Institut für Verkehrsplanung und Transportsysteme
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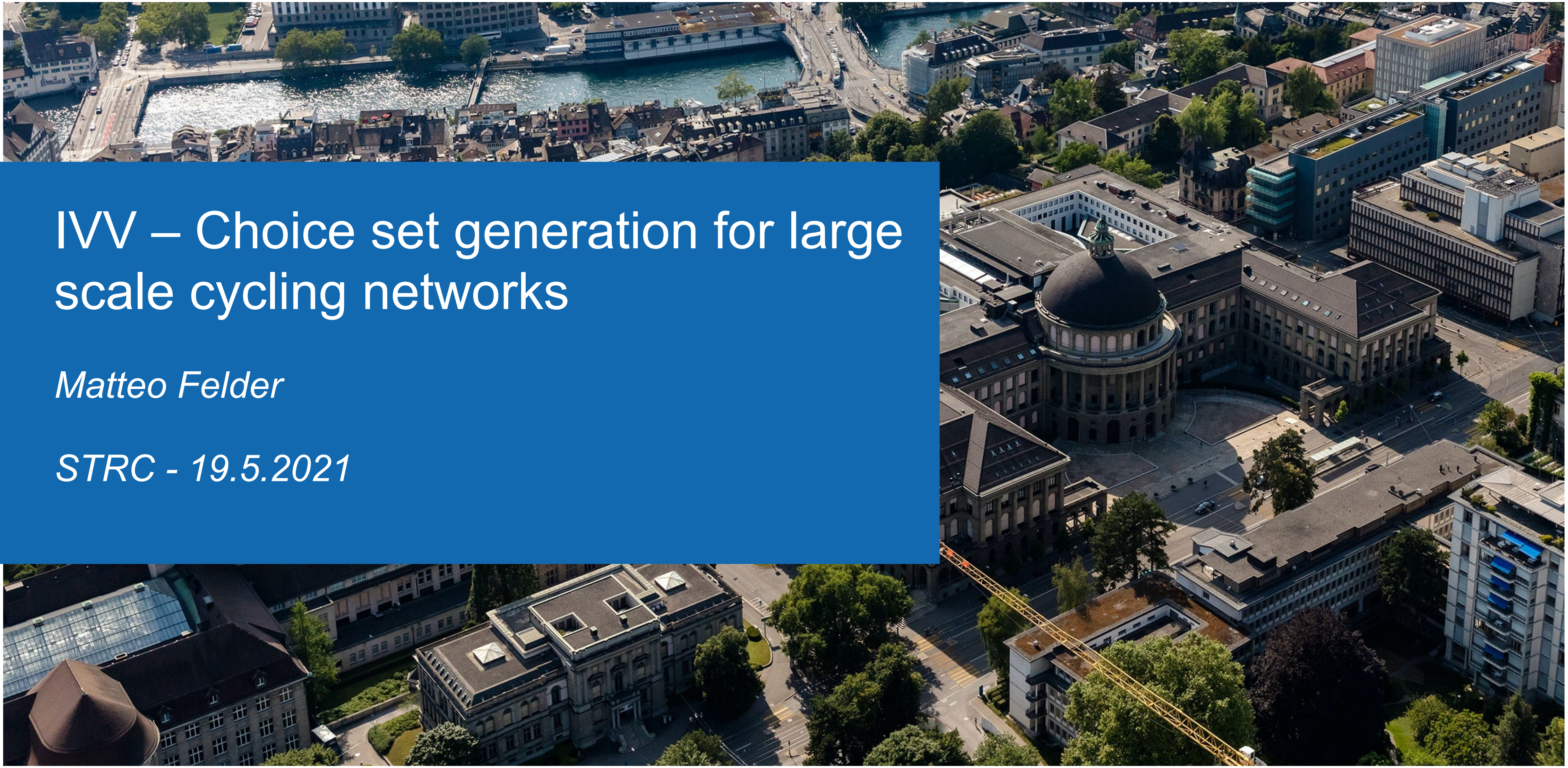

IVV – Choice set generation for large scale cycling networks

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STRC - 19.5.2021

Overview

- Motivation
- Preliminaries: Network / Data
- Choice set generation:
    - BFS-LE algorithm
    - Validation techniques
    - Preliminary results

