An integrated road traffic-emissions-CTM model chain to assess urban air quality at the street level for the Paris region

Marjolaine Lannes[1,2], Yelva Roustan[1], Nicolas Coulombel[2], Biao Yin[2], Tatiana Seregina[2]

[1] CEREA, Ecole des Ponts, EDF R&D, Marne-la-Vallée, France

[2] LVMT, Ecole des Ponts, Univ. Eiffel, Marne-la-Vallée, France

MATSim User Meeting

September 5, 2023

Introduction

Air quality challenge : mobility & emissions modelling

CONTEXT

- Public policies aiming to **improve air quality** focus on vehicle fleet regulation, low emission zones

- Need to assess the **effect of public transport policies** on urban air quality

© Cécile Guillard/*Reporterre*

Introduction

Air quality challenge : mobility & emissions modelling

CONTEXT

- Public policies aiming to **improve air quality** focus on vehicle fleet regulation, low emission zones

- Need to assess the **effect of public transport policies** on urban air quality

- Development of **modelling chain** from road traffic to chemical transport models in recent years [1] [2]

- **Uncertainties** remain little studied

© Cécile Guillard/*Reporterre*

Problem statement
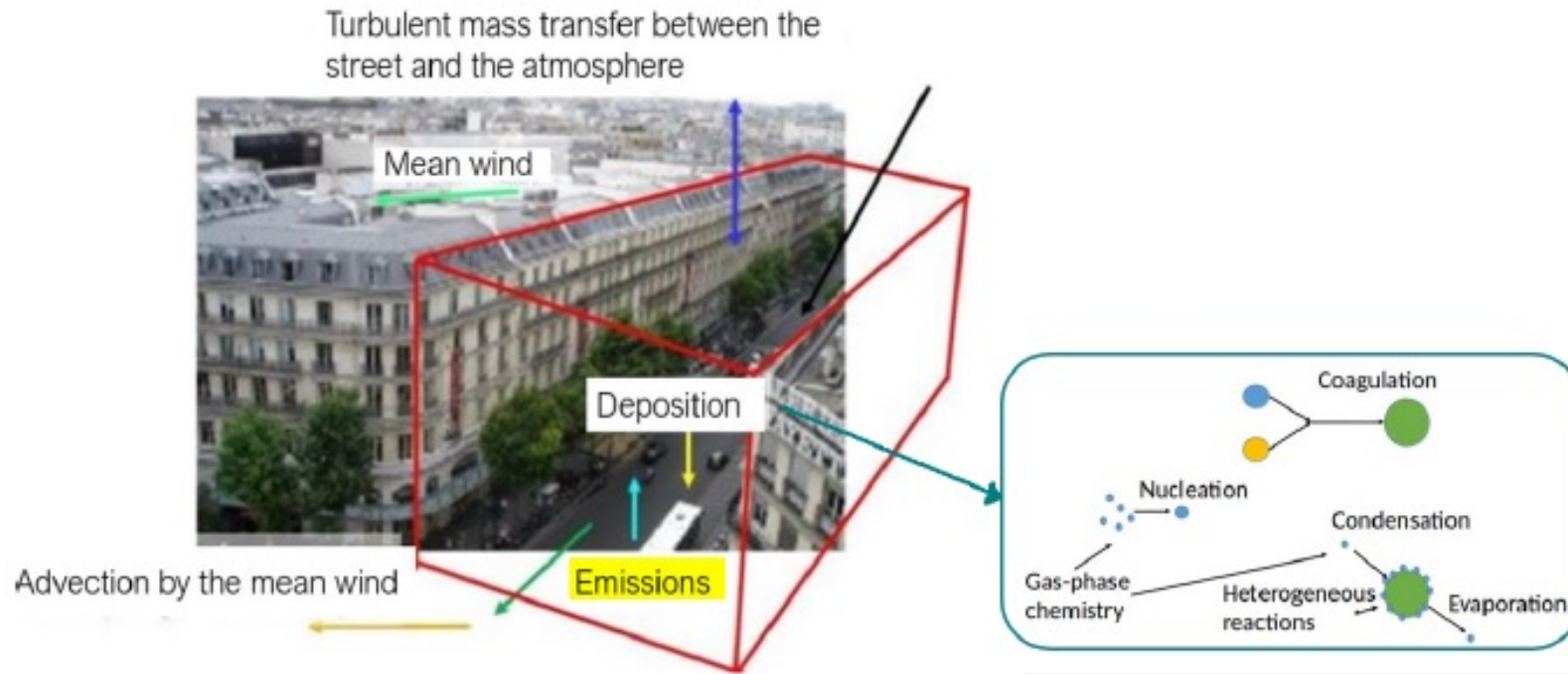
Representations of the different processes considered by MUNICH to compute concentrations in the street [3]

How to integrate high resolution traffic emissions into an air quality model based on street canyons?
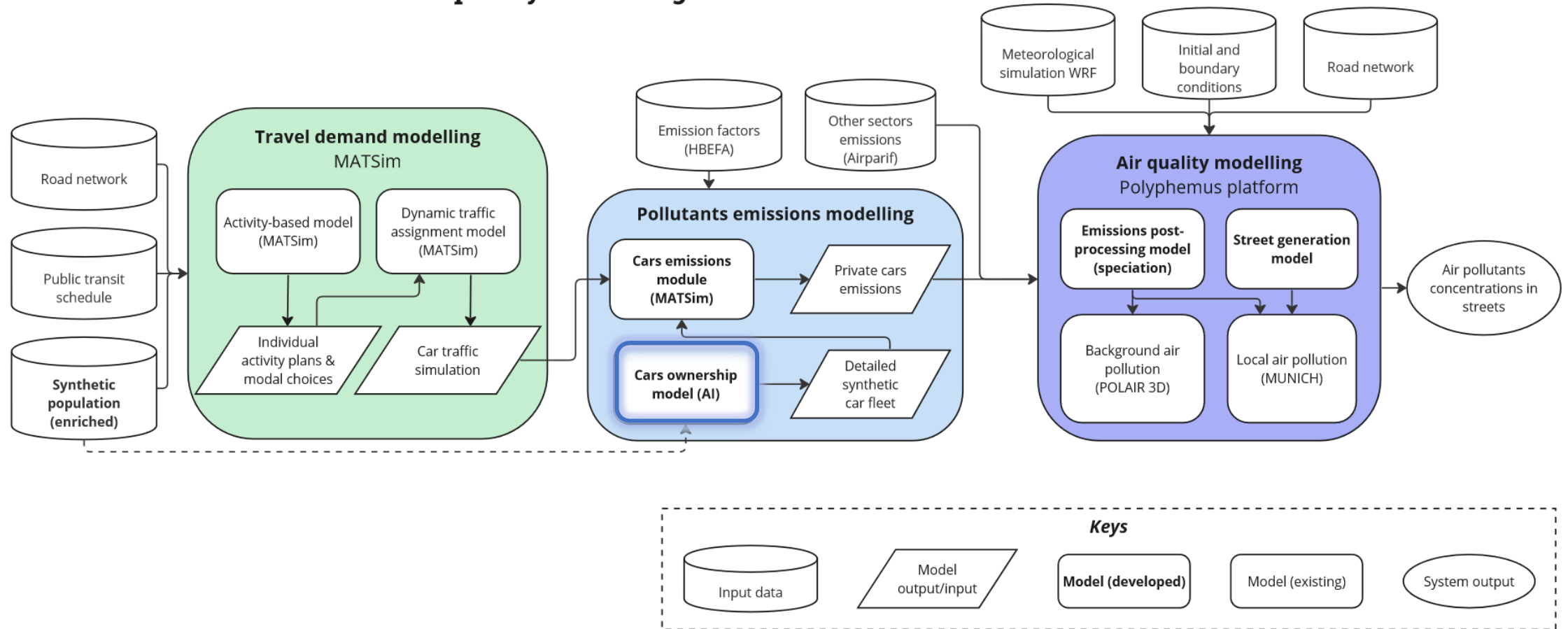
Methodology

The integrated modelling framework for air quality assessment:
travel demand - emissions - air quality modelling chain

Methodology

The integrated modelling framework for air quality assessment:
travel demand - emissions - air quality modelling chain

