AALBORG UNIVERSITY
DENMARK

Using Large Trajectory Dataset for Quantifying Mobility

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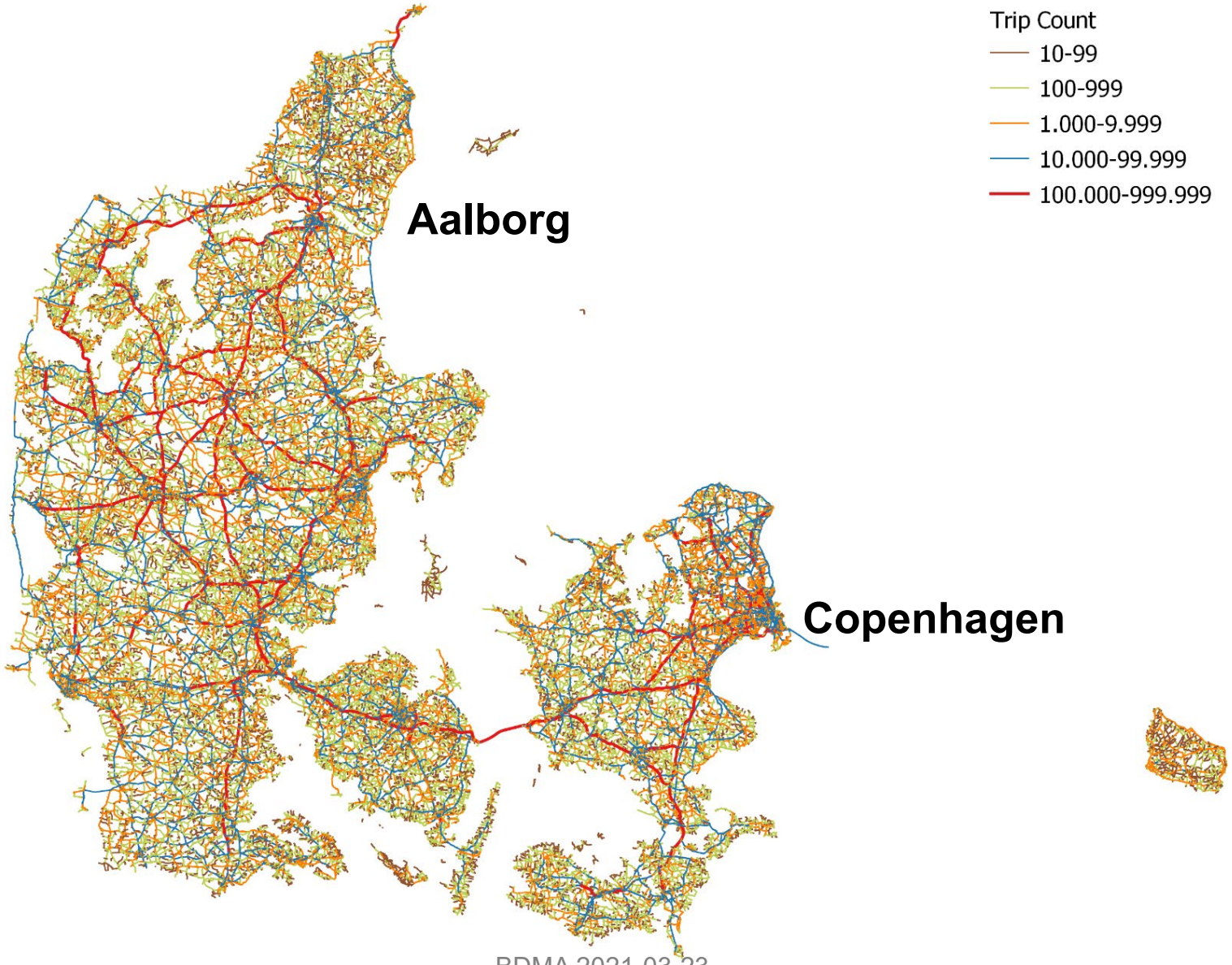
Agenda

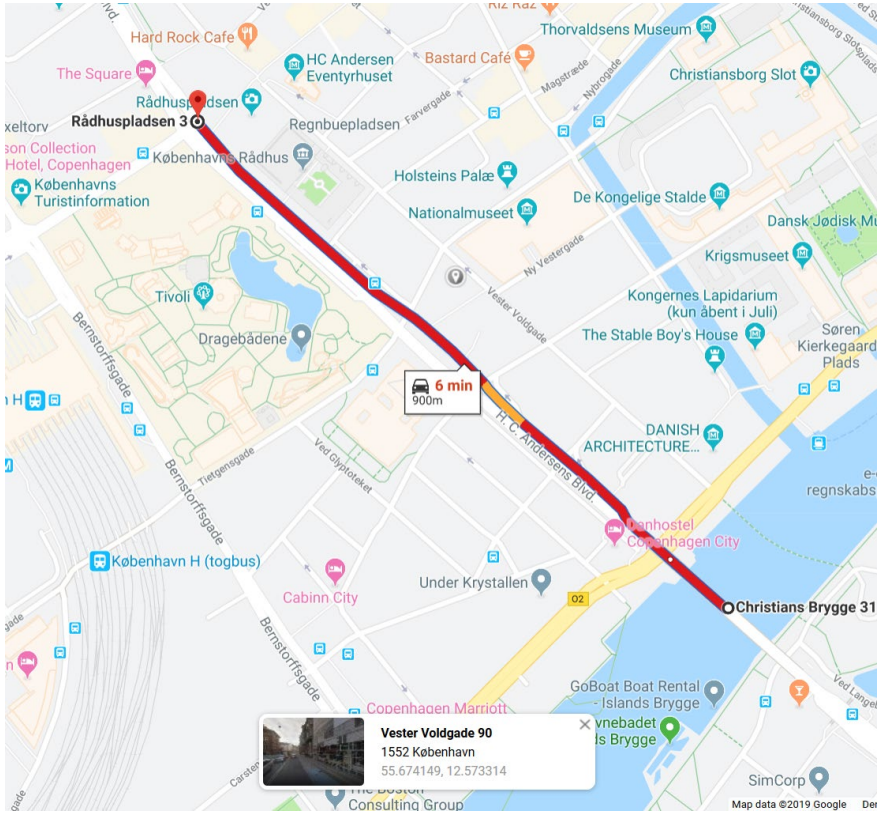
- Trajectory-based travel time
  - Why not single-segment based?
- Point-based versus trajectory-based travel-time
  - Does it matter?
  - A short comparison to induction-loop data
- Fuel consumption
  - Estimated from high-frequency GPS data
  - Real consumption from CANbus/OBDII data

