Health impact assessment of cycling network expansions in European cities

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- Mueller et al. forthcoming
- Under Review in Preventive Medicine

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on behalf of the PASTA consortium

Car-centric mobility plans

- Physical inactivity
- Greenhouse gas emissions
- High levels of air pollution
- High levels of noise pollution
- Traffic incidents with injury
- Space scarcity/ competing land use interests
  - Disappearance of natural outdoor environments and eco-systems
- Economic issues
  - Congestion costs
  - Financing infrastructure

Promoting a mode-shift to cycling

- Promising strategy to overcome aforementioned issues:
- Cycling can **(1)** provide transport, **(2)** increase physical activity (PA) levels and the bicycle is a **(3)** non-emitting mode of transport

… However, well-designed and safe infrastructure is needed to promote a mode shift to cycling …

Study objectives

We aimed to assess

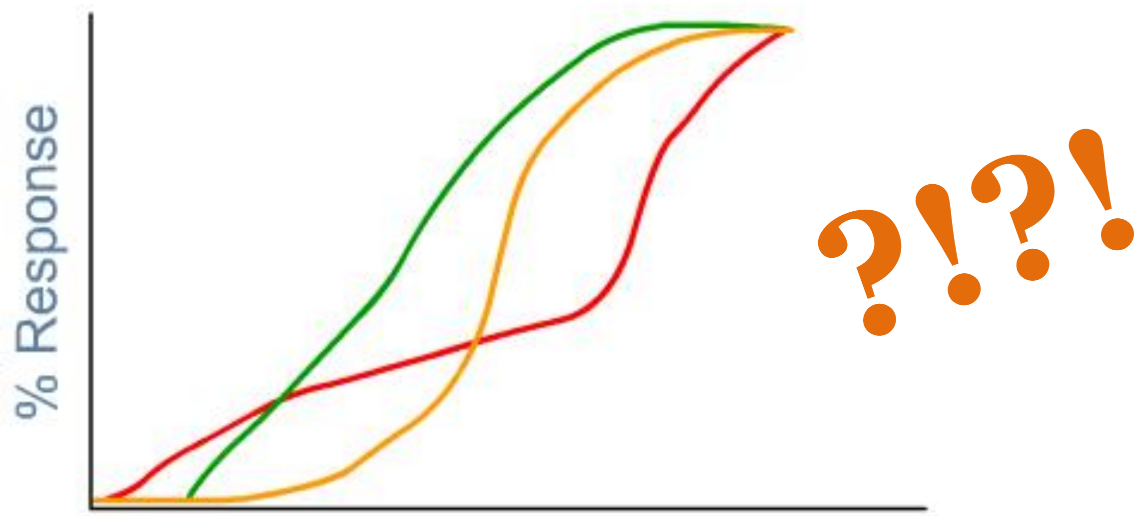
(1) the association between cycling network length (km) and cycling mode share (%)

(2) how an increase in cycling mode share might alter expected premature mortality in terms of changes in PA, exposure to air pollution and the risk of fatal traffic incidents

(3) the cost-benefit tradeoff between cycling network expansions and economic benefits from avoided premature mortality

- Link between cycling network and cycling mode share
    - (Buehler & Pucher 2012, Schoner & Levinson, 2014, Buehler & Dill 2015, Marqués et al. 2015, Schoner et al. 2015)

- Exposure-response relationship unknown in European cities



Cycling network length (km) → Cycling mode share (%) ?

Data sources I

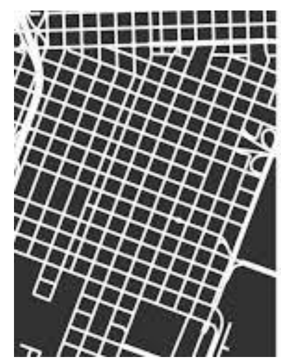
- Data on population size, cycling mode share and cycling network length for **167 cities located in 11 European countries**
  - (4 🇦🇹 7 🇧🇪 2 🇩🇰 20 🇫🇷 47 🇩🇪 15 🇮🇹 23 🇳🇱 14 🇪🇸 9 🇸🇪 2 🇨🇭 24 🇬🇧)

- Amongst those 167 cities were the **7 PASTA** cities
  - (Antwerp, Barcelona, London, Rome, Örebro, Vienna, Zurich)

- Other 160 cities were chosen based on
  1) Geographic representativeness of Northern, Central, Southern Europe
  2) Population size ≥100,000 people
  3) Mode share (%)
  4) Spatial boundaries of administrative municipality area

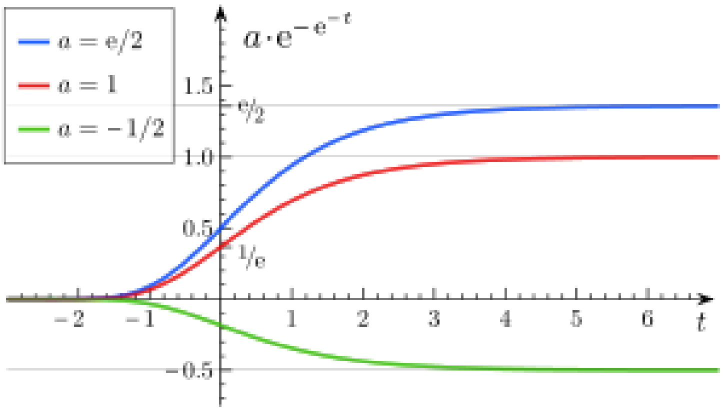
Data sources II

- Mode share (%)
  - European Platform on Mobility Management (EPOMM) Modal Split Tool (TEMS)
- Cycling network length (km)
  - OpenStreetMap (OSM)
    - Cycling network length for all 167 cities
    - Labels of designated, non-shared cycling ways
    - Street network length (km) for the seven PASTA cities