Marjolaine LANNES
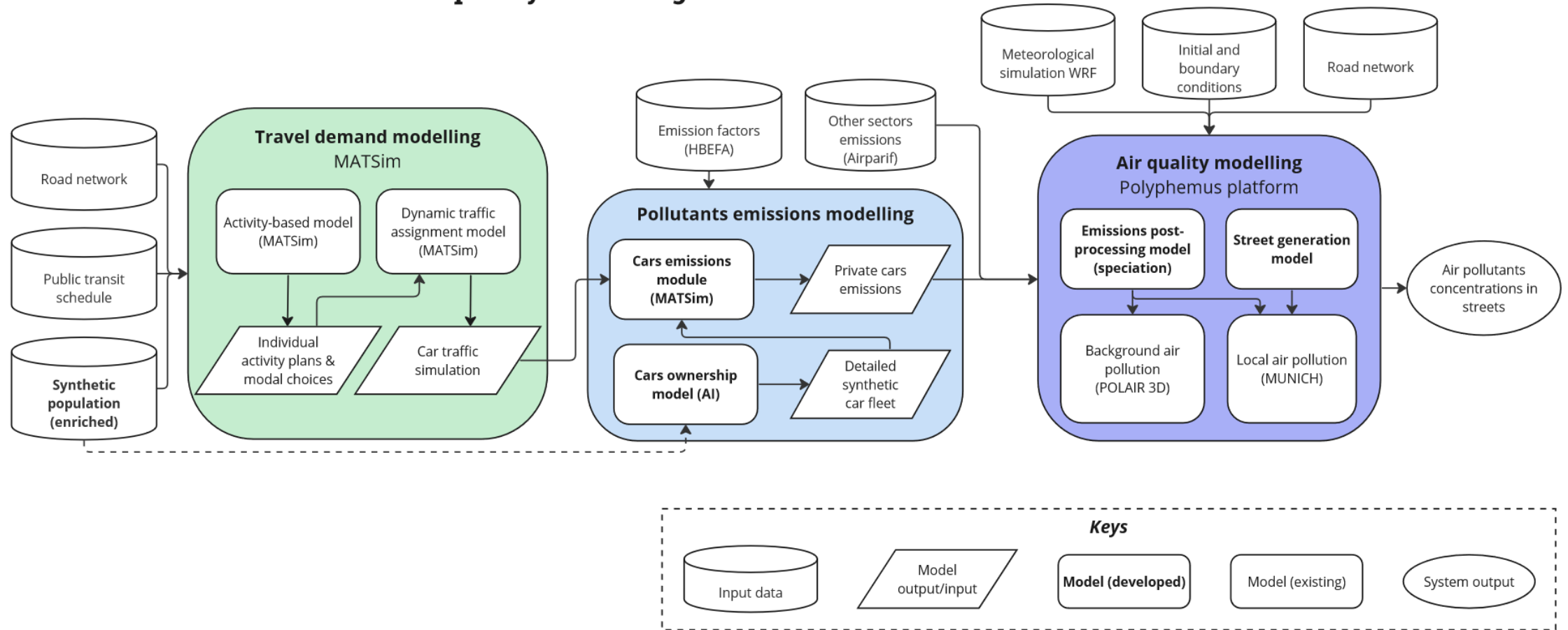
Methodology
Synthetic car fleet generation

POPULATION SYNTHESIS ENRICHMENT

- Socioeconomic variables : income, household type, housing type, max age, etc

- Built environment variables : parking at home and workplace
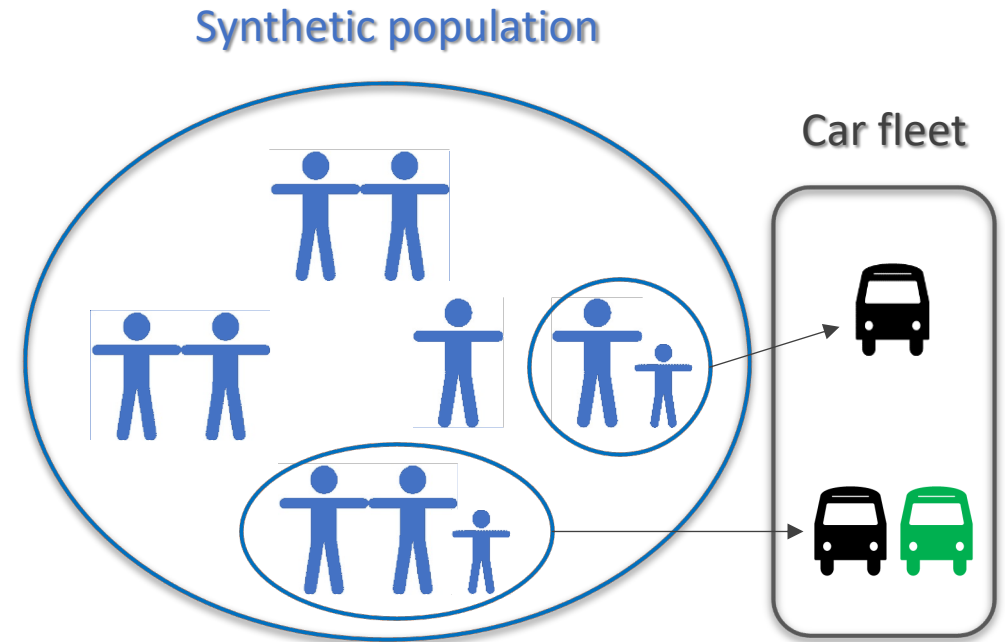
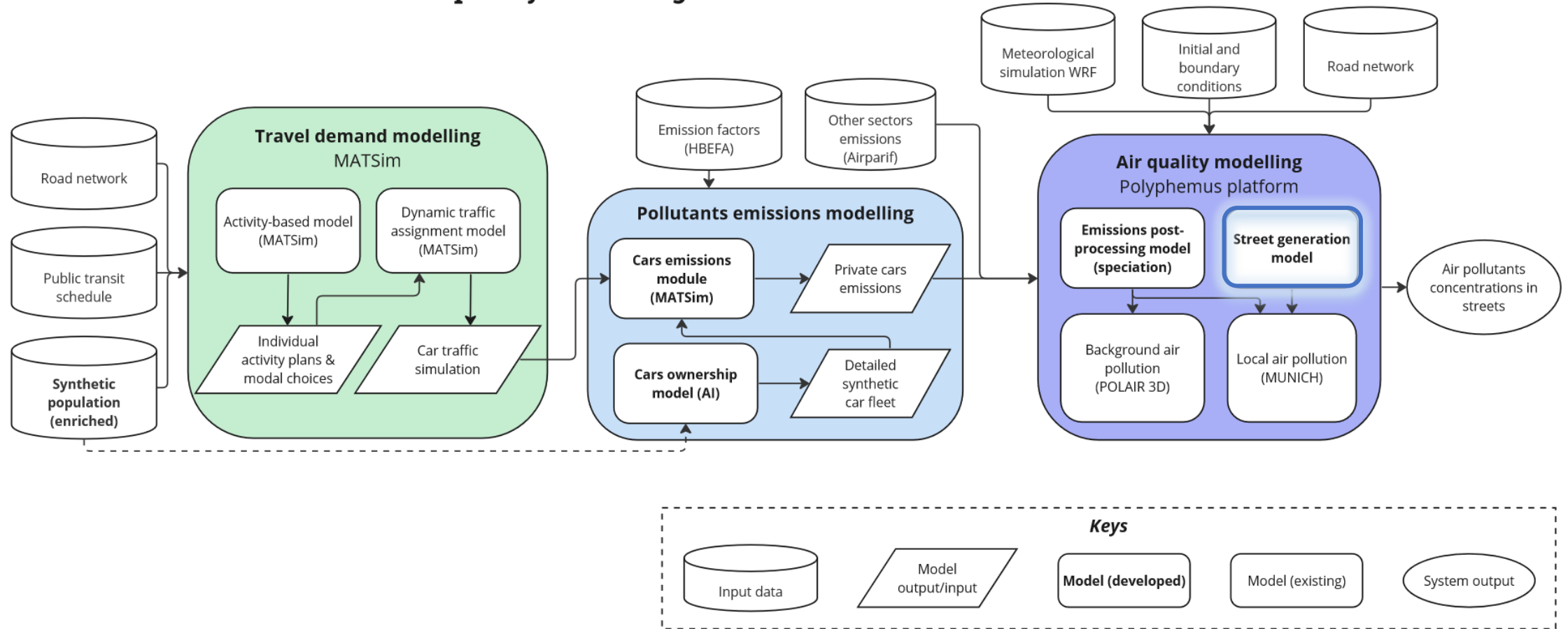- Features engineering : PT shares at home & workplace