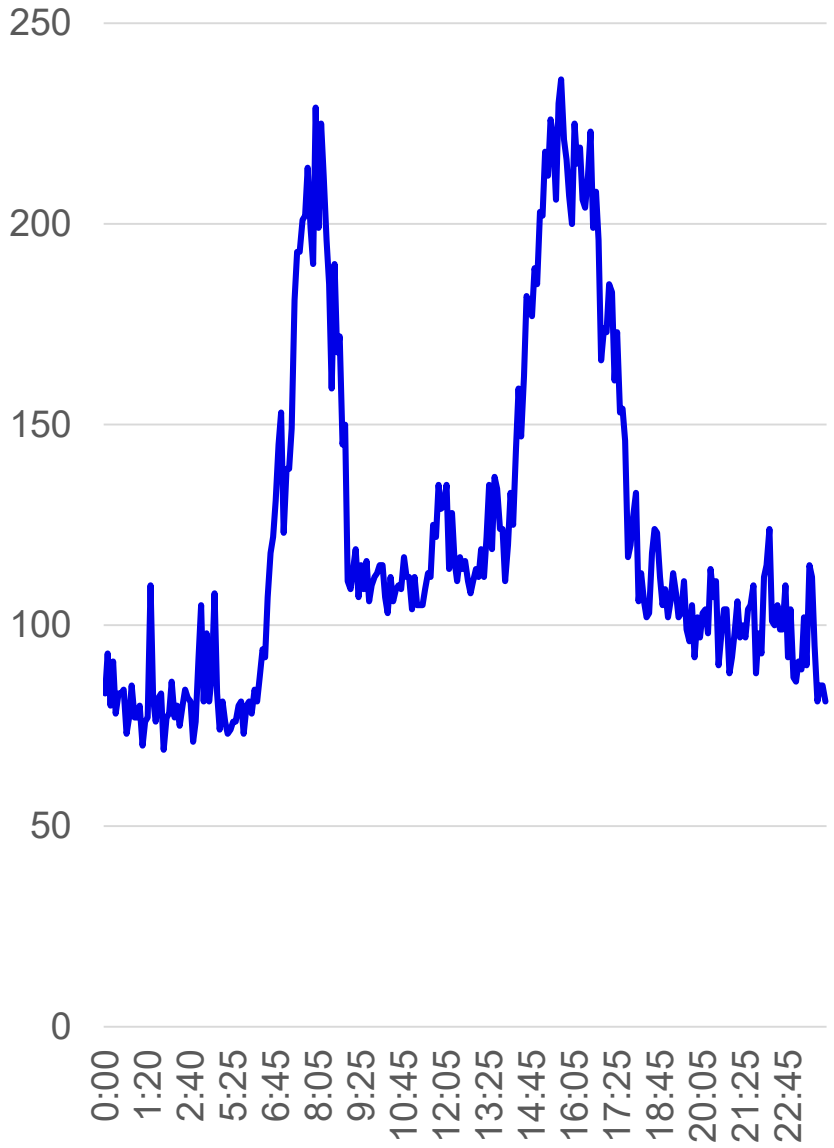
Trajectory-Based Travel Time

2020: Trip Count, Denmark



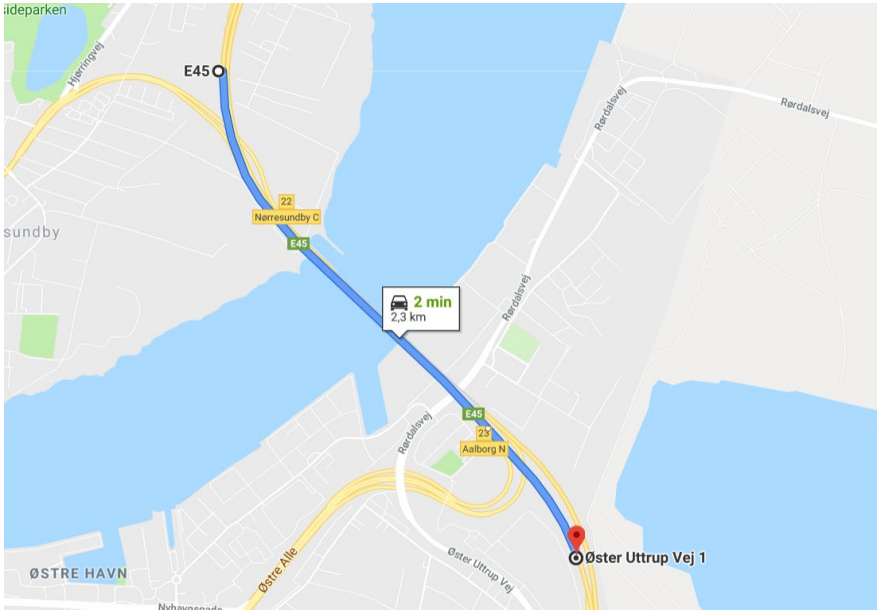
CPH: Langebro-Rådhuspladsen

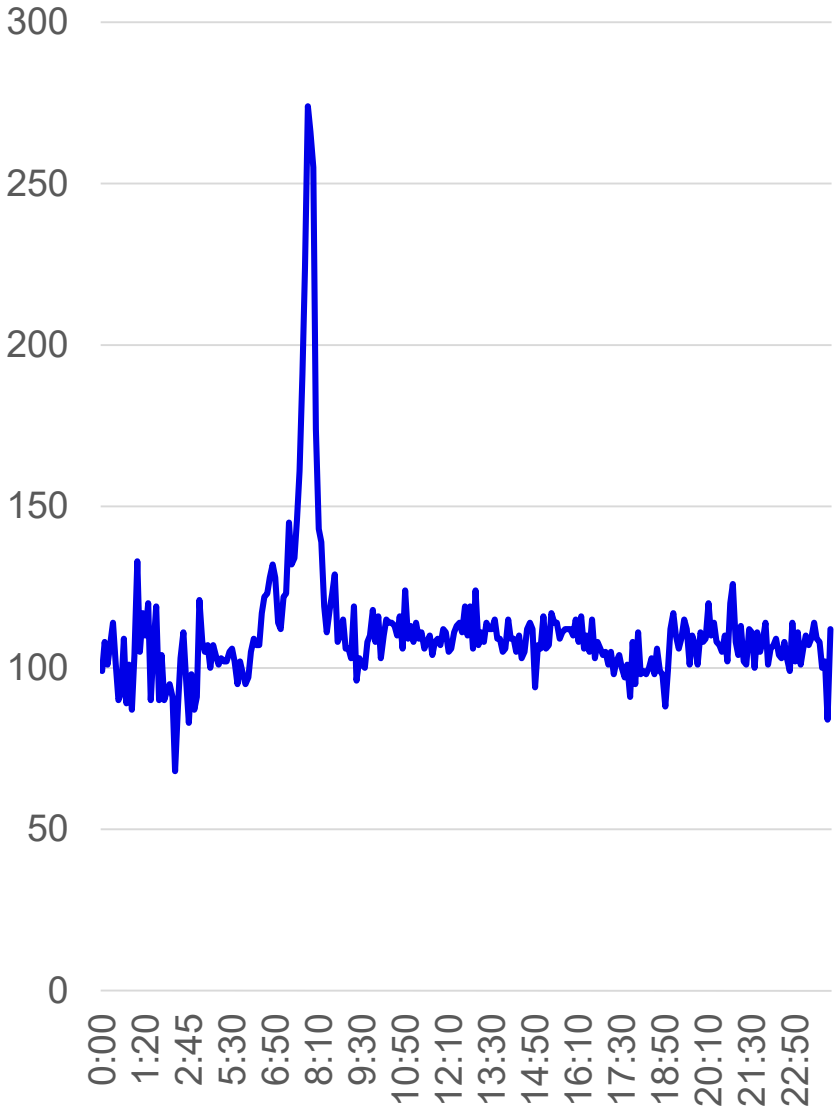




- Workdays
- 5 minutes resolution

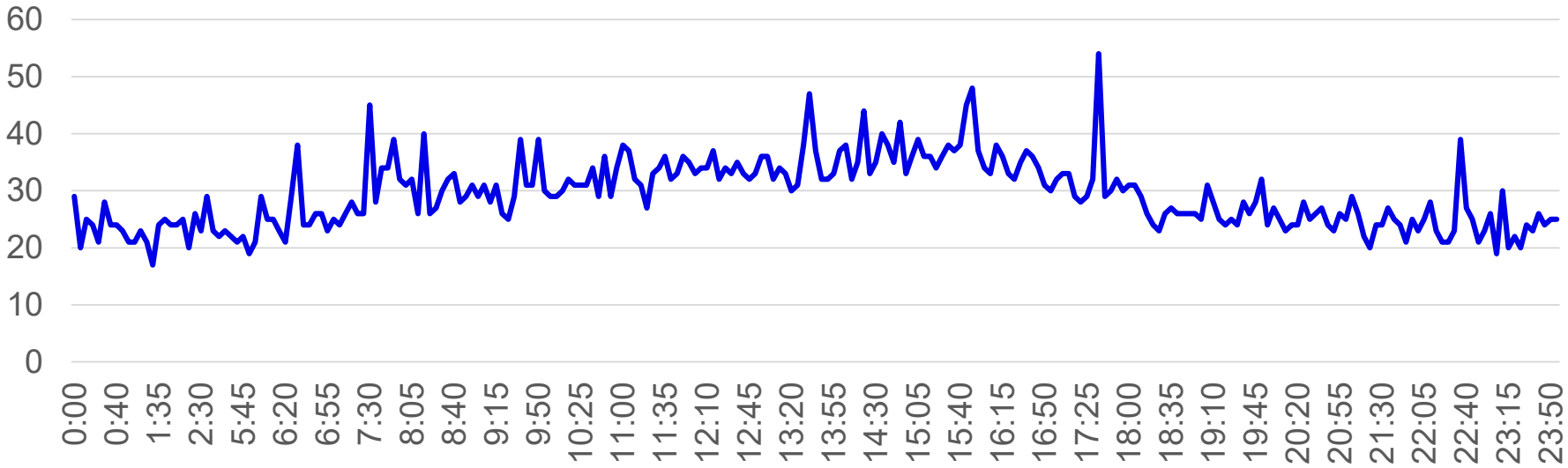
Aalborg: Travel-Time: Limfjordstunnel





- Workdays
- 5 minutes resolution

Svendborg (~27K Inhabitants)

