
# On the Computation of Accessibility Provided by Dynamic Transportation Modes

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# Involved Parties

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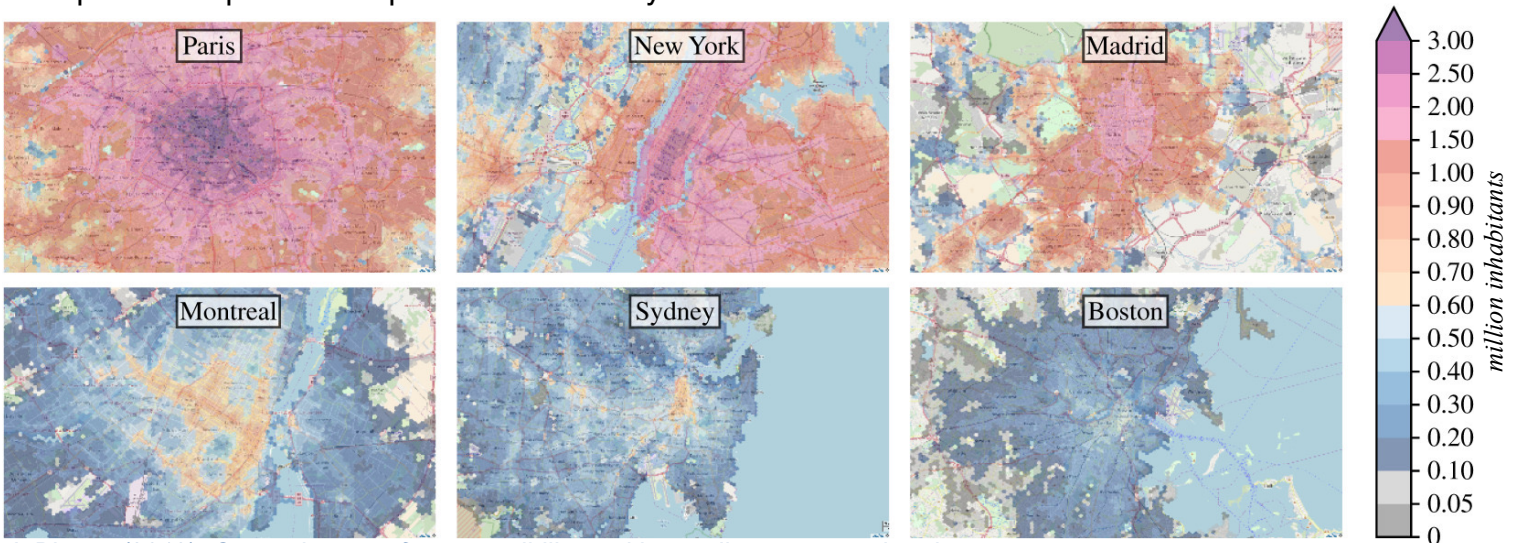
Comparison of public transport based sociality scores

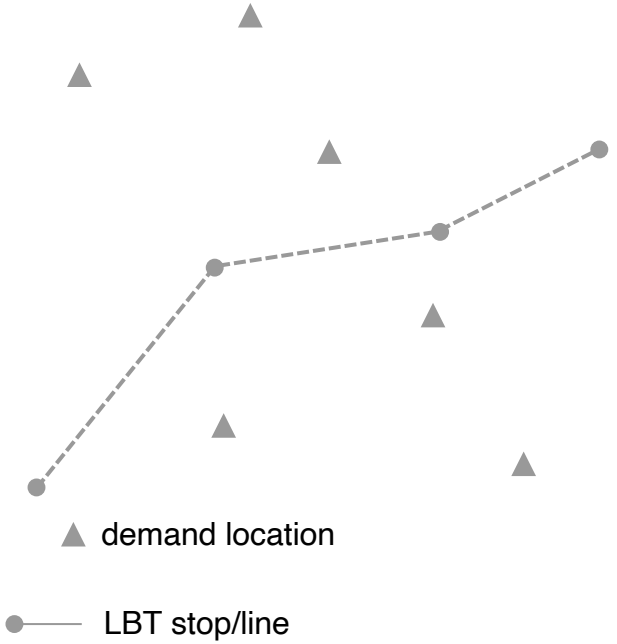



*I. Biazzo (2019). General scores for accessibility and inequality measures in urban areas*

**Motivation**

Integrating automated on-demand vehicles into public transit to improve mobility in suburban areas: a simulation-based approach.