- Non-linear least square regression to calculate corresponding cycling mode share (%)

$$y(t) = ae^{-be^{-ct}}$$



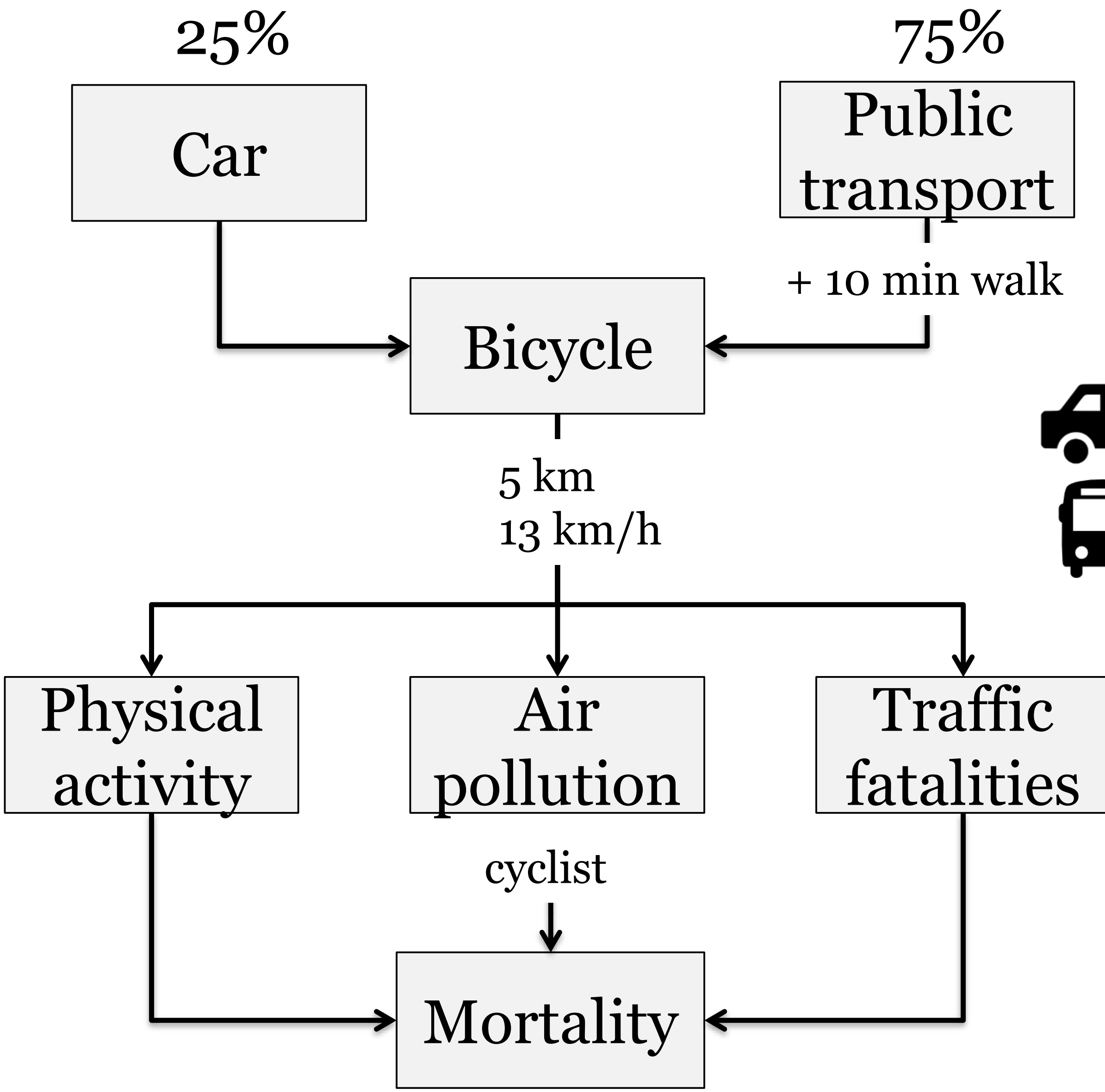
- *a* is the asymptote (i.e. maximal cycling mode share associated with cycling network)
- *b* sets the displacement along the x-axis
- *c* sets the displacement along the y-axis (i.e. growth rate)
- *t* is the cycling network length (km/ 100,000 persons)

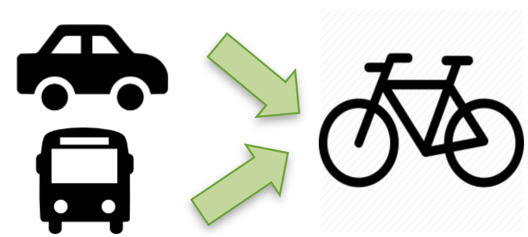
Scenario analyses

How do increases in cycling network length lead to increases in cycling mode share and therefore contribute to improvements in public health

- S1 10% increase in cycling network
- S2 50% increase in cycling network
- S3 100% increase in cycling network
- S4 all streets of city with cycling ways

Health impact assessment (HIA) model





Costs
- 2 million € per km (reconstructing road mixed traffic)
- 4,000 € per km/ year for maintenance (Scheepers et al. 2015)

Benefits
- Avoided premature deaths
- Value of Statistical Life (€ 3.2 – 7.2 million)