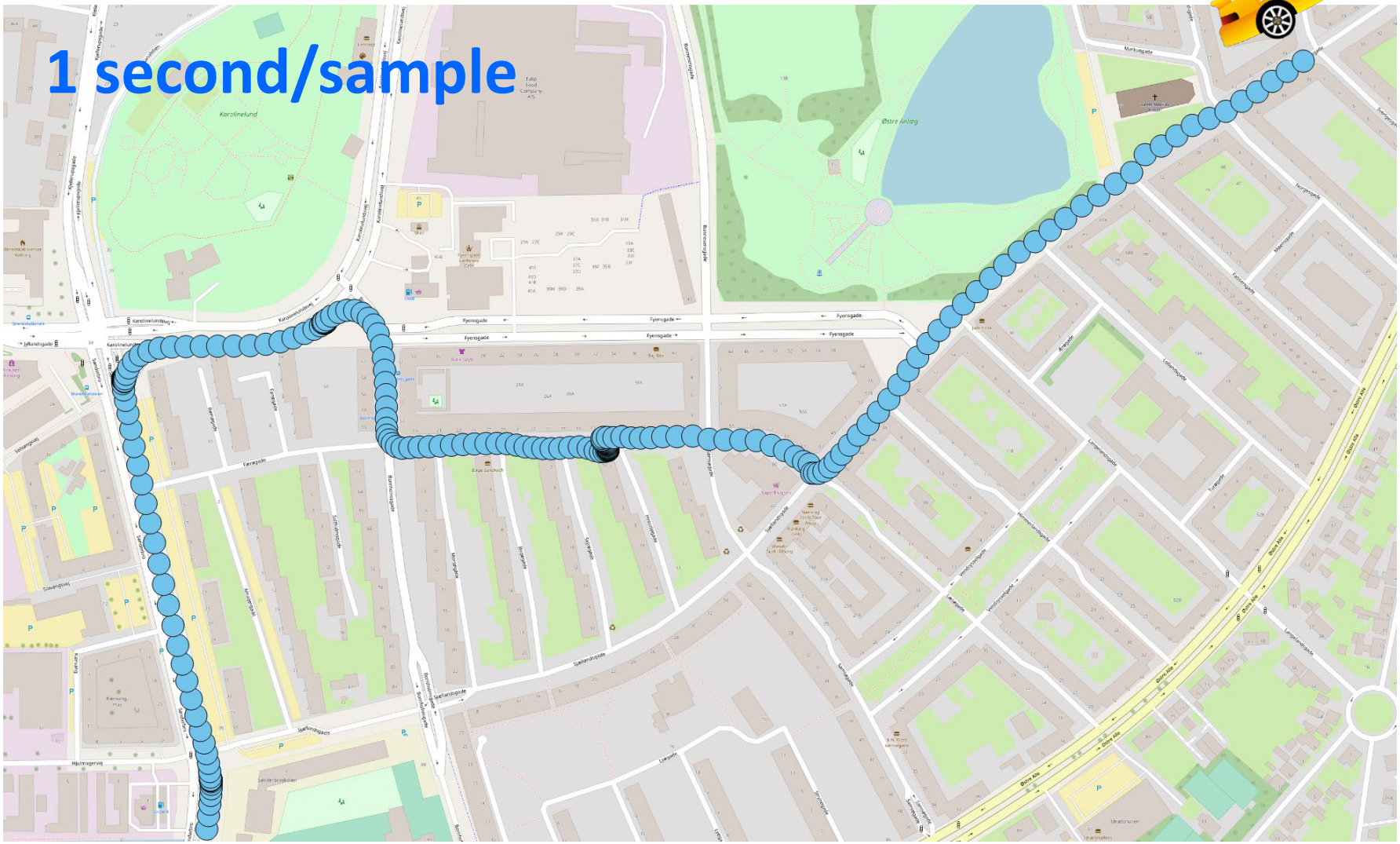


Summary: Trajectory Travel-Time

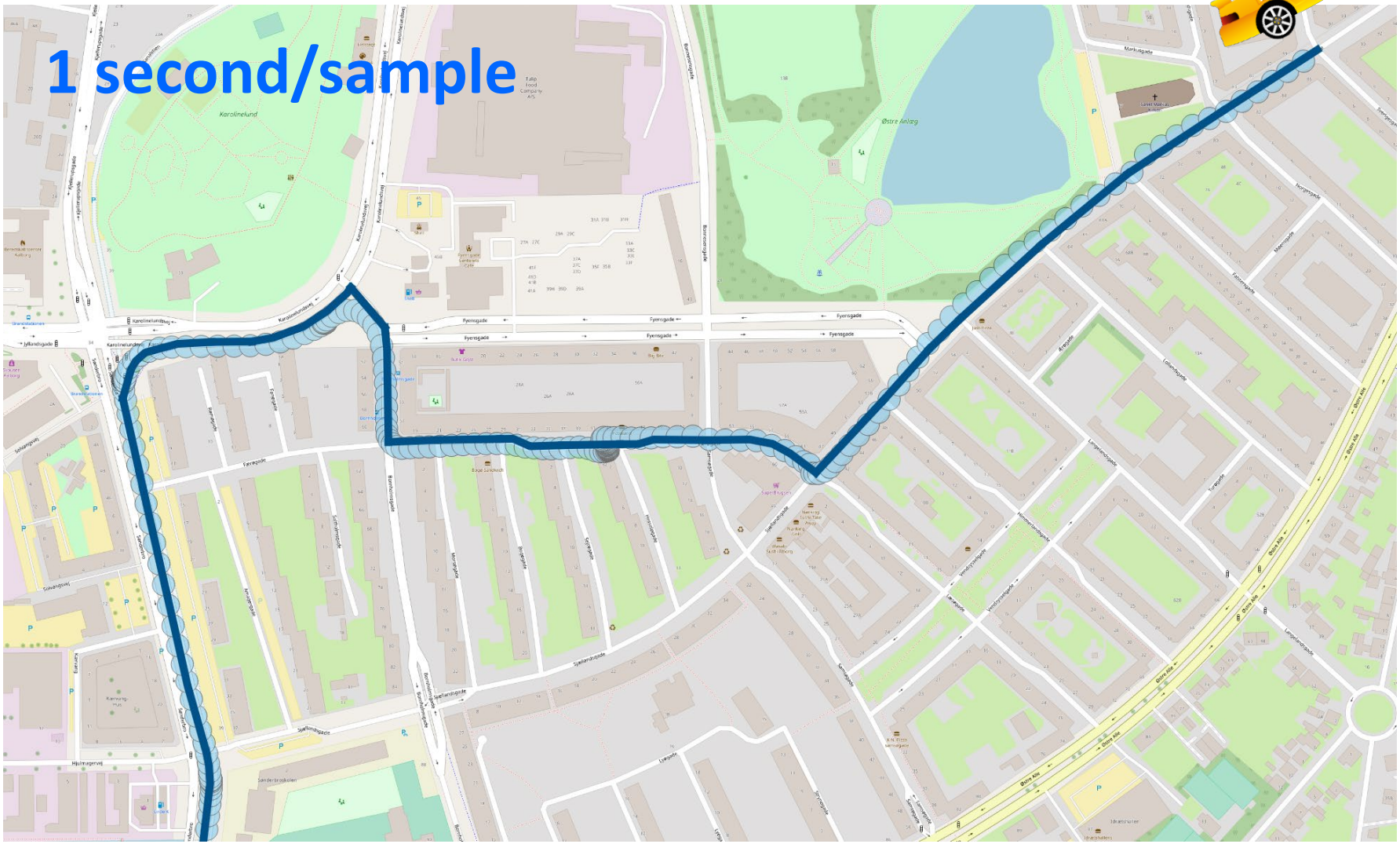
- Ground-truth = trajectory-based travel time A to B (!/?)
- Trajectory data gives insight on a sequence of segments
  - Through a city, a tunnel
  - Turn-times in intersections and round-abouts
- High-frequency GPS data is needed
  - <10-20 seconds data, we like 1-second data
  - Partners: ”This is too expensive!” (communication, storage, query)
- Limitations of our approach
  - Careful in areas with limited data
  - We use a road-segment level granularity (extremely efficient)
  - Partners requests putting start/end any place on the map
  - ... (properly something I am blind to ☺)
- GDPR is a major issue
  - Learn to live with it!