Synthetic population

Car fleet

Figure: Car fleet micro-representation based on households characteristics

Credit: flaticons

Marjolaine LANNES

Methodology

**The integrated modelling framework for air quality assessment:
travel demand - emissions - air quality modelling chain**
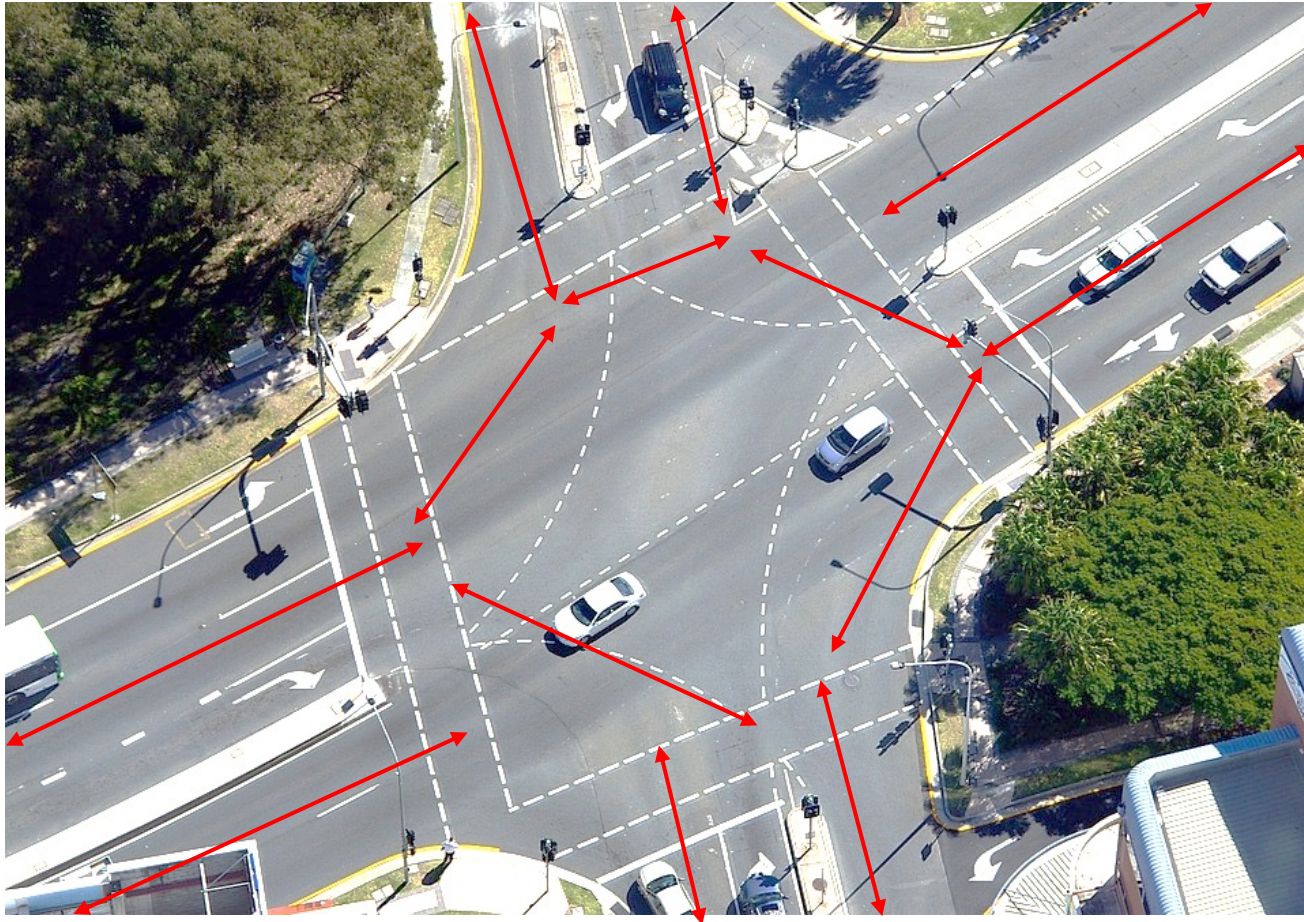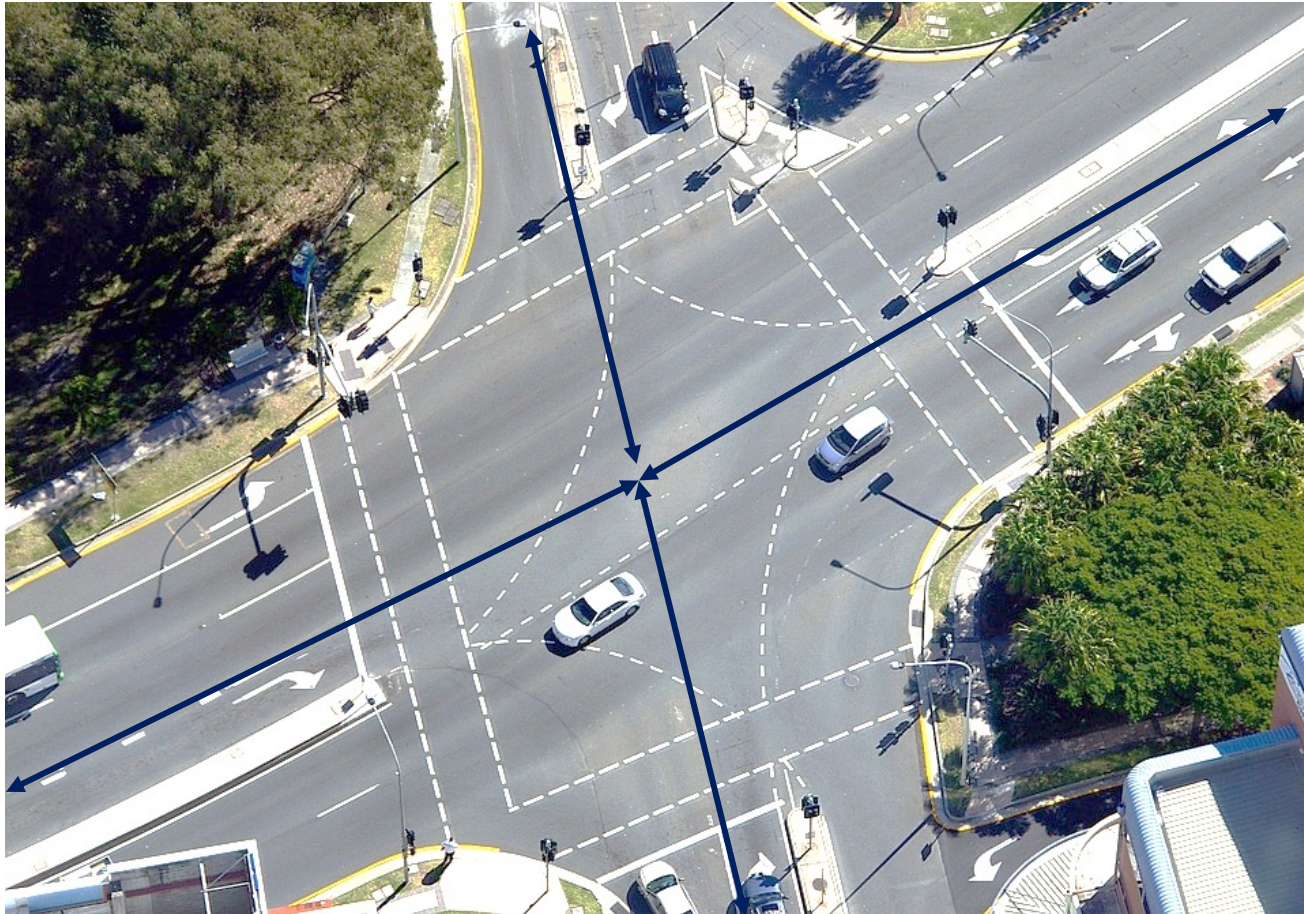
Methodology
How to couple a traffic model and an air quality model?

- In transportation models, **traffic lines** and **junctions** are used as a basis for urban modeling

Marjolaine LANNES

Methodology
How to couple a traffic model and an air quality model?