# Line Based Public Transport (LBT)

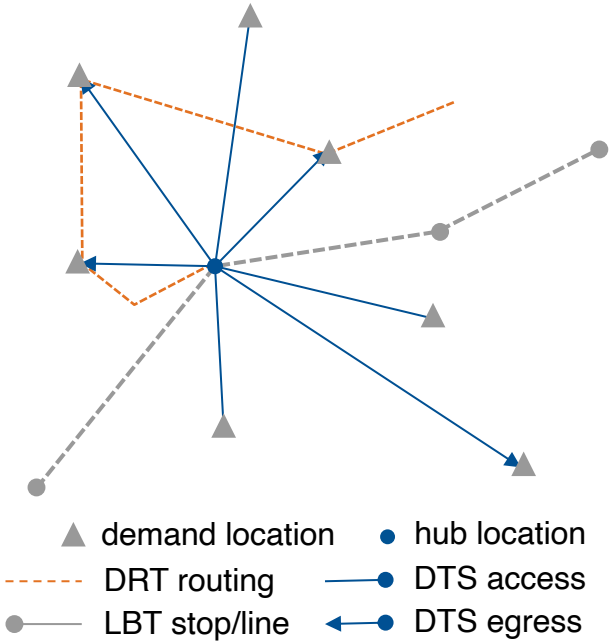



**Operation Schemes**
- Fixed schedule
- Fixed routes / stop locations
- Medium / high capacity

**Shortcoming**
- Catchment area limited around transit stops
- Not economically feasible for low-demand areas

**Service Representation:**
- Graph-based representation
- General Transit Feed Specification (GTFS)

# Dynamic Feeder Transport Systems (DTS)

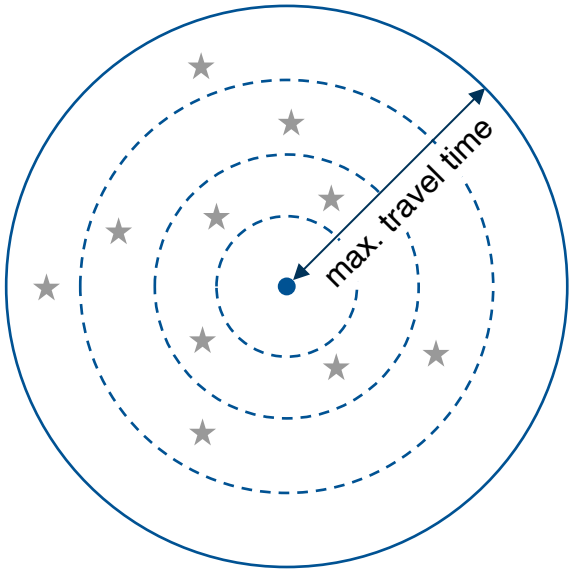



**Dynamic Feeder Transportation Systems**:
- access – to LBT station
- egress – from LBT station

**Trip Metadata:**
- wait time, search time, …
- travel time

**Dynamic Routing:**
- Routes are deviated by the search for vehicle or by pooling of passengers

# Accessibility




origin i ★ opportunities j from i within $t_{max}$

**Isochronic Accessibility measure**

$$A^i = \sum_{t_{ij}<t_{max}} n_j$$

$n_j = opportunities\ in\ location\ j$
$A_i = Accessibility\ at\ location\ i$

*E. J. Miller (2020). Measuring Accessibility: Methods and Issues*

**$t_{ij}$ is calculated on a graph**

Calculating Accessibility requires a graph,
but no graph representation of flexibles modes is available

**CityChrone**

- Calculations based on time-expanded graphs
- public transport network input format GTFS
- aggregation of origins in centroid of hexagons

*I. Biazzo (2022). CityChrone*

**Research Question**

How to calculate accessibility by intermodal DRT + conventional PT trips?

**State of the Art**

Existing tools rely on graphs for accessibility measurements:

Access to conventional PT stops via DRT

*Chandra et al. (2013)*

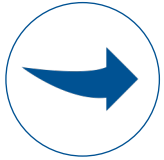
Activity-Based Accessibility

*Nahmias-Biran et al. (2021), Zegras et al. (2021)*

Automated Vehicle sharing

*Ziemke et al (2023)*

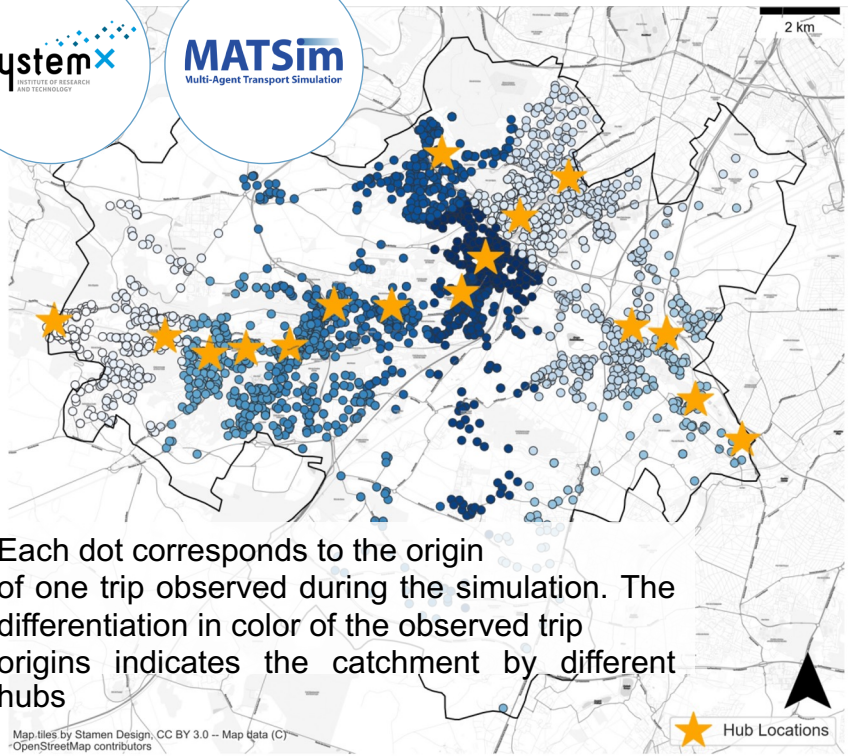
→ No tool available for non graph based modes