Point-Based versus Trajectory-Based Travel Time

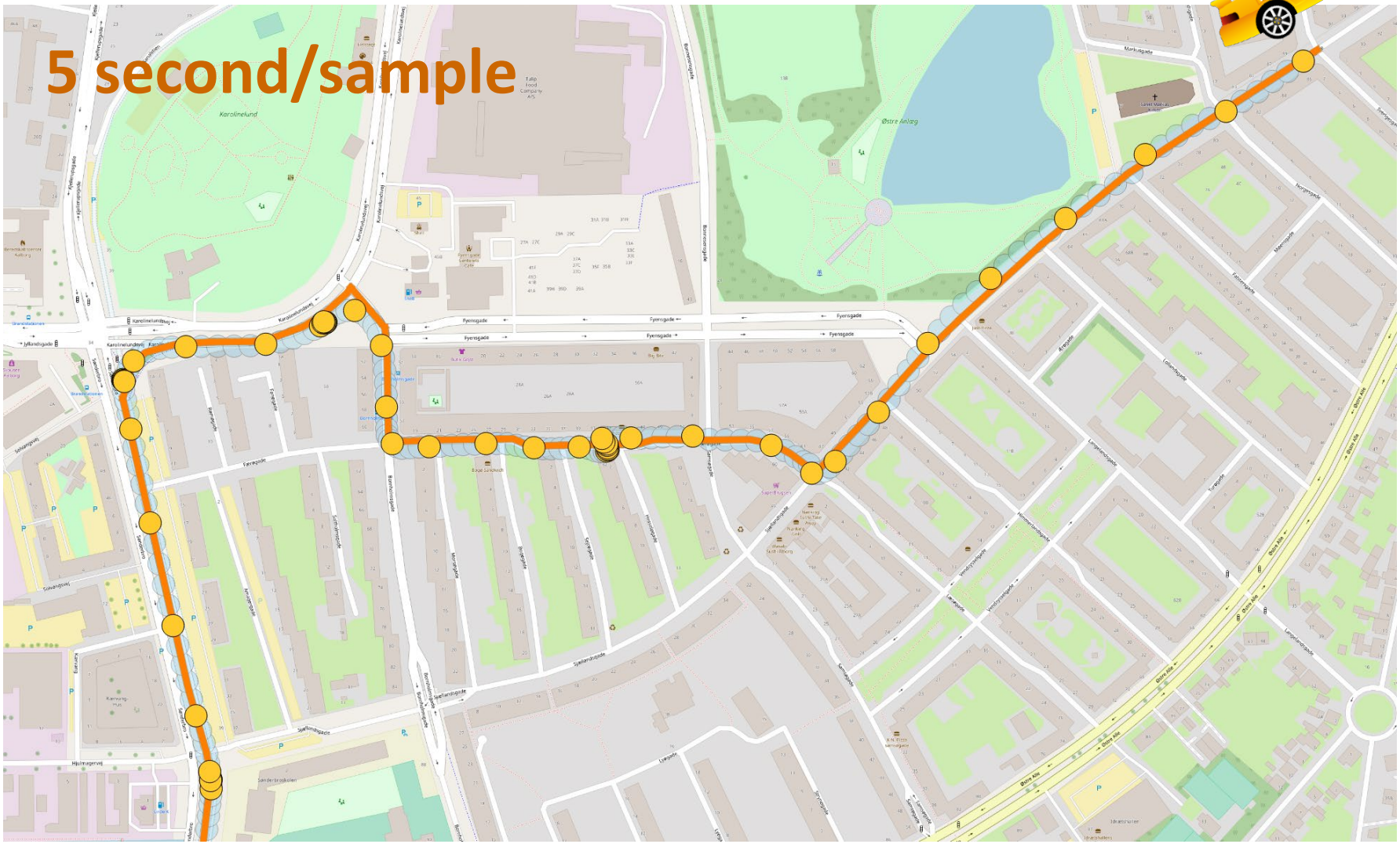
1 Second (1Hz) GPS Data



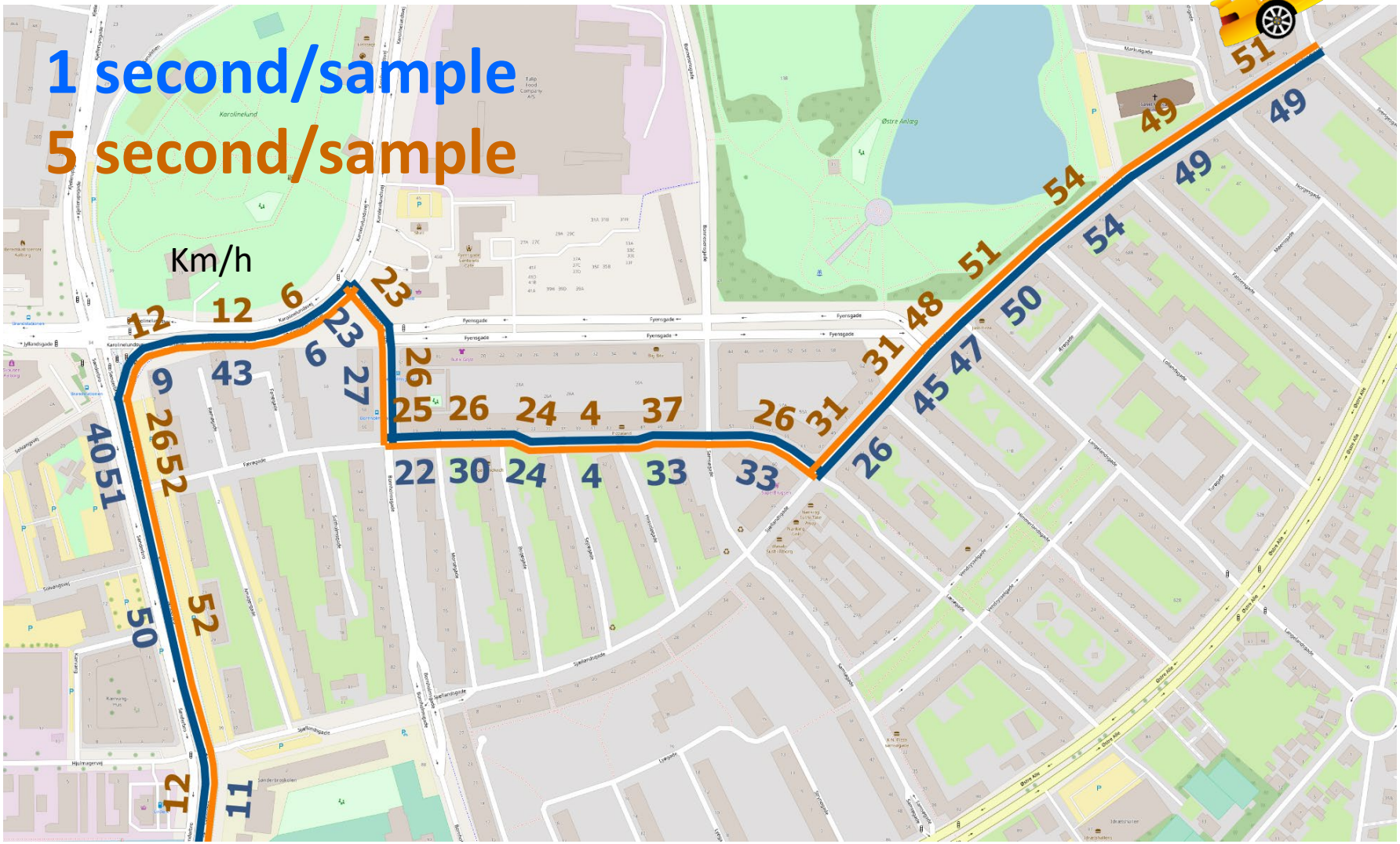
1 Second Trajectory



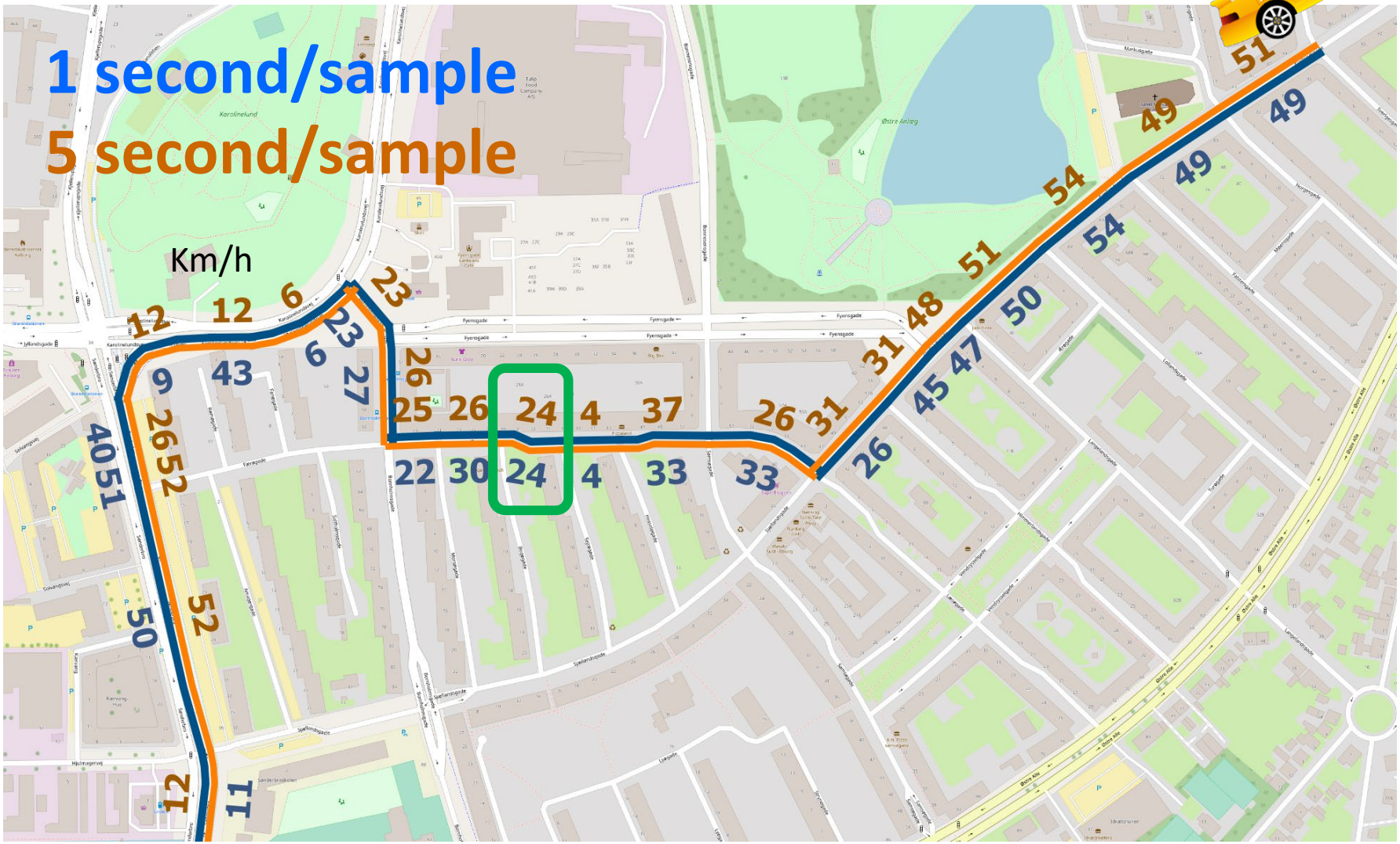
5 Seconds GPS Data/Trajectory



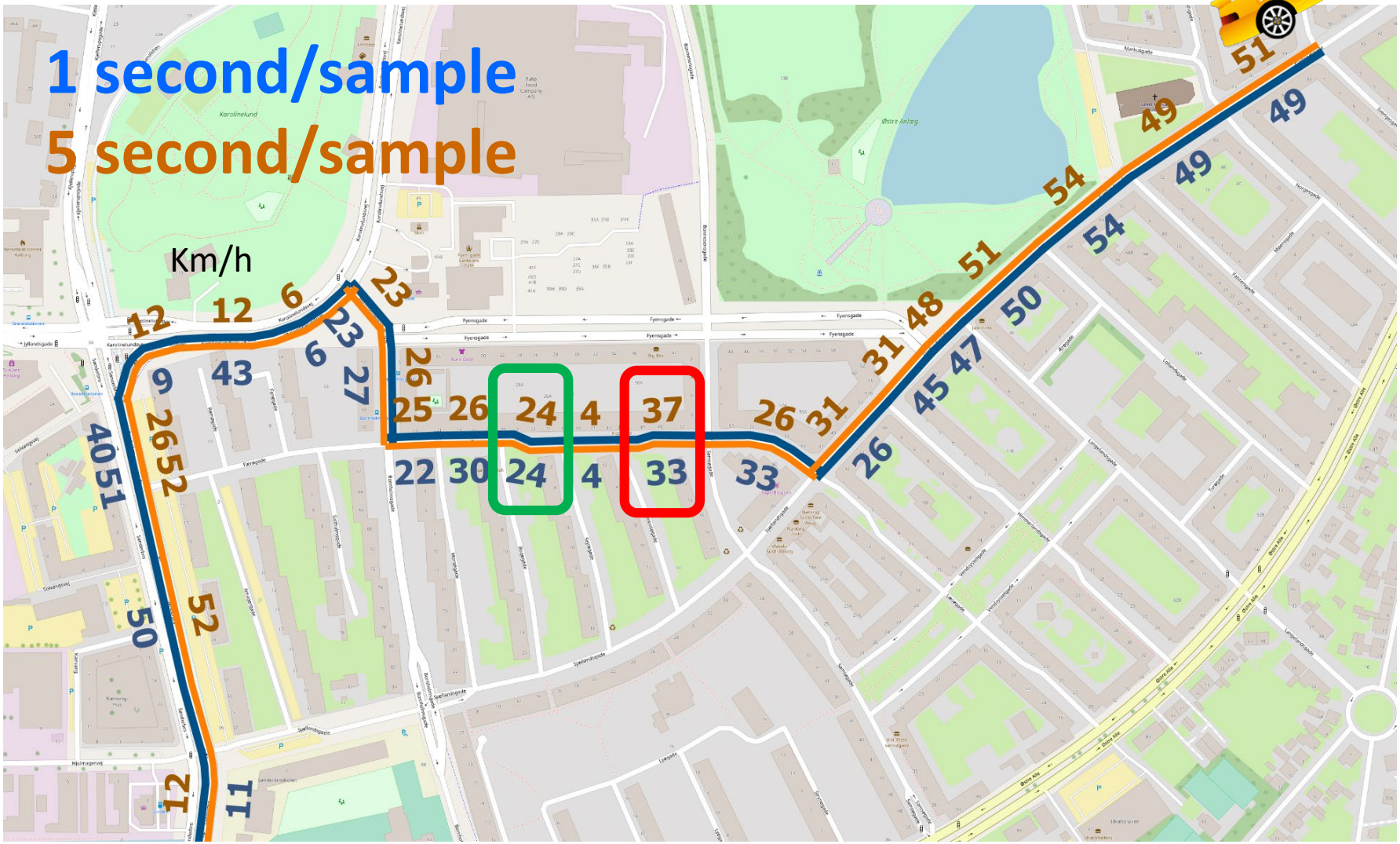
1 vs 5 Seconds – Computed Speeds



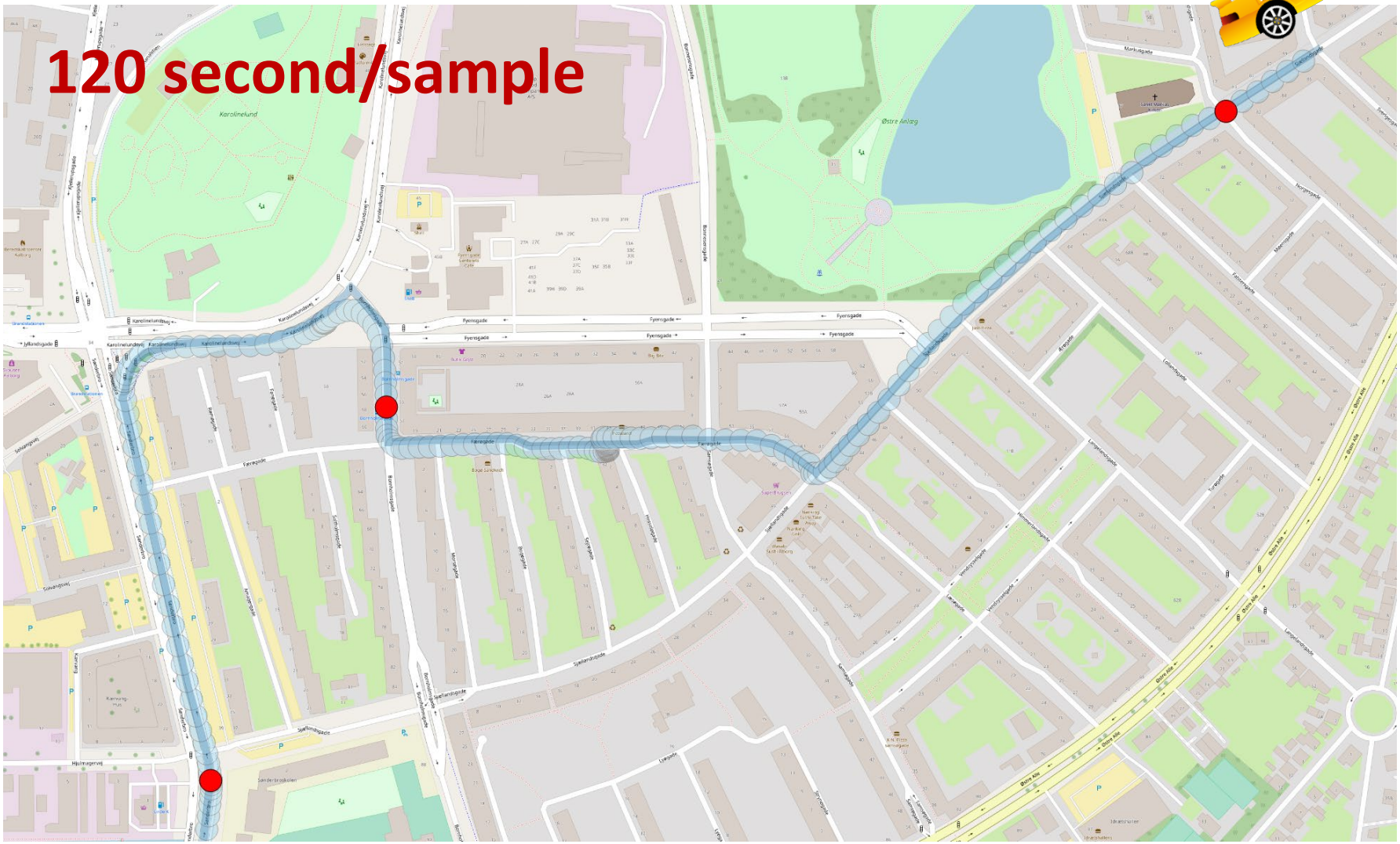
1 vs 5 Seconds – Computed Speeds



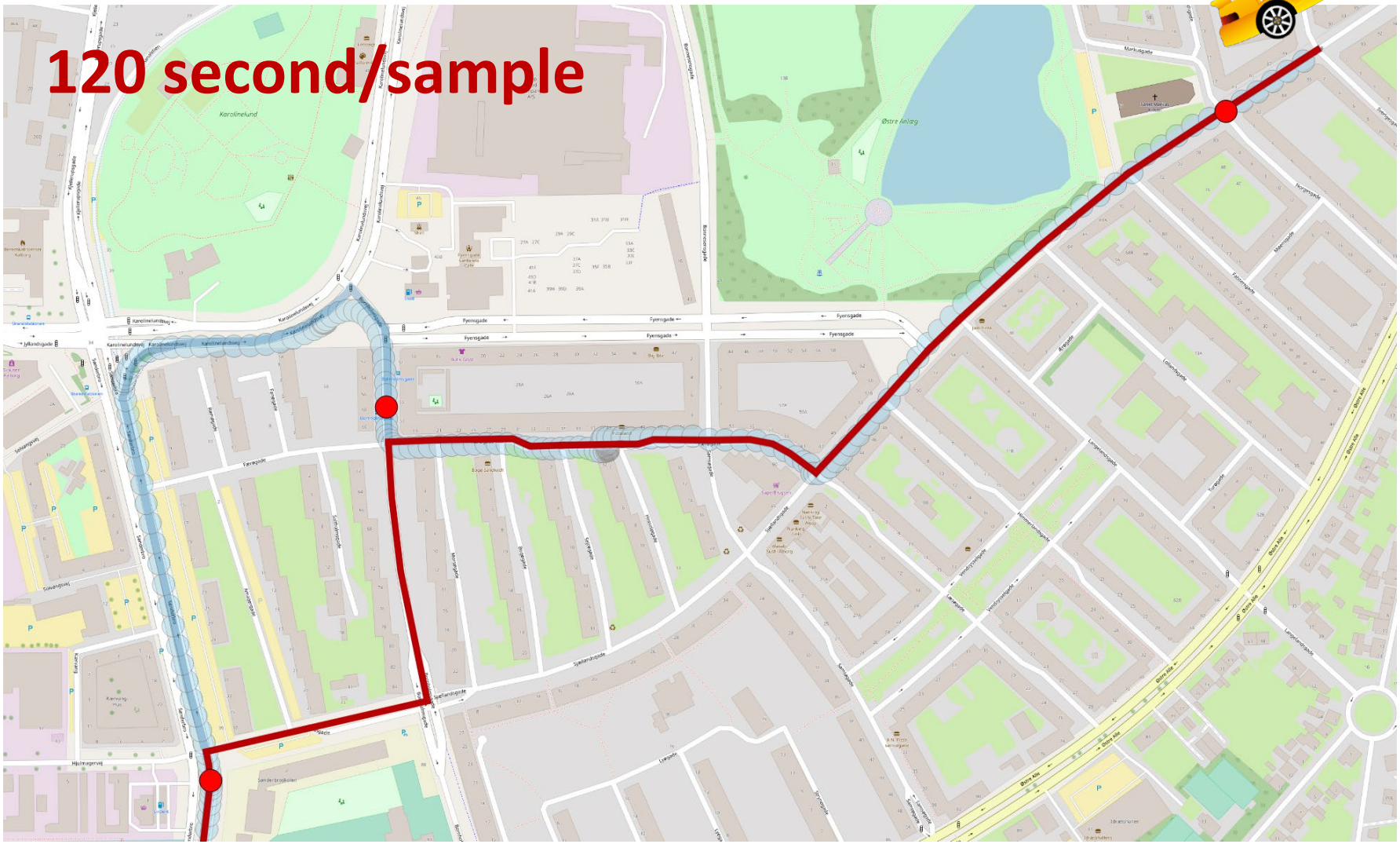
1 vs 5 Second – Computed Speeds