Long-term goals

(joint with Adrian Meister and Kay W. Axhausen)

- estimate a route choice model for cyclists in the city of Zurich
- incorporate route choice in agent-based simulator MATSim

Route choice modelling

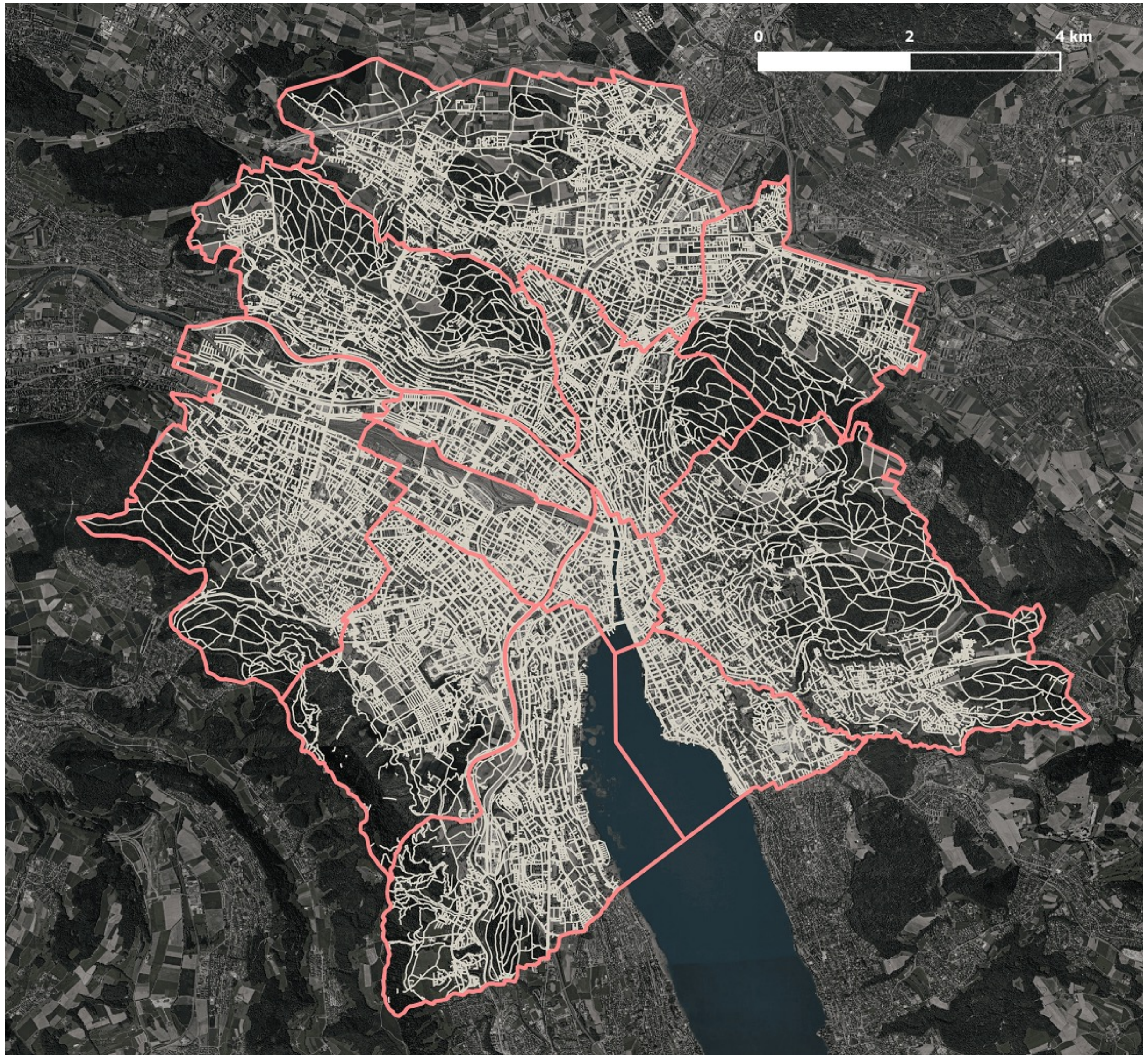
1. Match observed data to network

2. Choice set generation:
   - Dream: for a given origin and destination, identify all routes a traveler might consider (and only those)

3. Estimate a model to calculate route choice probabilities:
   - What is the probability that a given route is chosen from a specified choice set?