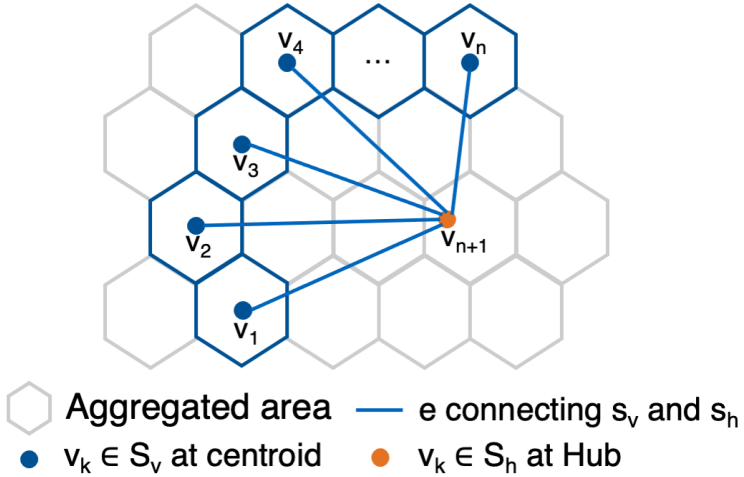
**Approach**

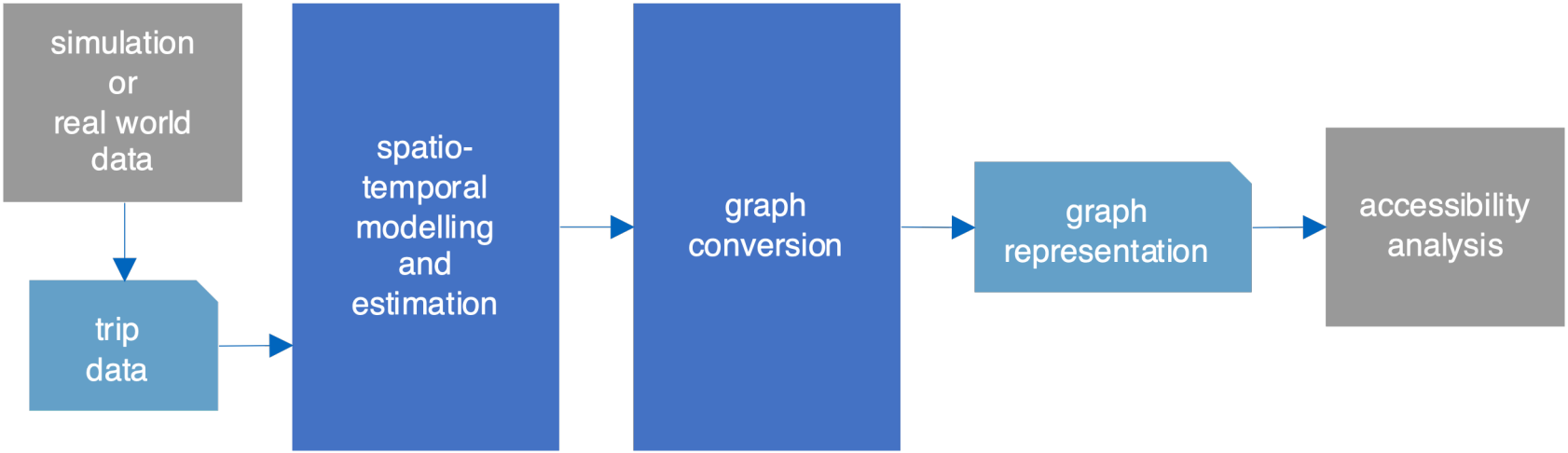
Development of a pipeline converting dynamic mode trips to graph-based representations.

Followed by Accessibility analysis with existing graphs bases accessibility tool.