120 Seconds GPS Data

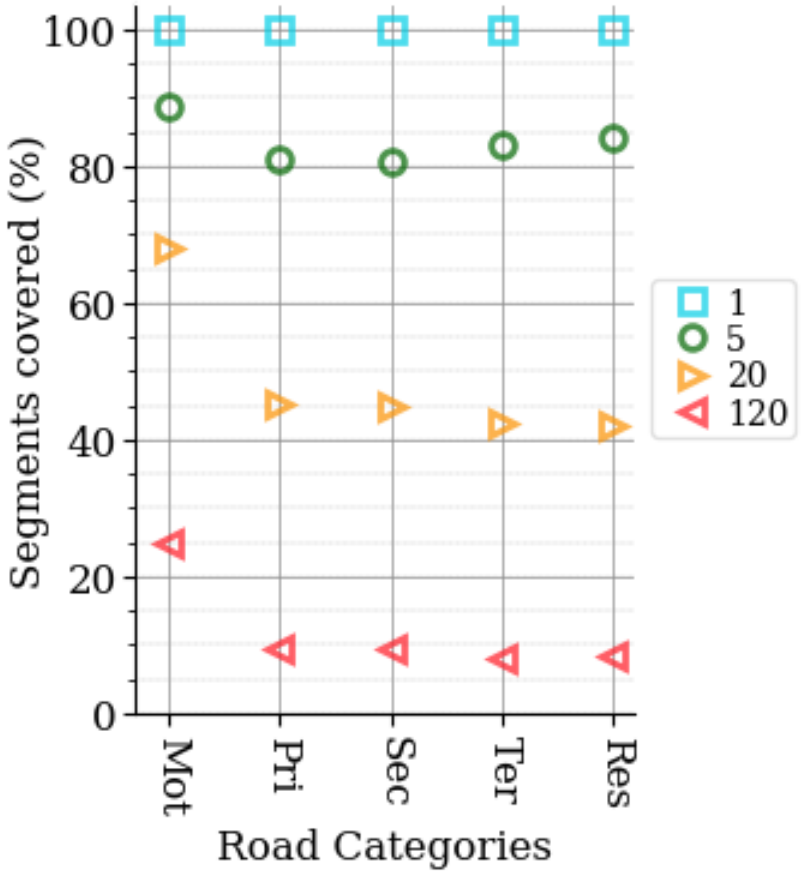


1 vs 120 Second - Wrong Trajectory

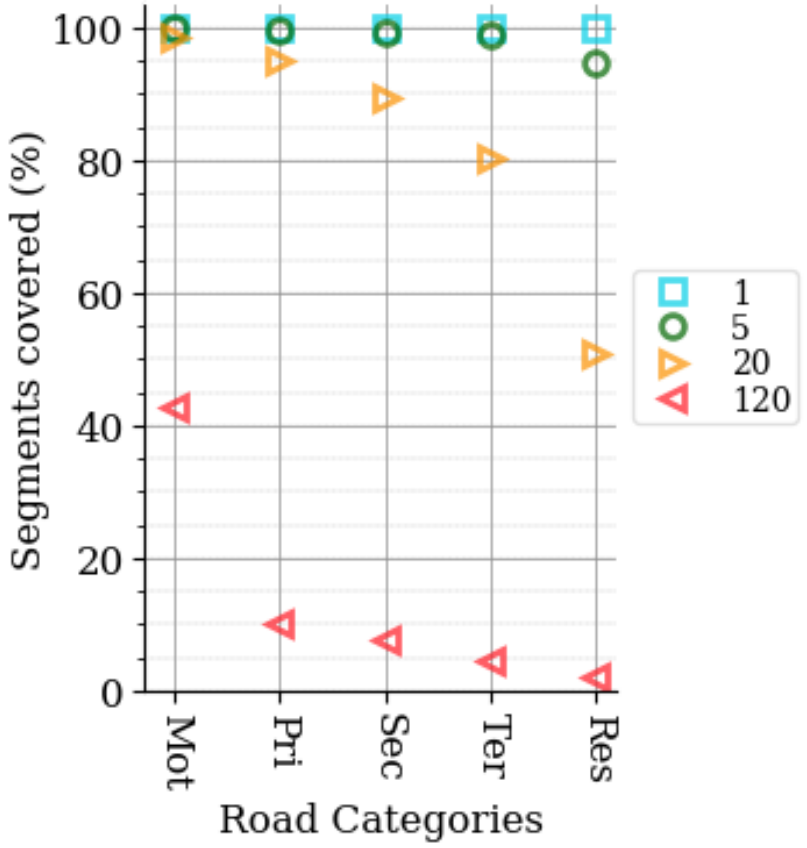


Road-Segment Coverage

Point Based



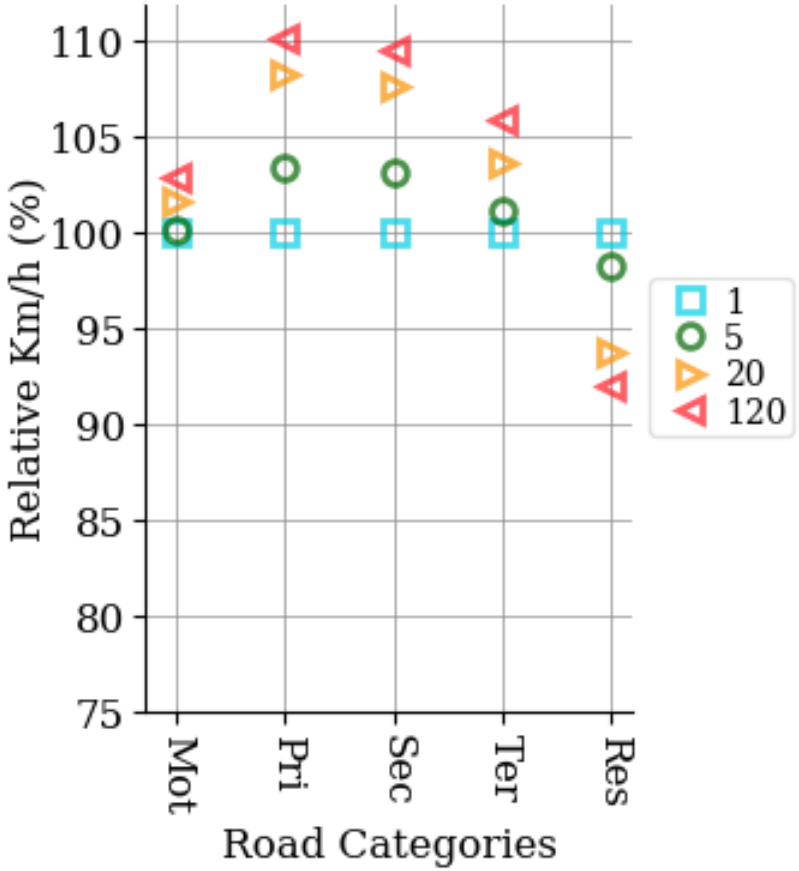
Trajectory Based



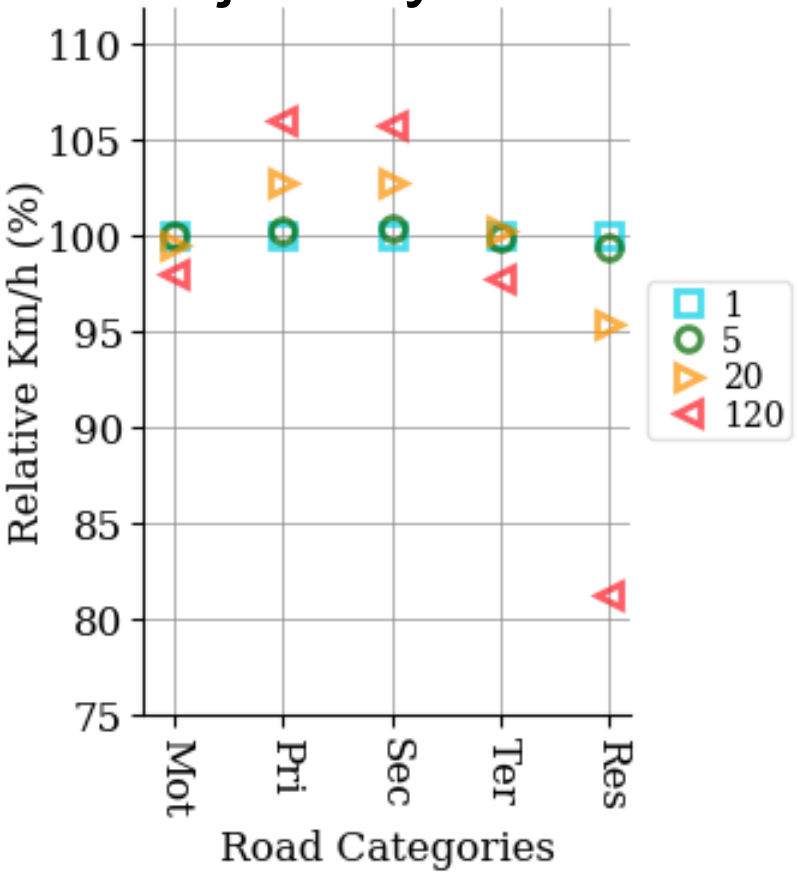
- Point based coverage quickly drops
- Trajectory based worse using 120-second data

Travel Time

Point Based

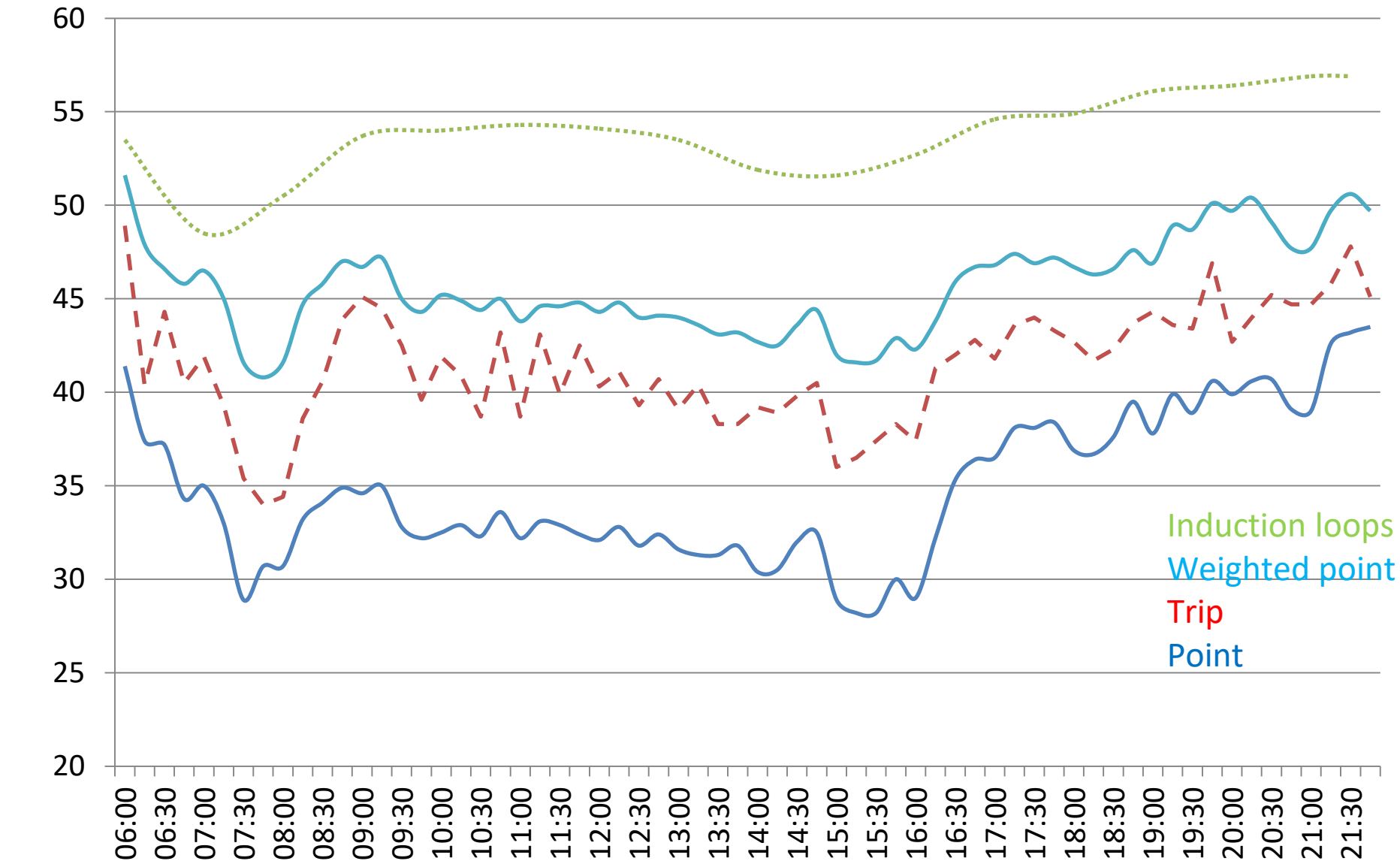


Trajectory Based



- Point based up to 3% off using 5-sec data
- Trajectory based has problems with 120-sec data

Østre Allé (ring 2), Aalborg, Denmark



Fuel Consumption

Introduction: Fuel Consumption

- Focus on reducing fuel consumption and emissions
  - SDG 11
- Limited knowledge about fuel consumption?
  - Very limited datasets available
- Estimated fuel consumption from GPS
  - We have a lot of it
  - How accurate is it?
- Which factors affect fuel consumption?
  - Elevation, weight, weather, wind, temperature etc.

