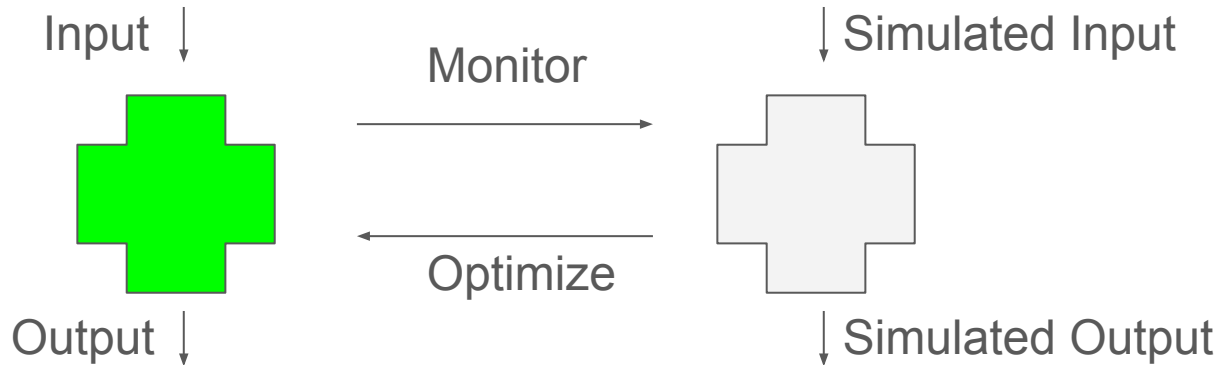# Data-Driven Digital Mobility Twins

Mahmoud SAKR

LocalRec@SIGSPATIAL23
November 2023 Hamburg

Digital Twins

- A concept that originated in the manufacturing industry.
- A digital replica of an industrial component: motor, cooling system, etc
- The physical device is monitored by sensors, which copy the state of the device to the digital replica
- The digital replica serves for observing the device and for "digitally first" simulations

Input ↓   ↓Simulated Input

           Monitor
           ──────────────→

           ←──────────────
           Optimize

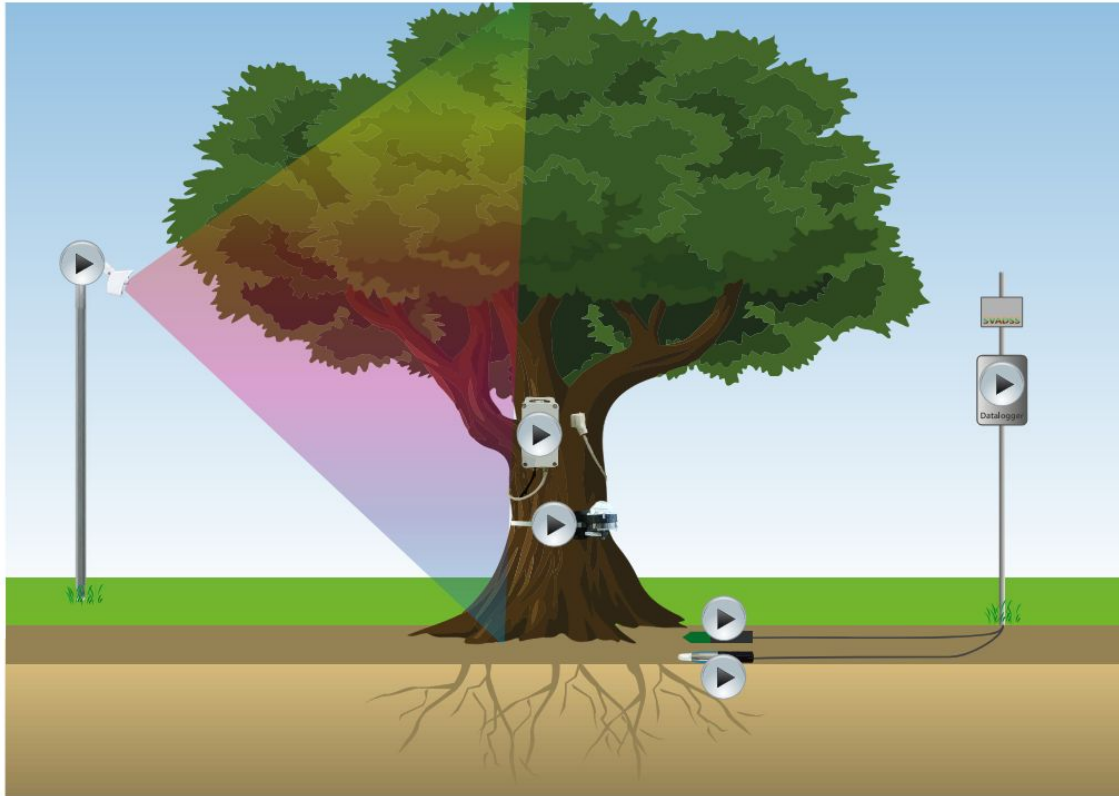Output ↓   ↓Simulated Output

SNCB Remote Diagnostic

- Automatic data collection
  - Onboard data sources:
    - Traction converters
    - Doors
    - HVAC
    - ETCS equipment
    - …
  - External data(still within the SNCB):
    - Databases
    - API's
    - ERP