- In transportation models, **traffic lines** and **junctions** are used as a basis for urban modeling

Methodology

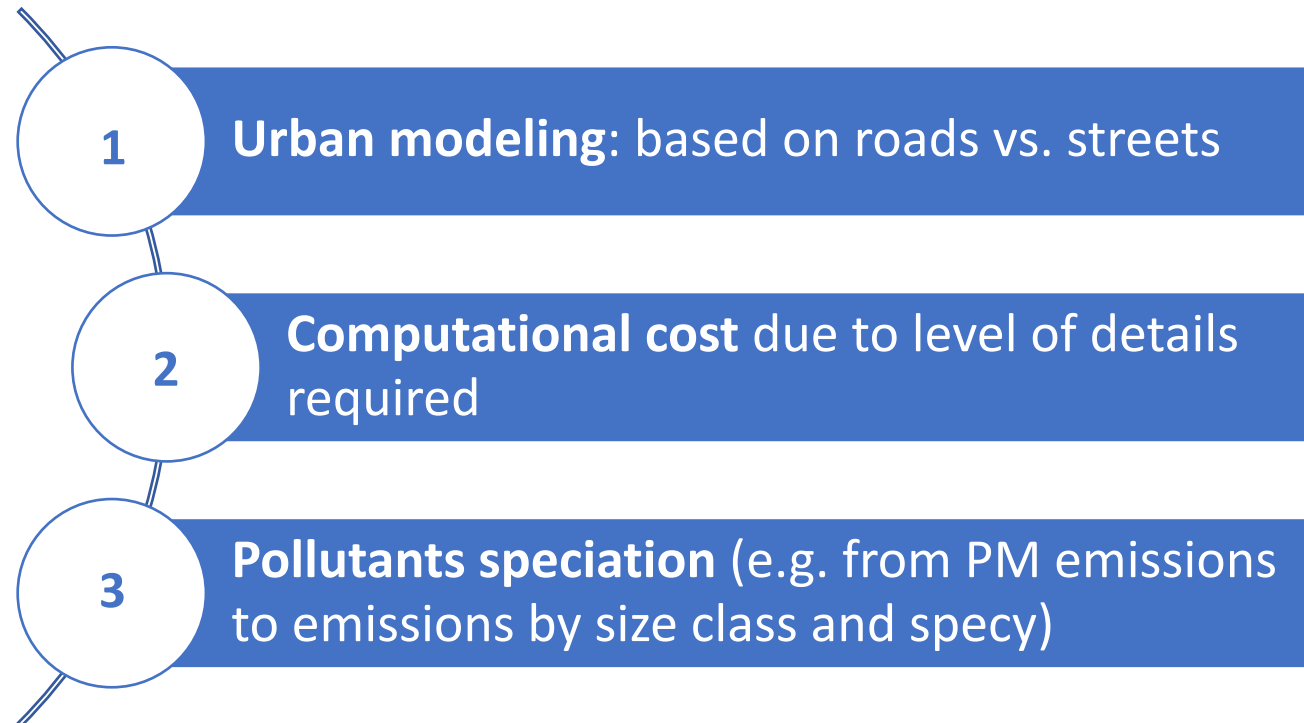## How to couple a traffic model and an air quality model?

- In transportation models, **traffic lines** and **junctions** are used as a basis for urban modeling

- Air transportation models rely on a **built environment** model based on streets and intersections

Marjolaine LANNES

Methodology
How to couple a traffic model and an air quality model?

Modeling
challenges

1   **Urban modeling**: based on roads vs. streets

2   **Computational cost** due to level of details required

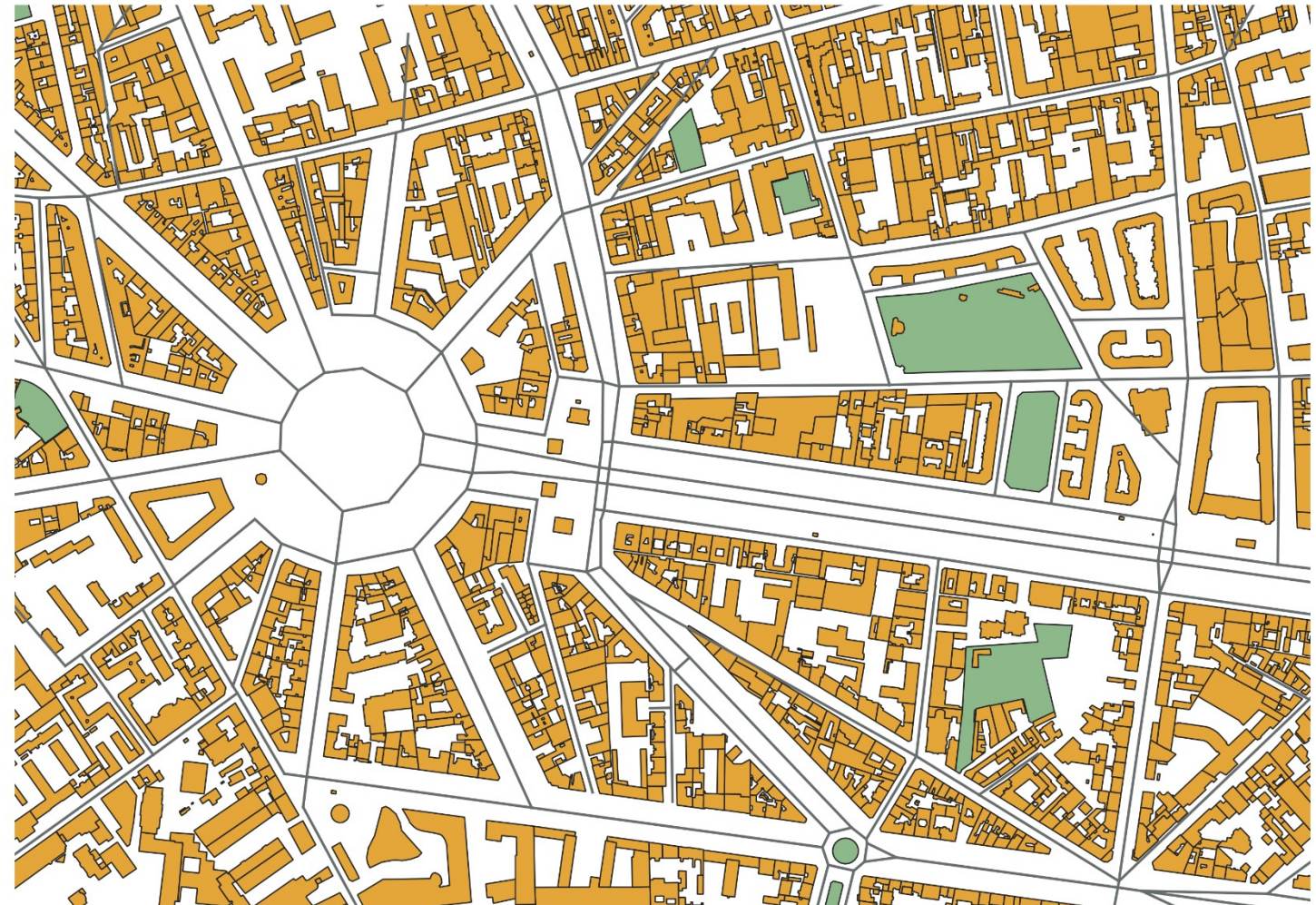**3**   **Pollutants speciation** (e.g. from PM emissions to emissions by size class and specy)

Marjolaine LANNES

Methodology
Street network generation

How to generate a street network for air quality modeling based on street canyons ?

