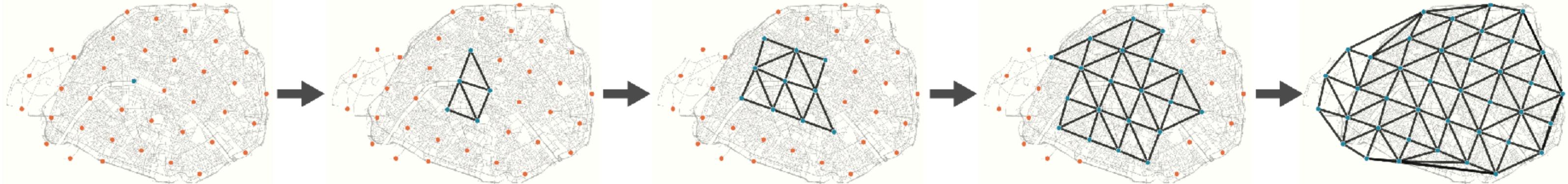
We build a greedy triangulation between points of interest

3) Order by growth strategy

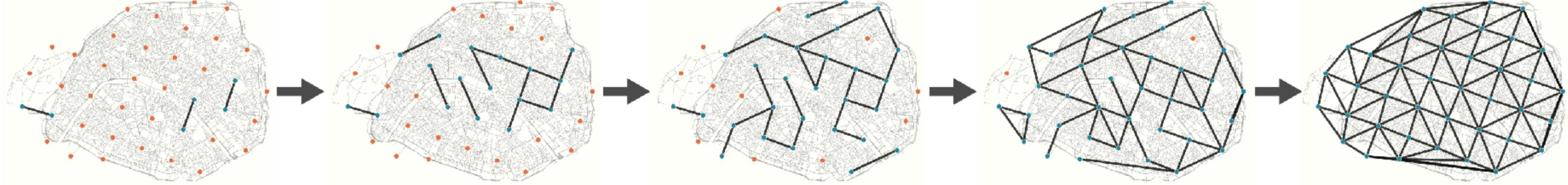
Betweenness



Closeness



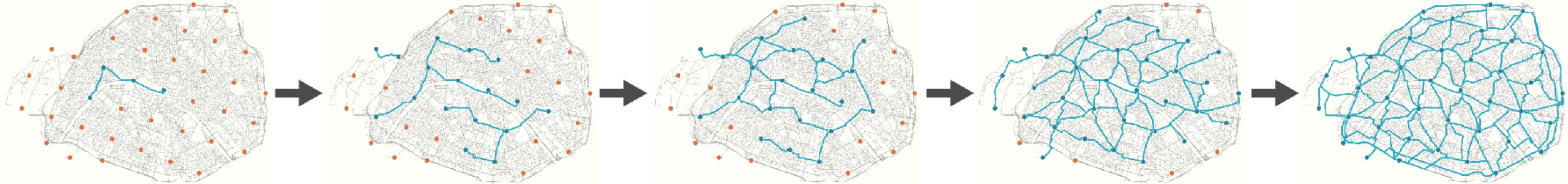
Random



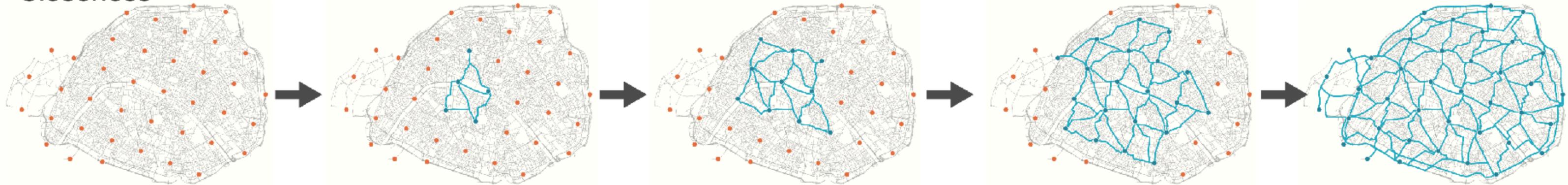
We build a greedy triangulation between points of interest

4) Route on street network

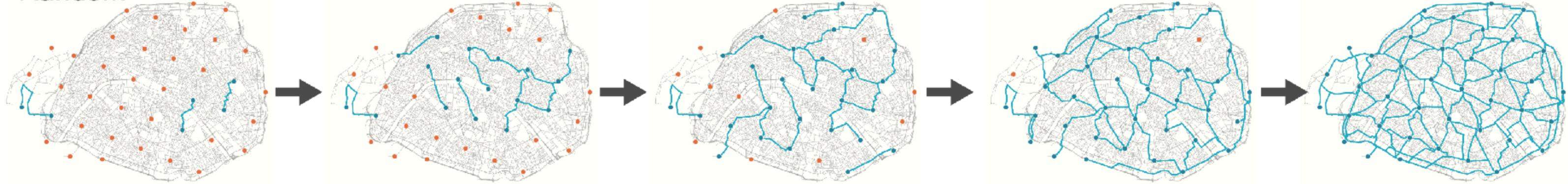
Betweenness



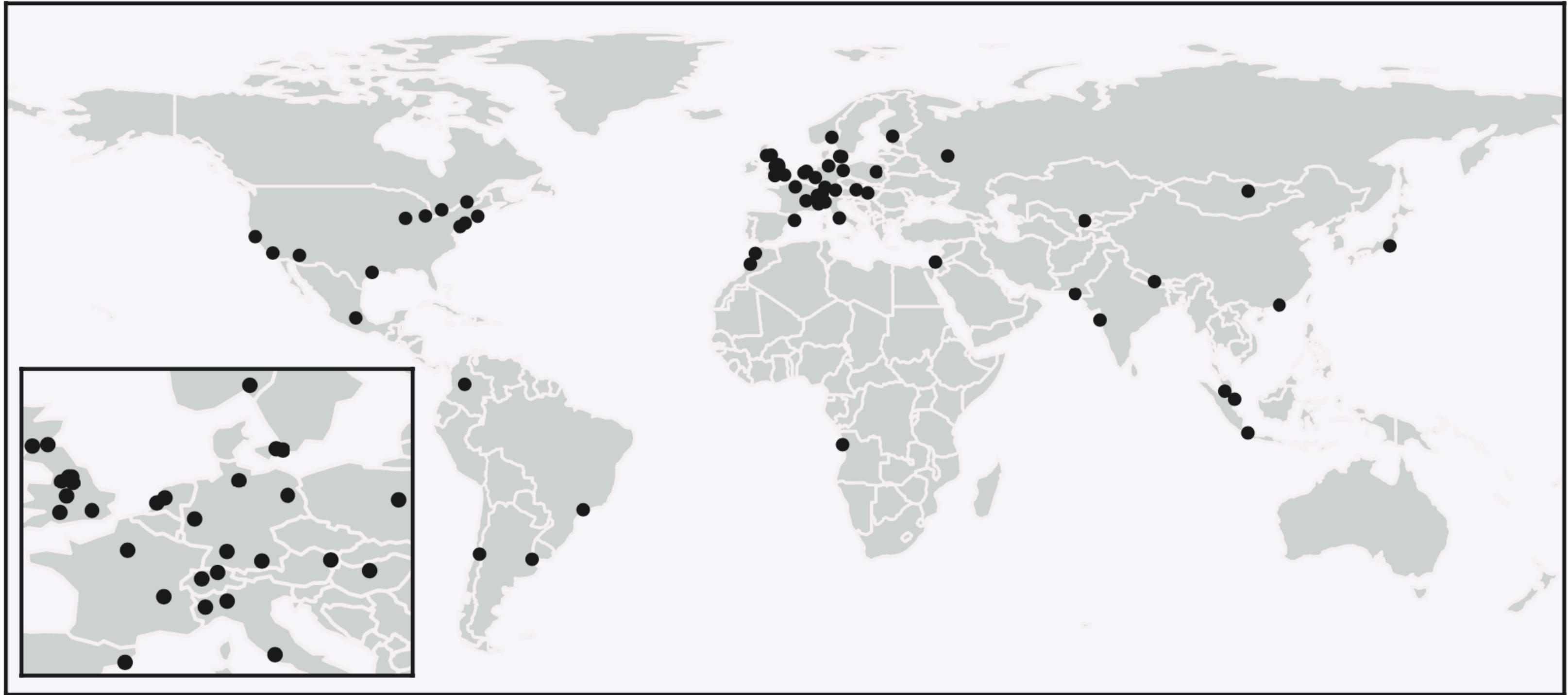
Closeness



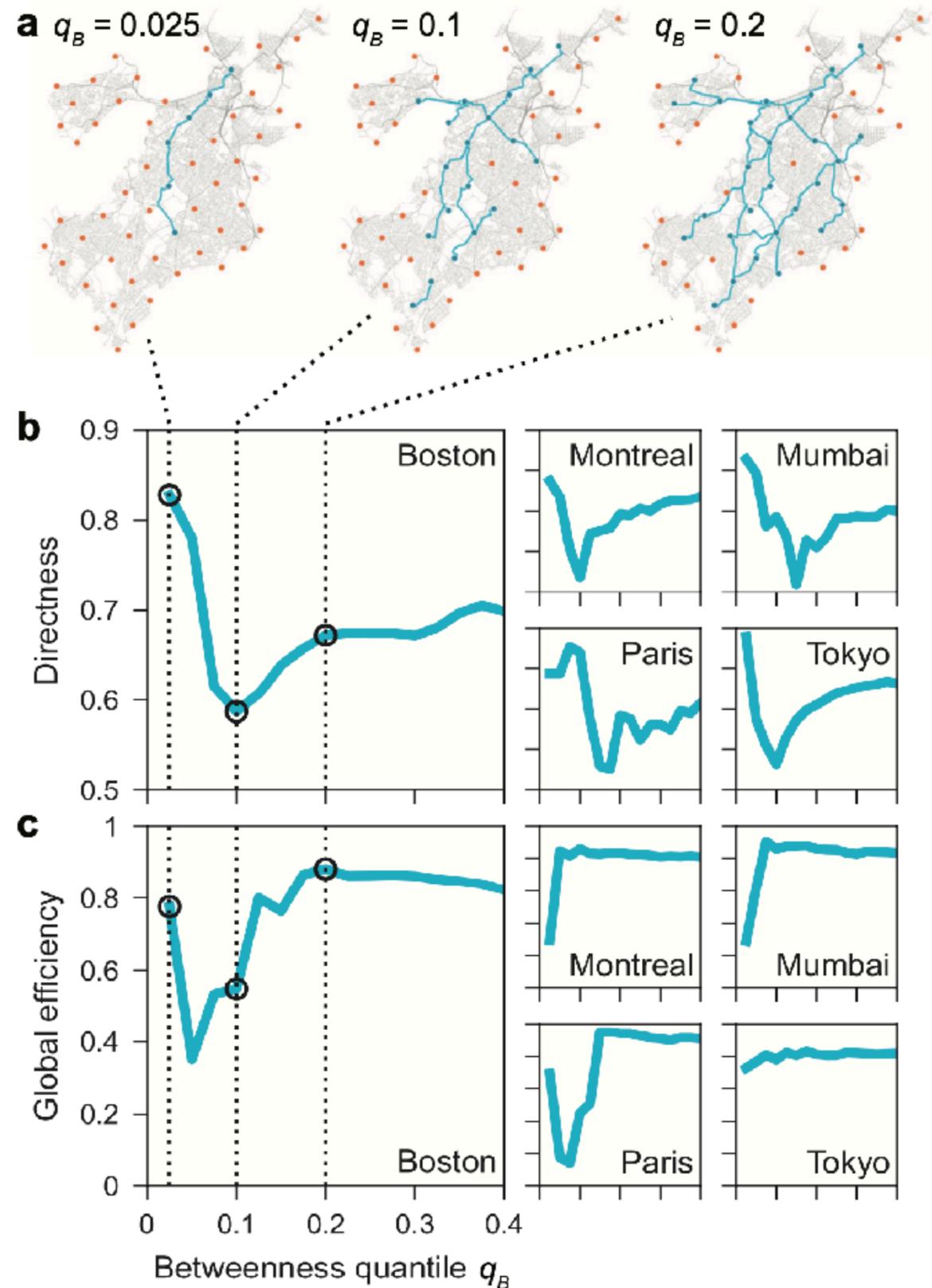
Random



We explore 62 cities



Result 1: First there is **decreasing** return of investment!