  ➢ Track & optimize asset performance

Traction converters
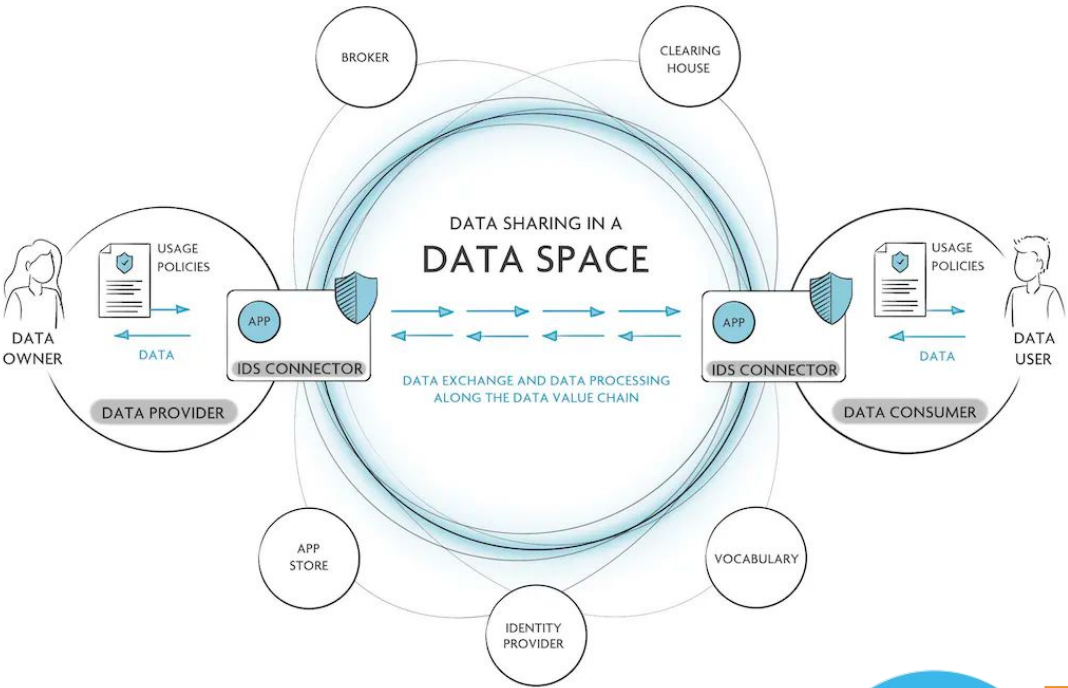
Pantograph

ETCS

Doors

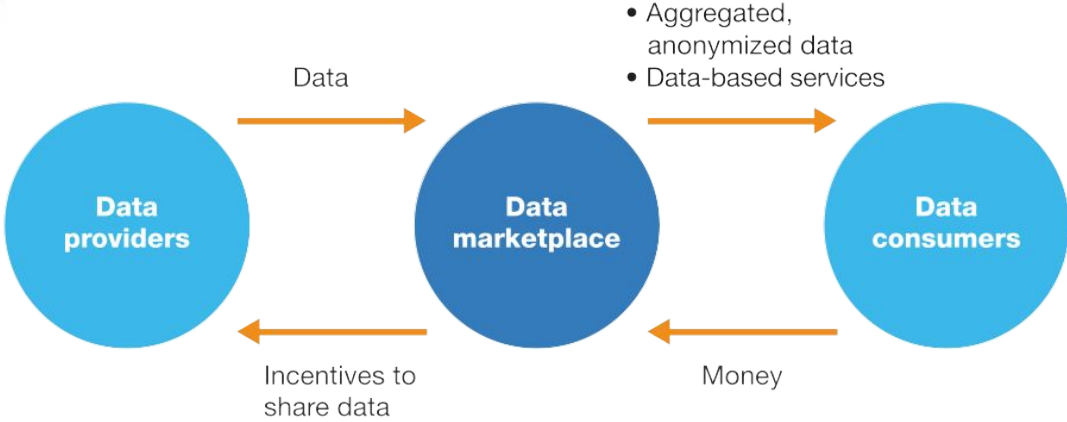HVAC
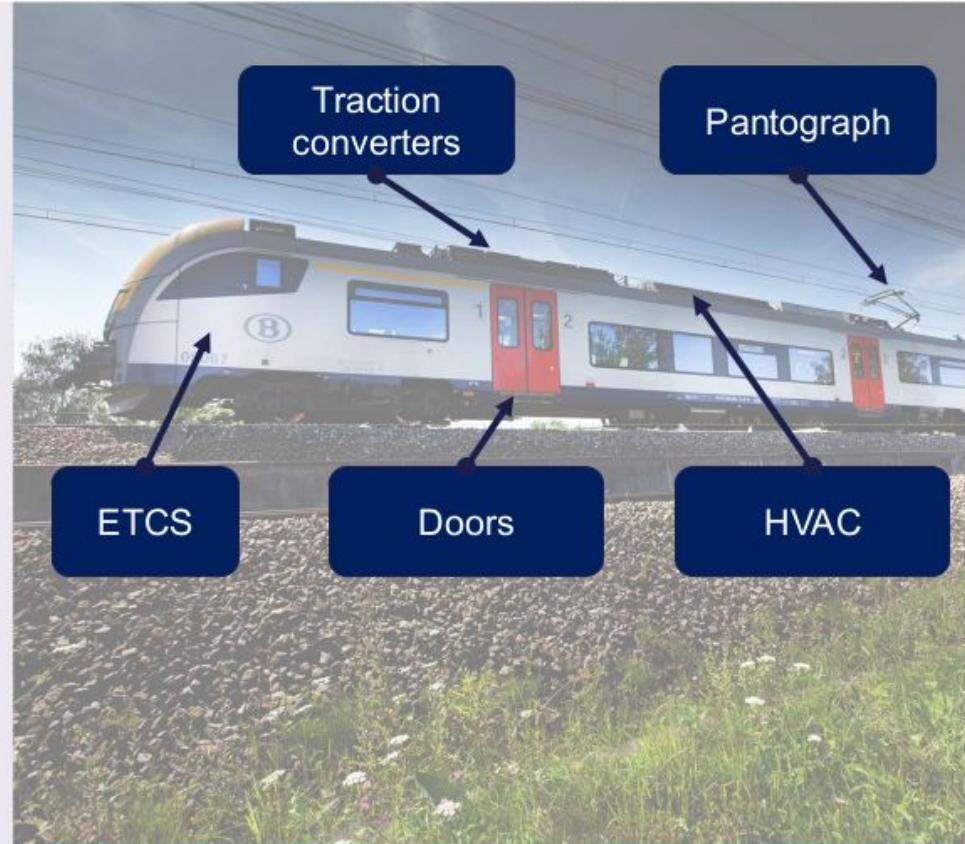
Berti - the talking tree in Ulm