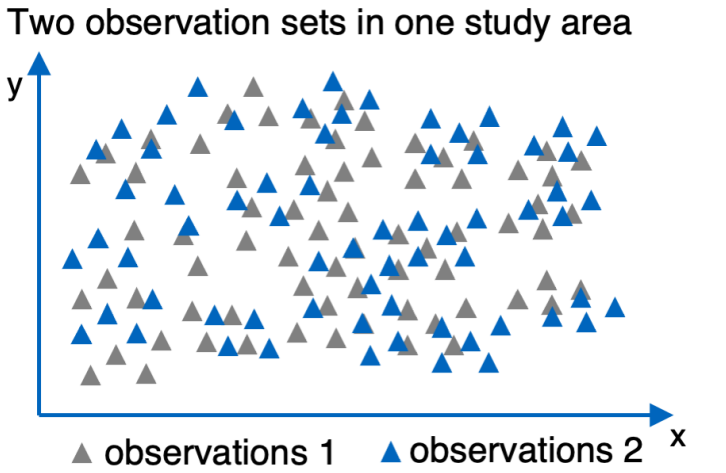



Each dot corresponds to the origin of one trip observed during the simulation. The differentiation in color of the observed trip origins indicates the catchment by different hubs




simulation or real world data
trip data
spatio-temporal modelling and estimation
graph conversion
graph representation
accessibility analysis

# Spatio-Temporal Random Field




Marked locations denote non-hub locations of trips

**Attributes of Marked Locations**

- origin, destination
- wait time w, travel time y

**Modelling as Random Field**

- Y(x,t) random field for travel time
- W(x,t) random field for wait time

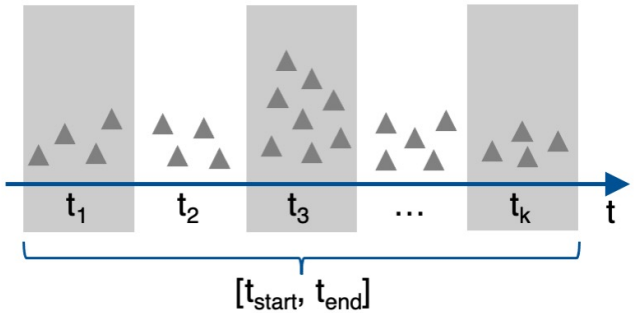
$$\lim_{N\to\infty} \mathbb{E}\hat{W}^s_{t_k,N}(\mathbf{x}) = \mathbb{E}W^s_{t_k}(\mathbf{x})$$

$$\lim_{N\to\infty} \mathbb{E}\hat{Y}^s_{t_k,N}(\mathbf{x}) = \mathbb{E}Y^s_{t_k}(\mathbf{x})$$

**Ordinary Kriging** is the chosen spatial estimator

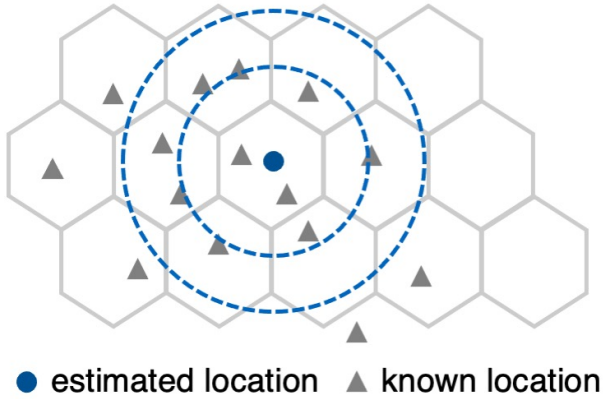
# Spatial & Temporal Aggregation

Temporal aggregation using time-slot




trips for one hub

Estimating using spatial autocorrelation




trips for one time-slot and hub

# Spatial Modelling / Ordinary Kriging

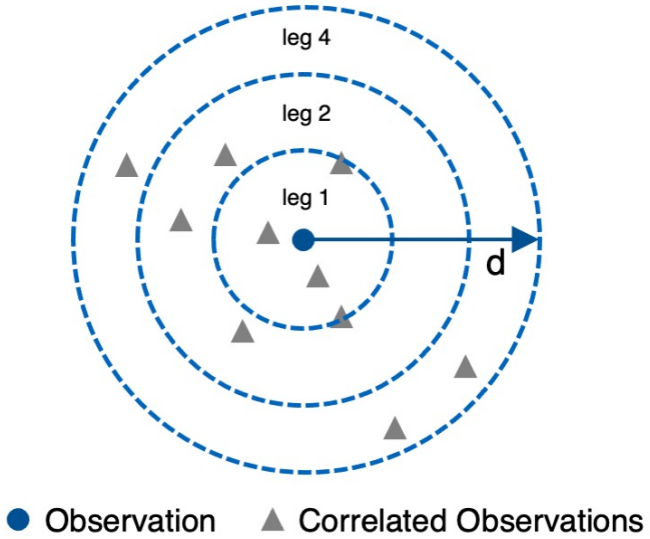
Estimation of waiting time for trips starting at centroid **u** at time $t_k$ and ending at station **s**:

$$\hat{w}^{s}(\mathbf{u}, t_k) = \sum_{i \in \mathcal{O}^{\mathbf{s}}_{t_k}} \lambda_i \cdot w_i$$