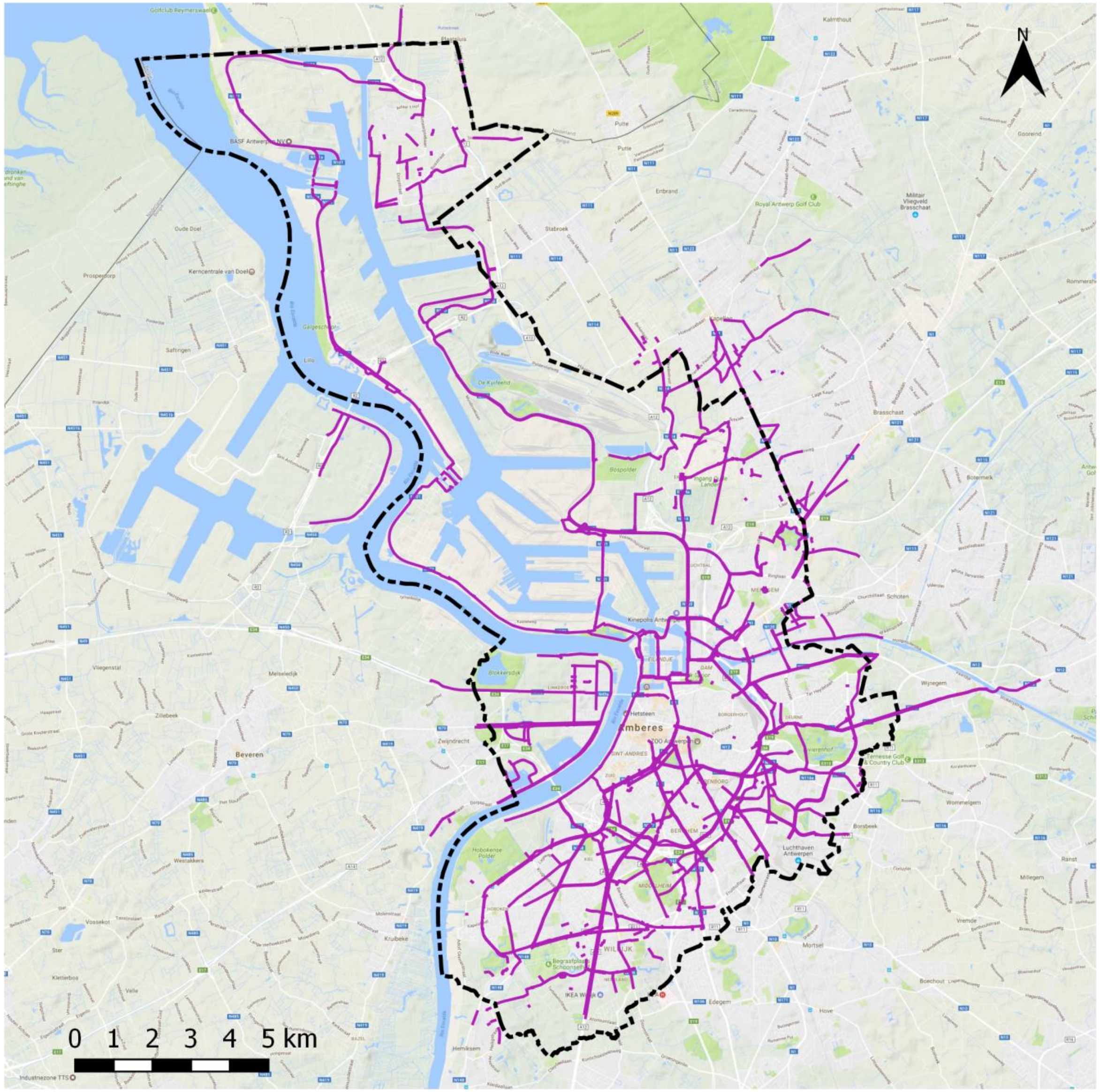
- 5-year buildup of health benefits
- 5% discounting rate
- Time horizon 30 years

Association between cycling network and cycling mode share

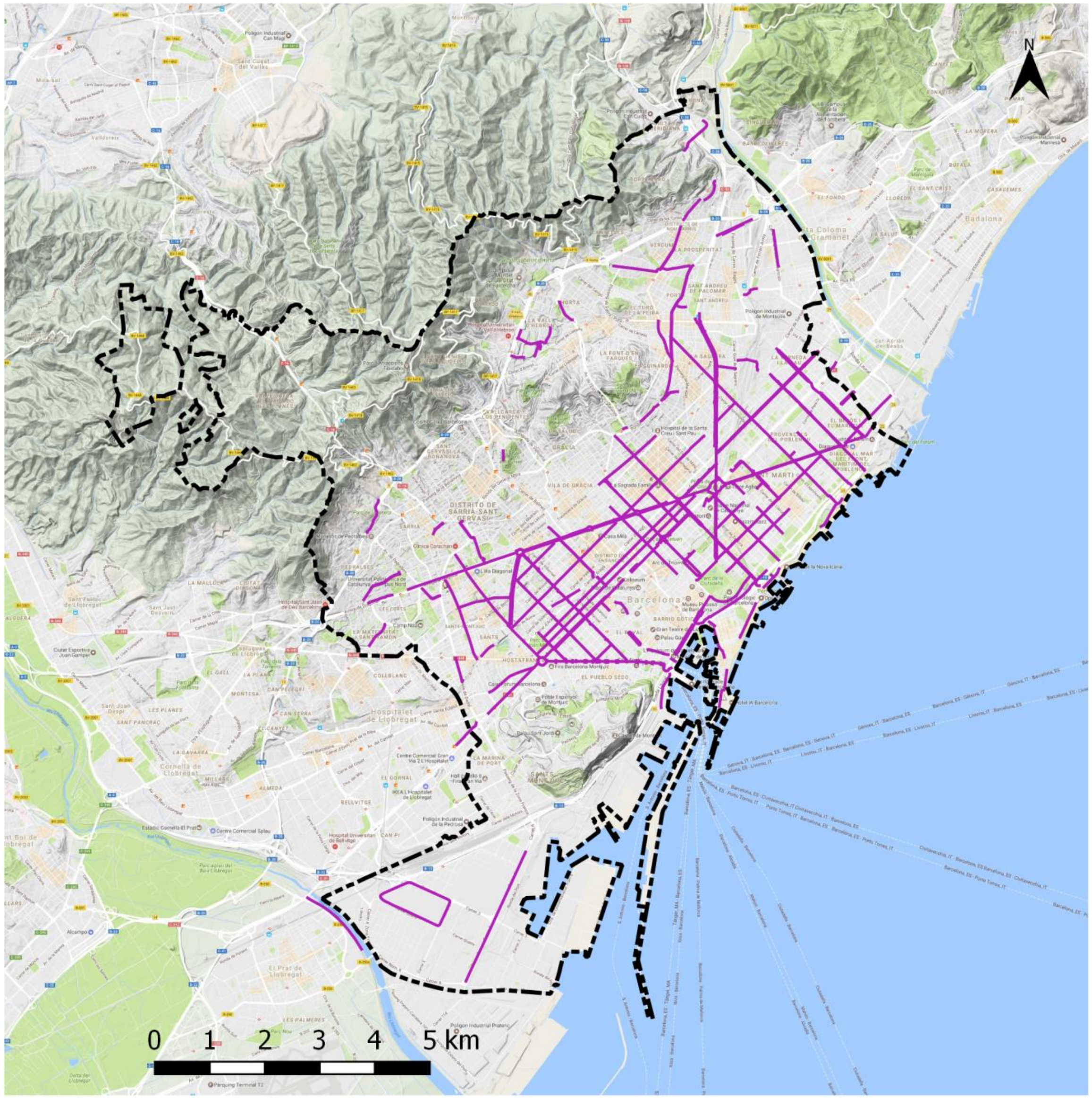
A cycling network length of 315 km/ 100,000 persons was associated with maximal cycling mode share of **24.7%** (99.9% of asymptotic value)