The pieces need to connect and to form cycles

Policy implication 1: **Invest persistently!**



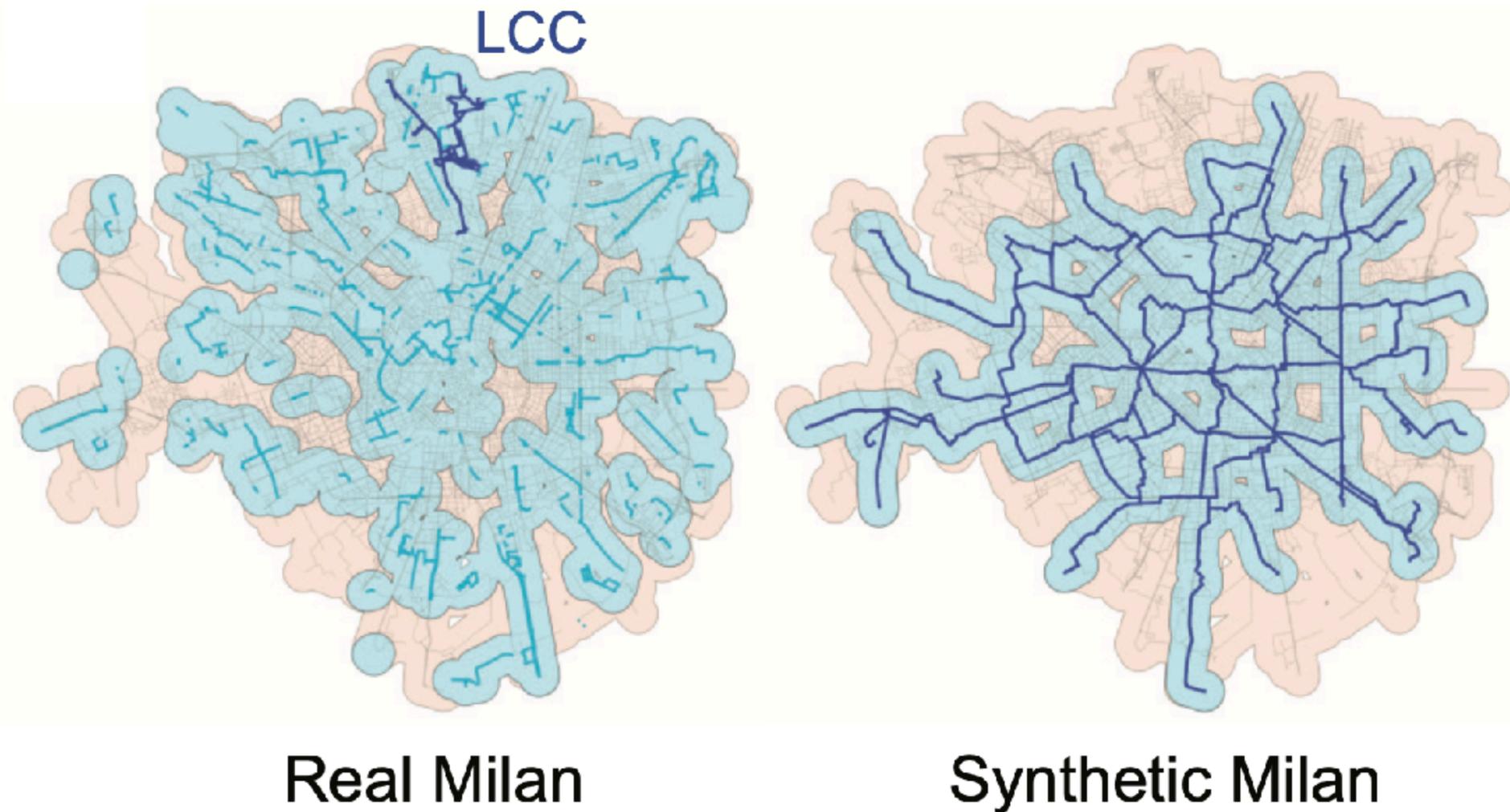
Brent Toderian ✓ @BrentToderian · Jul 30



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.**

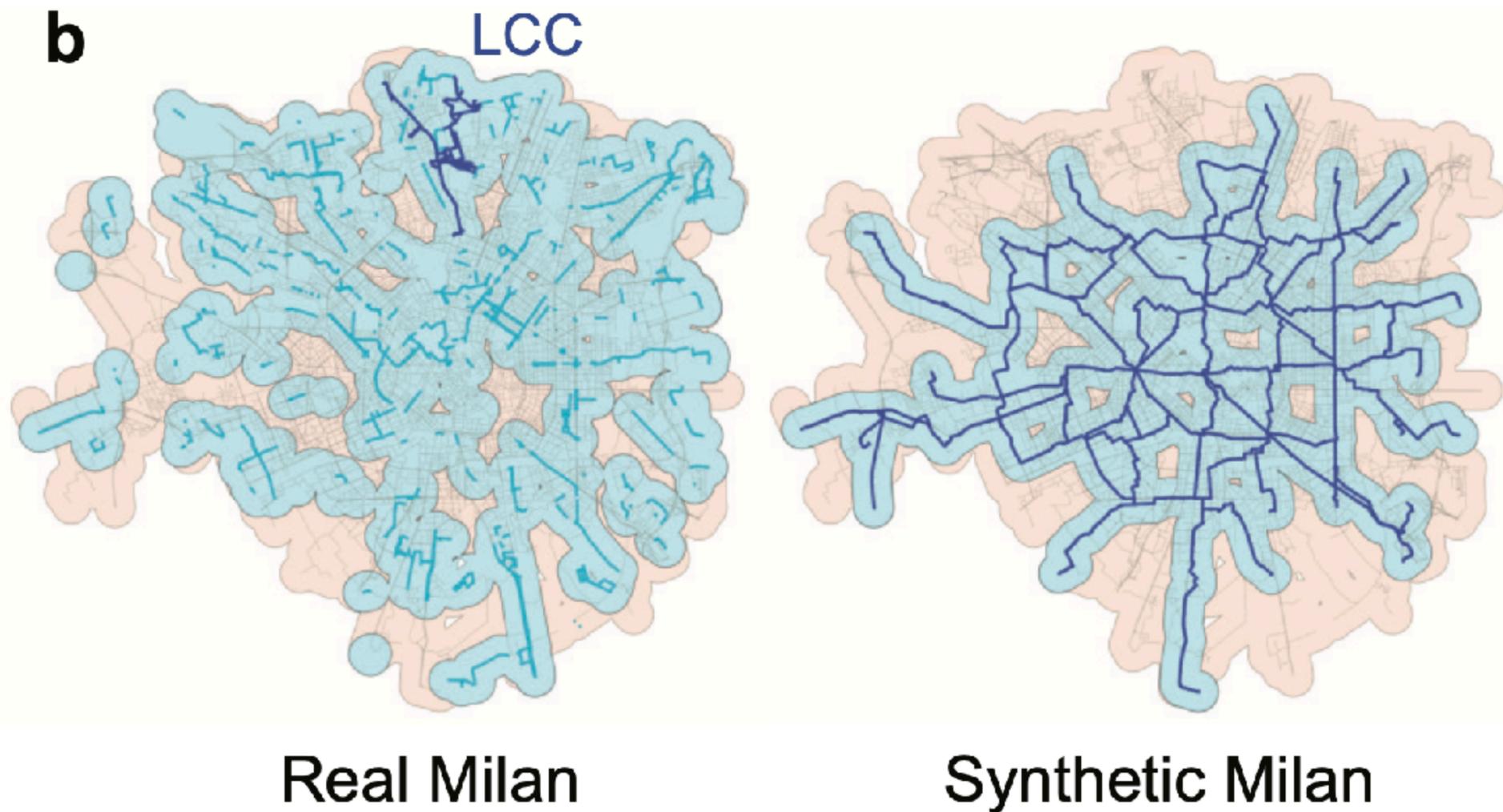
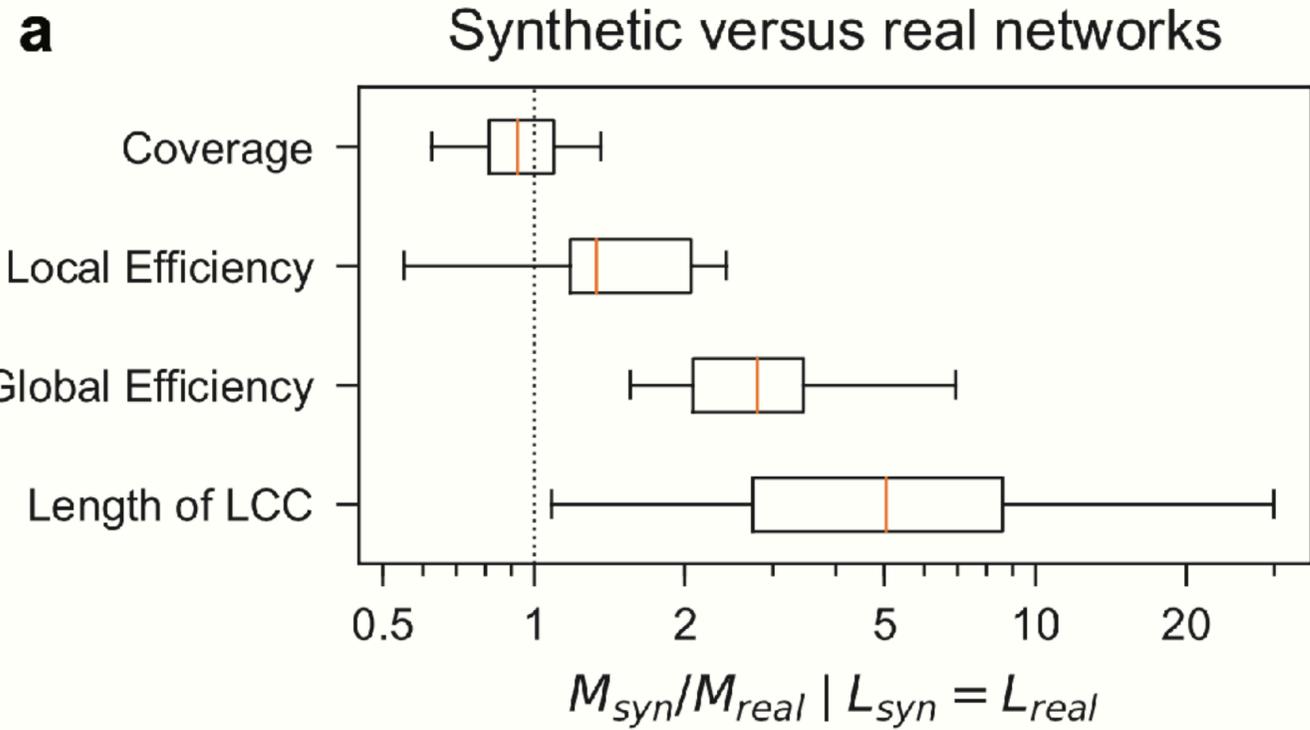
Result 2: It's not a network's length that matters but how you grow it