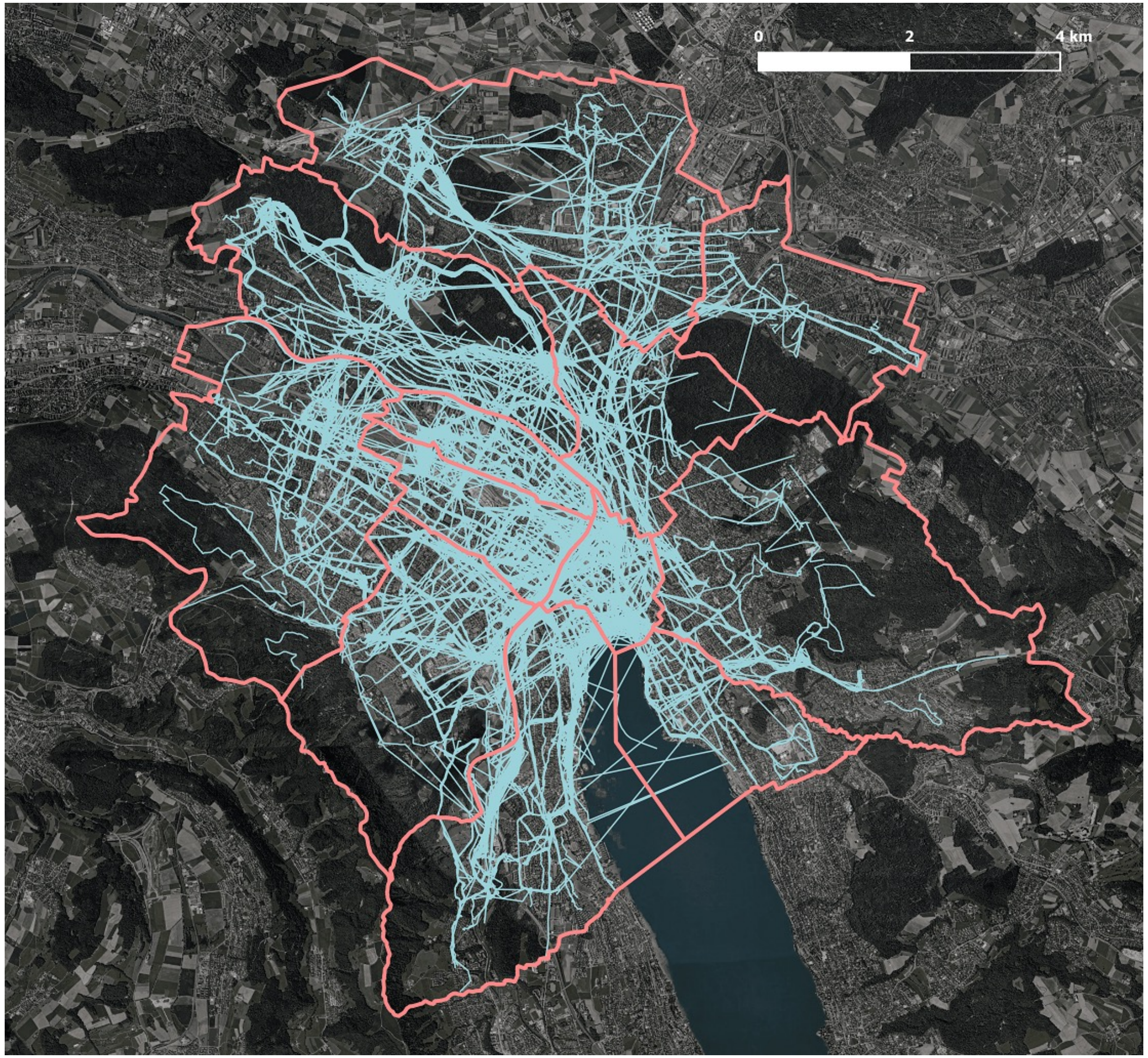
Data – Network

- OSM network
- ~150’000 uni-directional links
- ~75’000 nodes
- Area ~ 88 km^2
- Purely pedestrian links removed



Data – observed trips

- MOBIS-COVID study, MotionTag GPS tracking app
- approx. 6600 matched trajectories