PASTA City	Population	Car (%)	PT (%)	Bike (%)	Walk (%)	Cycling km (OSM)	Km/ 100,000 persons	Street km (OSM)	Km/ 100,000 persons
Antwerp	493,517	41	16	23	20	469.17	95.07	1651.74	334.69
Barcelona	1,620,943	26	40	2	32	159.54	9.84	1554.56	95.90
London	8,673,713	38	29	3	30	969.17	11.17	16439.74	189.54
Örebro	138,952	55	9	25	11	361.35	260.05	3045.27	2191.60
Rome	2,869,461	54	29	1	16	120.64	4.20	8281.36	288.60
Vienna	1,797,337	27	39	6	28	715.63	39.82	3946.11	219.55
Zurich	410,404	36	34	4	26	118.36	28.84	1193.59	290.83

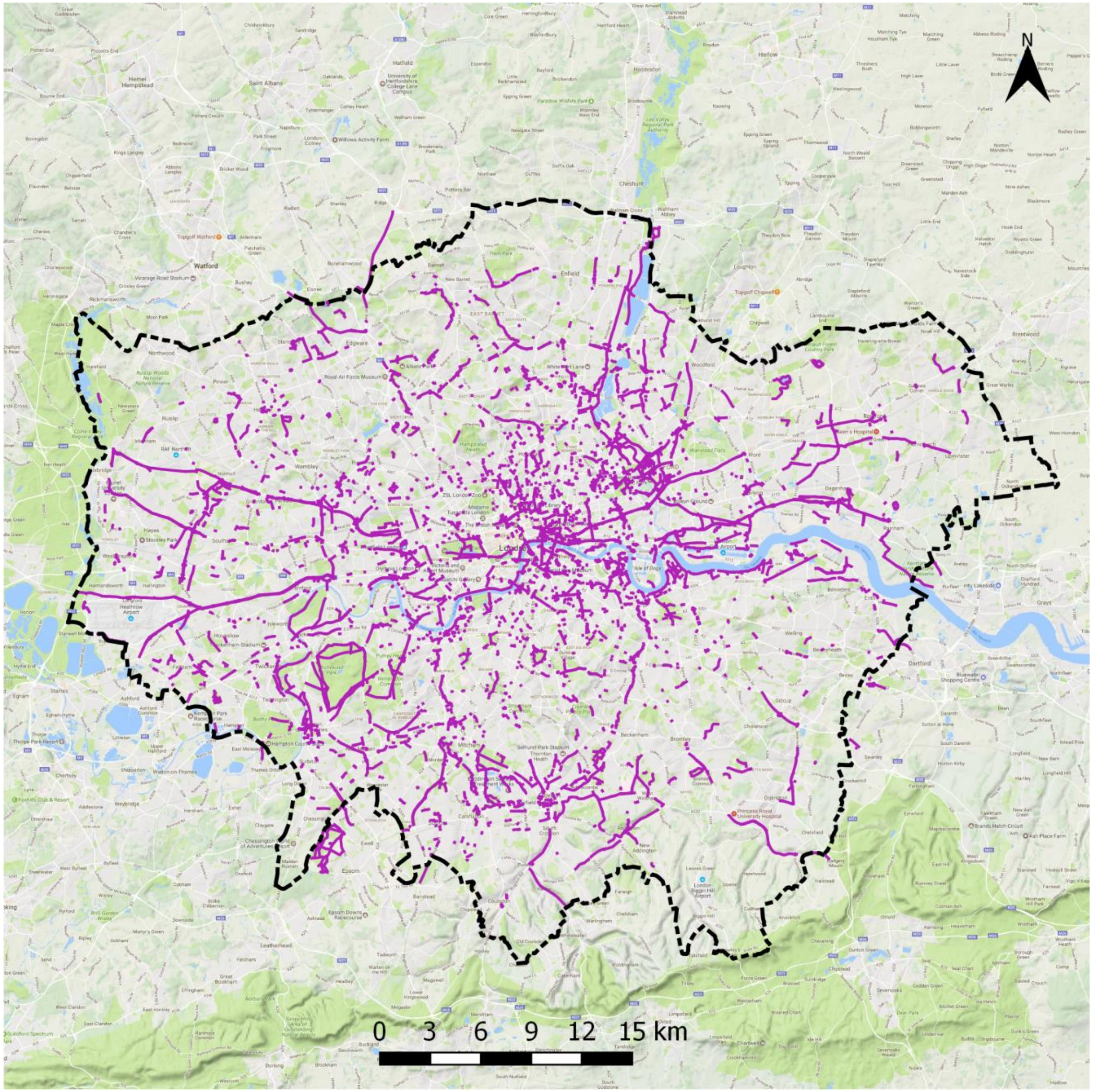
Antwerp, Belgium



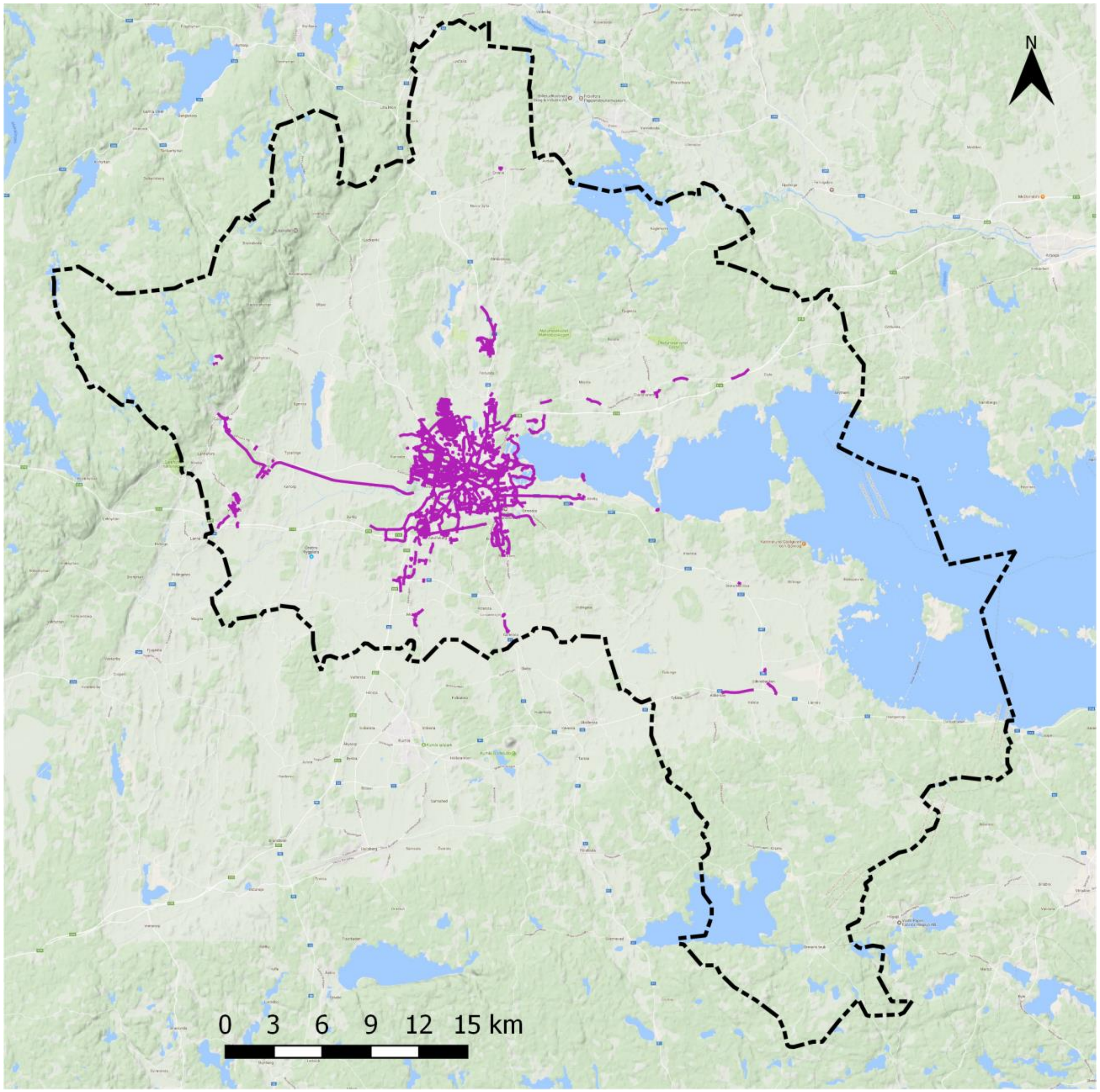
Barcelona, Spain



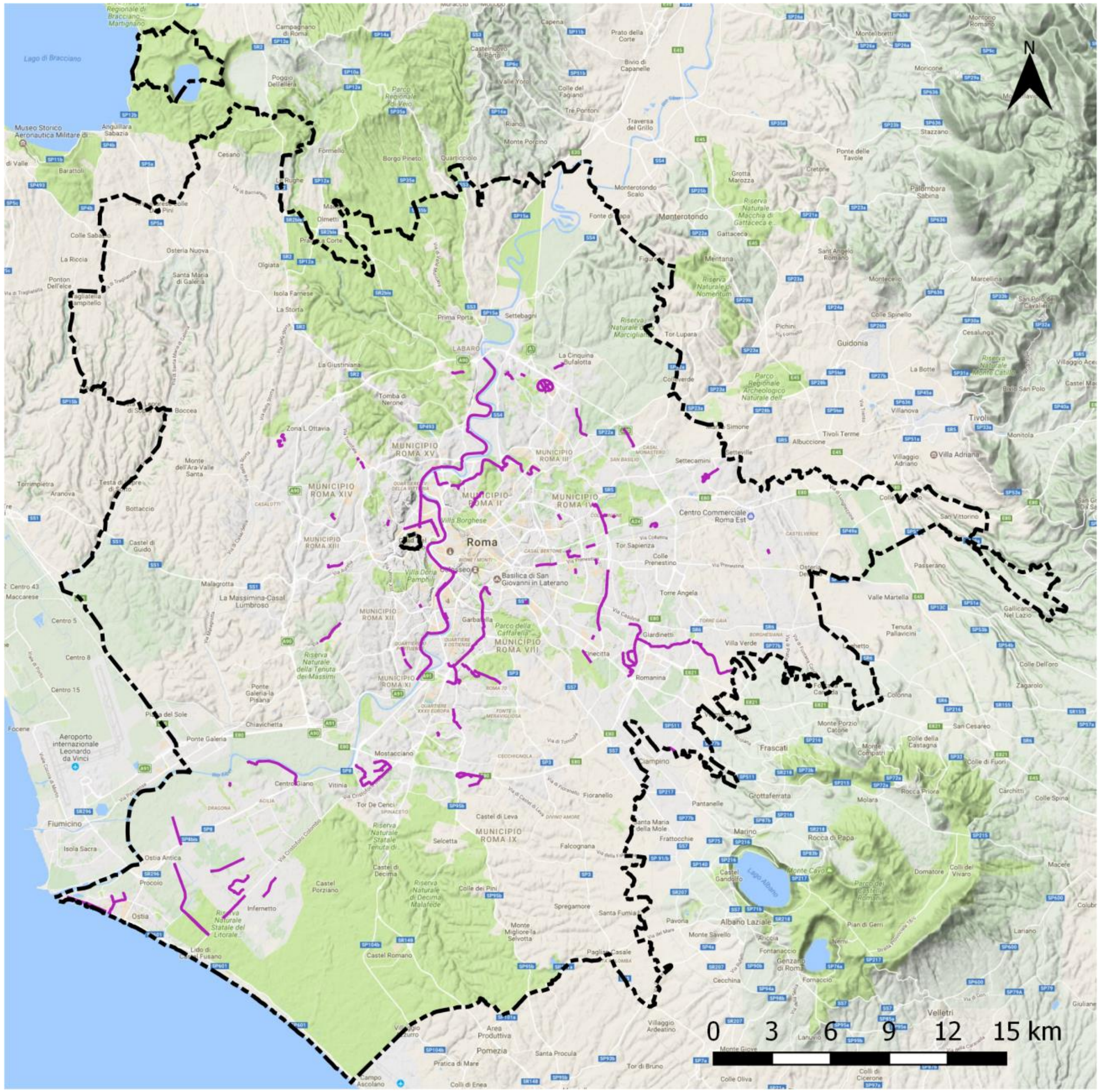
London, UK



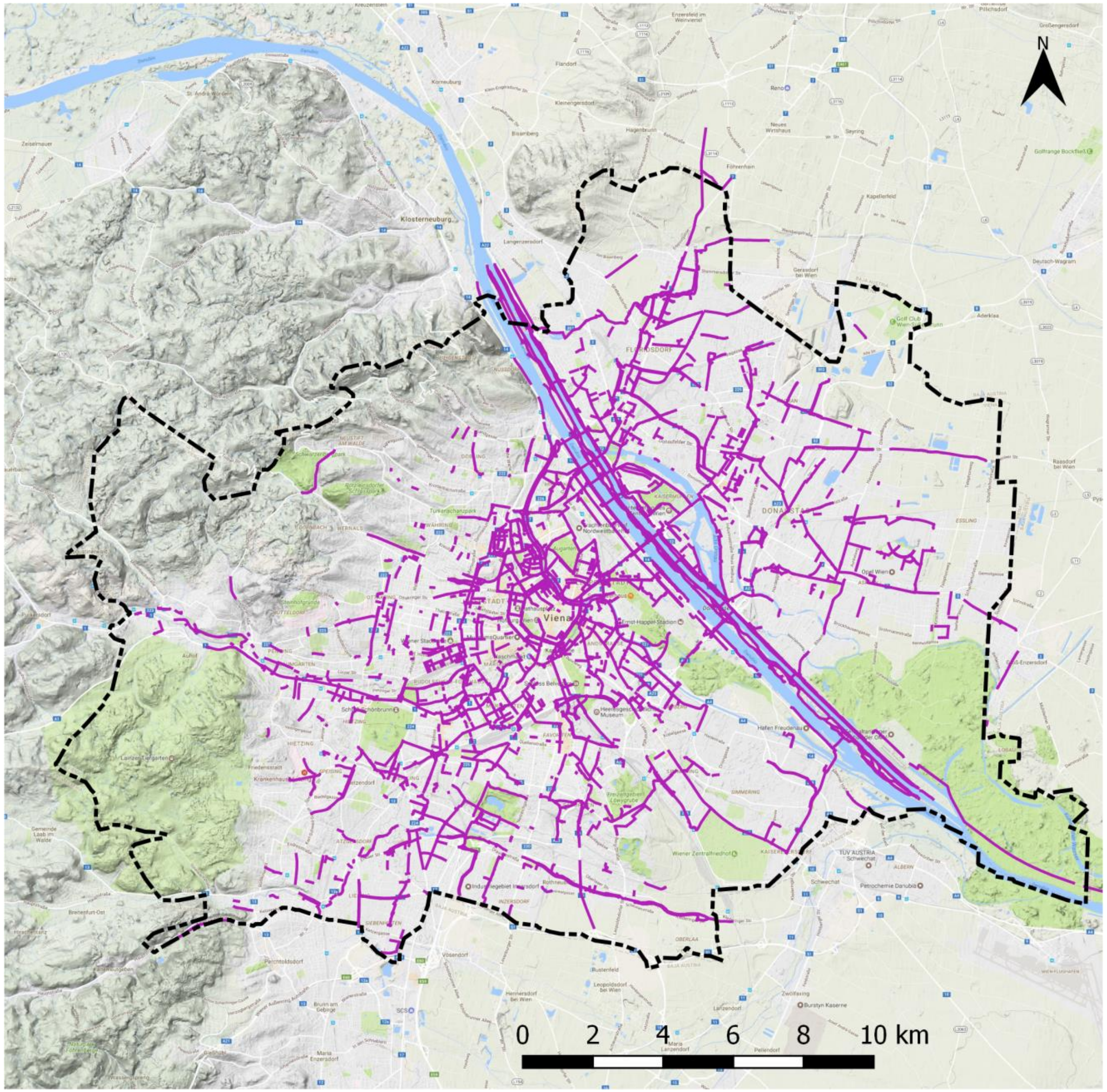
Örebro, Sweden



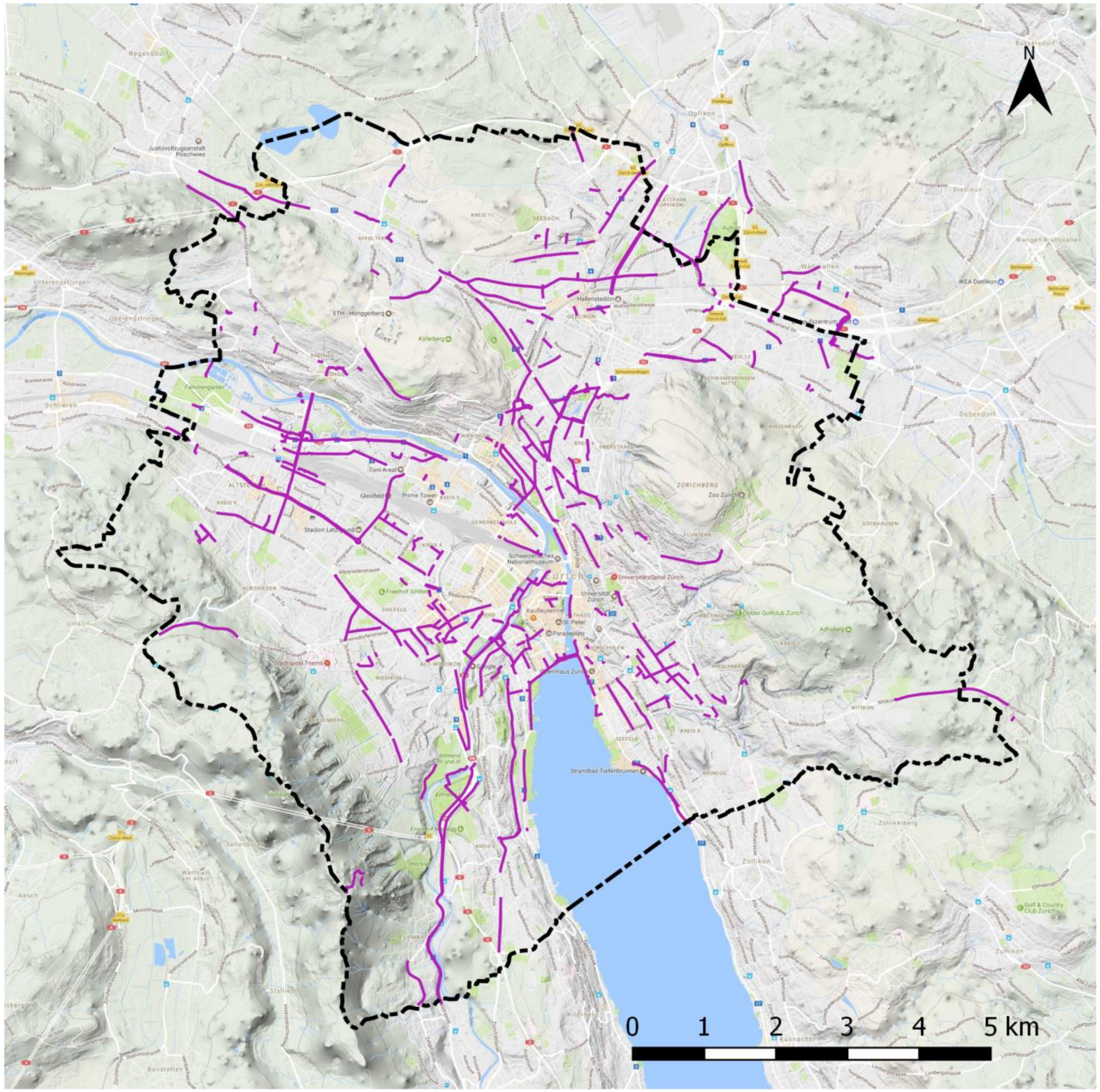
Rome, Italy



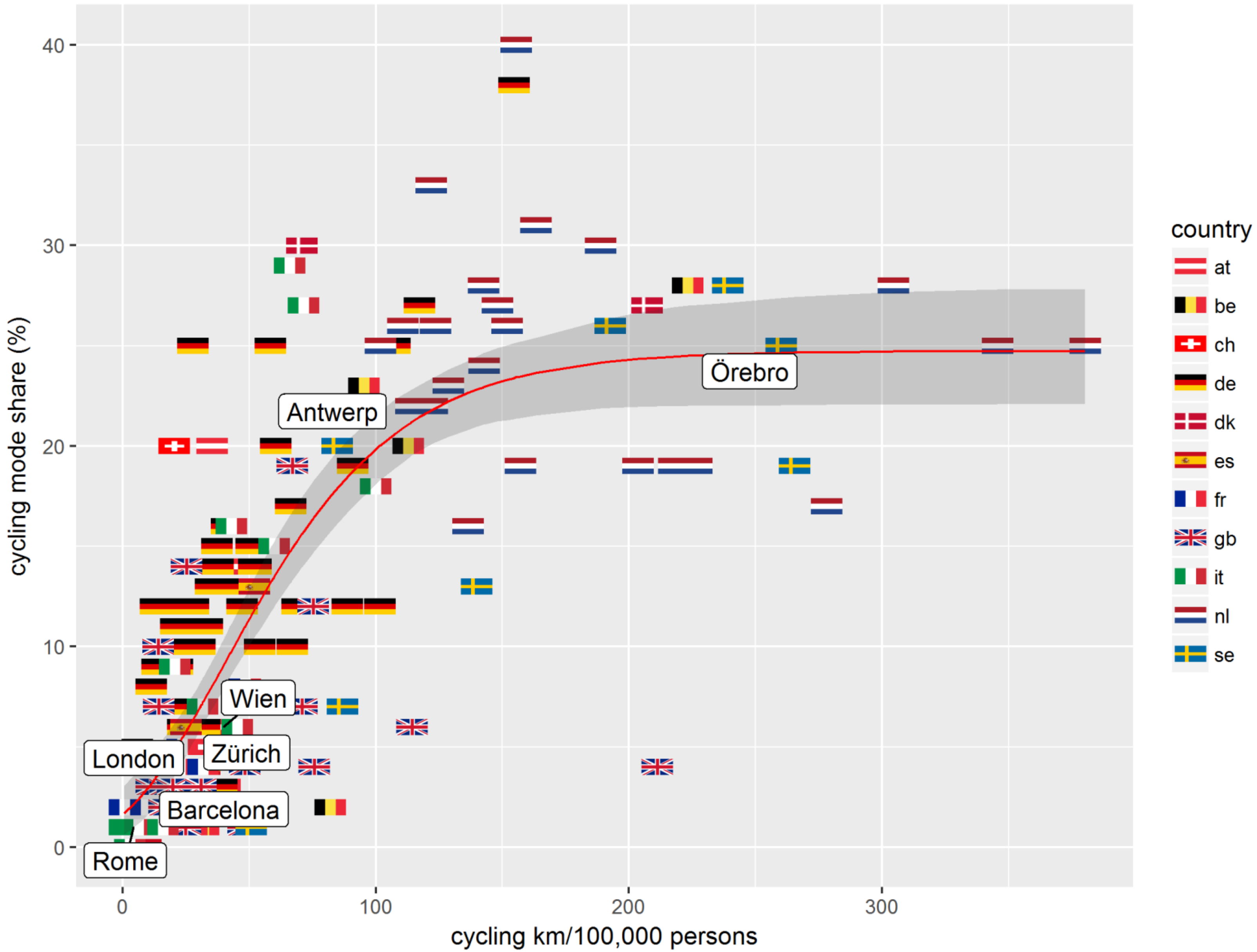
Vienna, Austria



Zurich, Switzerland



Results Gompertz growth model



Premature mortality impacts

	Scenario	Physical activity	Air pollution	Traffic fatalities	Total deaths	Total deaths (100,000)