At same length, we could
do much better

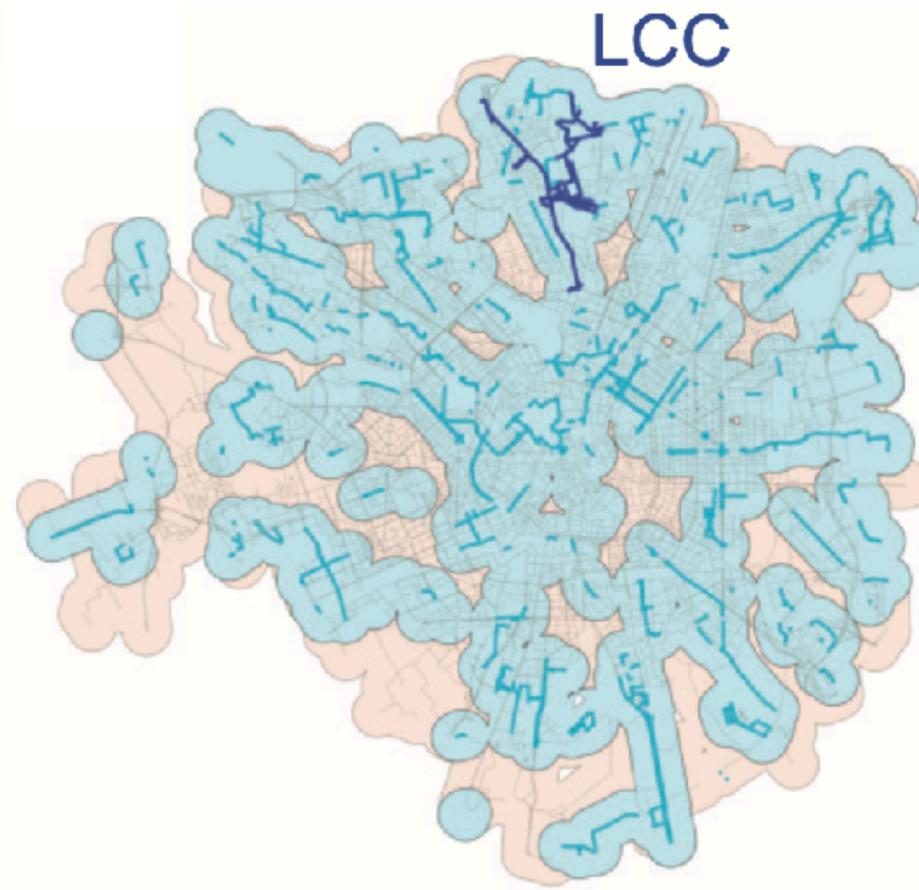


Result 2: It's not a network's length that matters but how you grow it

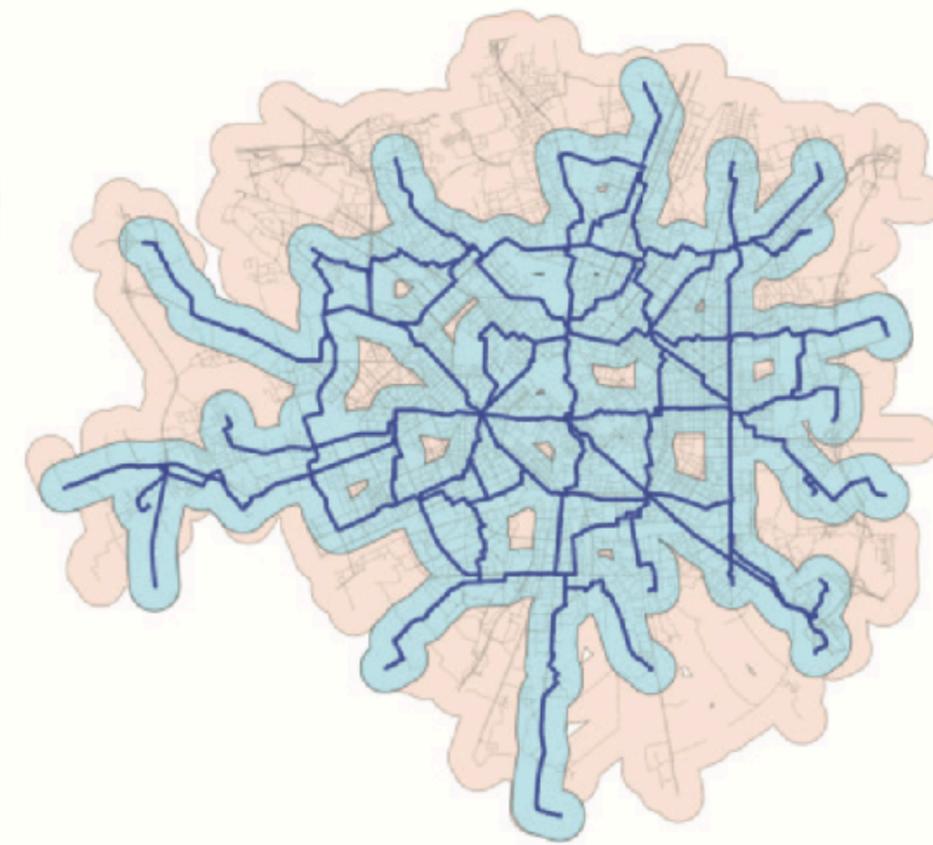
At same length, we could do much better



Avoid "random-like",
piecewise growth

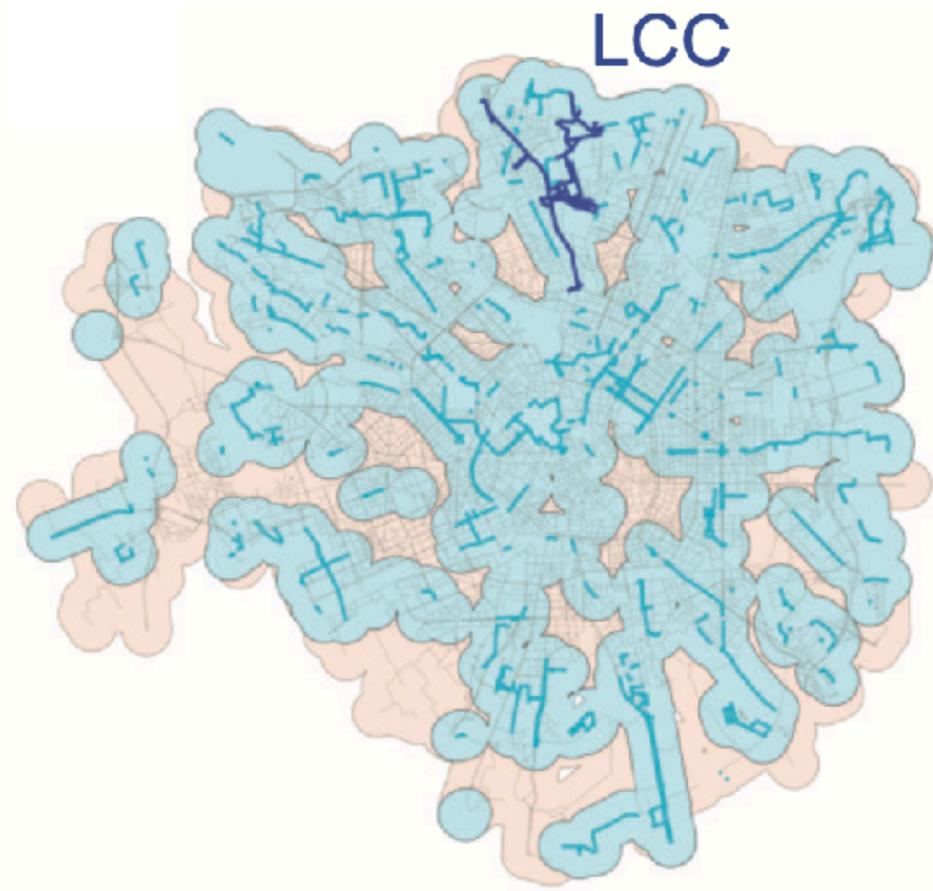


Real Milan

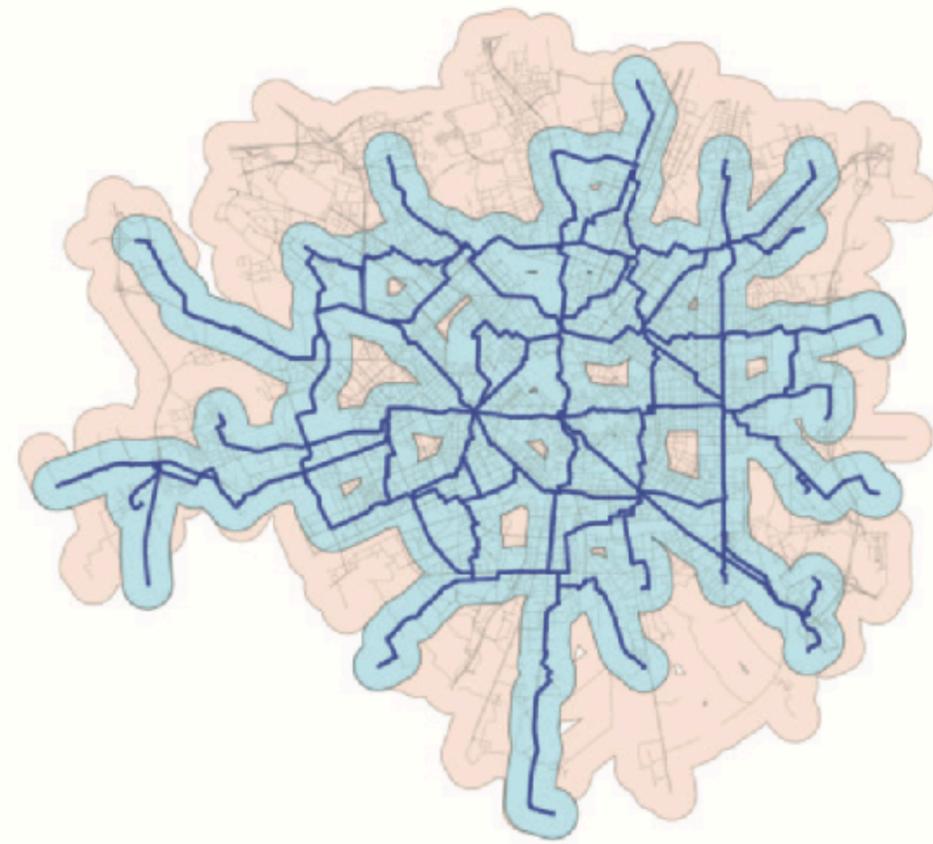


Synthetic Milan

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



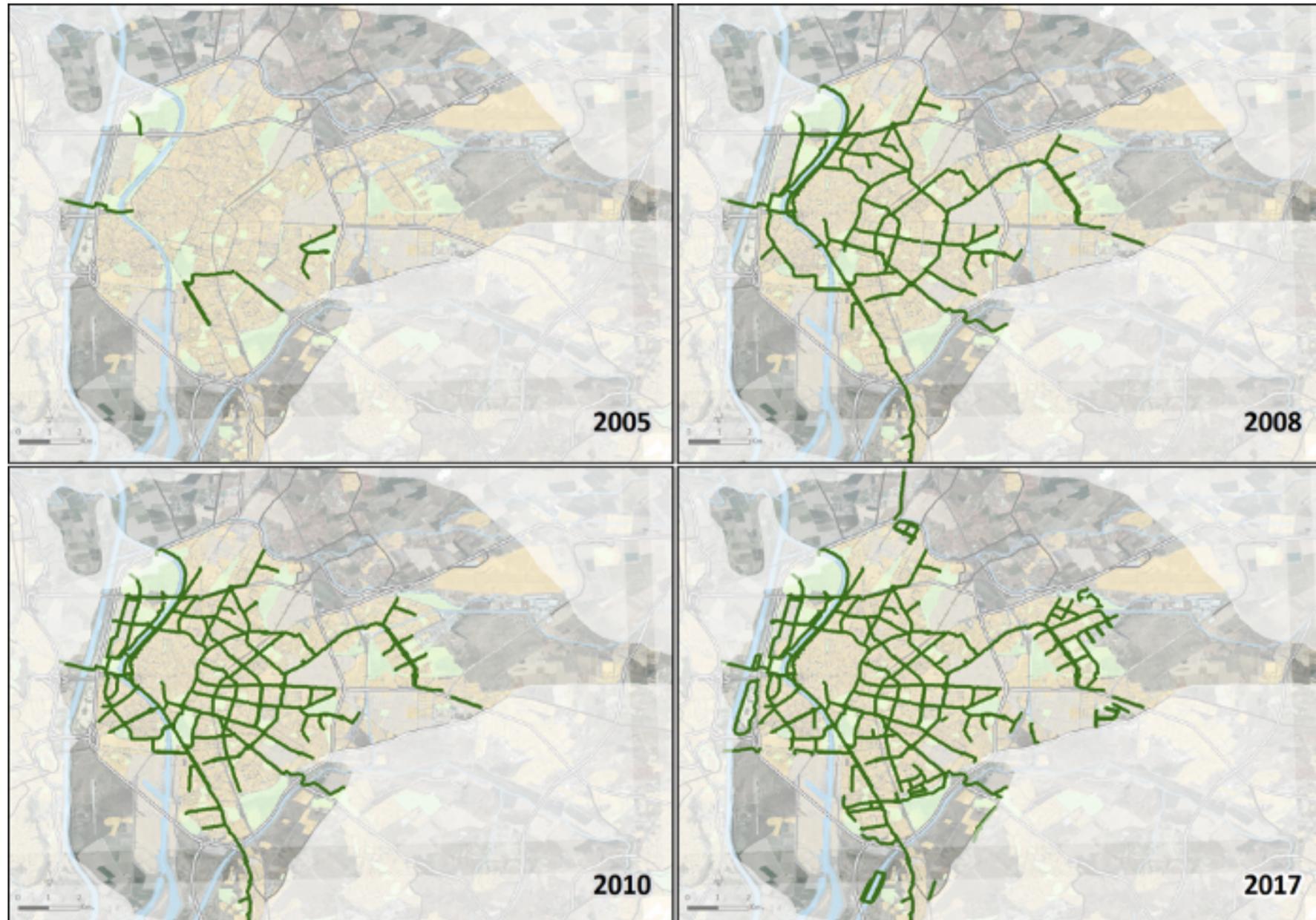
Real Milan



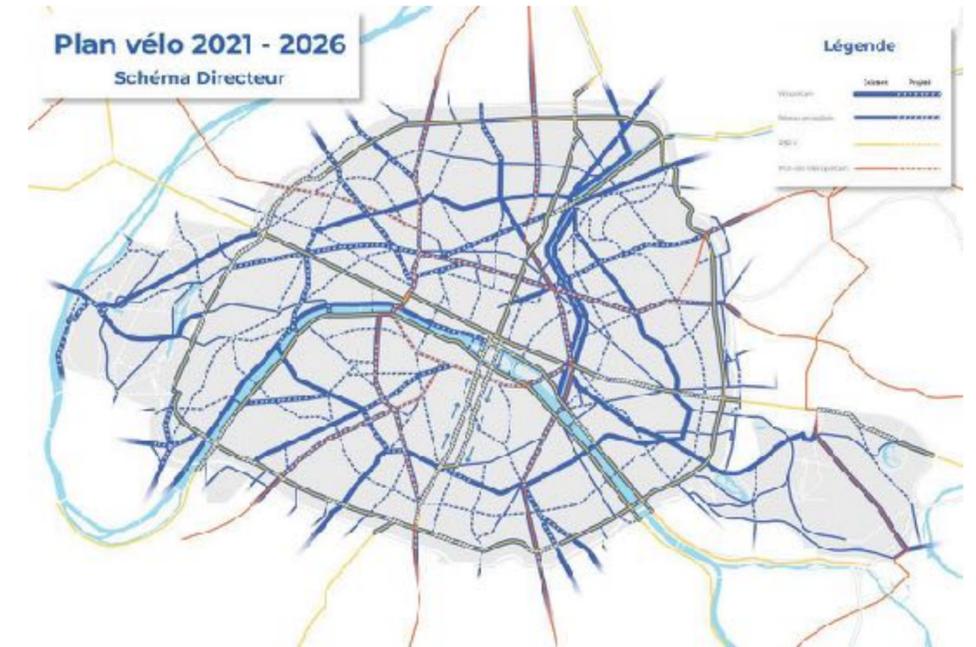
Synthetic Milan

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

Nope: See Seville



Also: Paris, Oslo, ...



There is
no excuse

Our procedure generates a first cohesive network

Can be refined arbitrarily:

Population density

Road type

Inclination

Traffic / Stress

Routes

....

Open-sourced at:

<https://github.com/mszell/bikenwgrowth>



Explore your city at [GrowBike.Net](https://growbike.net)

The interface features a sidebar on the left with the following city selection options:

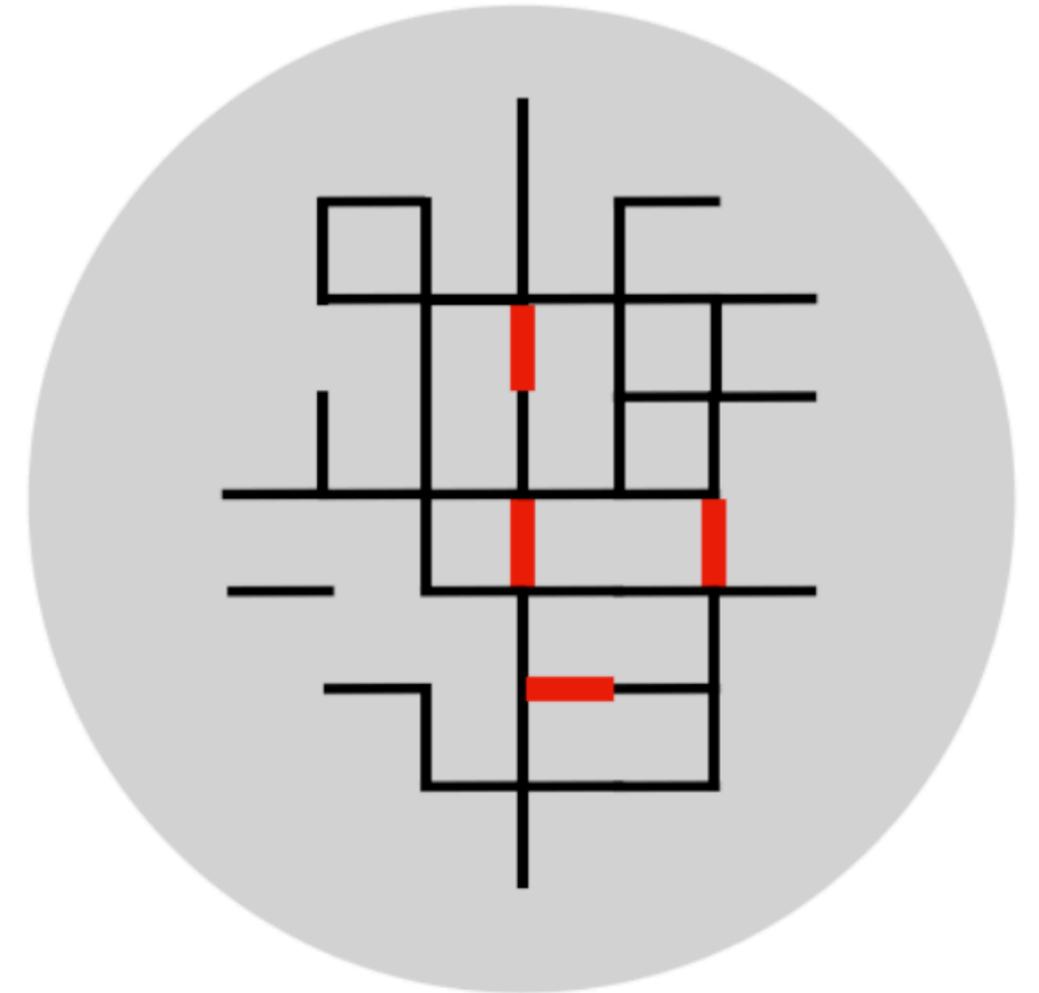
- Search city or country
- LONDON ENGLAND
- LOS ANGELES USA
- LUANDA ANGOLA
- LYON FRANCE** (highlighted)
- MALMO SWEDEN
- MANCHESTER ENGLAND
- MANHATTAN USA
- MARRAKESH MOROCCO

The map displays the city of Lyon and its surrounding areas, including Caluire-et-Cuire, Villeurbanne, and Bron. A blue cycling route is overlaid on the map, starting from the center of Lyon and extending to various points around the city. The route is composed of several segments, with blue dots marking key locations along the way.