“Descriptive route choice analysis of cyclists in Zurich.” 2021. Meister, Gupta, Axhausen. STRC

Challenges in cycling setting

- Cycling network is extremely complex
- Factors influencing route choice:
  - Travel time
  - Travel distance
  - Bike lanes
  - Traffic
  - Slope
  - Surface
  - Traffic lights
  - Left turns
  - Scenery
  - Nature
  - Weather
  - Fitness level

Breadth first search on link elimination (BFS-LE) algorithm
(Balmer 2009)

- Input:
    - Origin-destination (OD) pair
    - Network
    - Number of alternatives *k*
    - Link based cost function

- Output:
    - *k* routes from origin to destination

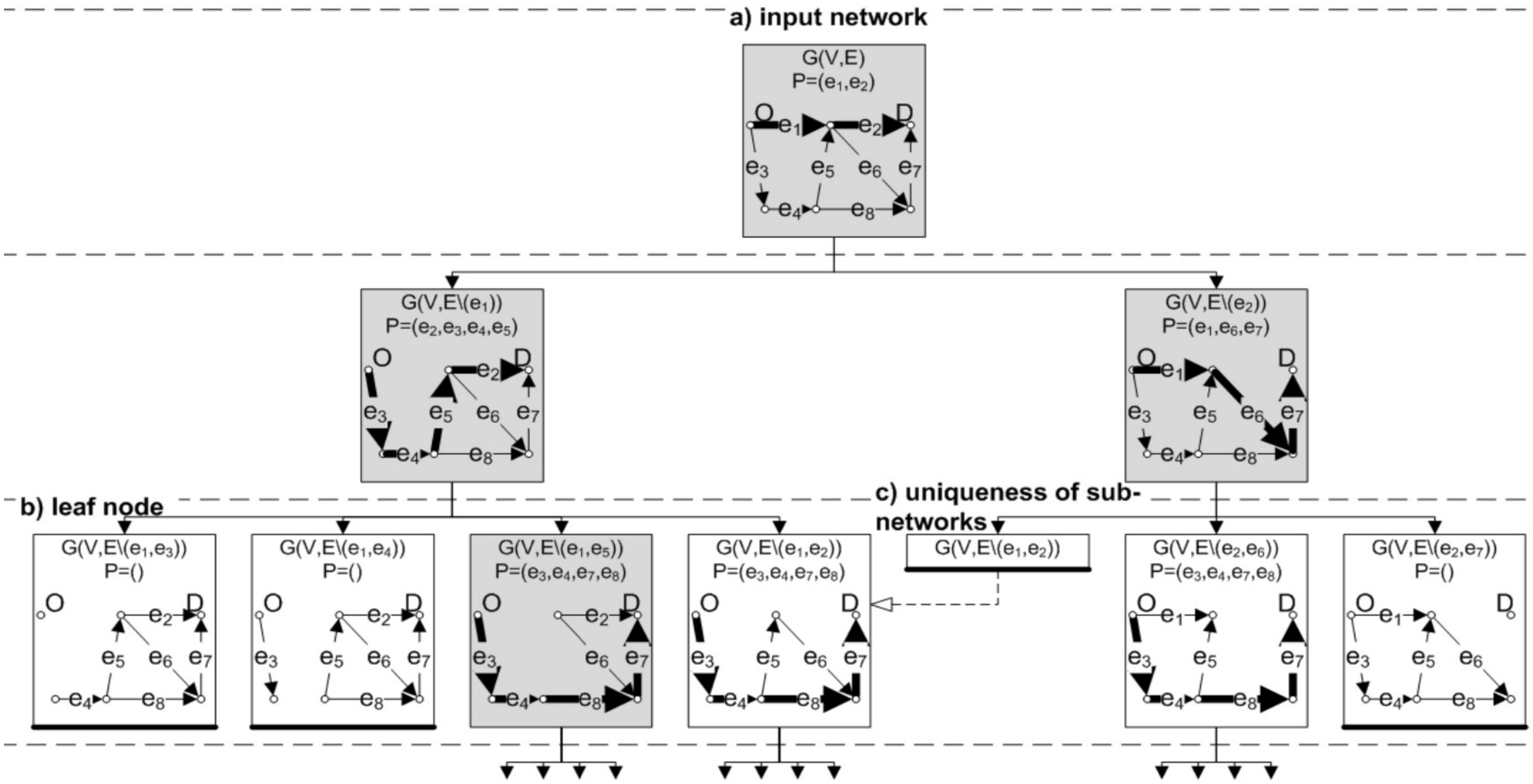
“Route choice sets for very high-resolution data.” 2013. Rieser-Schüssler, Balmer, Axhausen. Transportmetrica A: Transp. Sci. 825–845.