Antwerp	S1 10%	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
	S2 50%	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
	S3 100%	-6 (-9;-5)	1 (1;2)	0 (-2;2)	-5 (-8;-2)	-1 (-2;0)
	S4 all streets	-9 (-13;-7)	2 (1;2)	0 (-3;-3)	-7 (-11;-3)	-1 (-2;0)
Barcelona	S1 10%	-21 (-30;-16)	4 (1;5)	2 (-5;9)	-16 (-26;-5)	-1 (-2;0)
	S2 50%	-35 (-48;-25)	6 (1;8)	3 (-8;15)	-25 (-42;-9)	-2 (-4;1)
	S3 100%	-53 (-73;-39)	9 (2;12)	5 (-13;22)	-38 (-64;-13)	-2 (-6;1)
	S4 all streets	-340 (-474;-249)	60 (12;77)	31 (-81;114)	**-248 (-410;-86)**	**-15 (-36;5)**
London	S1 10%	-24 (-34;-18)	4(2;5)	2 (-6;10)	-18 (-30;-7)	0 (-1;0)
	S2 50%	-85 (-119;-63)	14 (8;18)	7 (-21;36)	-64 (-104;-24)	-1 (-3;1)
	S3 100%	-169 (-235;-123)	28 (16;35)	15 (-41;70)	-126 (-206;-47)	-1 (-6;3)
	S4 all streets	-1,617 (-2,255;-1,185)	265 (155;337)	141 (-394;677)	**-1,210 (-1,972;-447)**	**-14 (-56;28)**
Örebro	S1 10%	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
	S2 50%	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
	S3 100%	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