Data-Driven Mobility Digital Twins
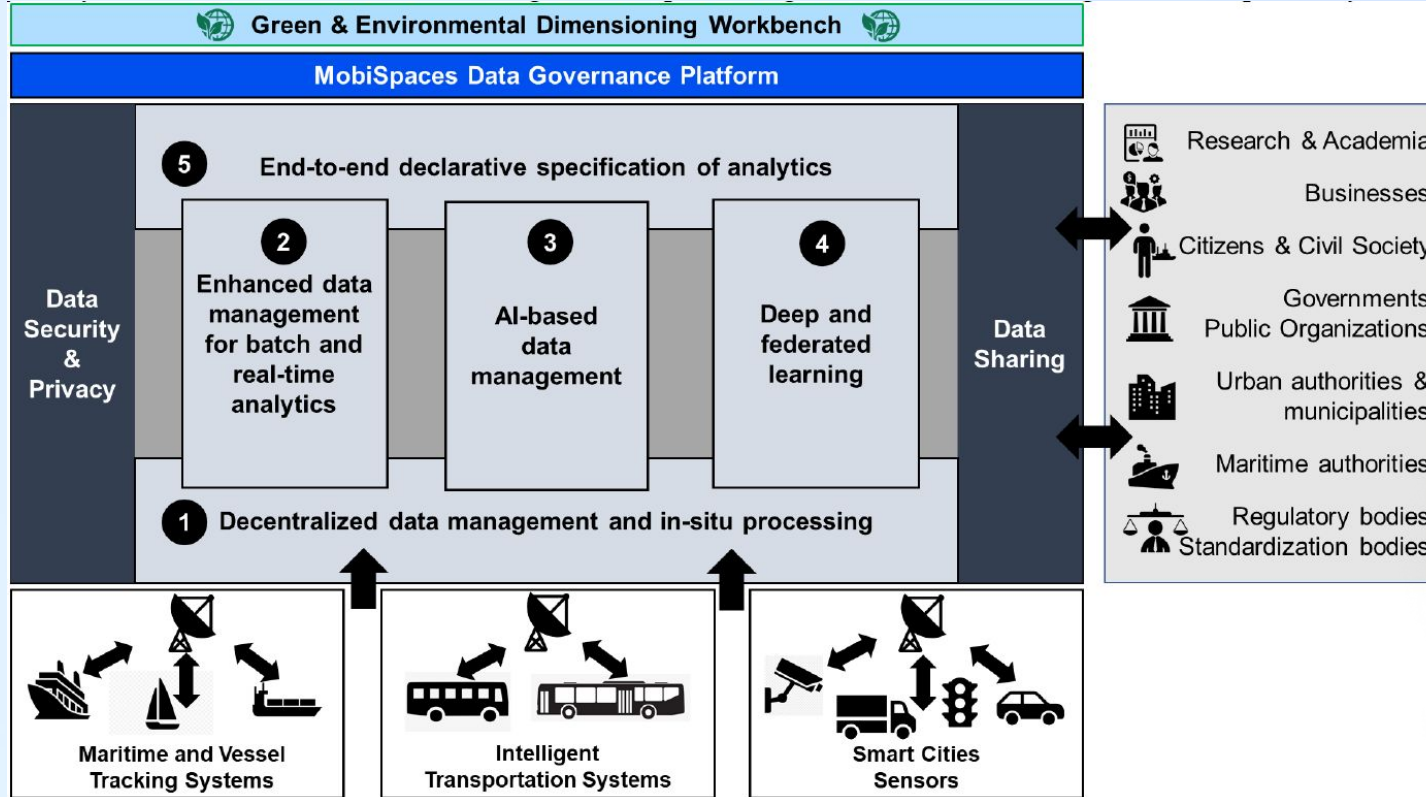
- Urban mobility is not a mechanical system
- But there is a lot of data that can help monitoring
- By combining several sources, visualizing, enriching, fusing, …:
  - Problems can be identified
  - Opportunities might emerge
  - Situational awareness can be improved
  - Recommendations can be made for decision making
  - Data collaboration can be encouraged
  - Synergies may be reached
  - …

Related Concepts

DATA SHARING IN A
DATA SPACE

DATA EXCHANGE AND DATA PROCESSING
ALONG THE DATA VALUE CHAIN

BROKER
CLEARING HOUSE
APP STORE
VOCABULARY
IDENTITY PROVIDER

DATA OWNER
USAGE POLICIES
DATA
IDS CONNECTOR
APP
DATA PROVIDER

USAGE POLICIES
DATA
IDS CONNECTOR
APP
DATA USER
DATA CONSUMER

© International Data Spaces

Data providers — Data → **Data marketplace**

- Aggregated, anonymized data
- Data-based services

Data marketplace → **Data consumers**

Incentives to share data

Money

McKinsey&Company

The Mobility Data Platform For Brussels

Unlock diverse, quality mobility data in Brussels for insights, planning, and innovation.

Register now | **Discover our API**
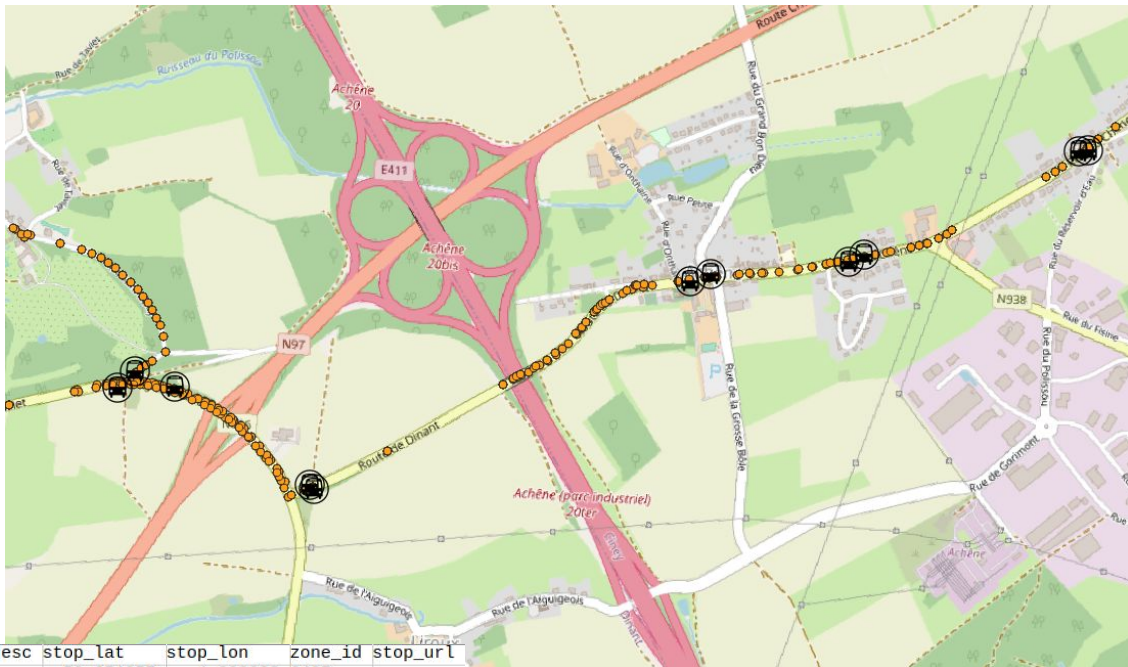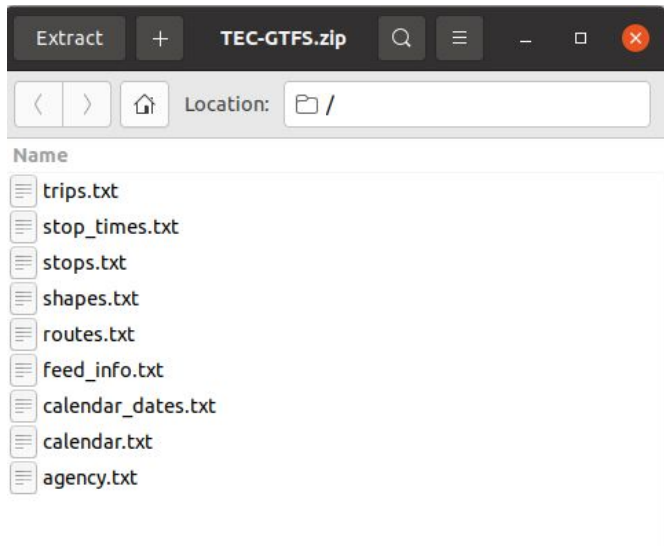
All the data you need in one place

Access diverse, quality-assured mobility data in Brussels for insights, planning, and innovation. Explore real-time and historical data from various sources like public transport, micro-mobility, railway, traffic, and air-quality feeds. Power your data-driven solutions for optimized urban mobility.