Road graph from OpenStreetMap

0   100   200 m
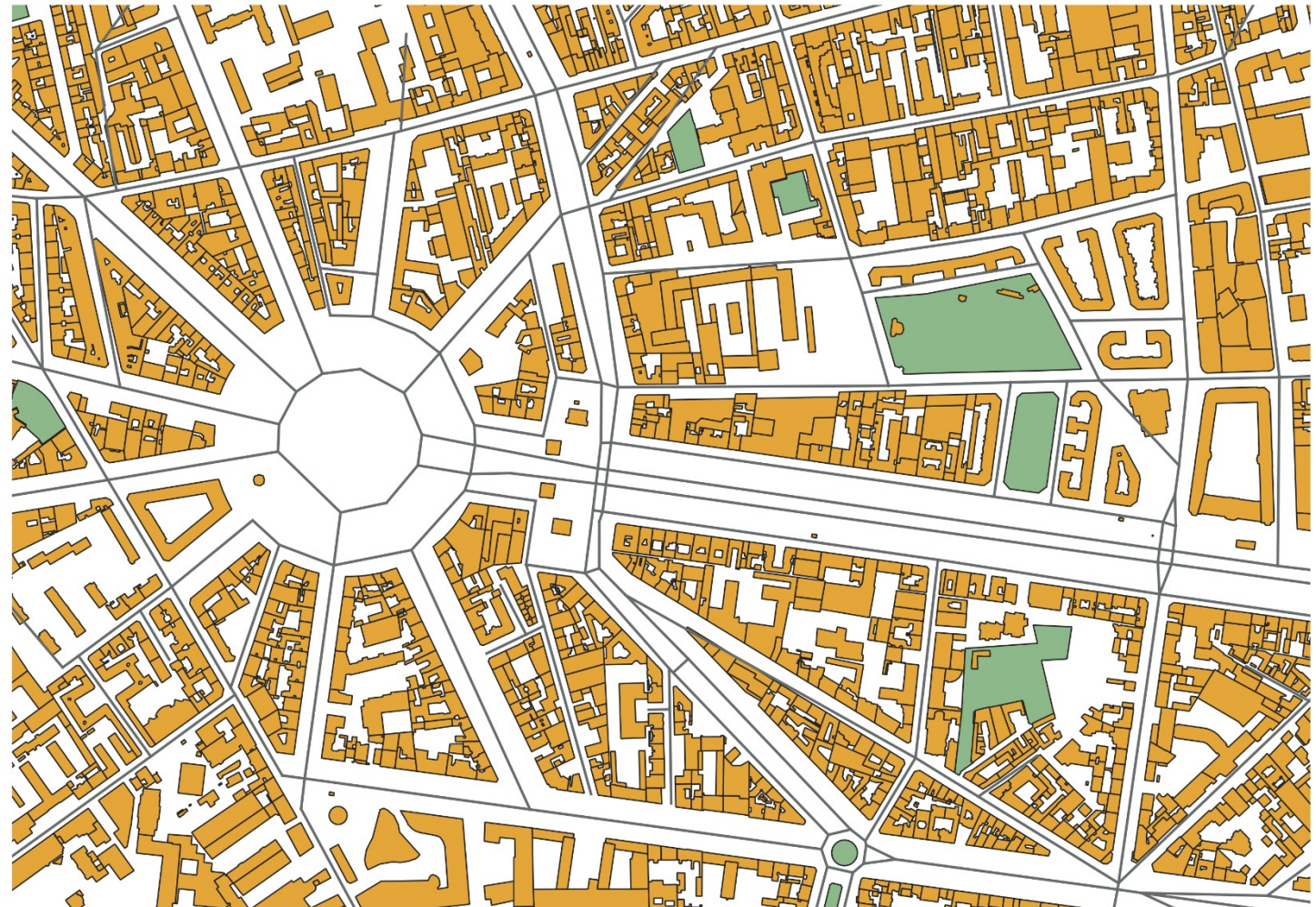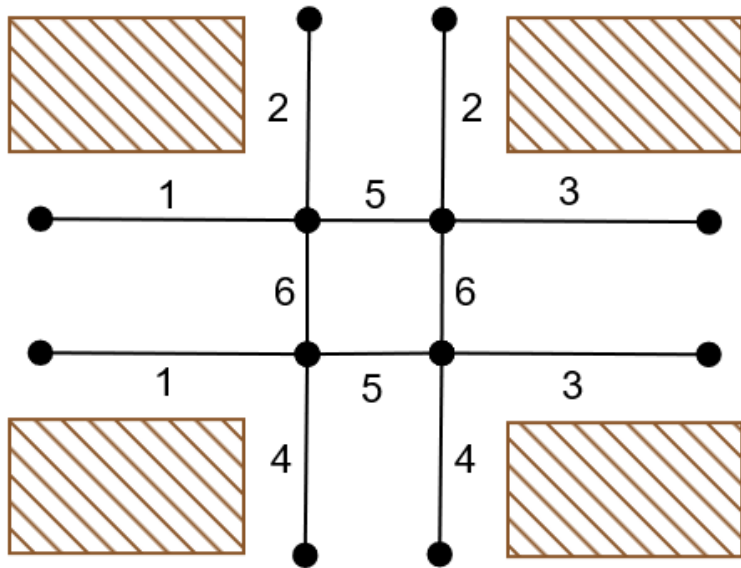
Marjolaine LANNES

Methodology
Street network generation

How to generate a street network for air quality modeling based on street canyons ?