	S4 all streets	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)	0 (0;0)
Rome	S1 10%	-27 (-38;-20)	5 (3;6)	2 (-8;11)	-21 (-34; -8)	-1 (-2;0)
	S2 50%	-33 (-46;-24)	6 (3;7)	2 (-9;13)	-26 (-41;-10)	-1 (-2;1)
	S3 100%	-40 (-56;-29)	7 (4;9)	2 (-11;15)	-31 (-50;-12)	-1 (-30;1)
	S4 all streets	-557 (-776;-408)	94 (55;119)	31 (-153;215)	**-433 (-695;-170)**	**-15 (-40;10)**
Vienna	S1 10%	-47 (-66;-34)	13 (8;17)	2 (-14;18)	-31 (-54;-9)	**-2 (-4;1)**
	S2 50%	-88 (-124;-64)	25 (15;32)	4 (-25;34)	-59 (-102;-16)	**-3 (-8;2)**
	S3 100%	-131 (-184;-96)	38 (22;48)	6 (-38;50)	-88 (-151;-24)	**-5 (-13;3)**
	S4 all streets	-219 (-307;-160)	63 (36;79)	10 (-63;84)	-146 (-252;-40)	-8 (-21;5)
Zurich	S1 10%	-14 (-19;-10)	3 (2;3)	2 (-3;7)	-9 (-16;-2)	**-2 (-4;-1)**
	S2 50%	-25 (-35;-18)	5 (3;6)	3 (-5;12)	-16 (-28;-4)	**-4 (-7;-1)**
	S3 100%	-38 (-53;-28)	7 (4;9)	5 (-7;18)	-25 (-43;-7)	**-6 (-11;-2)**
	S4 all streets	-87 (-122;-63)	17 (10;21)	12 (-17;42)	-58 (-100;-16)	-14 (-25;-3)

Rapid HIA for all 167 cities