At the bottom of the interface, there is a play button, a progress slider, and a 'Stage 24 | 69 km' indicator. Below the slider, there are buttons for 'Rail', 'Grid', 'B', 'C', and 'R'. The Mapbox logo is visible in the bottom left corner, and the text '© Mapbox © OpenStreetMap Improve this map' is in the bottom right corner.

3) Fixing bicycle networks

Few cities
Developed and
mostly connected



Find missing links

FixBike.Net

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

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



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

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

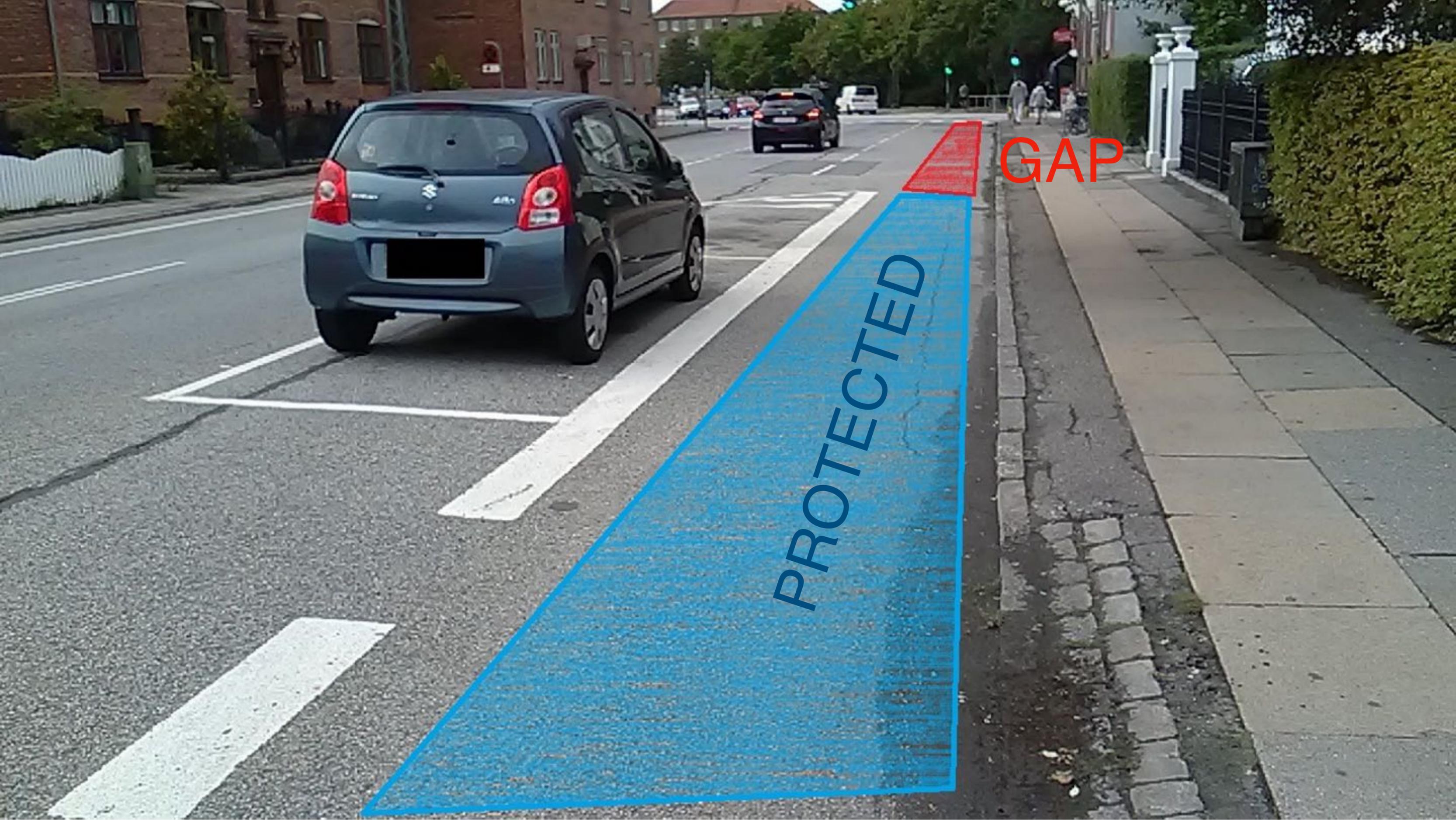
Still, there are a lot of "missing links".

How to find them?

How to prioritize them?







PROTECTED

GAP

From map to gap: **IPDC**

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



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

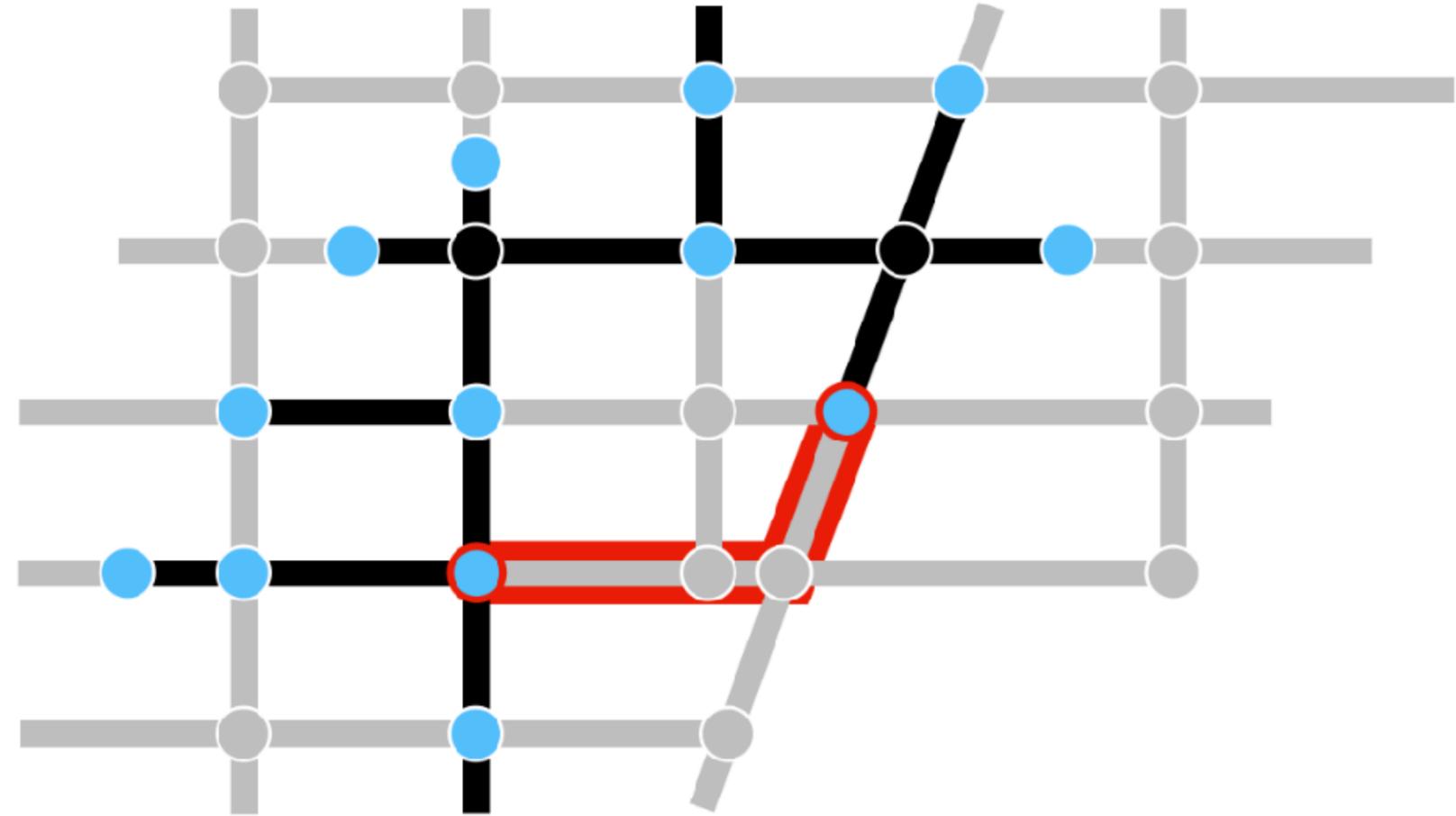
Multiplex network

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

2) Prioritize

We could find millions of gaps...

We need a metric to prioritize them.



2) Prioritize

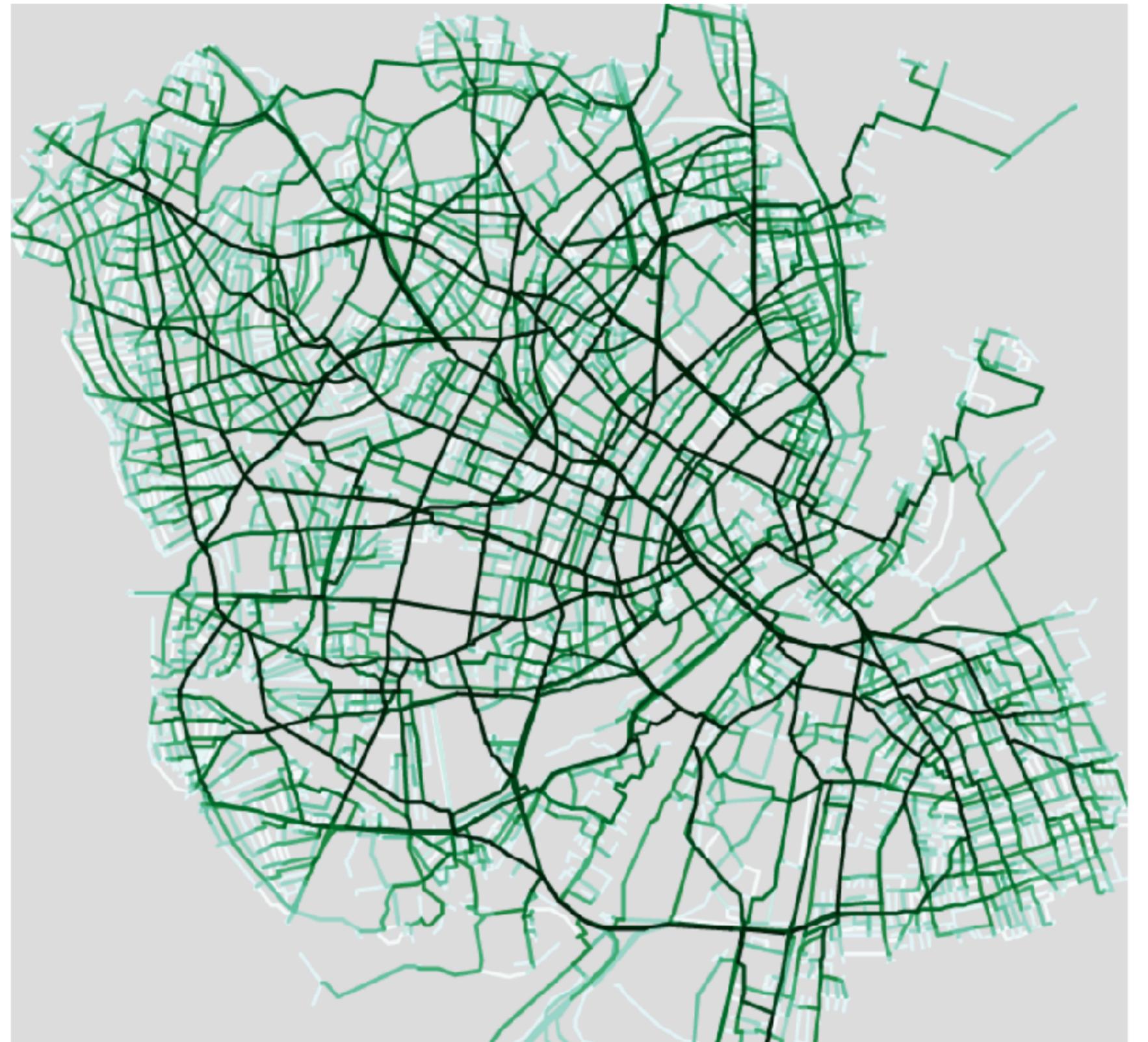


“If this gap was closed, how many meters cycled in mixed traffic would be avoided per investment unit?”