Data in a Mobility Digital Twin

	Planned	Operational
Stationary Infrastructure	Public transport stops, road infrastructure	Temporary road changes, Temporary bus stop, short-term inductive loop, etc
Moving objects	Public transit schedules,	Traffic volumes, travel times, vehicle positions, weather information, air quality, noise road incidents

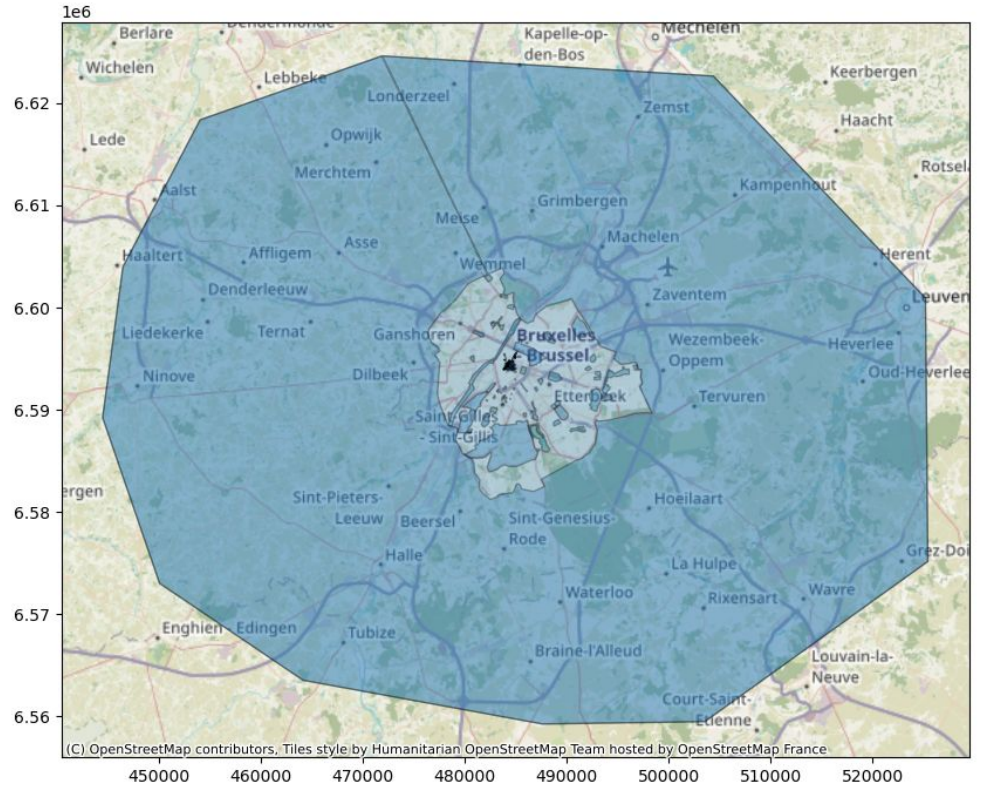**Table 1: A taxonomy of data in a mobility digital twin**

Maps & Static infrastructure - GTFS

Maps & Static infrastructure - Geofencing Zones

Besides GTFS, static map data
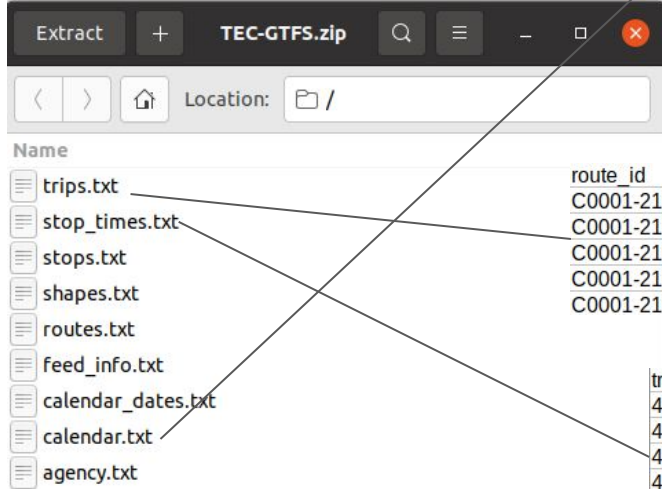typically exist in GeoJSON, Shape,
and CSV formats.

Map Conflation

- One challenge is that the different data sources might be using inconsistent base maps. Performing data Integration/fusion is not straightforward
- The figure illustrates the problem of computing a multimodal index
- Collaboration with Macq

Schedules

service_id	monday	tuesday	wednesday	thursday	friday	saturday	sunday	start_date	end_date
C2023-choi-Sem-Cong-44	1	1	0	1	1	0	0	20231204	20231219

TEC-GTFS.zip

Location: /

Name
- trips.txt
- stop_times.txt
- stops.txt
- shapes.txt
- routes.txt
- feed_info.txt
- calendar_dates.txt
- calendar.txt
- agency.txt

route_id	service_id	trip_id	trip_short_name	direction_id	block_id	shape_id
C0001-21560	C2023-choi-Sem-Cong-44	40597597-C2023-choi-Sem-Cong-44	5	0	7646768	C00010065
C0001-21560	C2023-choi-Sem-Cong-44	40597654-C2023-choi-Sem-Cong-44	9	0	7646893	C00010067
C0001-21560	C2023-choi-Sem-Cong-44	40597655-C2023-choi-Sem-Cong-44	21	0	7646832	C00010067
C0001-21560	C2023-choi-Sem-Cong-44	40597656-C2023-choi-Sem-Cong-44	1	0	7646768	C00010066
C0001-21560	C2023-choi-Sem-Cong-44	40597657-C2023-choi-Sem-Cong-44	33	0	7646914	C00010068

trip_id	arrival_time	departure_time	stop_id	stop_sequence	pickup_type	drop_off_type
40597665-C2023-choi-Sem-Cong-44	10:33:00	10:33:00	Cmtplac7	1	0	0
40597665-C2023-choi-Sem-Cong-44	10:35:00	10:35:00	Cmtfabi1	2	0	0
40597665-C2023-choi-Sem-Cong-44	10:36:00	10:36:00	Cmtstth1	3	0	0
40597665-C2023-choi-Sem-Cong-44	10:37:00	10:37:00	Cmtfoye2	4	0	0
40597665-C2023-choi-Sem-Cong-44	10:38:00	10:38:00	Cmtgrim2	5	0	0
40597665-C2023-choi-Sem-Cong-44	10:38:00	10:38:00	Cmtyern2	6	0	0