- If all **167 cities** with a total population of **75.2 million people**, achieved a cycling mode share of **24.7%** each year **10,091 premature deaths** (95% CI: 3,401; 16,781) could be avoided

- WHO study estimated 10,000 premature deaths preventable in 50 major cities worldwide under assumption that Copenhagen cycling mode share (=26%) was achieved for a similar population size of nearly 75 million people (WHO 2014)

Results cost-benefit analysis

- Cost-effective
- Largest cost-benefit ratios were found for 10% increase
    - Non-linearity of exposure response relationship

    - Rome € 70:1
    - Zurich € 62:1
    - Barcelona € 35:1
    - Vienna € 22:1
    - London € 8:1
    - Antwerp
    - Örebro

- S4 all streets: Cost-benefit ratios smaller
    - Large amount of additional infrastructure
    - Horizon of 30 years almost not being enough time to compensate

Limitations

- Univariate analysis
  - Ignored other built-environment, transport and socio-economic factors associated with cycling
- Ecological study design – no causal inference
  - Reverse causality? % ←→ Km
- Benefits are sensitive to contextual setting and underlying population and exposure parameters
- Ignored societal co-benefits of reduced air and noise pollution, reduced CO_2 emissions, improved social cohesion and mental health expected with reductions in motor traffic
- No stratification by age, sex, or socio-economic status
- Cost estimate might overestimate in other settings

Strengths

- Comprehensive insight into association between cycling network, cycling mode share and associated health impacts
- OSM data for cycling infrastructure has been described of fairly good quality (Hochmair et al., 2013), ensures standardized data extraction method and reproducibility

- Practical policy implications – expansions of cycling networks may increase the cycling mode share, therefore, contribute to global health promotion and meeting sustainable development goals
- With ambitious expansions of cycling networks, health benefits will most likely be the largest

Thank you!

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