Fuel Consumption Models

- Different models with different features
  - Instantaneous consumption vs aggregated
    - Second by second or a per trajectory
  - Absolute consumption versus arbitrary measure
  - Road grade or no road grade

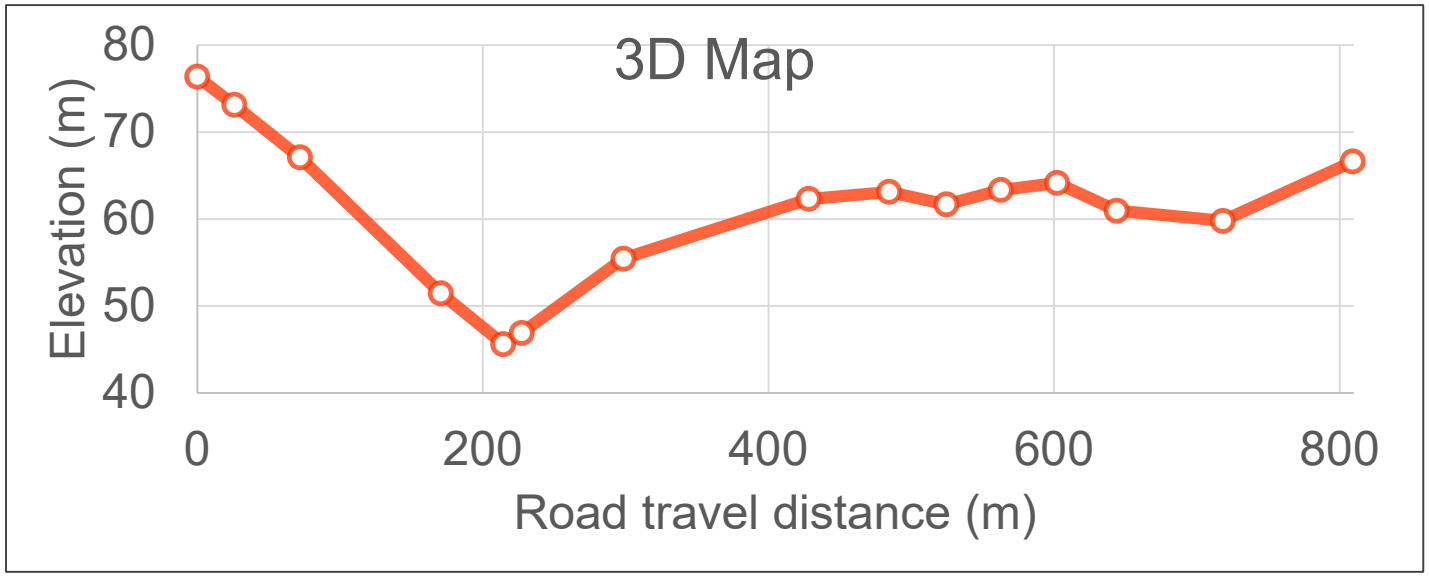
- SIDRA TRIP fuel consumption model
  - Operating cost, fuel consumption, and emission models in aaSIDRA and aaMOTION [Akçelik and Besley, CAIRT '03]
  - Absolute second-by-second fuel consumption estimates in *ml/s*
  - Takes into consideration road grade

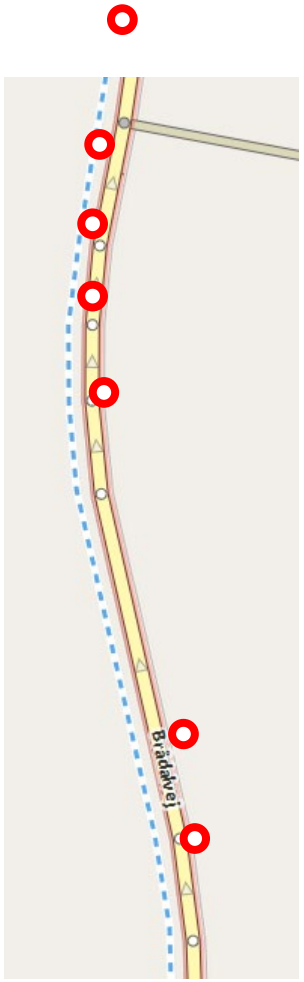
Data Foundation

- GPS
  - 1Hz including instantaneous fuel consumption
  - Millions of km of driving in Denmark
- CANbus
  - 1Hz GPS/CANbus
  - ~43K km of driving in Denmark
- OpenStreetMap Road Network of Denmark
  - 2 million edges
- Digital Elevation Model of Denmark
  - 2.6 million 100x100 raster tiles
  - 10 meter resolution
- Weather Data
  - NOAA hourly historic weather archive

Elevating Road Network (3D)

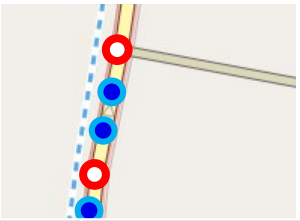
- Method: Map match GPS data and elevate road network
  - Elevate every existing connection point in road network with DEM
- 3D road network (3D map)
- Quality dependent on resolution of points in the road network

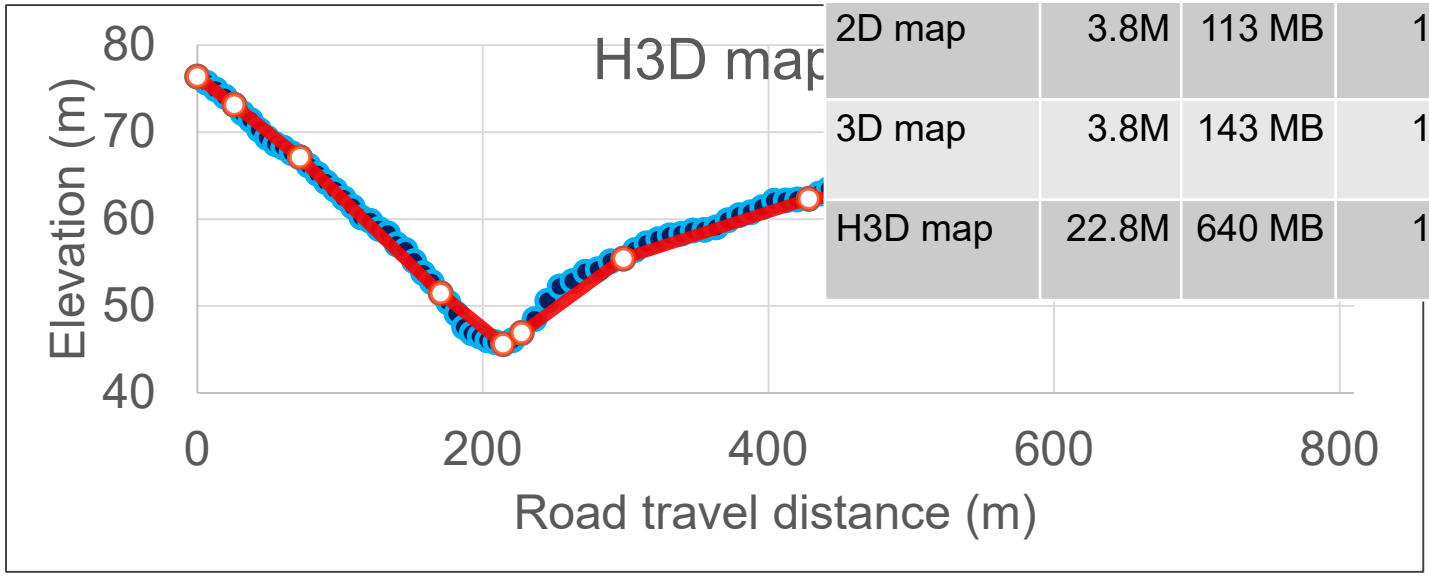




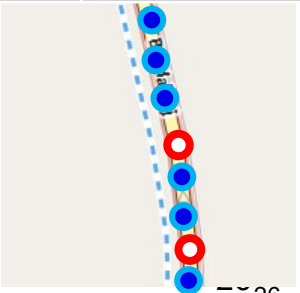
Elevating Road Network (H3D)

- Method: Split and elevate road network
  - Elevate every 10 meter of road network with DEM
- High-precision 3D road network (H3D map)
- Independent on map resolution

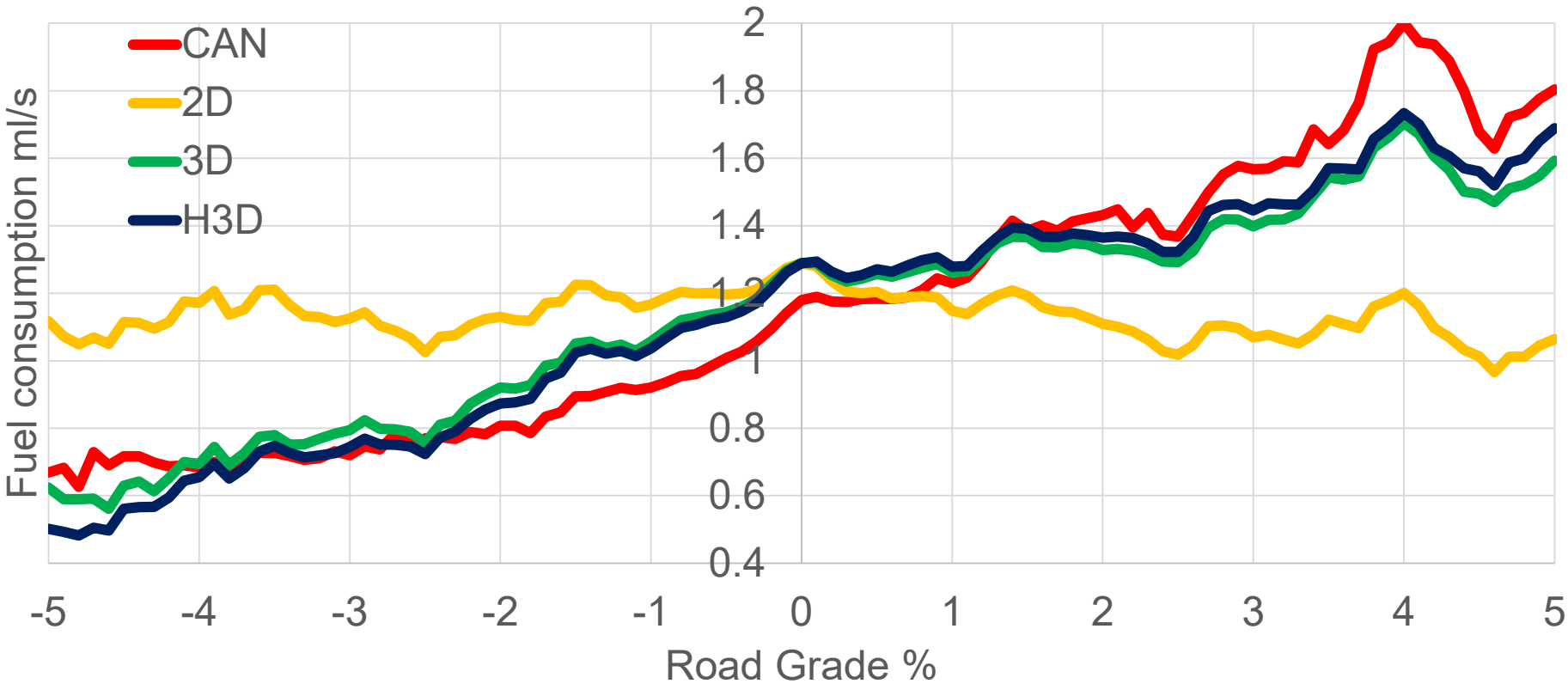




Denmark	Points	Size	Roads	Query speed
2D map	3.8M	113 MB	151 253 KM	1.0x
3D map	3.8M	143 MB	151 289 KM	1.0x
H3D map	22.8M	640 MB	151 291 KM	2.2x