Cyclic moving object representation

Thomas Behr, Victor Teixeira de Almeida, and Ralf Hartmut Güting. 2006. Representation of periodic moving objects in databases. In Proceedings of the 14th annual ACM international symposium on Advances in geographic information systems (GIS '06). Association for Computing Machinery, New York, NY, USA, 43–50. https://doi.org/10.1145/1183471.1183480

Real-time Vehicle Position and Delays

- Multiple formats: json, GTFS-RT
- Readily map-matched data
- Example challenges
  - Missing vehicle IDs
  - Missing map
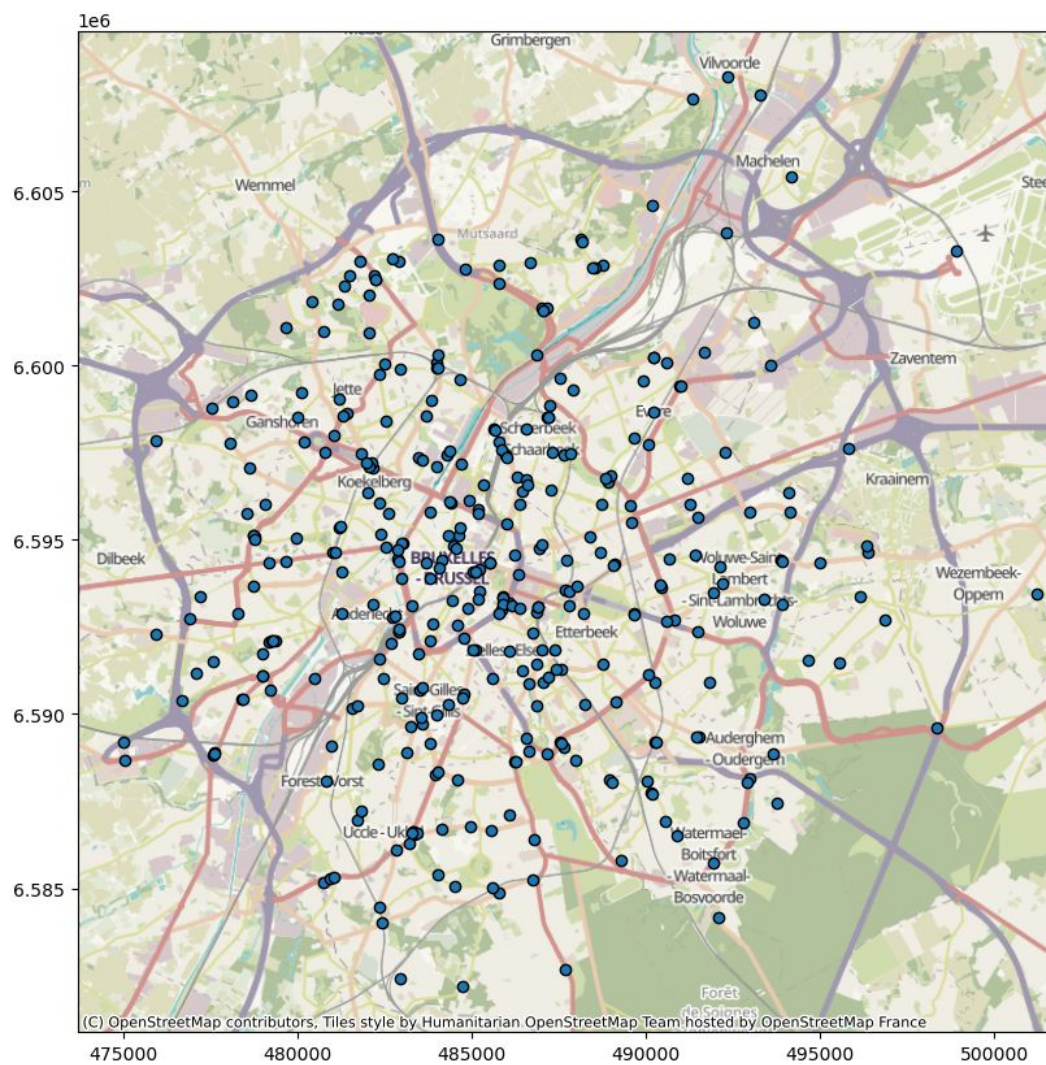
Micromobility - GBFS

last_updated: 1699690459
ttl: 0
version: "2.2"
▼ data:
  ▼ en:
    ▼ feeds:
      ▼ 0:
          name: "system_information"
          url: "https://mds.bolt.eu/gbfs/2/336/system_information"
      ▼ 1:
          name: "free_bike_status"
          url: "https://mds.bolt.eu/gbfs/2/336/free_bike_status"
      ▼ 2:
          name: "system_pricing_plans"
        ▼ url: "https://mds.bolt.eu/gbfs/2/336/system_pricing_plans"
      ▼ 3:
          name: "gbfs_versions"
          url: "https://mds.bolt.eu/gbfs/2/336/gbfs_versions"
      ▼ 4:
          name: "vehicle_types"
          url: "https://mds.bolt.eu/gbfs/2/336/vehicle_types"
      ▼ 5:
          name: "geofencing_zones"
          url: "https://mds.bolt.eu/gbfs/2/336/geofencing_zones"