Observed wait time of DRT trip *i*

Observed DRT trips ending at station **s**

Weight of the contribution of observation *i* in the estimation at **u**

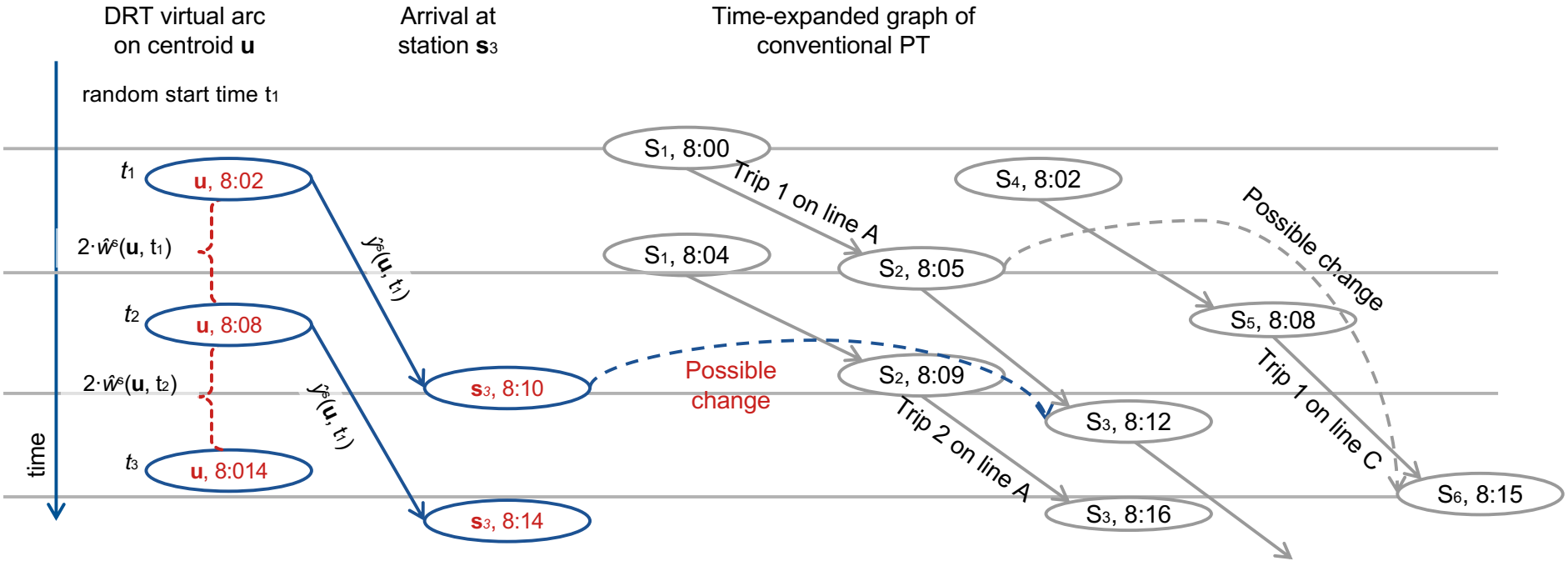



*dist*(**u**,**u**$_i$) ↗ ⇒ $\lambda_i$ ↘

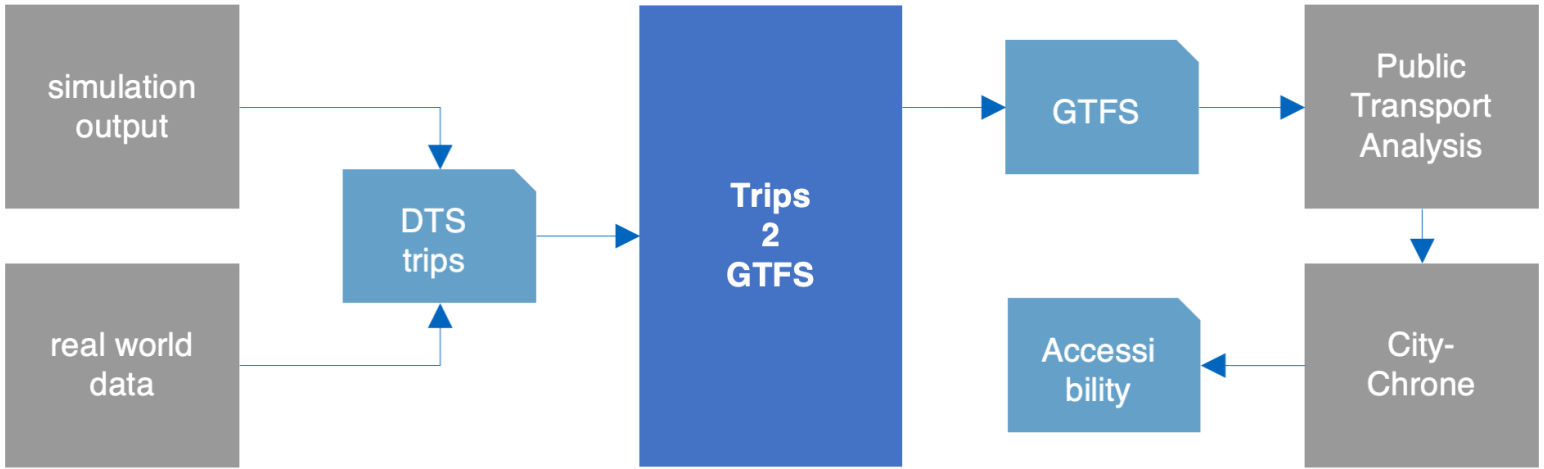
# Time-expanded graph

*Virtual fixed bus line* representing DRT.