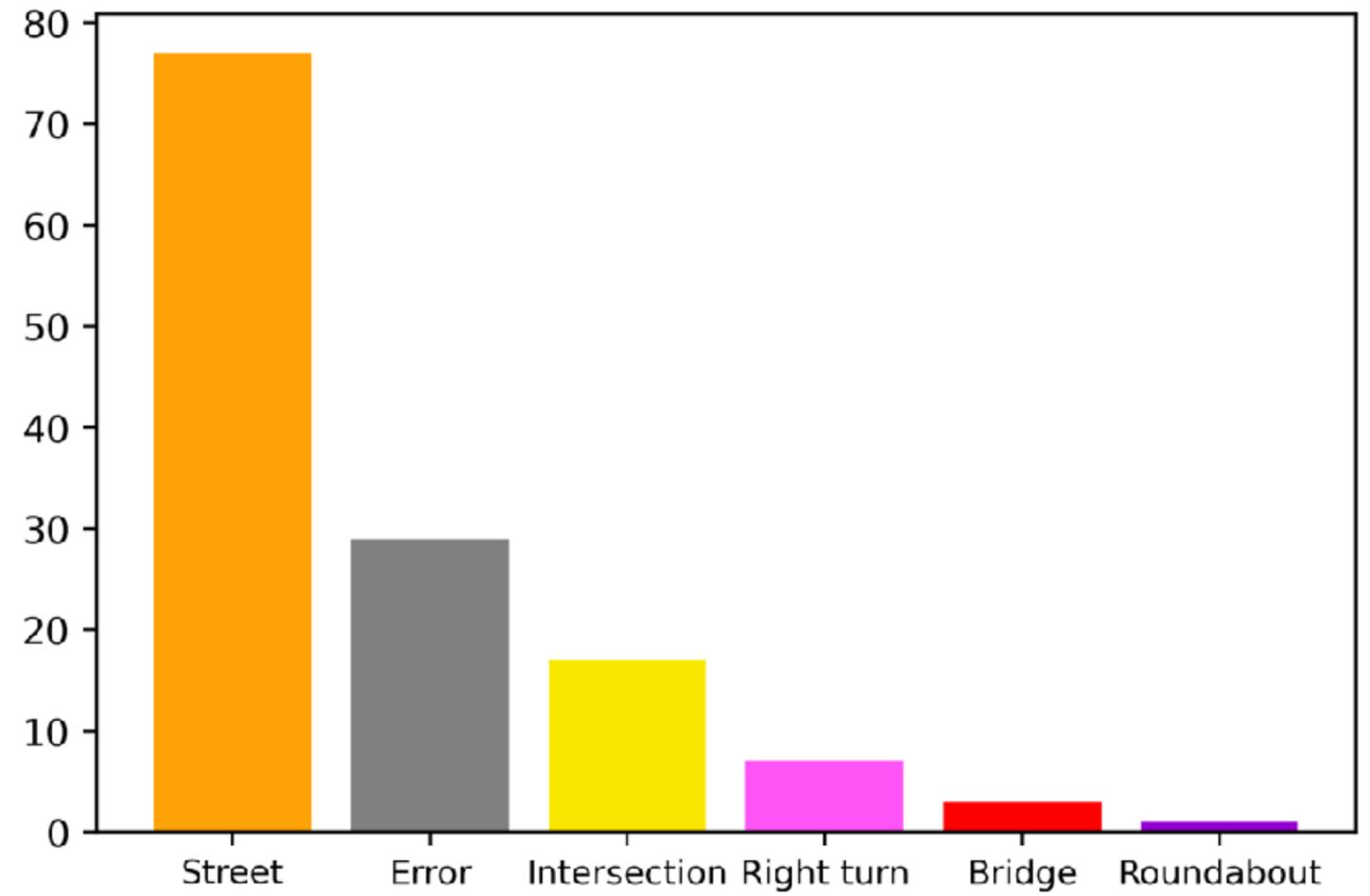


We can use betweenness centrality as a proxy for flow

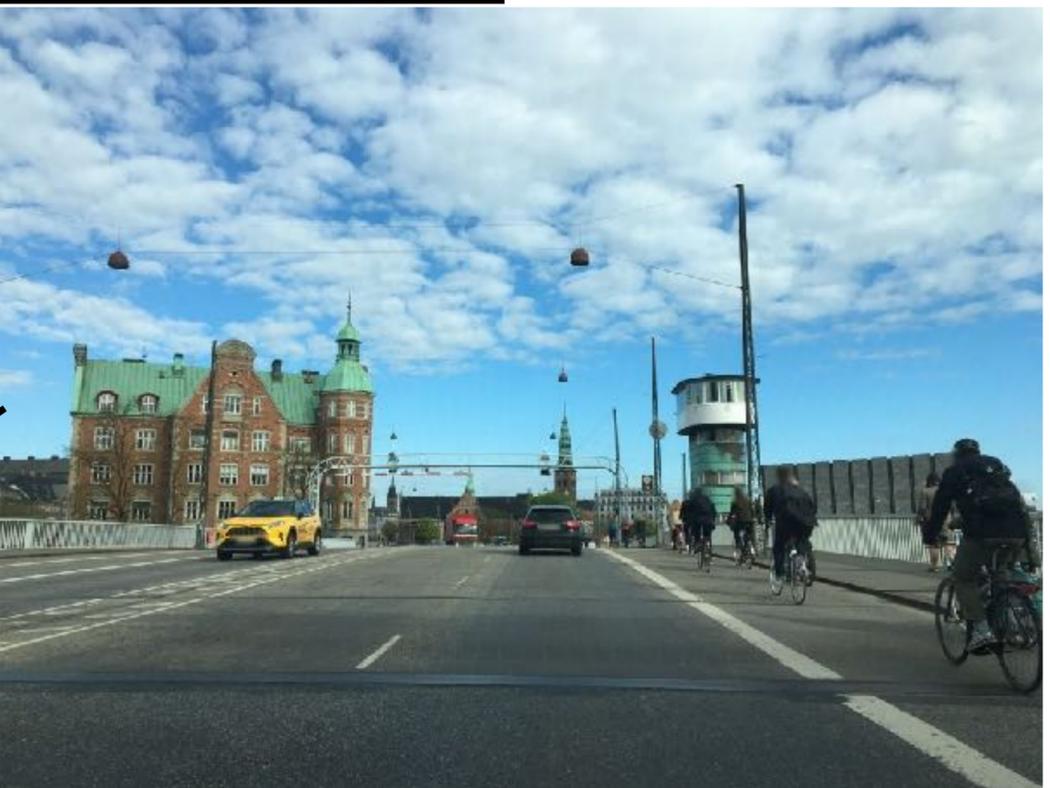
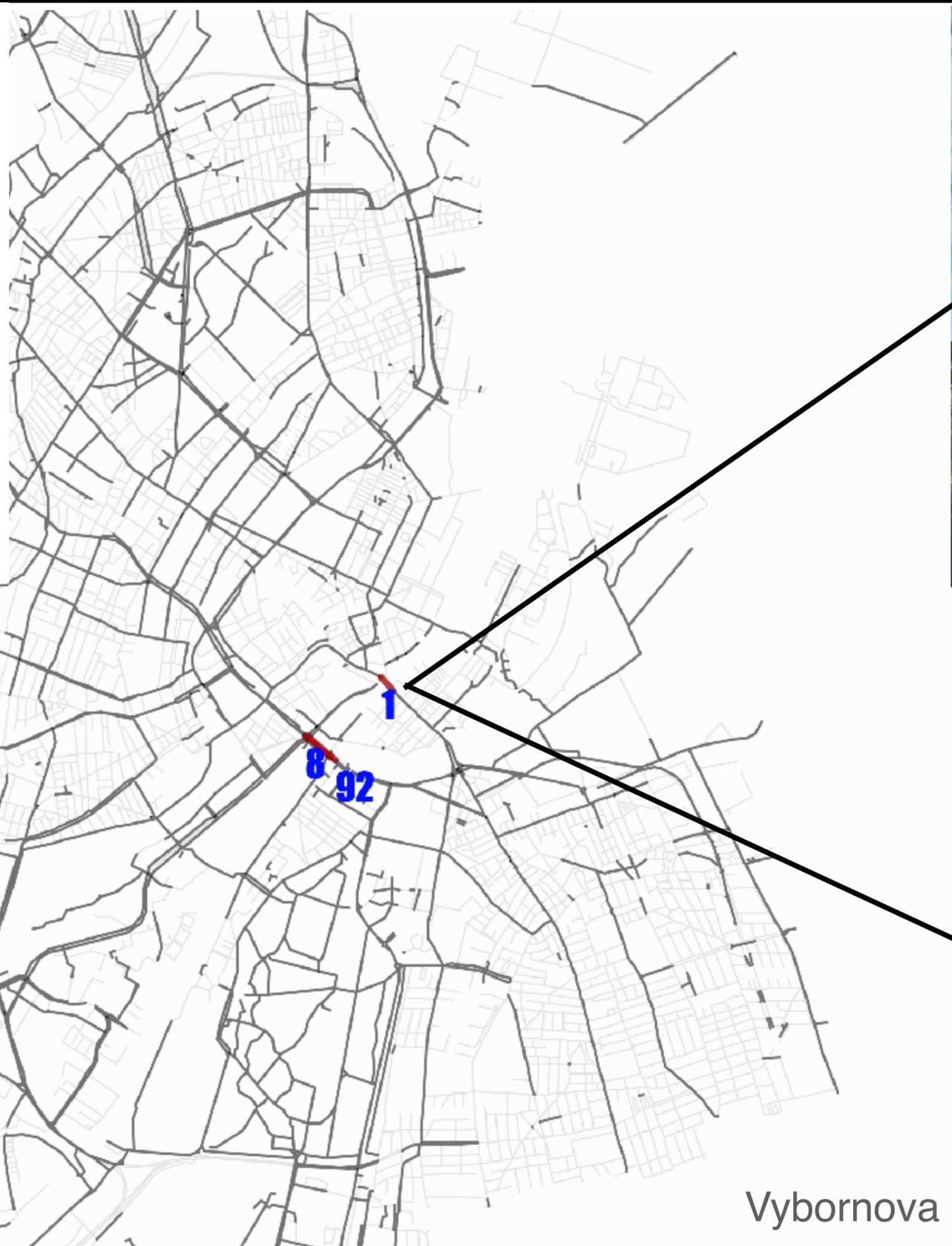
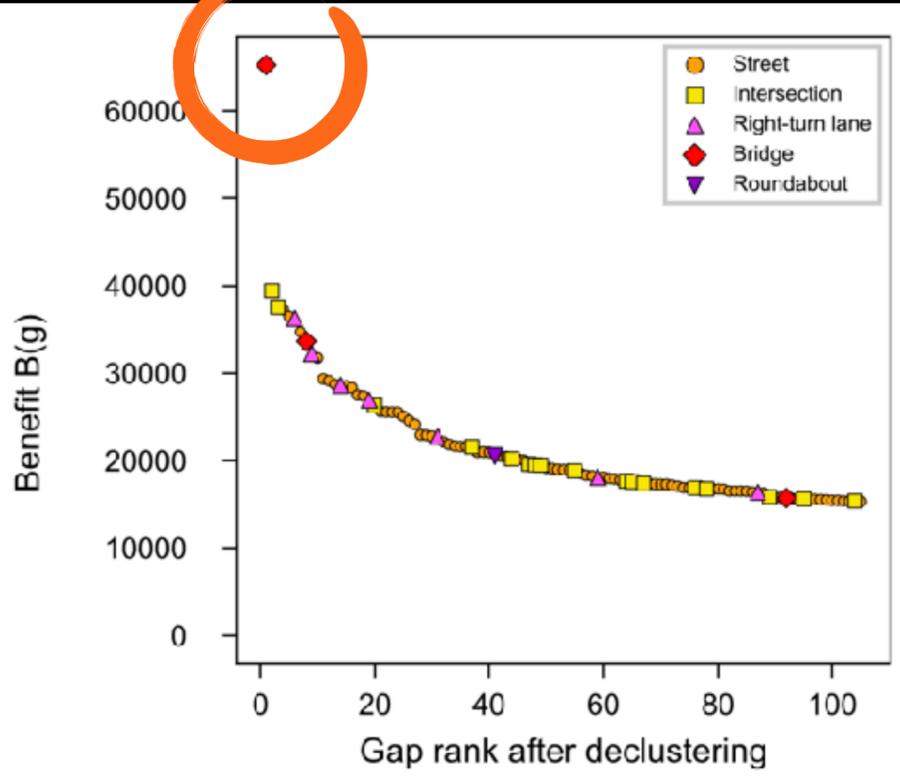
$$C_B(i) = \sum_{i \neq j \neq k} \frac{\sigma_{jk}(i)}{\sigma_{jk}}$$