Advantages of BFS-LE

- Works well for car mode (network simpler, travel cost = travel time/distance)
- Generally faster than other choice set generation algorithms

- How does it perform on cycling networks?

Breadth first search on link elimination (BFS-LE) algorithm



"Route choice sets for very high-resolution data." 2013. Rieser-Schüssler, Balmer, Axhausen. Transportmetrica A: Transp. Sci. 825–845.

Breadth first search on link elimination (BFS-LE) algorithm

Multi-attributed cost function:

- OSM-highway type
- OSM-bicycle friendly tags

$$c_a = (c(a) + o(a)) \cdot l_a + e(a)$$

$$\begin{aligned} c(a) &= \text{ cost factor} \\ o(a) &= \text{ one-way penalty} \\ l_a &= \text{ length of link } a \\ e(a) &= \text{ elevation cost} \end{aligned}$$

Breadth first search on link elimination (BFS-LE) algorithm

Multi-attributed cost function:

$$c_a = (c(a) + o(a)) \cdot l_a + e(a)$$

highway =	$\mathbf{c(a)}$ bicycle infra.	$\mathbf{c(a)}$ no bicycle infra.
cycleway	1.0	-
footway/ path/ pedestrian/ road/ track	1.0	3.0
primary(_link)	1.2	3.0
secondary(_link)	1.1	1.6
tertiary(_link)/ unclassified	1.0	1.3
residential / living-street / service	1.0	1.1
steps	-	40.0

Breadth first search on link elimination (BFS-LE) algorithm

Multi-attributed cost function:

- OSM-highway type
- OSM-bicycle friendly tags
- Link penalty

$$c_a = (c(a) + o(a)) \cdot l_a + e(a)$$

$$c_a^{(0)} = c_a$$

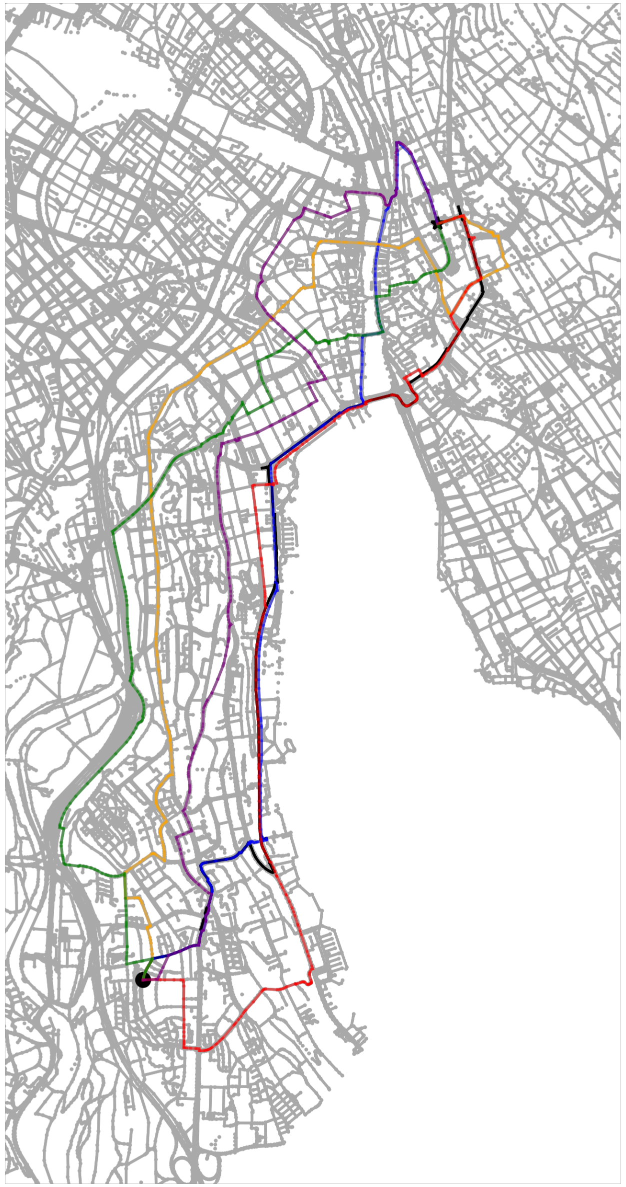
$$c_a^{(k)} = c_a + \mu \cdot n_a^{(k)} \cdot l_a$$