1. Identify roads to group together
2. Transform links
3. Transform nodes

Road graph from OpenStreetMap

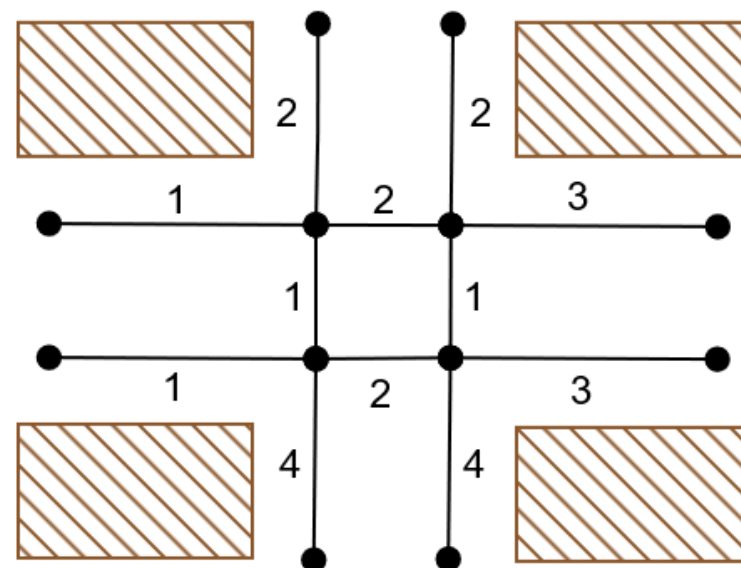0   100   200 m

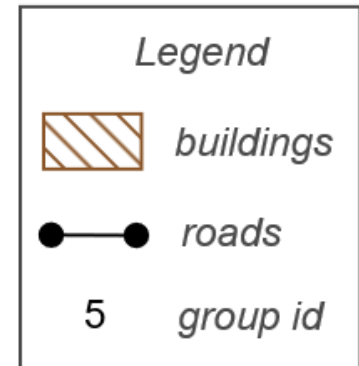Marjolaine LANNES

Methodology

Street network generation : 1) groups identification

Step 1: parallel roads identification

Step 2: perpendicular groups
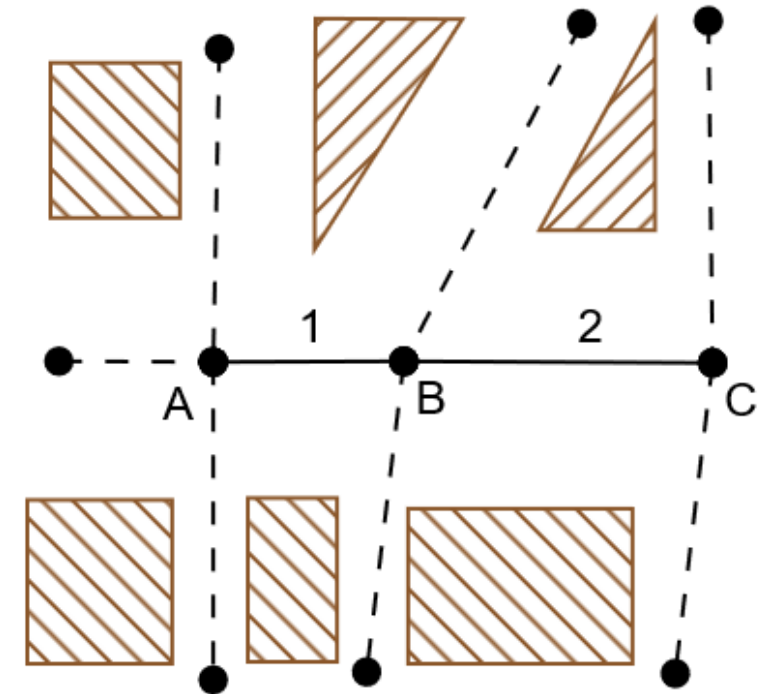
Legend

buildings

roads
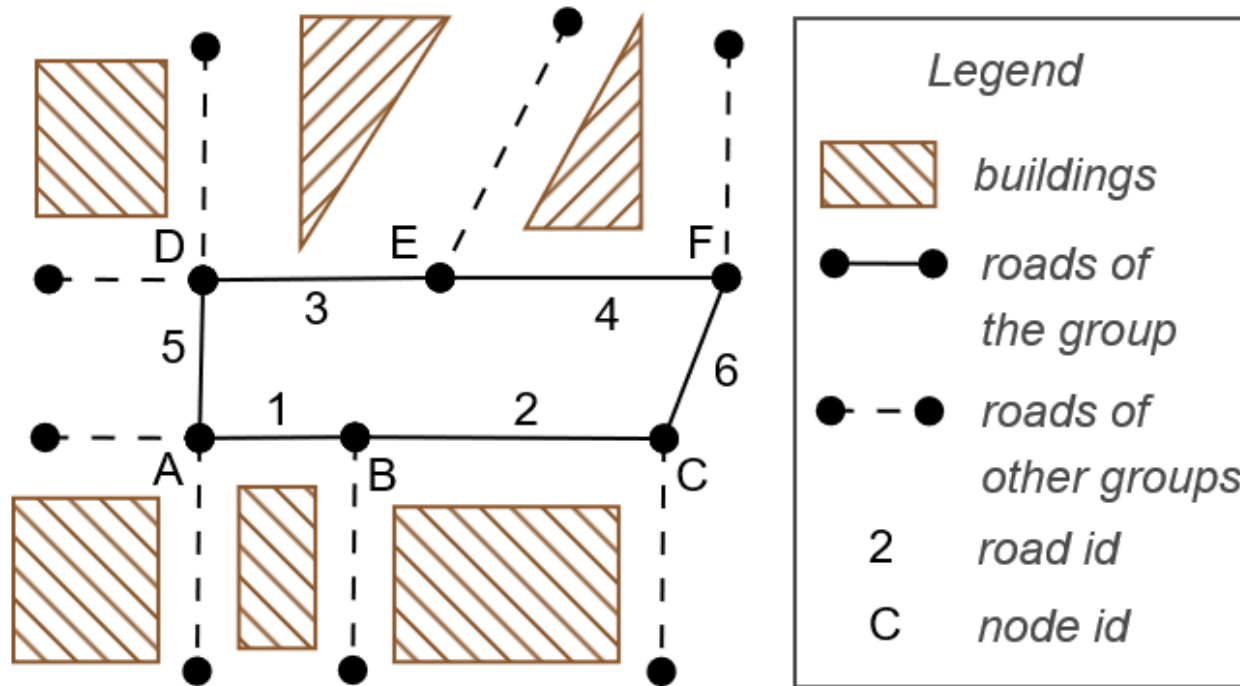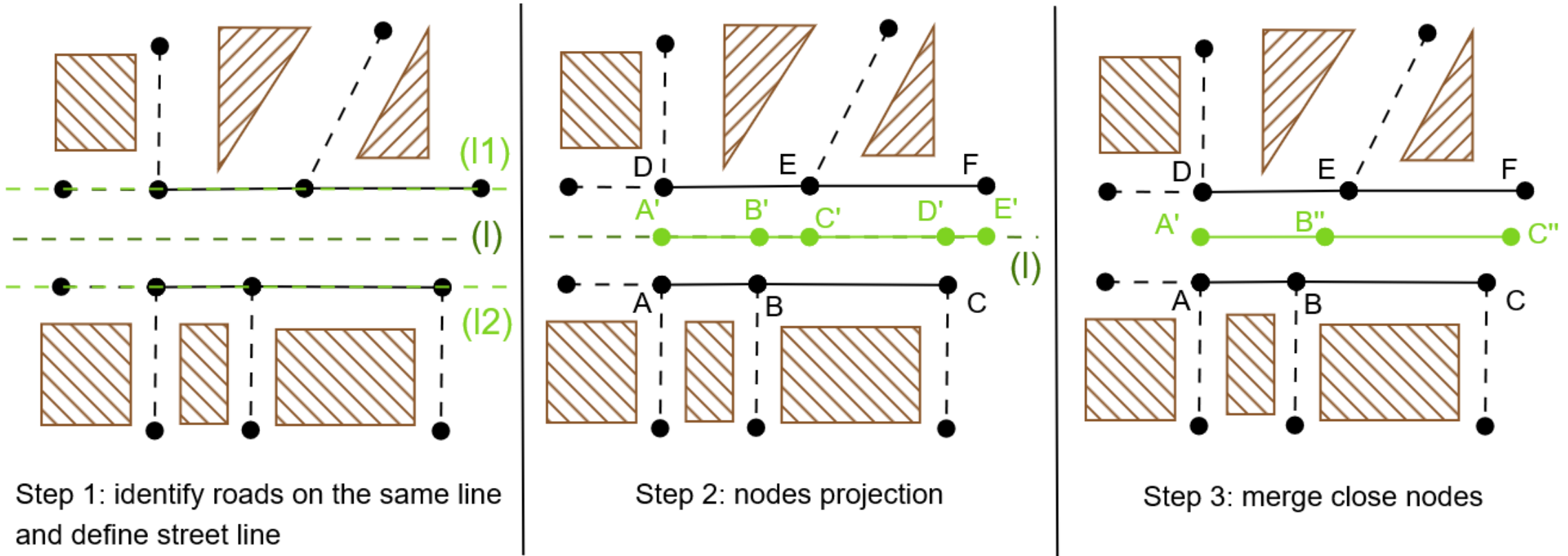
5 group id

Methodology

Street network generation : 2) links transform

Methodology

Street network generation: 2) links transform

Step 1: identify roads on the same line and define street line
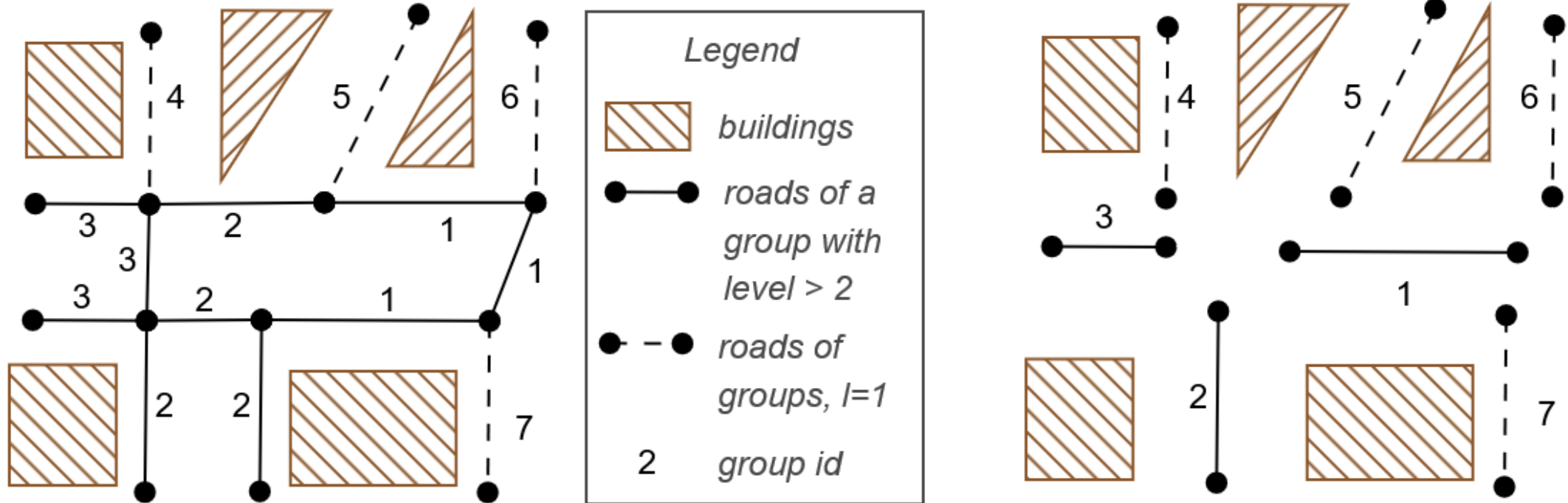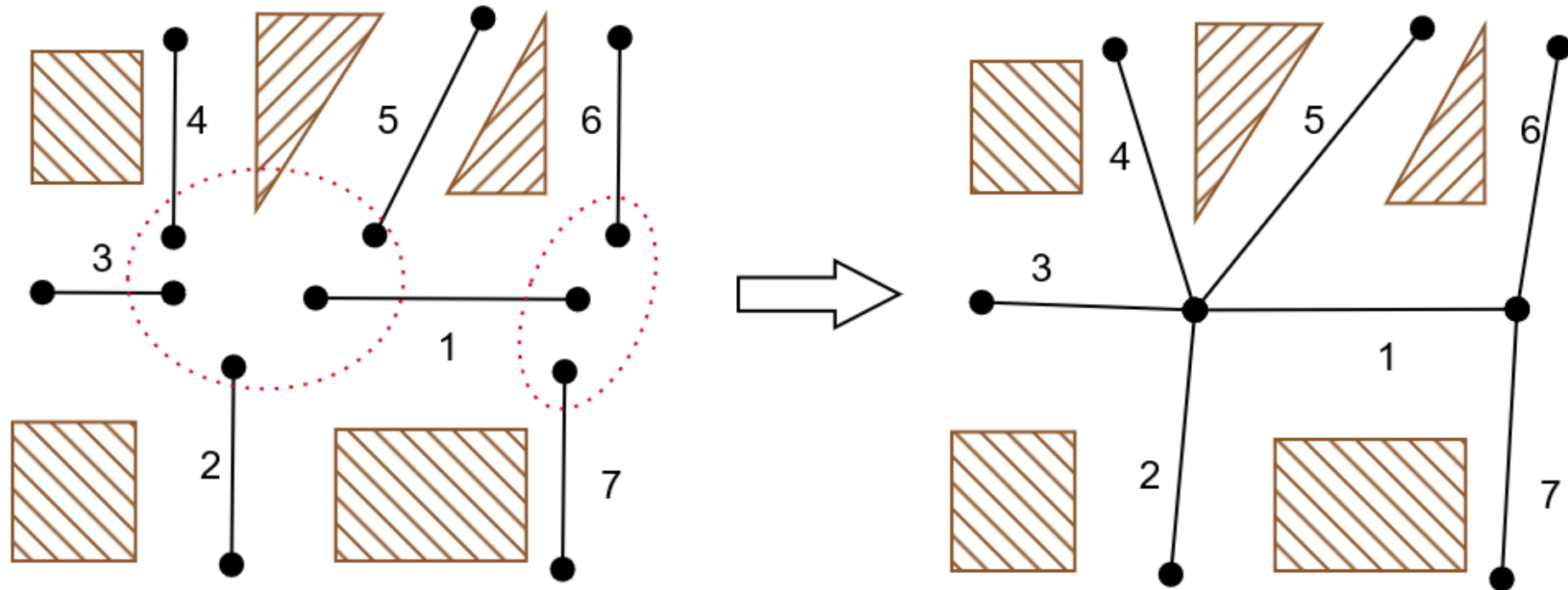
Step 2: nodes projection