Performance of this virtual bus
=
expected performance of DRT, estimated via Kriging

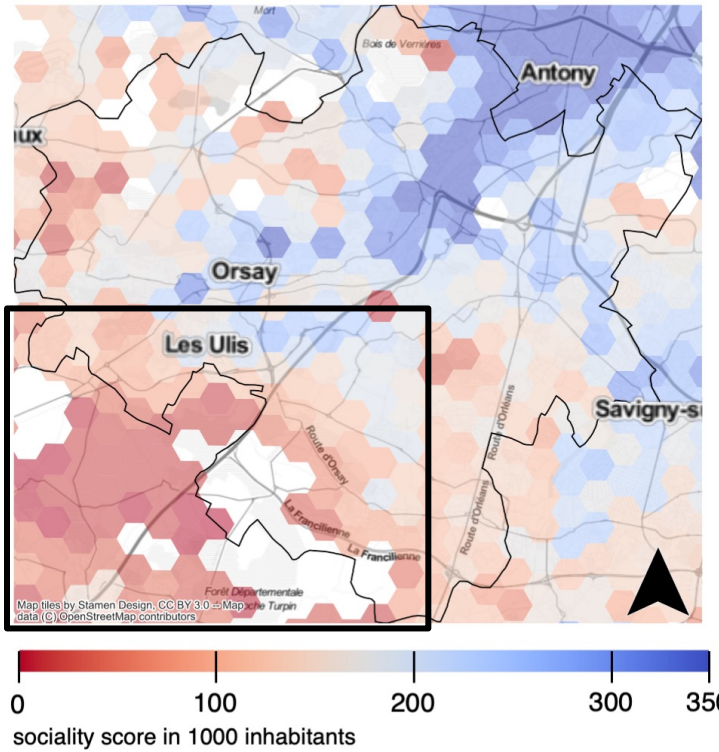


# Implemented Workflow



## Sociality Score – Access Only – Morning Peak 07:00 – 10:00

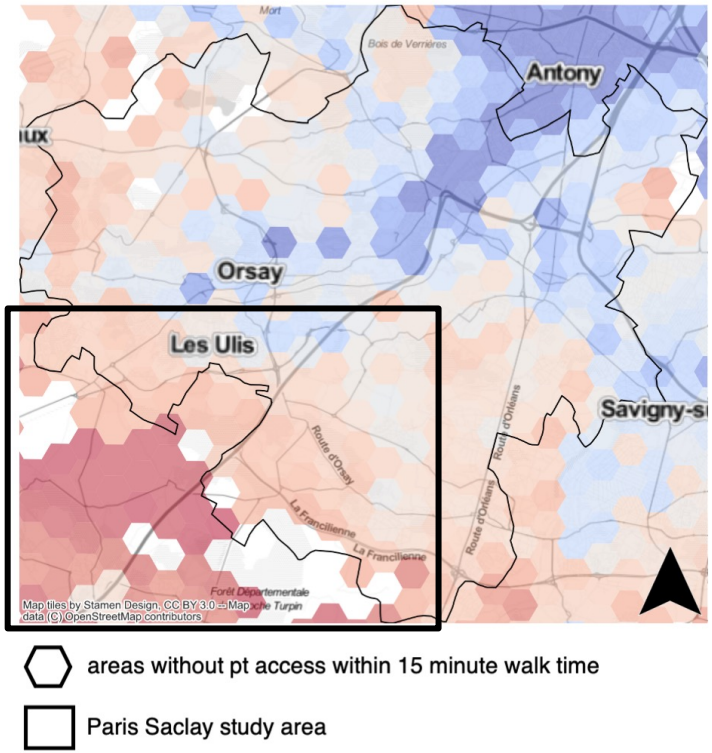
base case





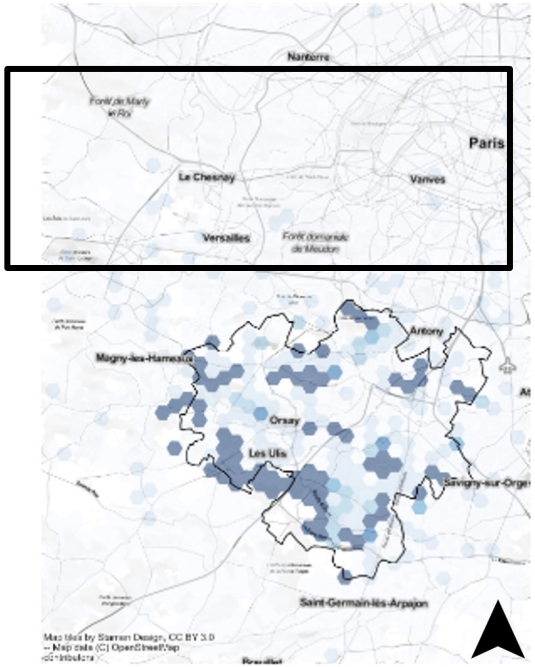


DRT integration

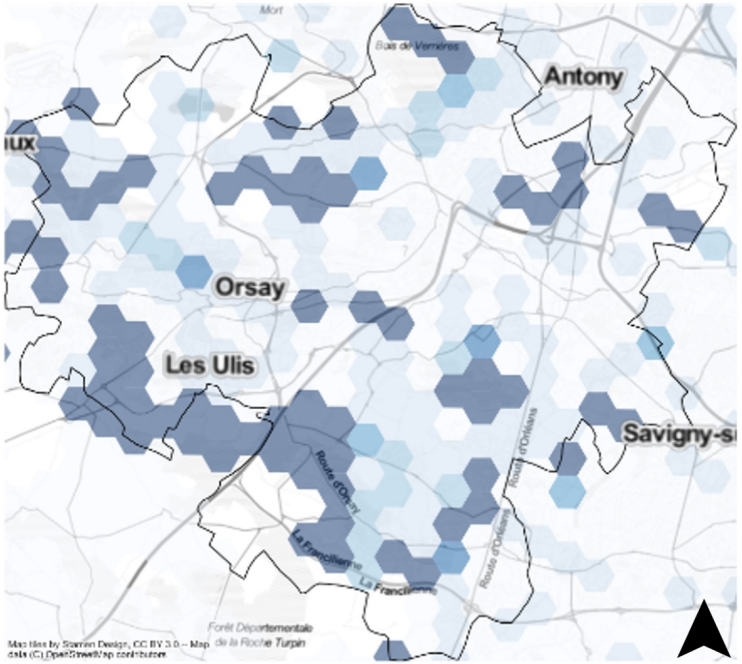


## Sociality Score Improvement – Access Only – Morning Peak 07:00 – 10:00

Île-de-France

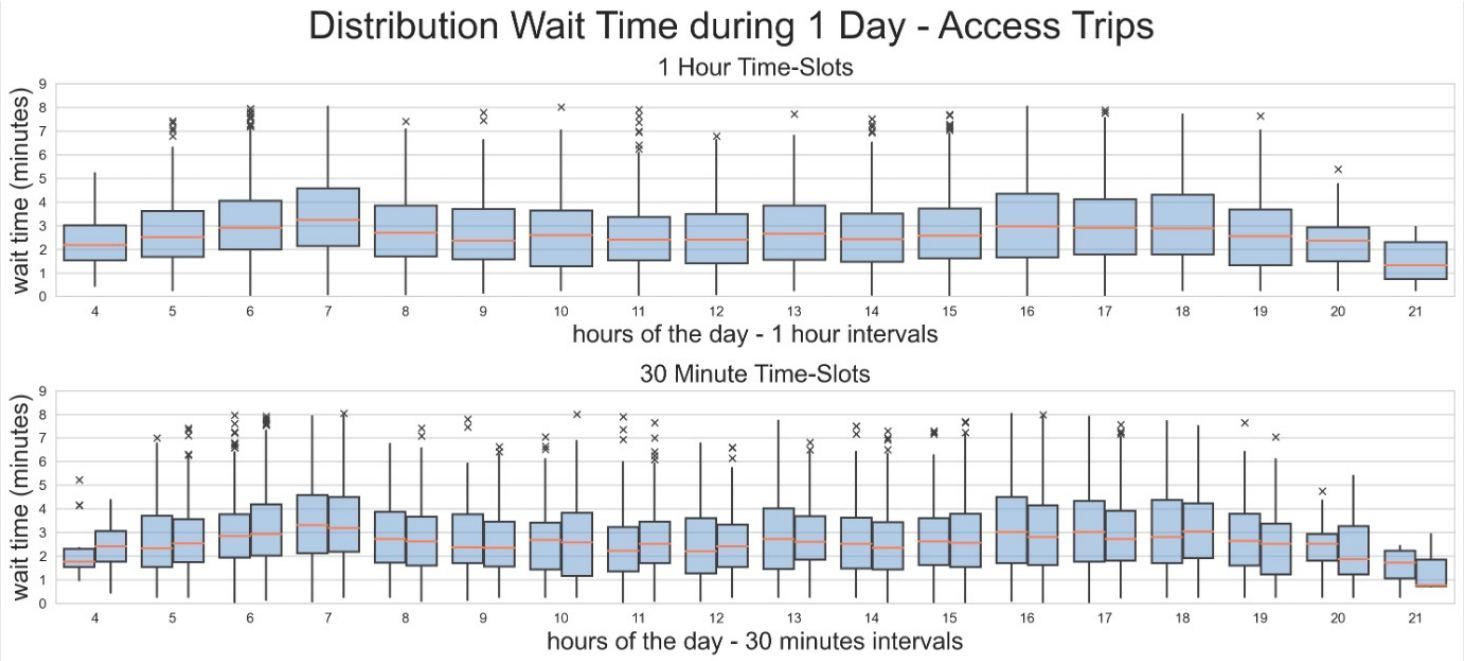


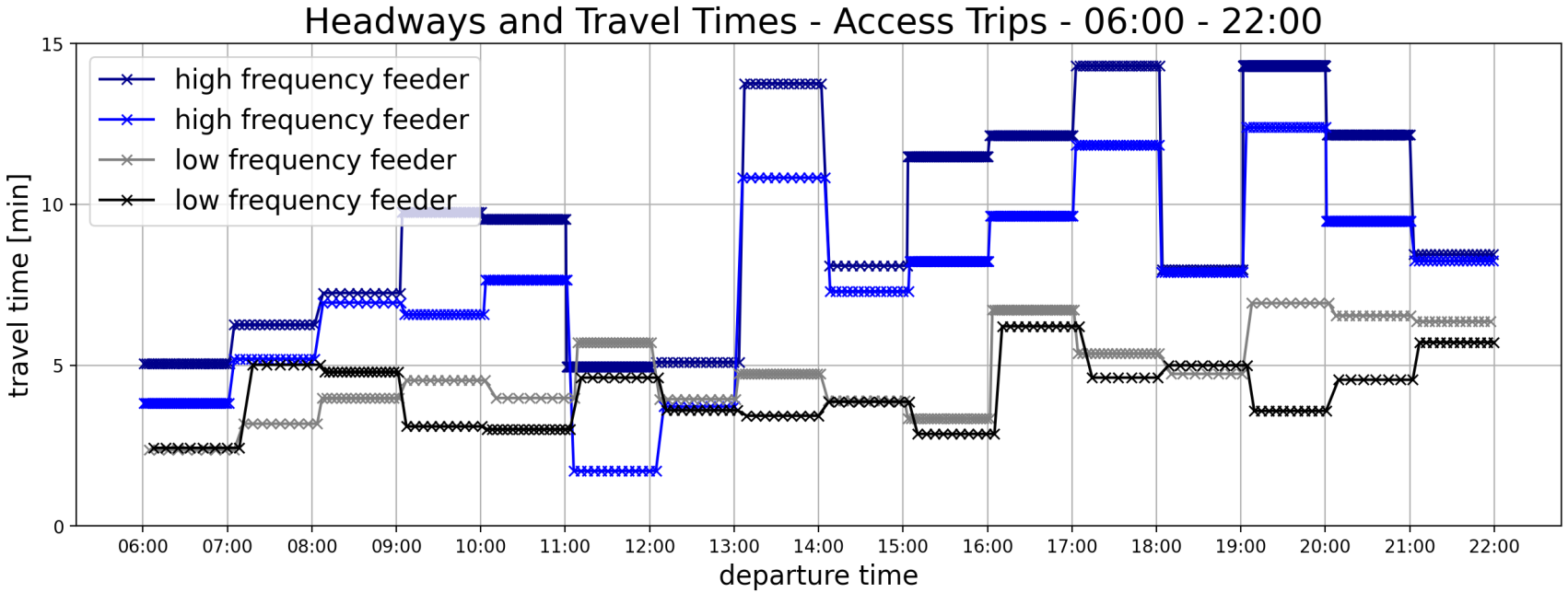

Paris Saclay

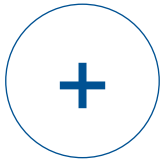




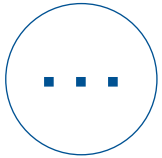
Paris Saclay study area


Distribution Wait Time during 1 Day - Access Trips
1 Hour Time-Slots
wait time (minutes)
hours of the day - 1 hour intervals
30 Minute Time-Slots
wait time (minutes)
hours of the day - 30 minutes intervals


Headways and Travel Times - Access Trips - 06:00 - 22:00
high frequency feeder
high frequency feeder
low frequency feeder
low frequency feeder
travel time [min]
departure time
0
5
10
15
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00



- **Accessibility calculation** for DRT as public transport feeders
- **Easy transferability** of methodology to other modes
- **Preserving** spatial and temporal patterns
- Inclusion of **variable data sources** (e.g. simulation, real world)



- **In-depth verification** of graph representation needed
- **Calibration** of estimator
- Inclusion of other spatial and temporal data to improve model
- Replace spatial aggregation with **3D Kriging**


**On the Computation of Accessibility Provided by Dynamic Transportation Modes**

Thank You for the Attention

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