last_updated: 1699691069
ttl: 300
version: "2.2"
▼ data:
  ▼ bikes:
    ▼ 0:
        bike_id: "94bde24e-a1e8-4534-afa3-47c2aeec0a63"
        lat: 50.86246871948242
        lon: 4.354008197784424
        current_range_meters: 25920
        pricing_plan_id: "3e57845a-f6ac-5edc-8a82-5a5a4ace436a"
        vehicle_type_id: "3f5cc22d-7d83-5948-8c3d-e2834b75aada"
        is_reserved: false
        is_disabled: false
   ▶ rental_uris: {…}
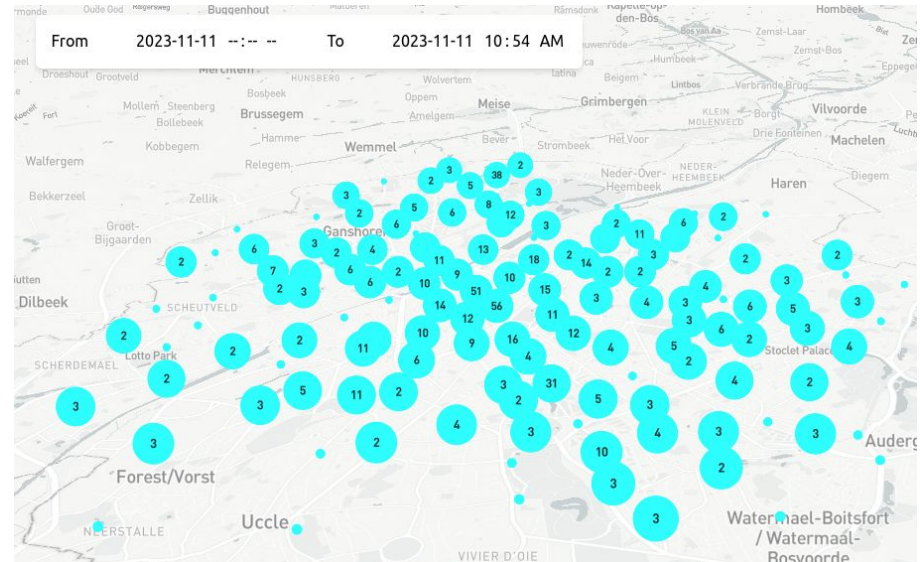
Micromobility - Free bikes

Provider	Average number of idle e-bikes	Total updates in one month	Unique e-bikes id's in one month	Ratio ids to bikes	Ratio ids to updates
Lime	3,494	31,199,786	10,380,004	2,970.8	0.33
Pony	1,135	10,089,929	9,836,028	8,666.1	0.97
Bolt	4,289	38,300,289	168,222	39.2	0.0044

ID change pattern

- Per GBFS update
- Per certain duration
- Per trip
- We found that these patterns are not strictly followed. Some randomization is added.
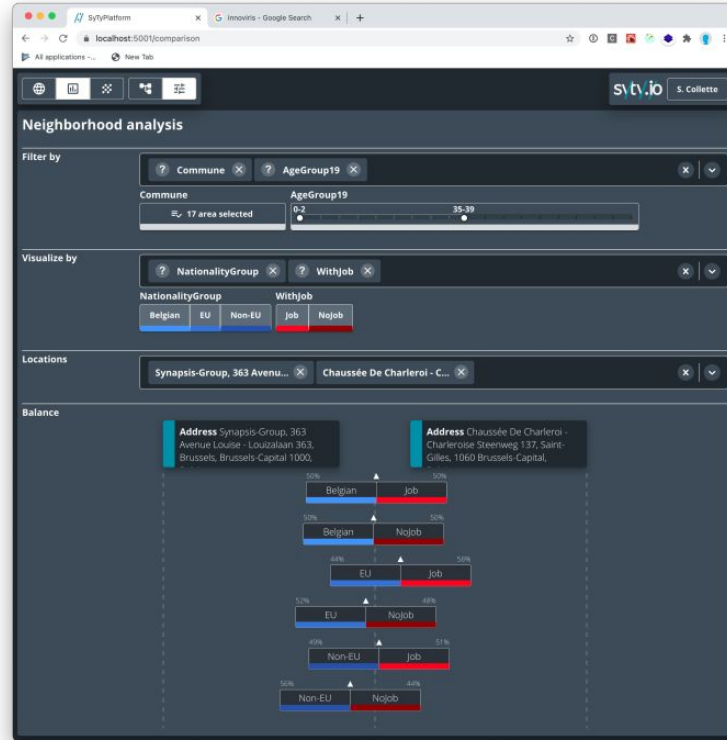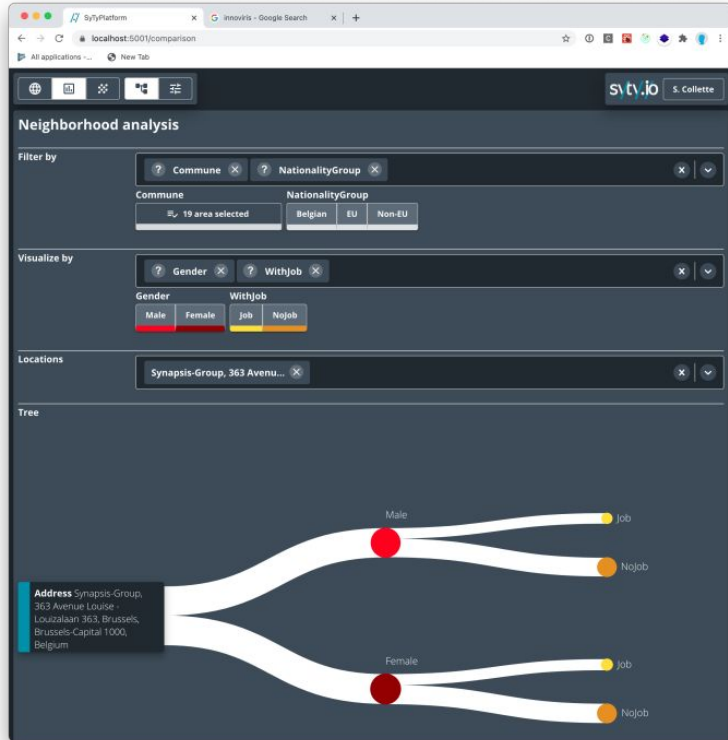
Traffic
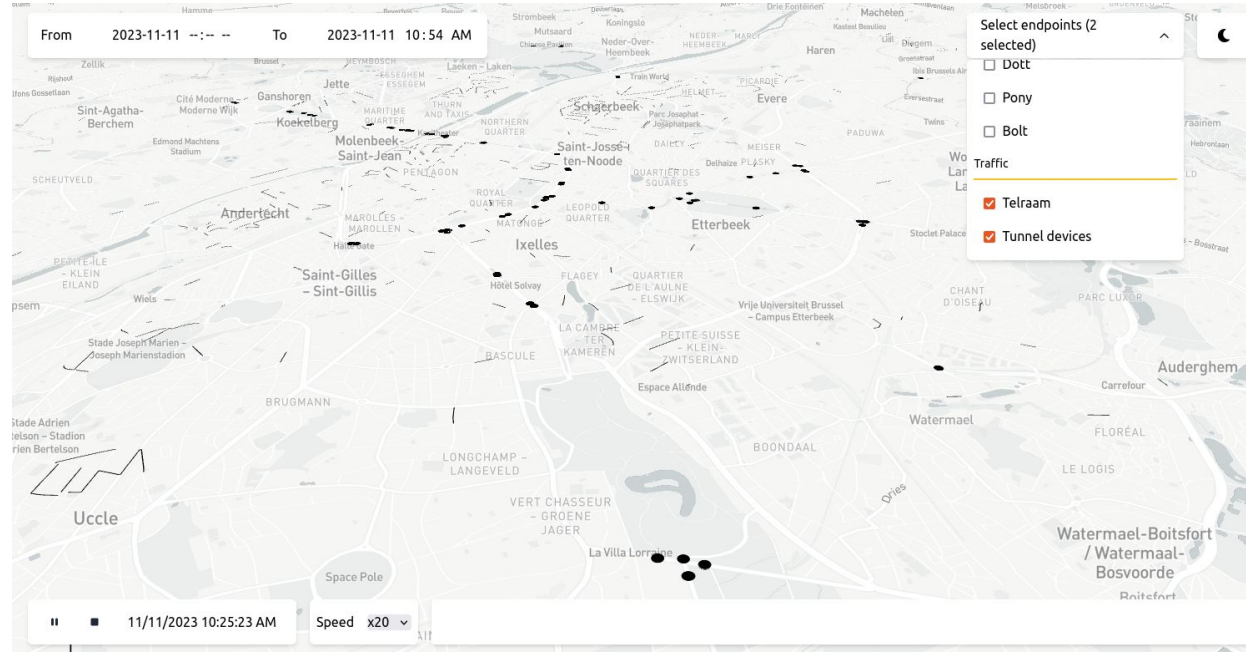
Others