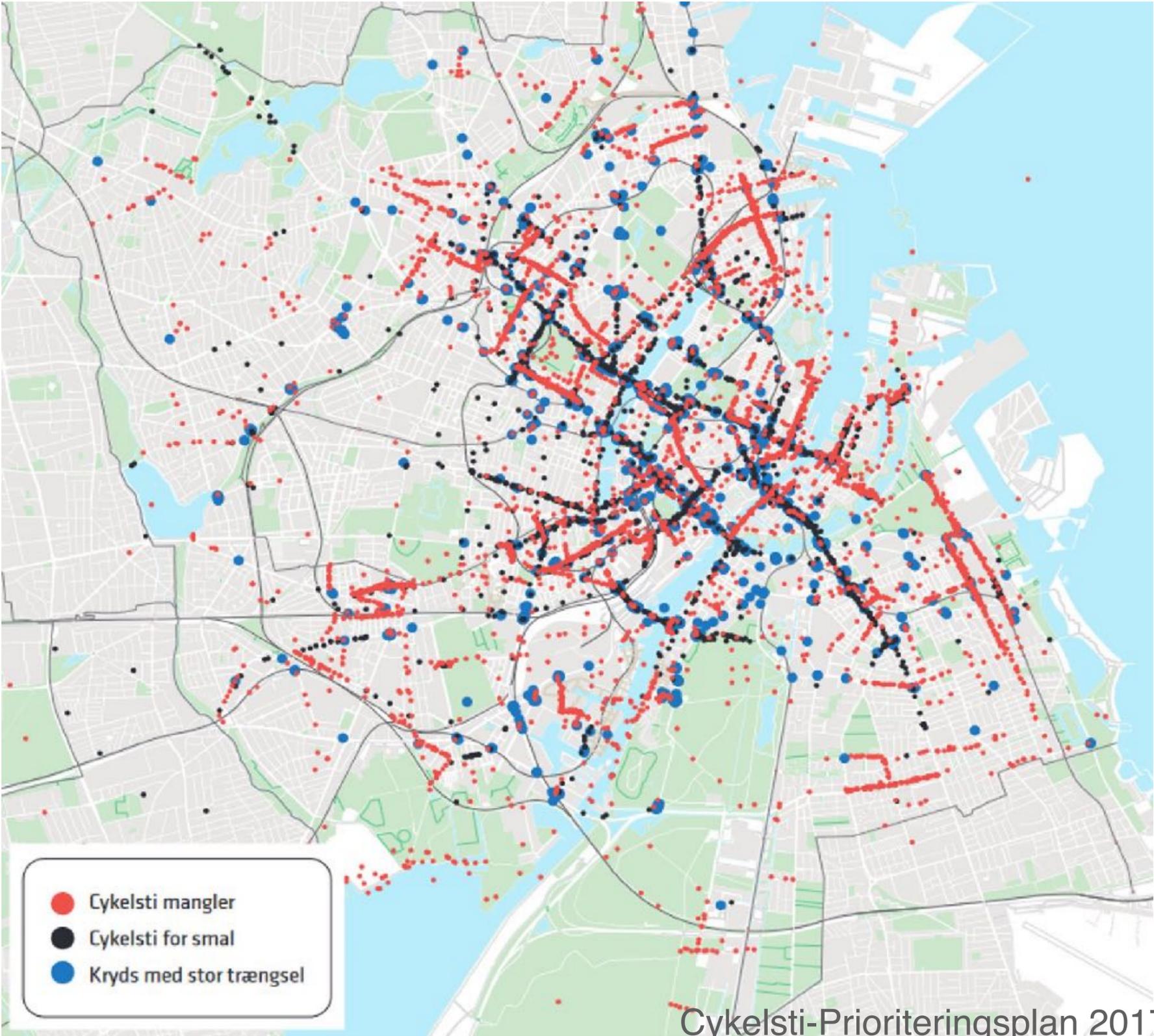
4) Classify: Our top 105 gaps



The most important gaps are bridges



Evaluation: Comparison with Cykelsti-Prioriteringsplan



Evaluation: Comparison with Cykelsti-Prioriteringsplan



Evaluation: We find many overlaps

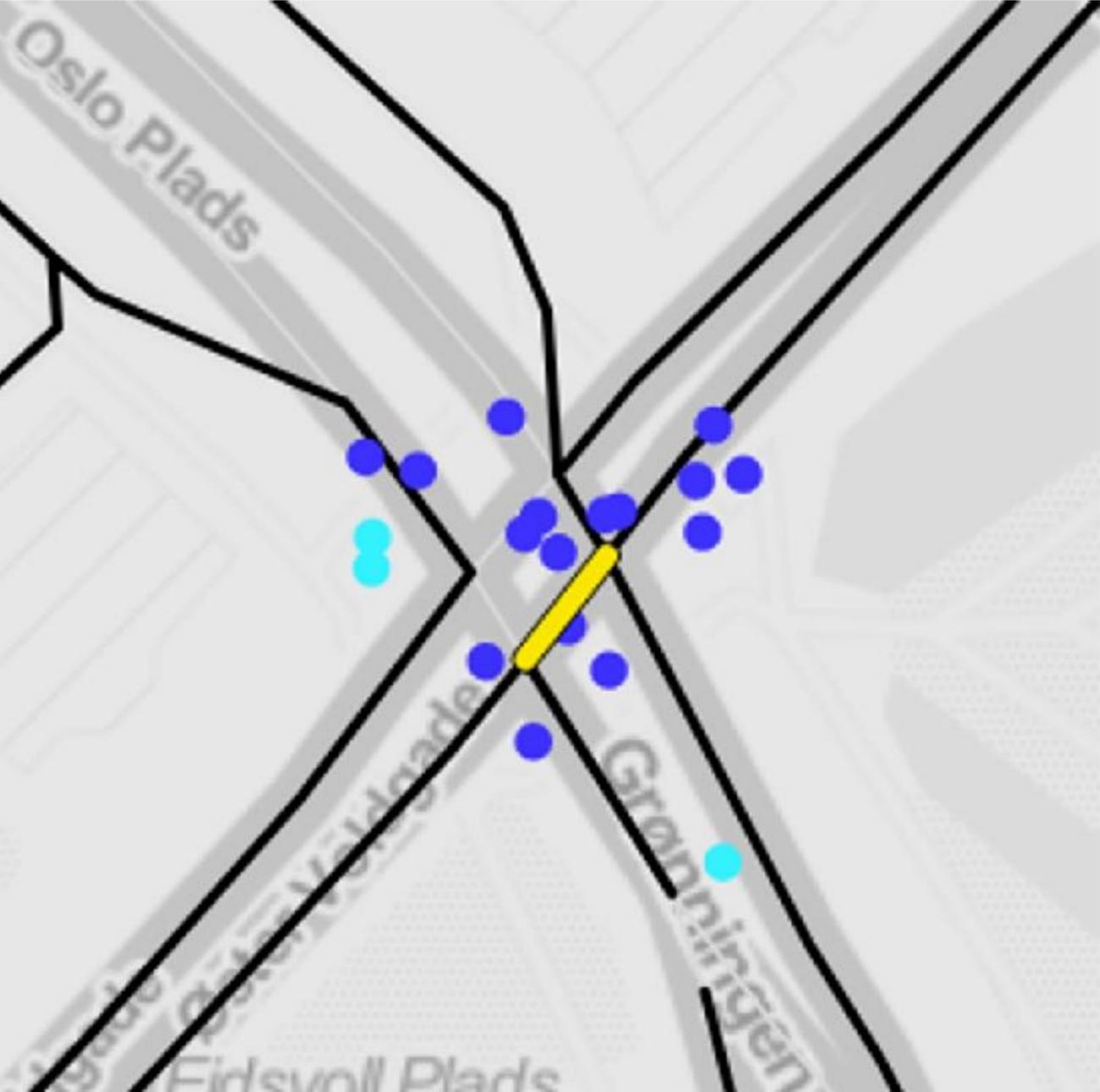


Nørregade

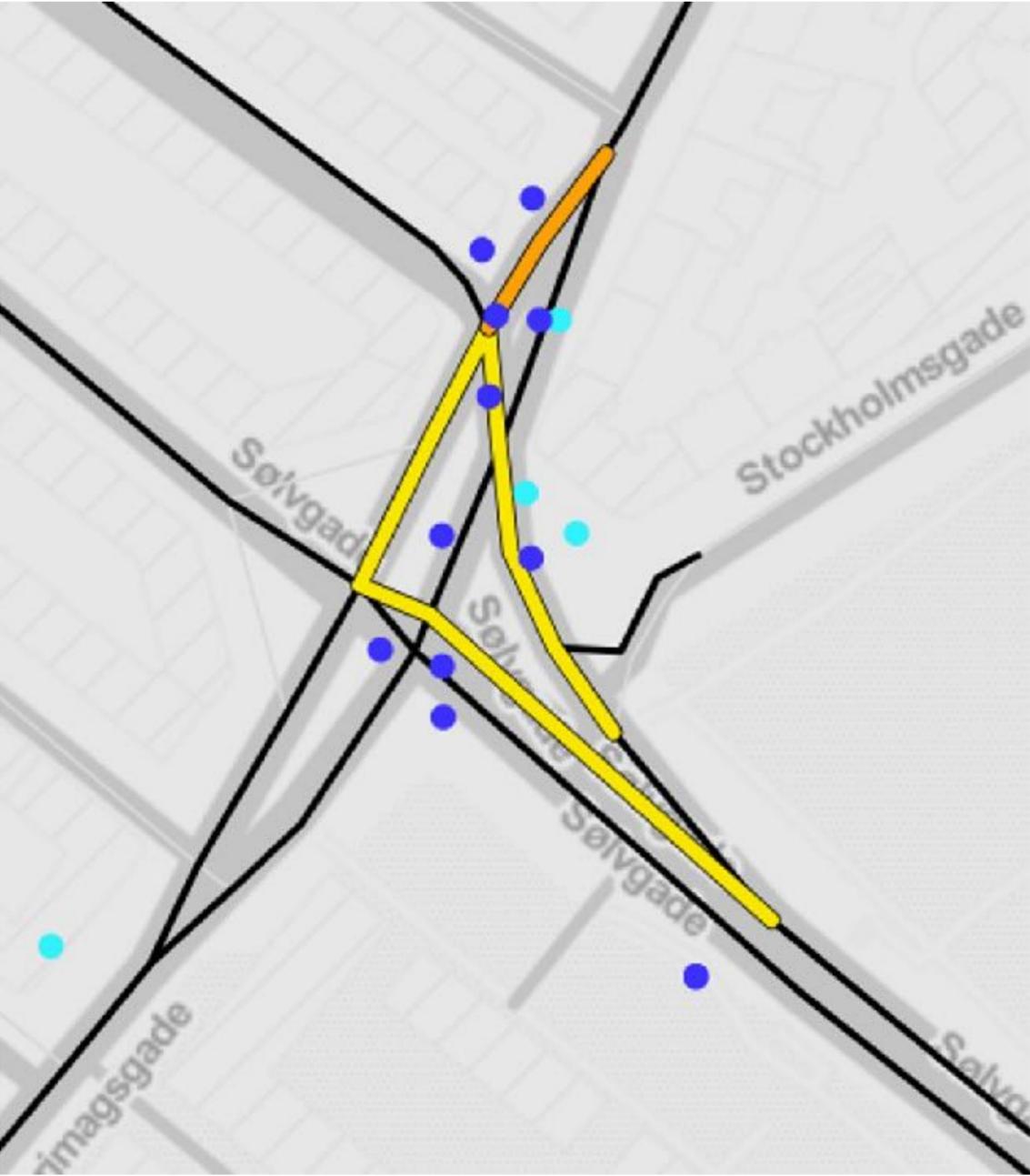


Rantzausgade

Evaluation: We find many overlaps



Østerport



Sølvtorvet

If your city is:

not developed

Los Angeles



Grow persistently with
focused investments

If your city is:

not developed

Los Angeles



Grow persistently with
focused investments

medium developed

Budapest



Connect with
right strategy

If your city is:

not developed

Los Angeles



Grow persistently with
focused investments

medium developed

Budapest



Connect with
right strategy

well developed

Copenhagen



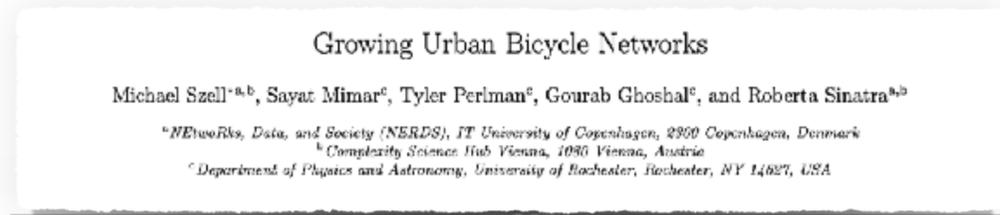
Close the most
important gaps

If your city is:

not developed

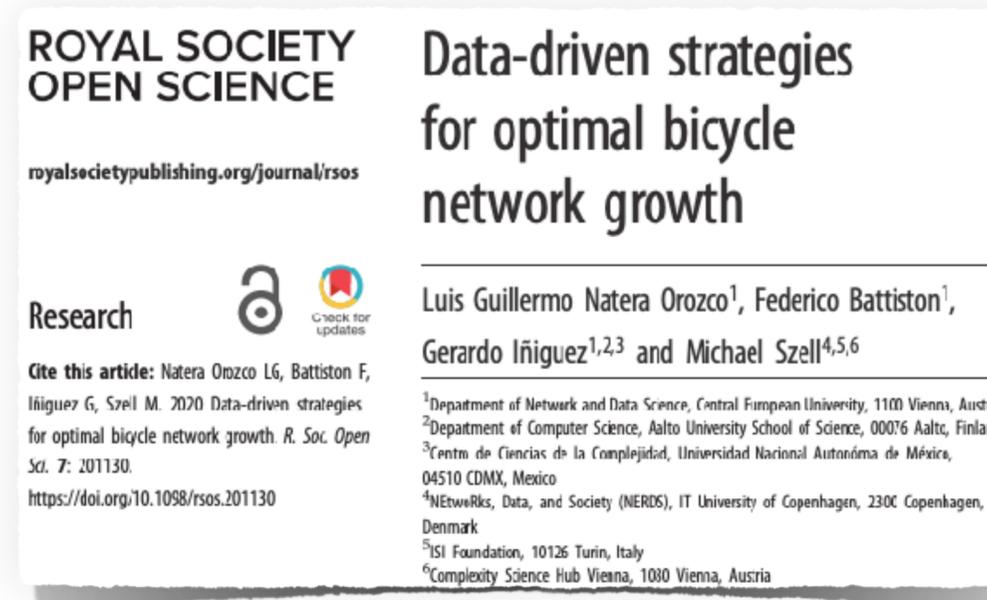
medium developed

well developed



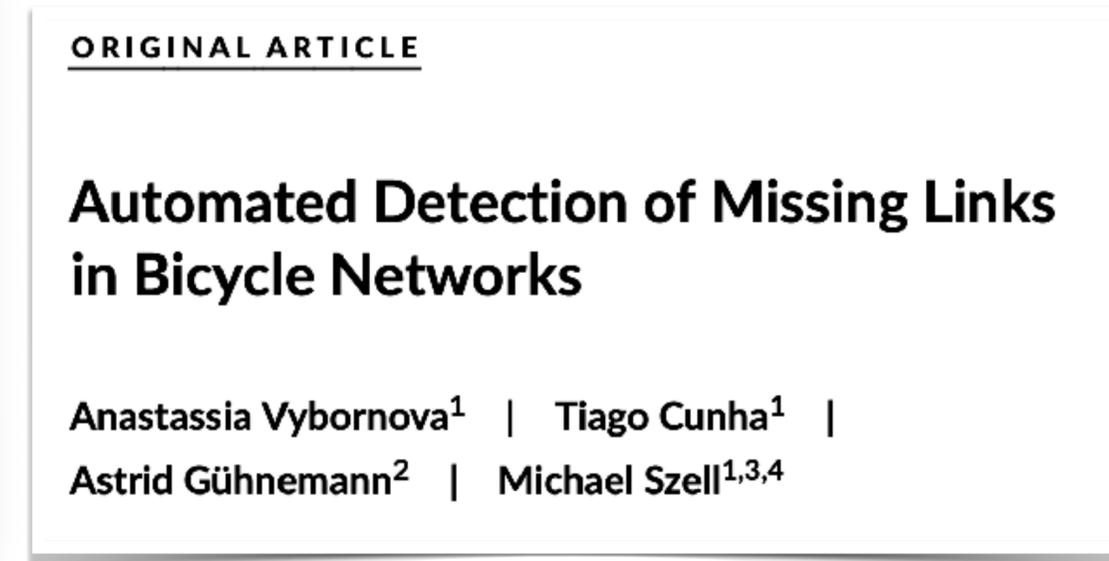
<https://arxiv.org/abs/2107.02185>

Grow persistently with focused investments



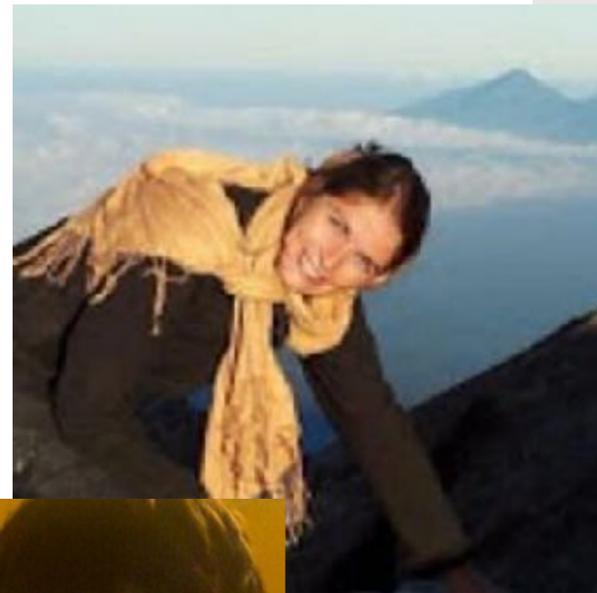
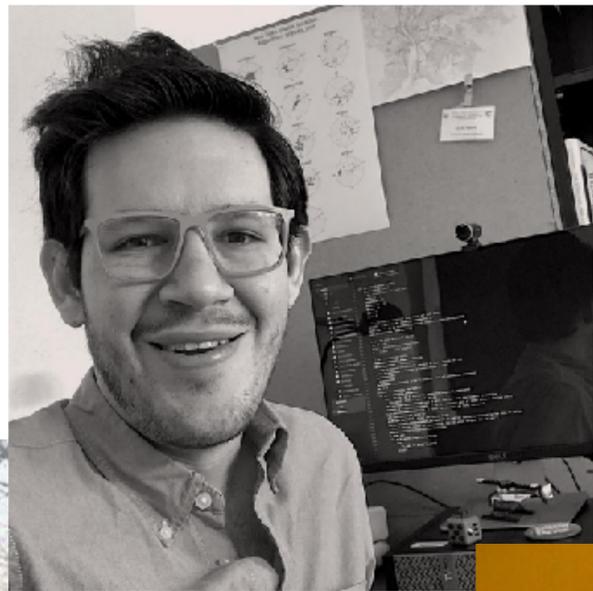
<https://royalsocietypublishing.org/doi/10.1098/rsos.201130>