$$\mu = \text{ link penalty}$$

$$k = \text{ number of routes computed up to current iteration}$$

$$n_a^{(k)} = \text{ number of routes that use link } a$$

Breadth first search on link elimination (BFS-LE) algorithm



Validation techniques of choice set generation algorithms

- Replication of observed route
- “Reasonableness” (no unreasonable routes in choice set)
- Similarity measures (quantify overlap among alternatives)
- Model estimation performance

Choice set evaluation – replication of observed route

- Replication of observed route lower than results in the literature due to high network complexity

alternatives	100 %	> 90 %	> 80 %	> 70 %
5	0.03	0.11	0.21	0.33
10	0.04	0.13	0.25	0.37
15	0.04	0.14	0.27	0.39
20	0.05	0.15	0.28	0.41
Ref: (20 alt.)	0.68	0.75	0.80	0.85

Reference: “Efficiency of choice set generation methods for bicycle routes.” 2014. Halldórsdóttir et al. Euro. J. Transp. Infrastruct. Res. 332–348.

Choice set evaluation – replication of observed route

- Buffer of 20m width around observed route

alternatives	100 %	> 90 %	> 80 %	> 70 %
5	0.03 / 0.08	0.11 / 0.23	0.21 / 0.36	0.33 / 0.47
10	0.04 / 0.10	0.13 / 0.26	0.25 / 0.40	0.37 / 0.53
15	0.04 / 0.11	0.14 / 0.28	0.27 / 0.43	0.39 / 0.55
20	0.05 / 0.12	0.15 / 0.29	0.28 / 0.45	0.41 / 0.58
Ref: (20 alt.)	0.68	0.75	0.80	0.85

Reference: “Efficiency of choice set generation methods for bicycle routes.” 2014. Halldórsdóttir et al. Euro. J. Transp. Infrastruct. Res. 332–348.

Choice set evaluation – similarity among alternatives

- Path size factor of route i:
  (Ben-Akiva, Bierlaire, ’99)

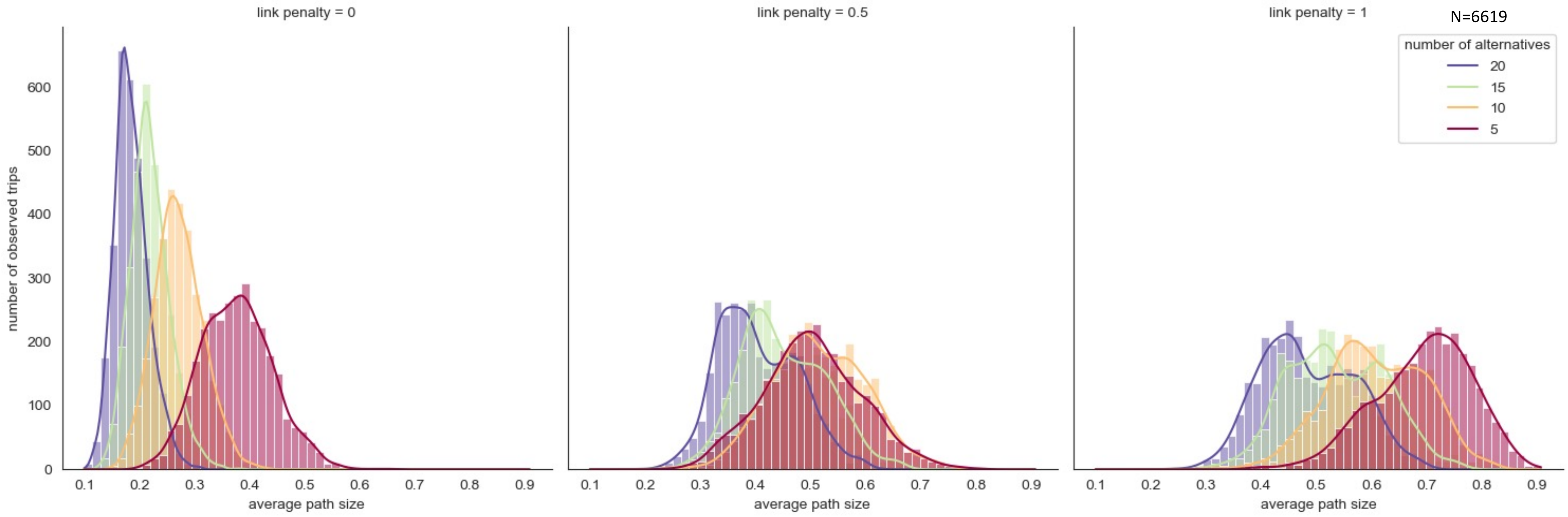
$$PS_i = \sum_{a \in \Gamma_i} \frac{l_a}{L_i} \frac{1}{\sum\limits_{j \in C} \delta_{aj}}$$