Road Grade's ~ Fuel Consumption



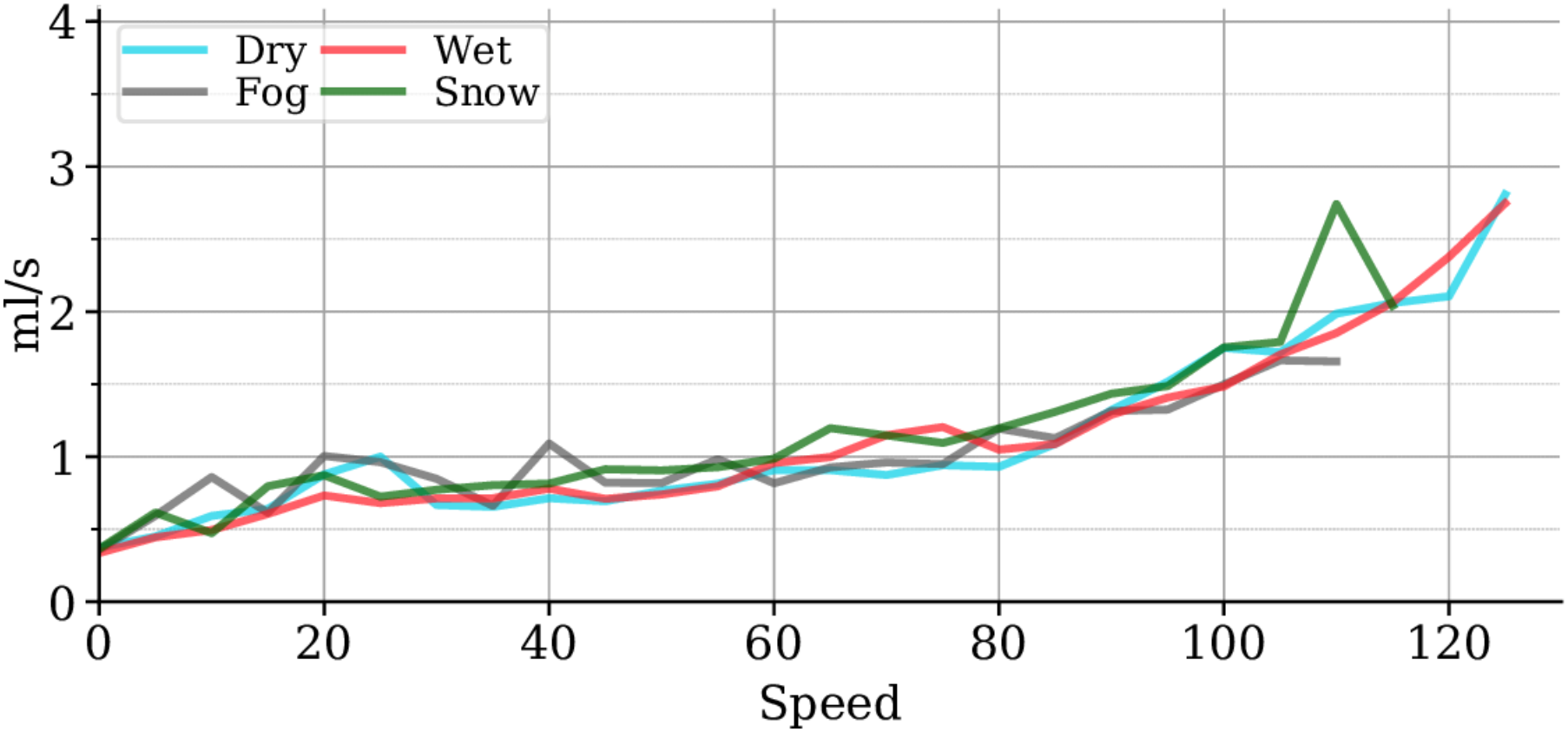
- 2D not suitable (even in Denmark)
- H3D slightly more accurate than 3D
  - Not worth the extra effort

SIDRA Trip Evaluation: Single Vehicles

Citroën C4	Measured [ml/s]	2D Map %	3D map %	H3D map %
All data	0.97	96%	97%	97%
Constant speed	1.28	99%	100%	100%
Accelerating	1.37	106%	110%	109%
Decelerating	0.55	76%	76%	77%
Driving uphill	1.43	63%	78%	77%
Driving downhill	0.54	170%	132%	134%

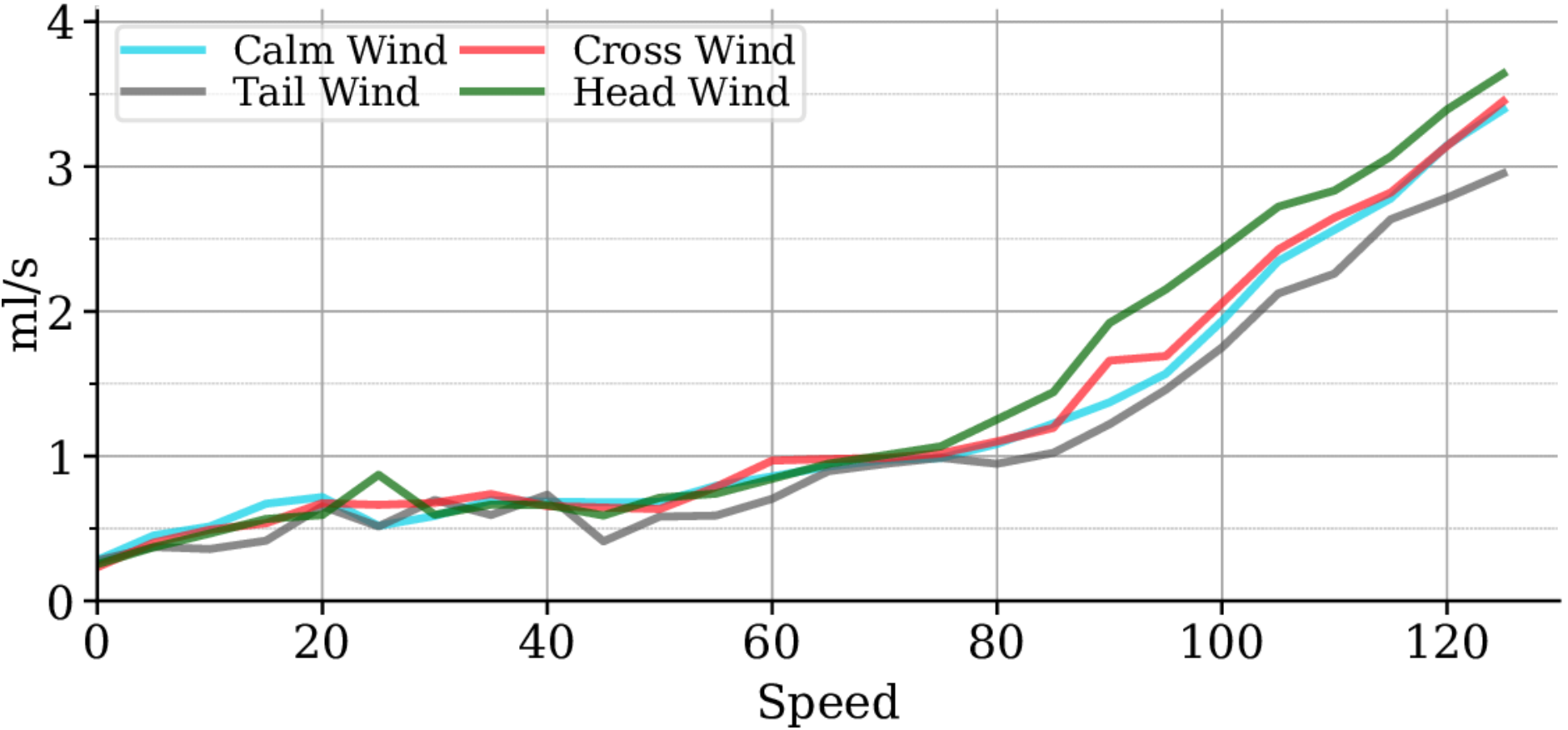
Peugeot 206+	Measured [ml/s]	2D Map %	3D map %	H3D map %
All data	0.99	95%	98%	98%
Constant speed	1.44	98%	98%	98%
Accelerating	1.63	102%	103%	103%
Decelerating	0.41	76%	76%	77%
Driving uphill	1.39	66%	89%	88%
Driving downhill	0.65	143%	96%	98%

Weathers and Fuel Consumption



- Fog and snow indicates a slight increase in the fuel consumption
  - Too little data?

Wind and Fuel Consumption



- Some wind impact above 70 km/h
- Speed much more important than wind!

Summary: Fuel Consumption

- Present a model for elevating road network
  - Evaluates on 2D, 3D, High-precision 3D map
- Hard to accurately estimate the fuel consumption from GPS
  - Even though the model has been calibrated to the individual vehicles
  - Constant speed and accelerations fairly accurate
- Different vehicles yield different model performance
  - Performance of fuel consumption model varies across different vehicles
- Other factors affecting fuel consumption
  - Weather and temperature is related to fuel consumption
  - Wind is related to fuel-consumption estimation/usage
    - Not incorporated in the fuel consumption models!

Summary: Overall

- GPS data good source of information about traffic
- Integration of GPS data with other data sources
  - Spatial/temporal integration point
- The sampling period of GPS data is important for travel-time
  - Huge differences 1-second versus 120-second data

- New topics for the Daisy Research Group
  - Energy source: Electric vehicles (EVs)
  - Vehicles types: Today mostly person cars, trucks and bicycles
  - Data types: Induction loops and weather
  - From mostly batch to near real-time processing

- We are open for collaboration

Thank you for your attention!