Step 3: merge close nodes

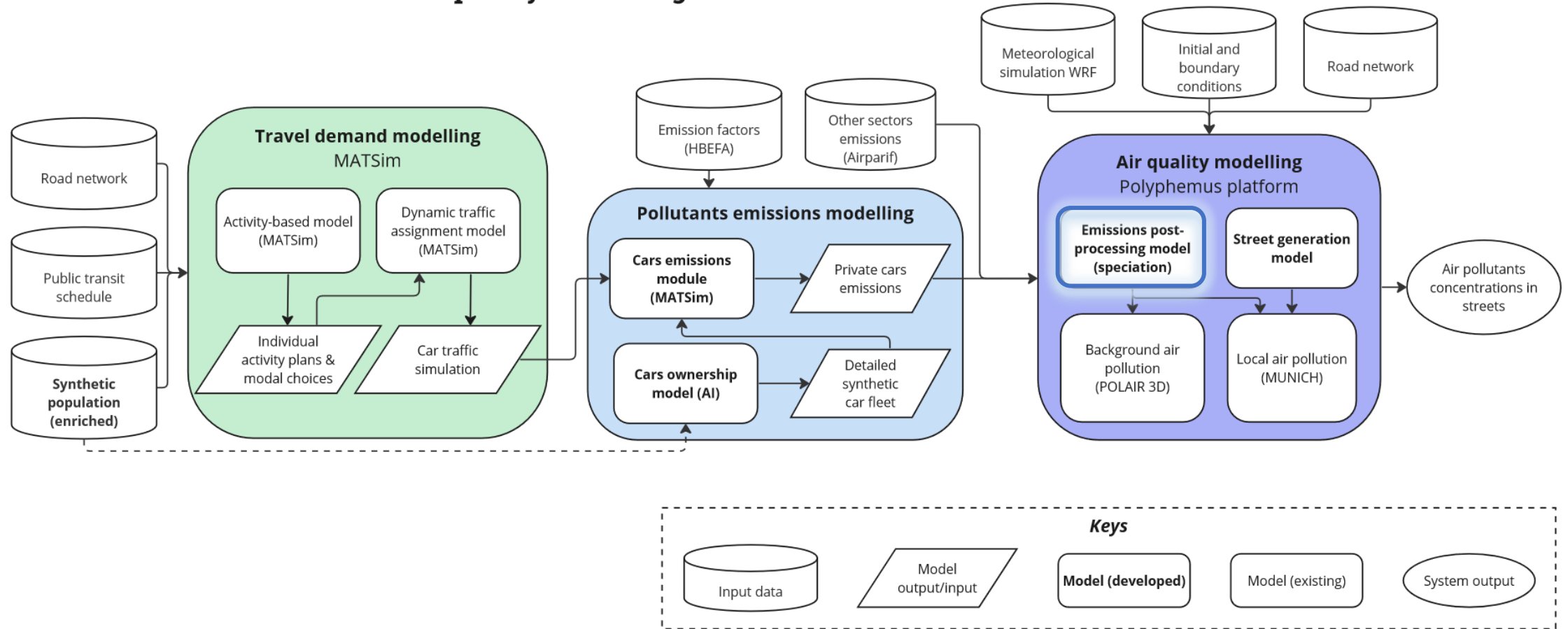## Street network generation : 3) nodes transform

Methodology
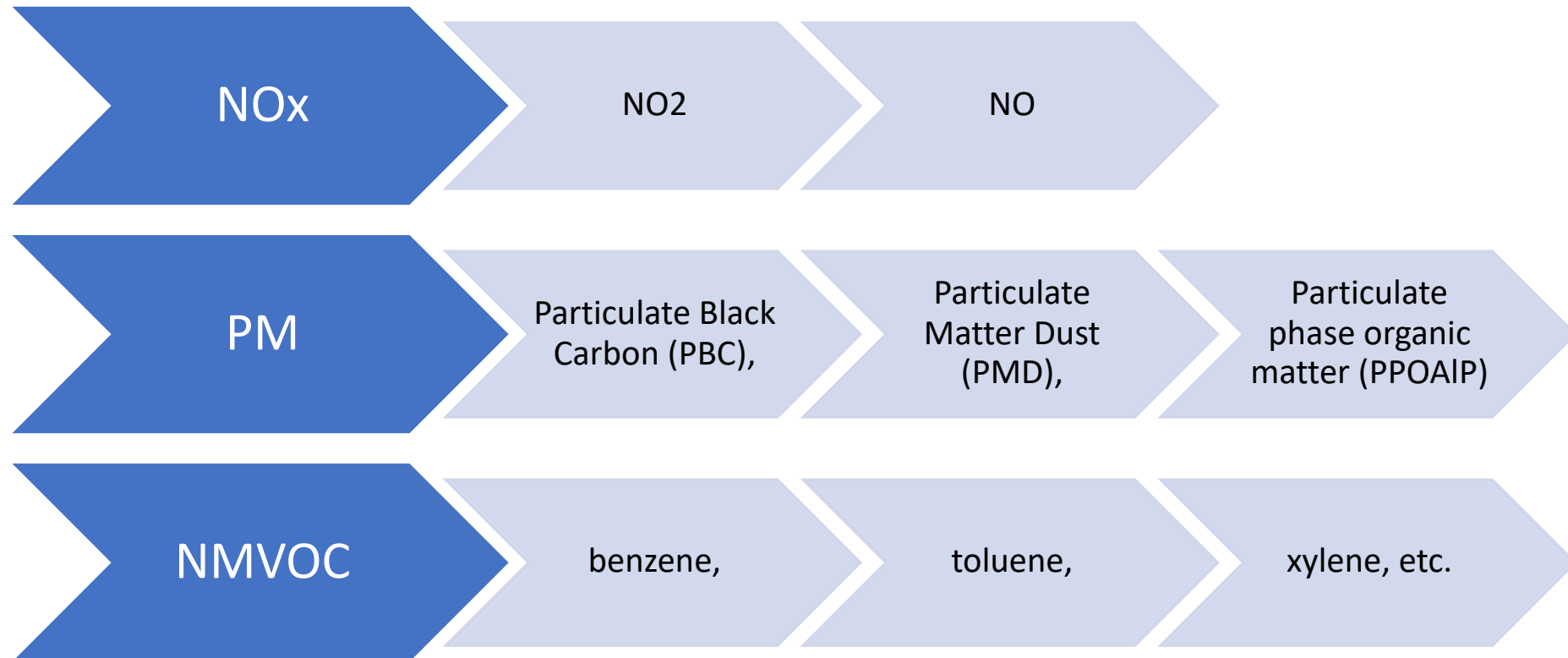
Street network generation : 3) nodes transform

Methodology

The integrated modelling framework for air quality assessment:
travel demand - emissions - air quality modelling chain

Methodology
Pollutants speciation based on COPERT

NOx	NO2	NO	

PM	Particulate Black Carbon (PBC),	Particulate Matter Dust (PMD),	Particulate phase organic matter (PPOAlP)

NMVOC	benzene,	toluene,	xylene, etc.