Connect with right strategy



<https://arxiv.org/abs/2201.03402>

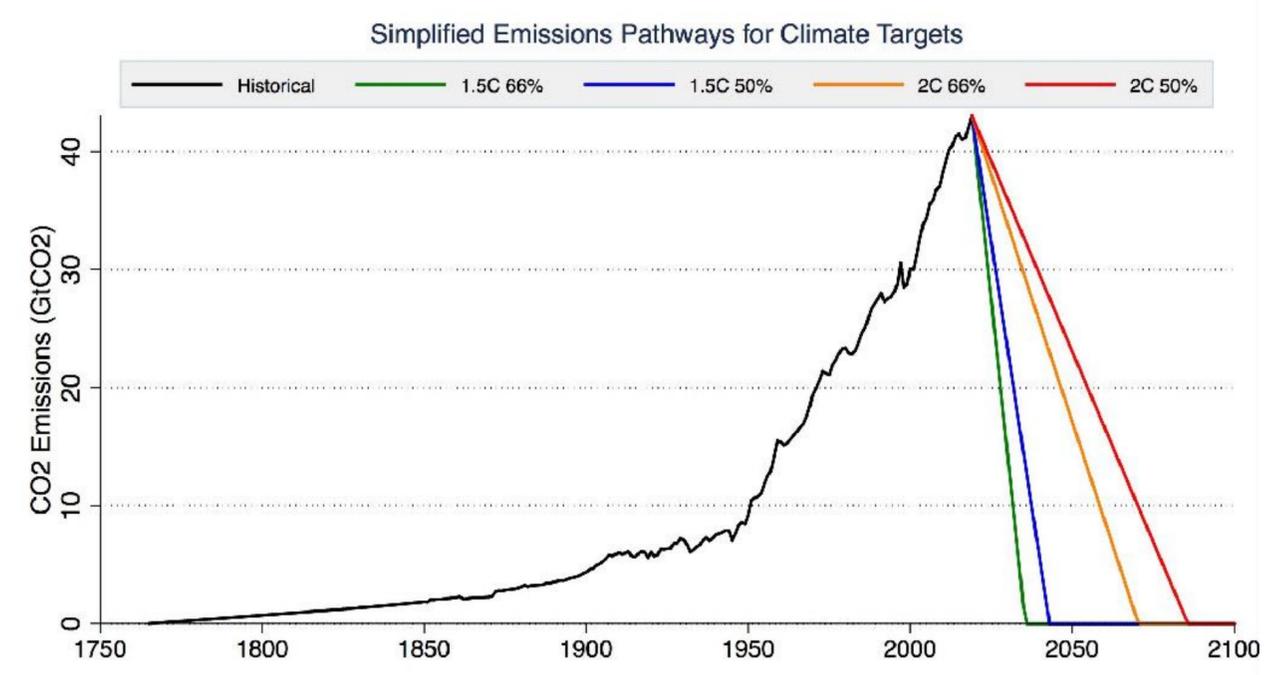
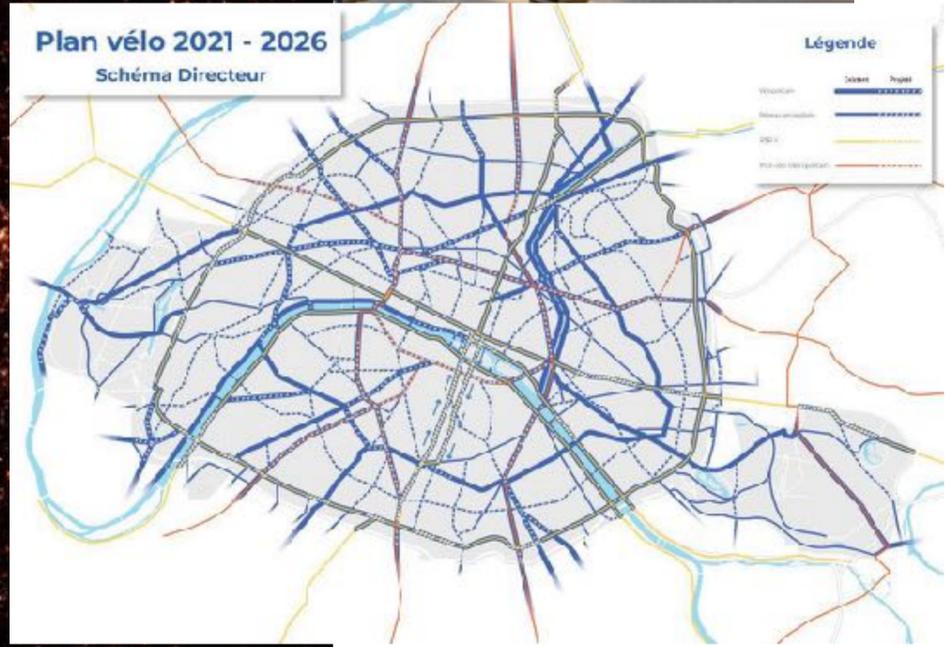
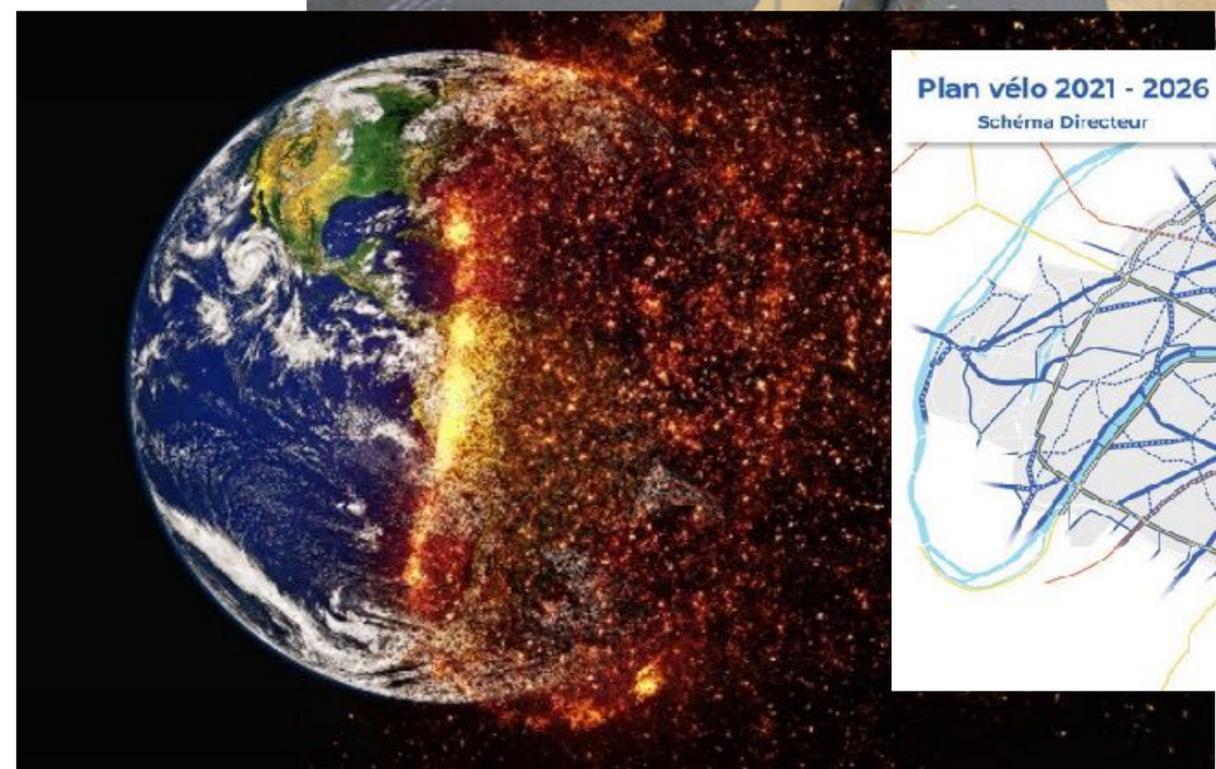
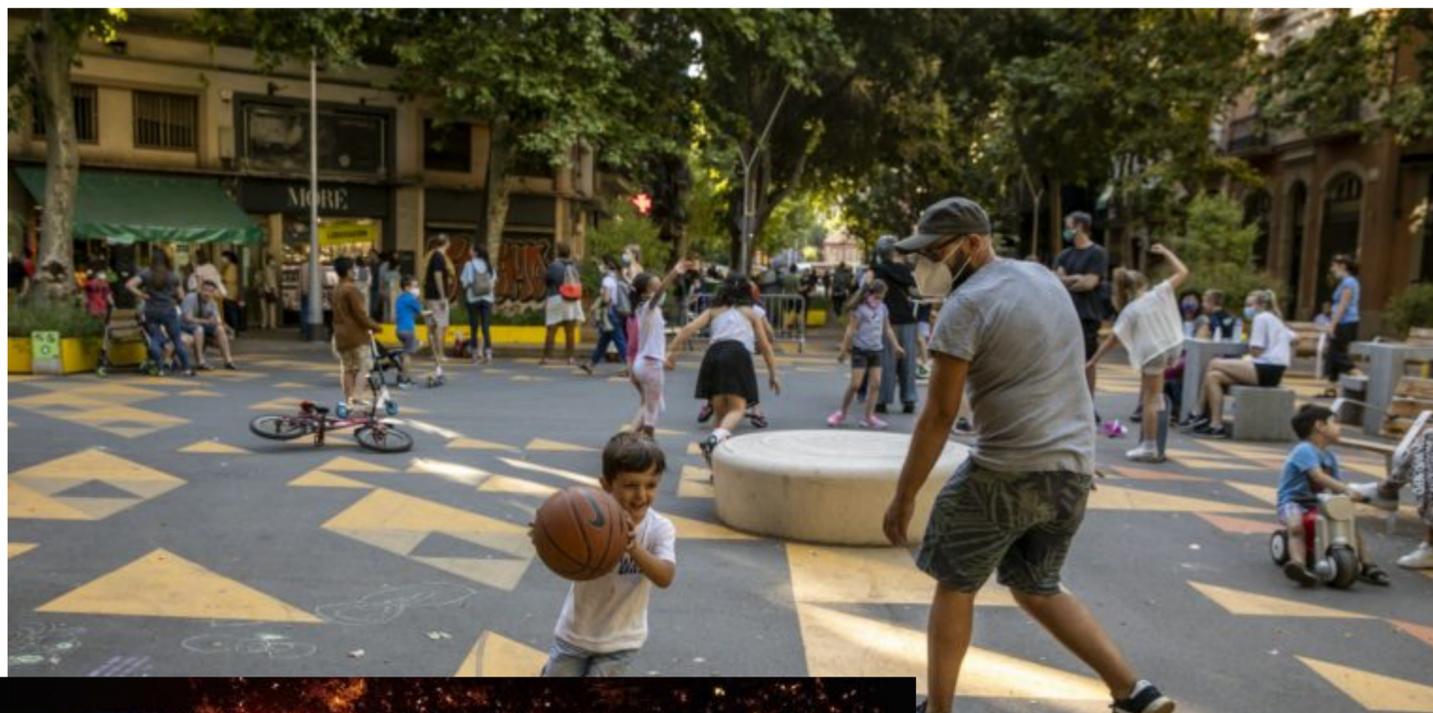
Close the most important gaps



Szell et al, arxiv:2107.02185 (2021)
 Klanjic et al, socarxiv:89cyu (2021)
 Natera Oroczo et al, R Soc Open Sci 7 (2020)
 Vybornova et al, Geographical Analysis (2022, in print)