- Parking availability
- Weather
- Air-quality
- Street works
- Events calendar
- Trash pickup tracks
- …

Simulation

nr	Name of the dataset	Accessibility level [Open access, Confidential]	Description	Data Type	Data Format	Data Scheme
1	Event Calendar Scheveningen	Open access	Date, times and additional information about events and holidays at Scheveningen Area	Time-based data	excel	Date, time, event type, description, amount of people expected
2	Parking data	Open access	Real-time information on occupancy of public parking garages in Netherlands	Numeric	json via API	https://data.openparking.nl /index/view.php
3	Public transport data	Open access	Information on public transport schedules, timetables and real-time locations of buses, trains and trams.	Temporal-spatial traffic data	json, xml	https://ndovloket.nl /documentatie.html
4	Shared Mobility data	Open access	Real-time location data of the parked shared mobility objects (scooters, bicycles) in the Netherlands.	Location of parked shared mobility objects, occupancy of designated parking areas	json via API	https://api.deelfietsdashboard .nl/dashboard-api/public /vehicles_in_public_space
5	Weather information	Open access	Historical, real-time and future information on weather conditions.	Weather related data	https://dataplatform.kn mi.nl/dataset/	https://dataplatform.knmi.nl /dataset/
6	Resono: Mobile App Counting	Confidential/Closed	Historical data on hourly visits on different beach areas in Scheveningen and The Hague Area	Numeric	csv, text	Area, nr of visits
7	Bicycle counting Netherlands	Open access	Historical data on bicycle counting systems in the Netherlands.	Numeric	csv, excel	Location, count per hour per direction
8	Bridge openings	Open access	Information on bridge openings	Numeric	XML	https://docs.ndw.nu/datex2 /v2.3/semantiek/interpretatie-brugopening/
11	Floating Car Data	Shared	Travel time data based on floating car data collected from a smart phone app	Temporal-spatial traffic data	csv, excel, Blob	Travel time per segment per minute
12	Loop Detector Data	Shared	Speed and flow data from double loop detectors in the network	Temporal-spatial traffic data	csv, excel, Blob	Speed and flow per location per minute

Challenge - data management
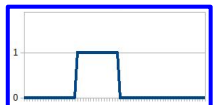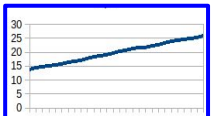
Between March and October ~ 256 GB

efficiency

flexibility

Database   Data lake
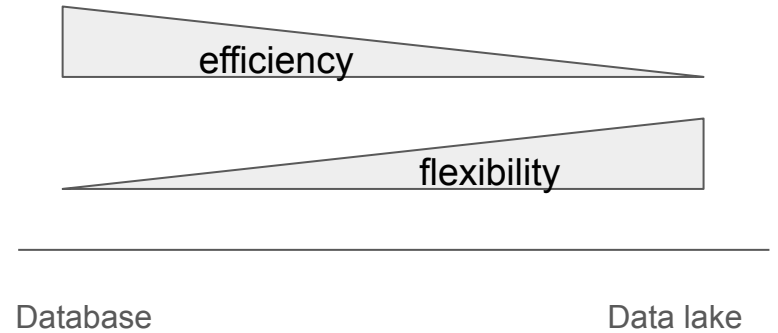
MobilityDB
Compression rate 450%
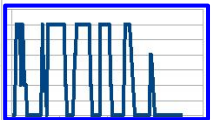
timestamp	moving_state	trip_id	sp1	ssa	driver_gender	driver_age	speed_label
10:10.1		1	c521b0b0	13.64	309	F	32	city
10:10.2		1	c521b0b0	14.2	288	F	32	city
10:10.3		1	c521b0b0	14.56	356.5	F	32	city

16,000 records per trip

10:10.4							city
10:10.5							city
10:10.6							city
10:10.7		1	c521b0b0	16.15		F	32	city
10:10.8		1	c521b0b0	16.7	93	F	32	city
10:10.9		1	c521b0b0	16.99	69	F	32	city
10:11.0		1	c521b0b0	17.55	49.5	F	32	city

100 trip_id
1.6 million rows
165 MB

moving_state	trip_id	sp1	ssa	driver_gender	driver_age	speed label
	c521b0b0			F	32	