$$\begin{aligned}
\Gamma_i &= \text{ set of links of route } i \\
l_a &= \text{ length of link } a \\
L_i &= \text{ length of route } i \\
\delta_{aj} &= 1 \text{ if link } a \text{ is on route } j \text{ and } 0 \text{ otherwise} \\
C &= \text{ choice set}
\end{aligned}$$

- Number between 0 and 1
  - close to 0, large overlap
  - close to 1, small overlap
- Portion of route i that constitutes an independent alternative

Choice set evaluation – similarity among alternatives

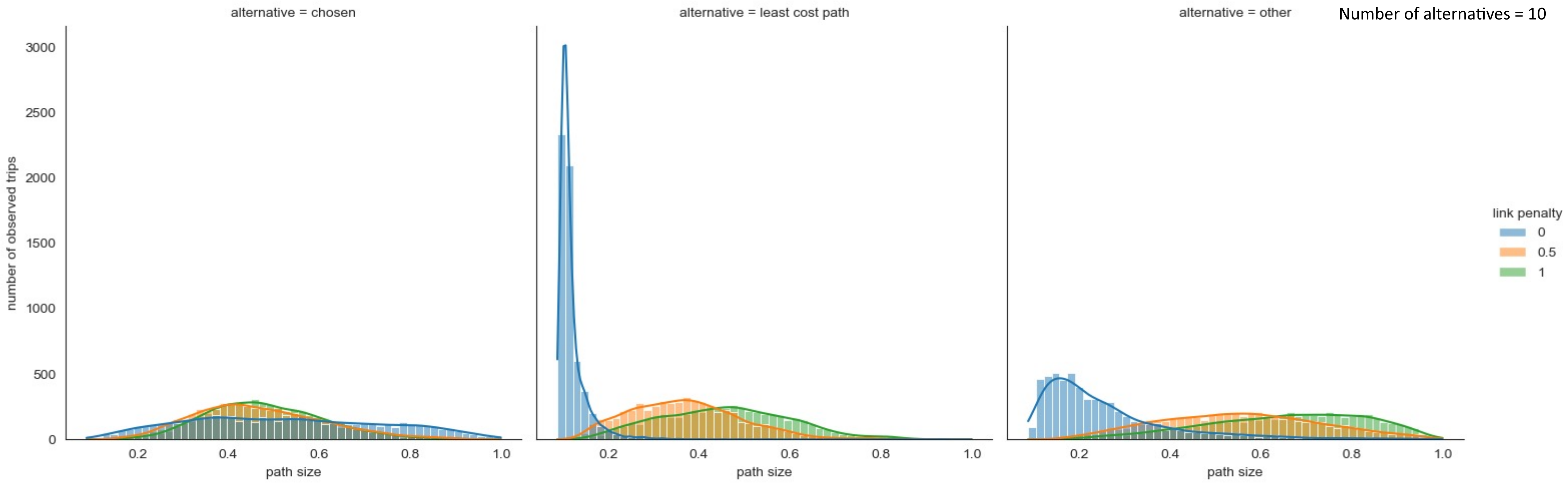
- Path size factor:
  - close to 0, large overlap
  - close to 1, small overlap
- Link penalty leads to more heterogenous choice set