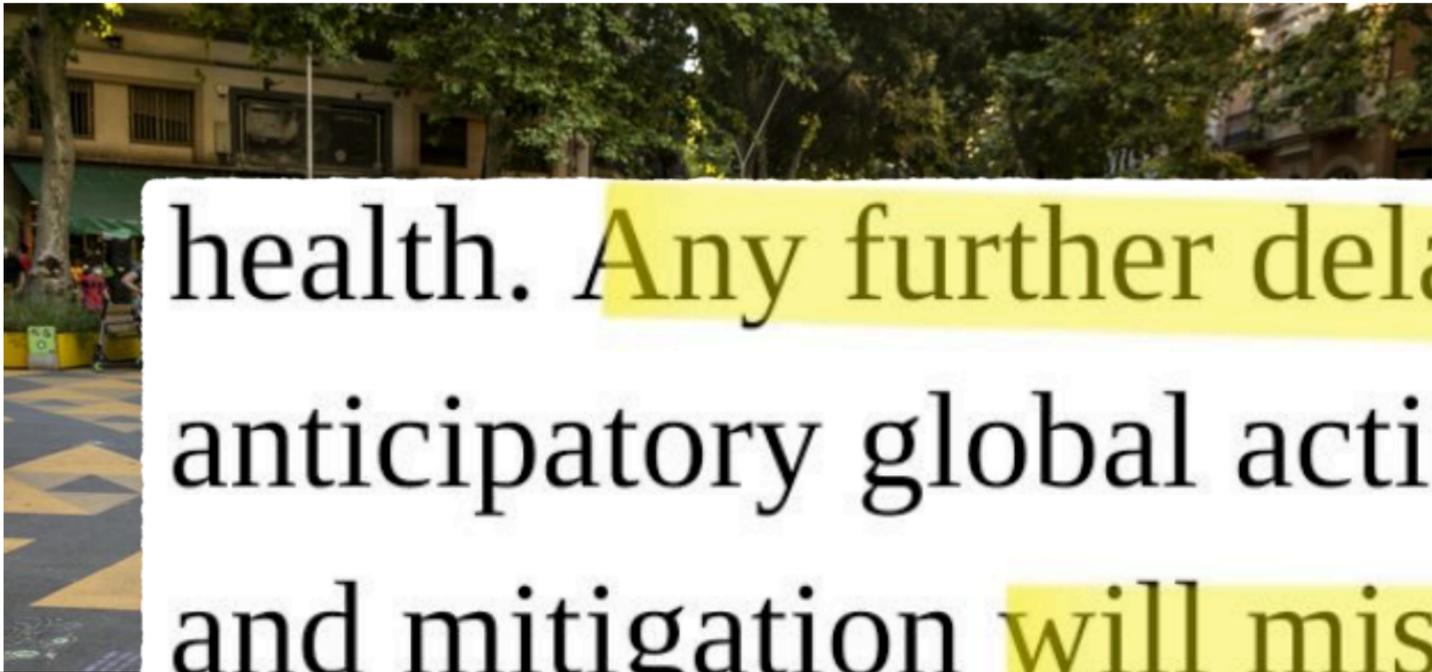
To make cities better, we need *radical* transformation ASAP

E-cars help against CO₂, but only as a LAST RESORT

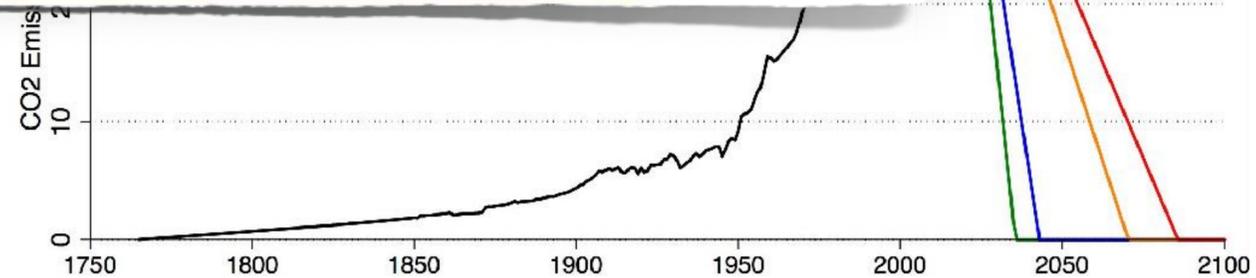
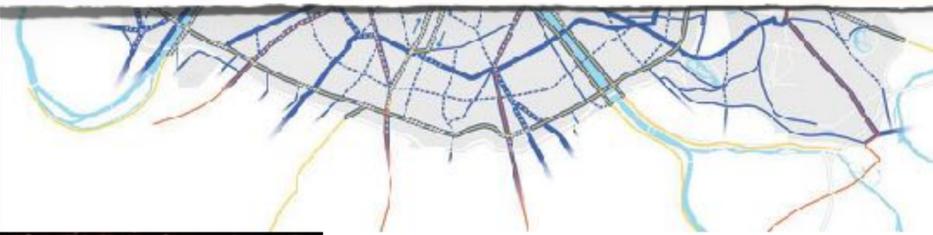
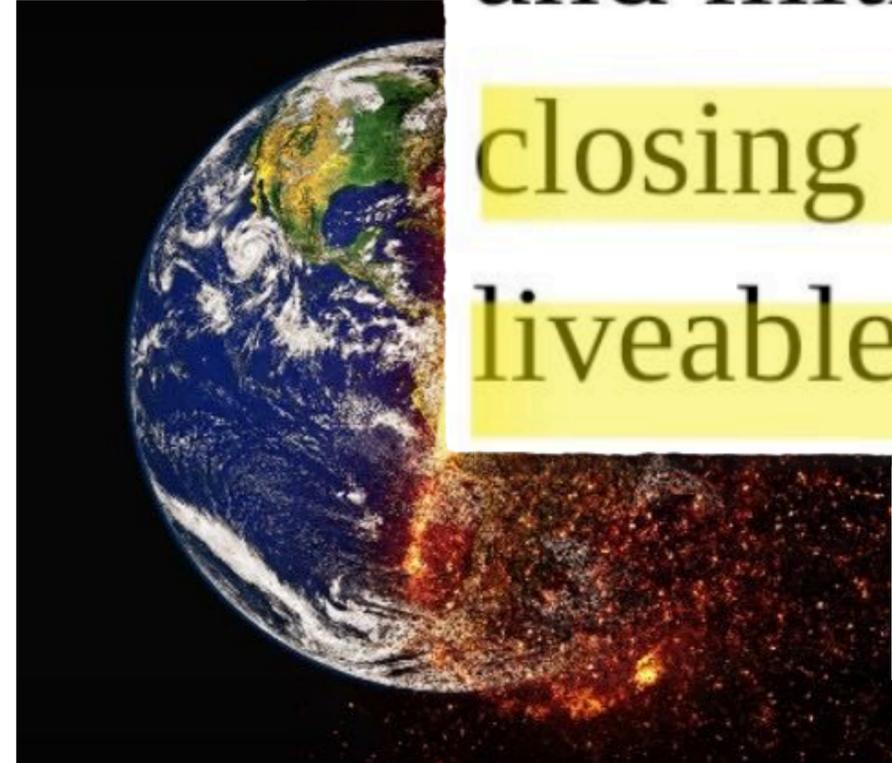


To make cities better, we need *radical* transformation ASAP

E-cars help against CO₂, but only as a LAST RESORT

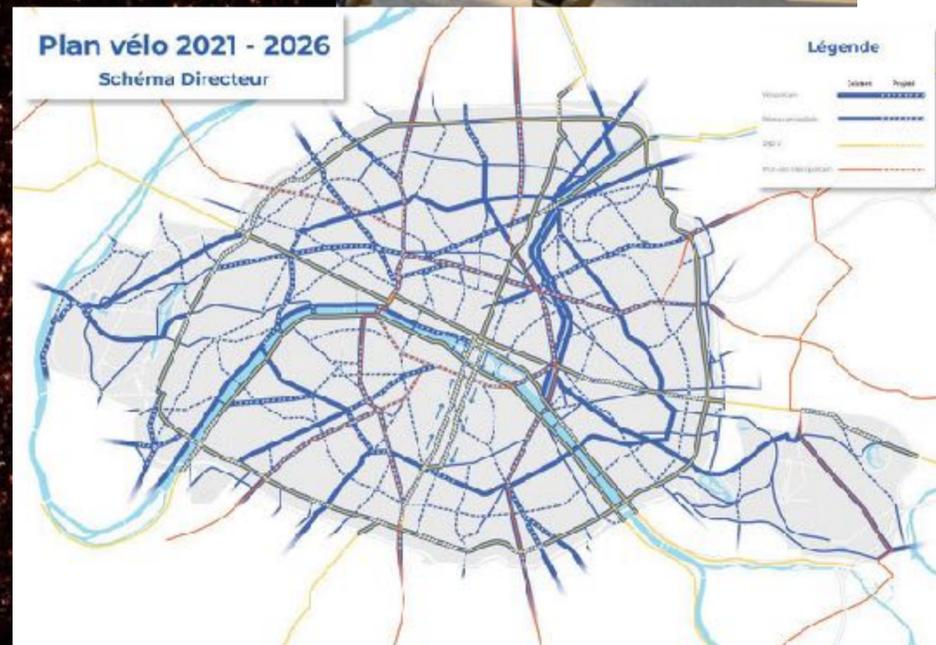
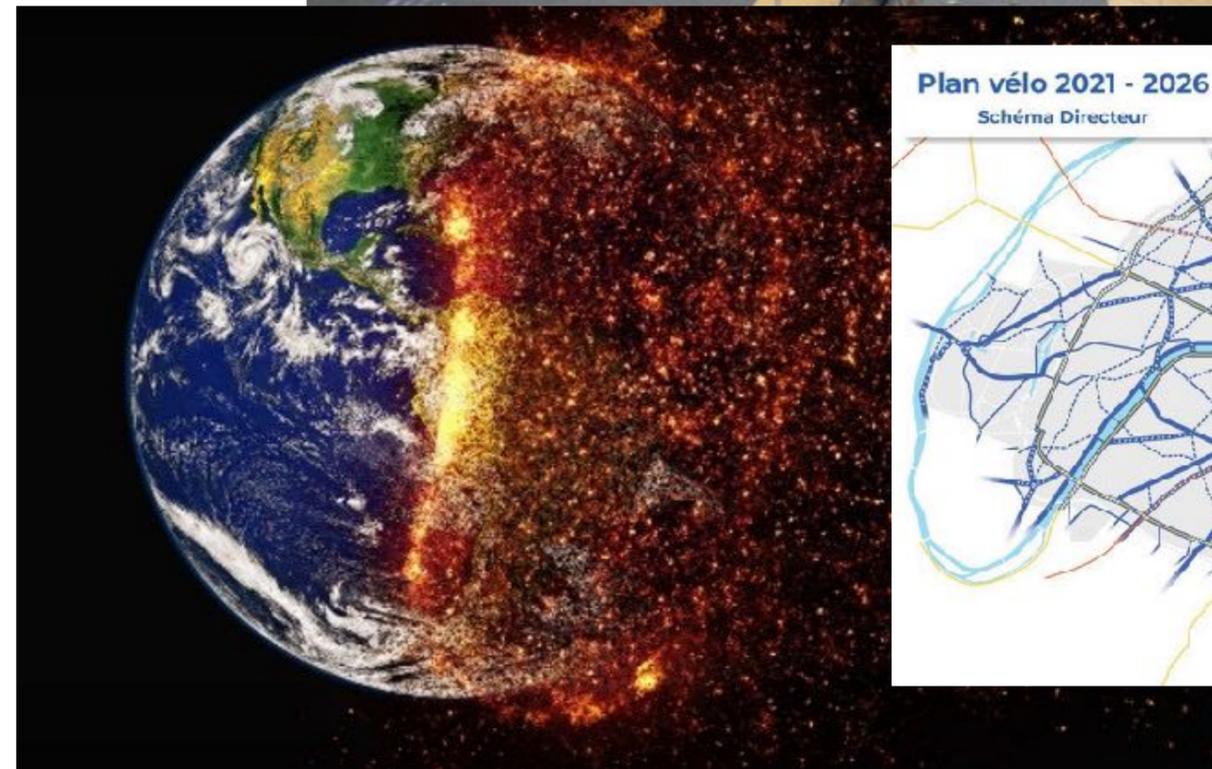
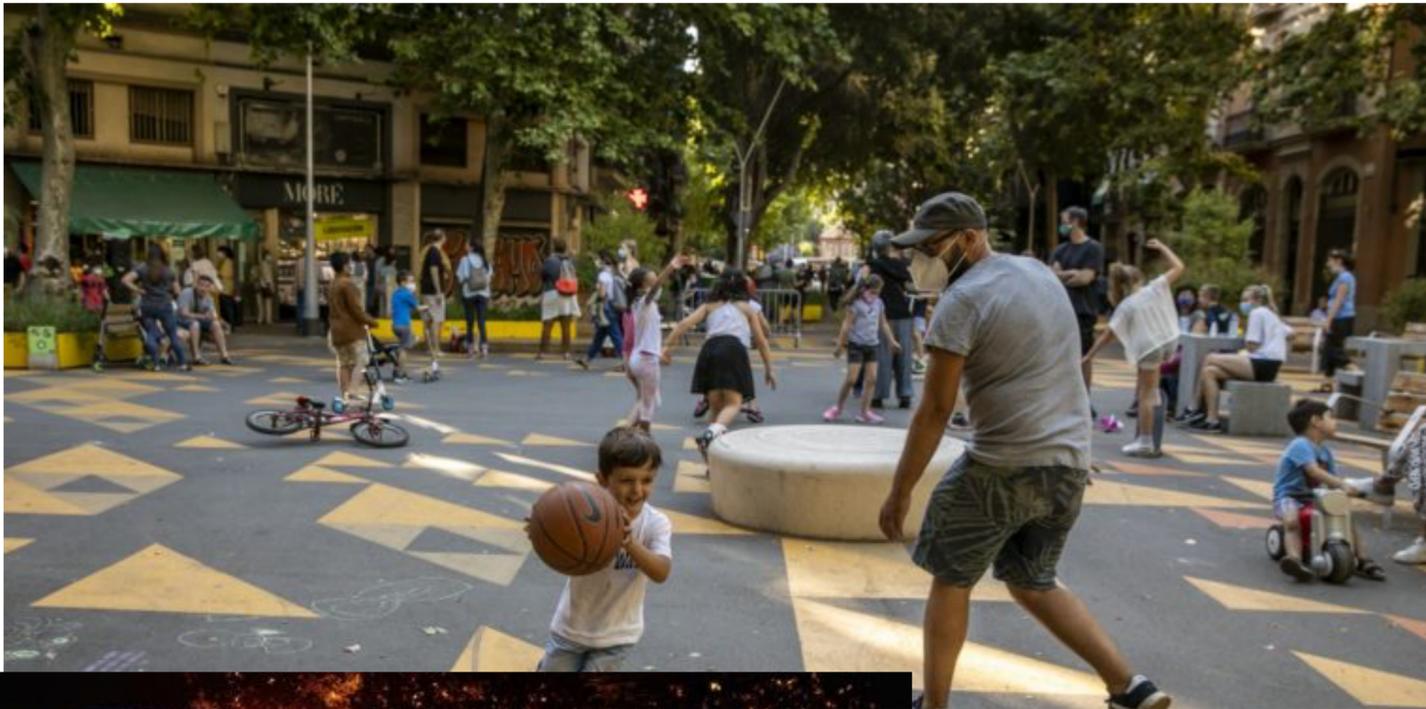


health. **Any further delay** in concerted anticipatory global action on adaptation and mitigation **will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all.**



To make cities better, we need *radical* transformation ASAP

Why is it so hard?



We need a:

Editorial

Human-Centric Data Science for Urban Studies

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