100 trip_id
100 rows
37 MB

Spatiotemporal Proximity: Smart Advertising
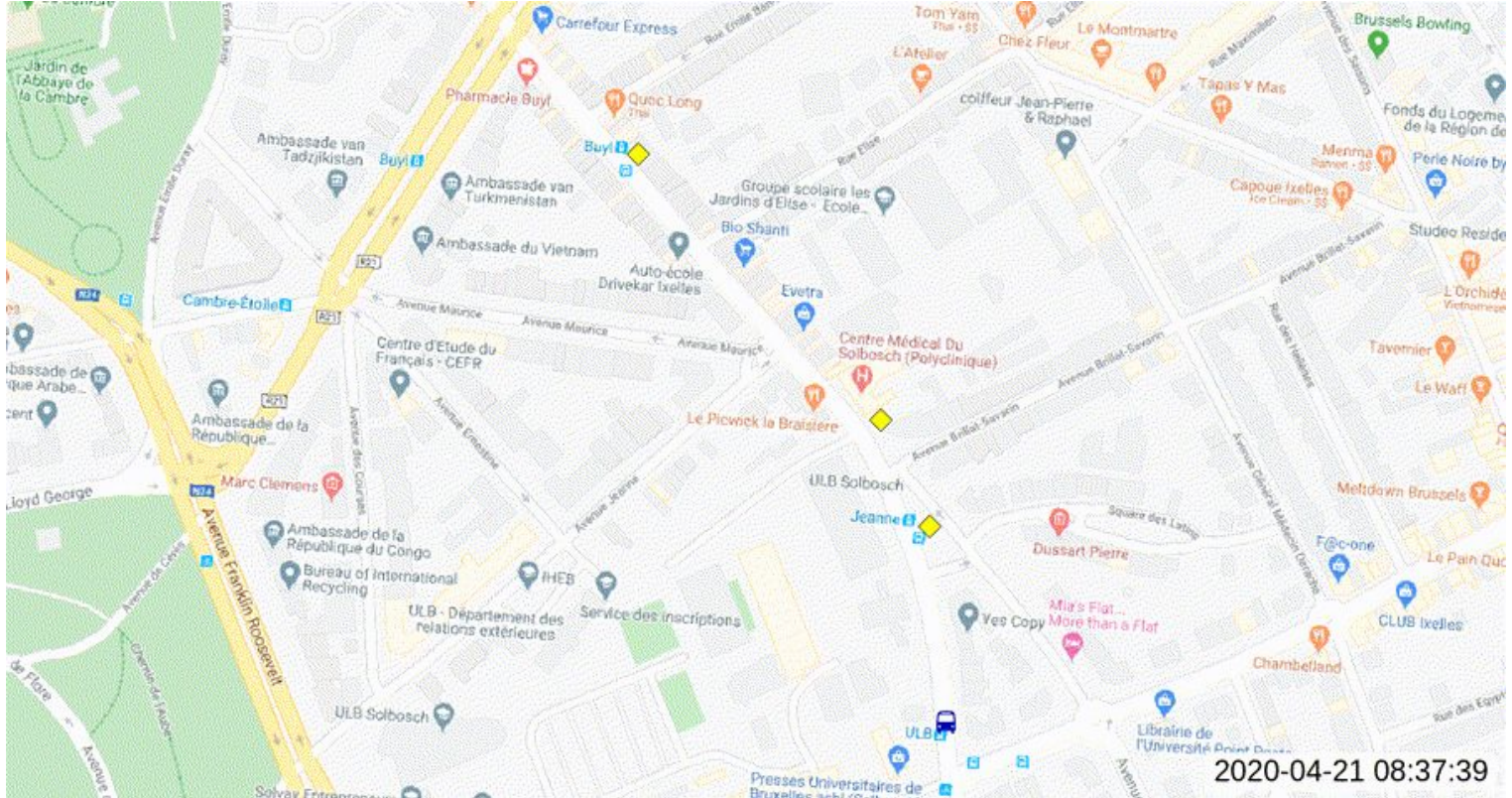
Micromobility Hubs
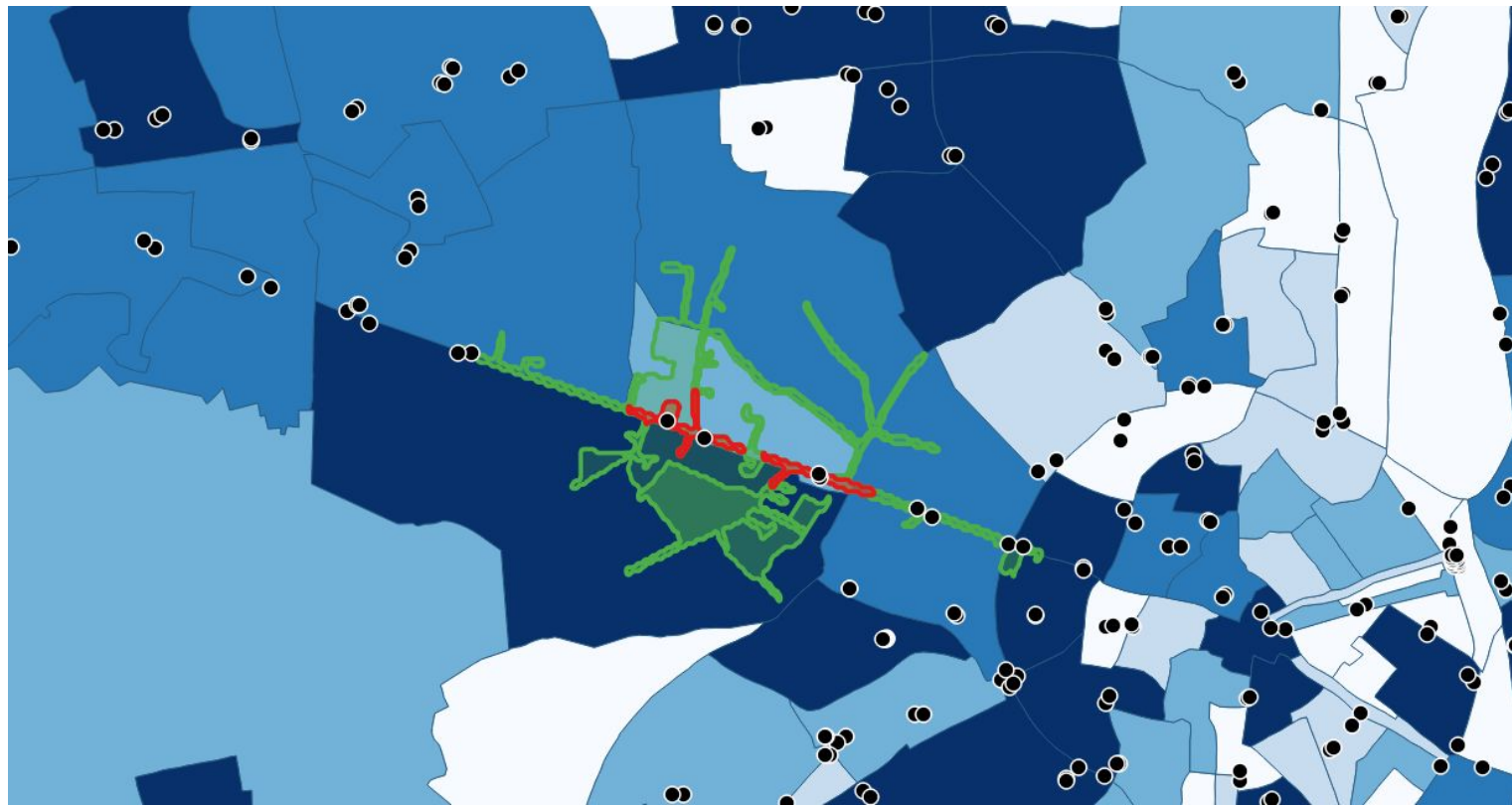
Thanks for listening

On behalf of

- Aissa Abdoul-Aziz
- Ahmed Ahmed
- Kainaat Amjid
- Helin Demierel
- Prashant Gupta
- Gaspard Mertens
- Bahare Salehi