Choice set evaluation – similarity among alternatives

- No link penalty: alternatives follow least cost path
- Link penalty leads to more heterogenous choice set

Number of alternatives = 10



Preliminary results – path size logit model estimation

- Utility of route i: $$U_i = V_i + \beta_{PS} \ln PS_i + \epsilon_i$$

- Deterministic utility of route i: $$V_i = \beta_{\text{distance}} L_i + \beta_{\text{uphill}} UH_i + \beta_{\text{bikelanes}} BL_i + \beta_{\text{trafficsignals}} \frac{TS_i}{100}$$

$$\begin{aligned} L_i &= \text{ length of route } i \text{ [km]} \\ UH_i &= \text{ share of route } i \text{ going uphill} \\ BL_i &= \text{ share of route } i \text{ with cycling infrastructure} \\ TS_i &= \text{ number of traffic signals on route } i \end{aligned}$$

- Probability that route i is chosen: $$P(i) = \frac{e^{V_i + \beta_{PS} PS_i}}{\sum_{j \in C} e^{V_j + \beta_{PS} PS_j}}$$

Preliminary results – model estimation

- Path size logit model estimation (estimated with biogeme)
- 6619 OD pairs
- Choice set = chosen route + 5 alternatives

- Only link penalty = 0 gives negative distance parameter
- Other parameters have signs as expected

Link penalty = 0

Name	Value	Std err	t-test
beta_bikelanes	0.222	0.0453	4.9
beta_distance	-0.256	0.0485	-5.28
beta_path_size	2.46	0.0378	64.9
beta_trafficsignals	-1.49	0.194	-7.71
beta_uphill	-3.68	0.268	-13.7

Link penalty = 1

Name	Value	Std err	t-test
beta_bikelanes	0.345	0.0405	8.52
beta_distance	0.956	0.0435	22
beta_path_size	-7.16	0.106	-67.5
beta_trafficsignals	-1.5	0.178	-8.41
beta_uphill	-3.73	0.28	-13.3

https://biogeme.epfl.ch

Preliminary results – model estimation

- Path size logit model estimation (estimated with biogeme)
- 6619 OD pairs
- Choice set = chosen route + 10 alternatives

- Only link penalty = 0 gives negative distance parameter
- Other parameters have signs as expected

Link penalty = 0

Name	Value	Std err	t-test
beta_bikelanes	1.56	0.0417	37.3
beta_distance	-1.05	0.0486	-21.6
beta_path_size	2.35	0.0315	74.8
beta_trafficsignals	-1.66	0.194	-8.56
beta_uphill	-3.42	0.253	-13.5

Link penalty = 1

Name	Value	Std err	t-test
beta_bikelanes	1.22	0.0323	37.9
beta_distance	0.0111	0.0394	0.282
beta_path_size	-4.59	0.0779	-59
beta_trafficsignals	-1.63	0.16	-10.2
beta_uphill	-3.18	0.23	-13.8

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Preliminary results – model estimation

- Path size logit model estimation (estimated with biogeme)
- 6619 OD pairs
- Choice set = chosen route + 15 alternatives
- Parameters have signs as expected

Link penalty = 0

Name	Value	Std err	t-test
beta_bikelanes	2.1	0.0438	47.9
beta_distance	-1.55	0.0512	-30.2
beta_path_size	2.41	0.0297	81.2
beta_trafficsignals	-1.68	0.198	-8.52
beta_uphill	-3.44	0.251	-13.7

Link penalty = 1

Name	Value	Std err	t-test
beta_bikelanes	1.6	0.0313	51.1
beta_distance	-0.698	0.0419	-16.6
beta_path_size	-2.88	0.0702	-41
beta_trafficsignals	-1.49	0.157	-9.46
beta_uphill	-2.84	0.21	-13.5

https://biogeme.epfl.ch

Conclusions

- For simple models (linear, with few variables), BFS-LE without link penalty and 5 alternatives suffice
- More complex models require a large choice set (see Adrian Meister’s talk)
- More heterogeneous choice sets require more alternatives to produce parameters with signs as expected

  (link penalty = 0.5, alternatives >= 10; link penalty = 1.0, alternatives >= 15)

Thank you!