Methodology
Emissions and chemical-transport modelling

Models	Representation	Spatial resolution and urban modeling	temporal resolution	Chimical representation
HBEFA	Pollutants emissions	Road-oriented graph representation	minute	Primary emissions for aggregated species (PM, COV, etc)
POLAIR-3D	CTM for background concentrations + secondary aerosols	Grid (1 to 3 km resolution)	hour	Includes secondary chemical generation of pollution
MUNICH	CTM for canyon streets concentrations + secondary aerosols	Street-oriented graph representation	hour	idem

Case study

Île-de-France

Surface	12 012.00 km²	Dwellings	5 795 907
Population	12 174 880	Households	5 184 985
Density	1 013.5/km²	Household size	2.3
Active population	8 010 367	Median income	23 230 €
Employment rate	66.7%	Cars: 1 / 2+	44.7%/21.1%

Source: INSEE (2017)

Île-de-France Scenario

Sample size	100%
Emissions Events file	~150 GB
Total Runtime for processing and calculations (emissions by type per link)	~5h

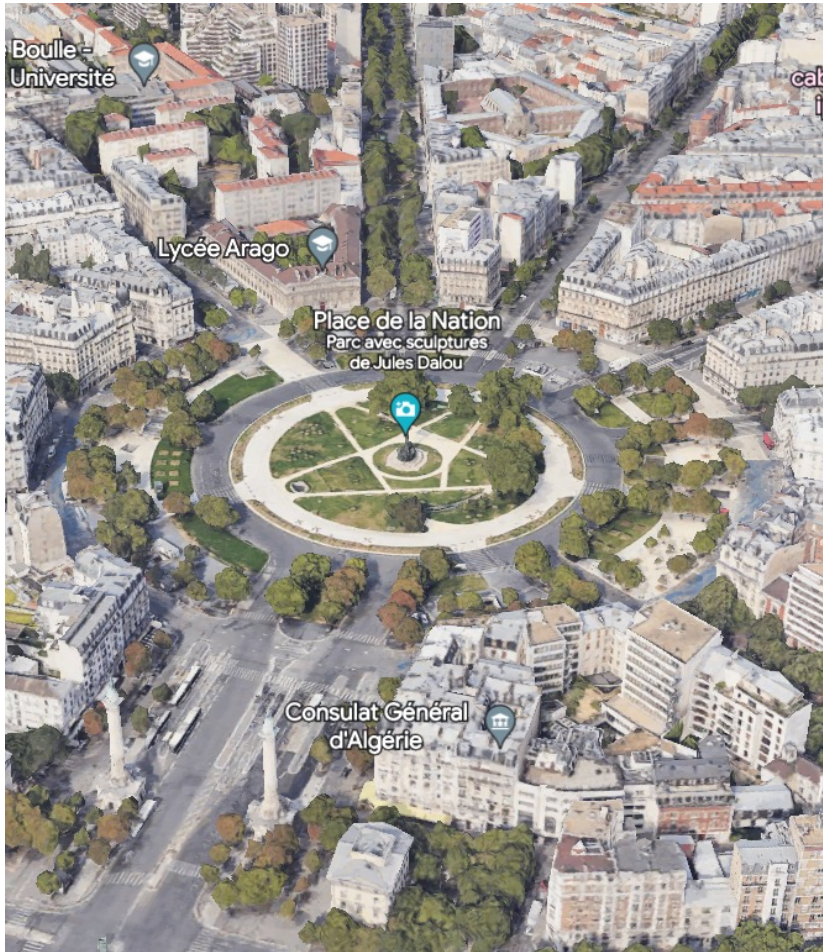Machine with a **64 core CPU**, Intel®Xeon®Platinum 8368 CPU @ **2.40GHz**, and **768 GB** available memory.

Marjolaine LANNES
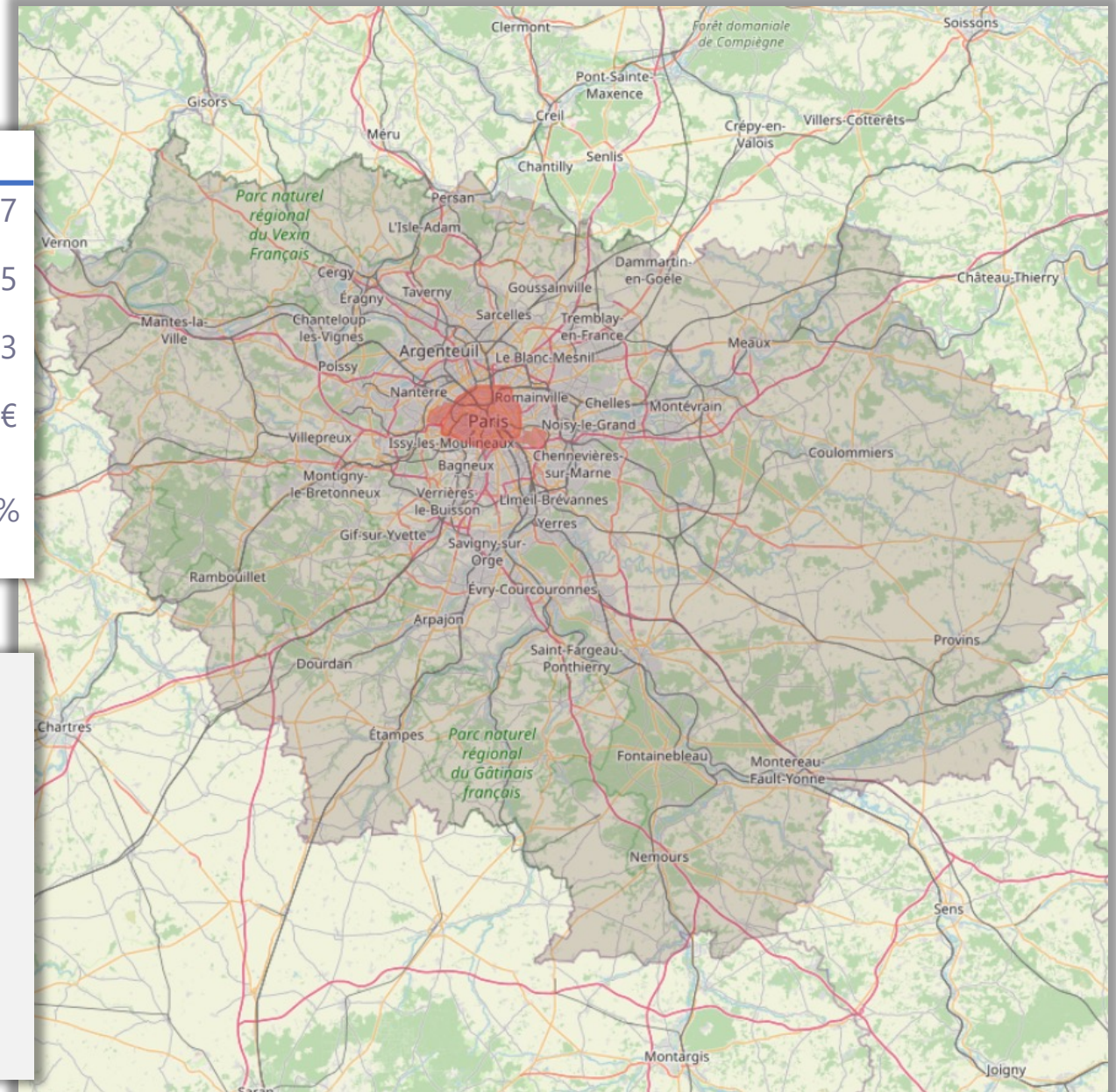
First results
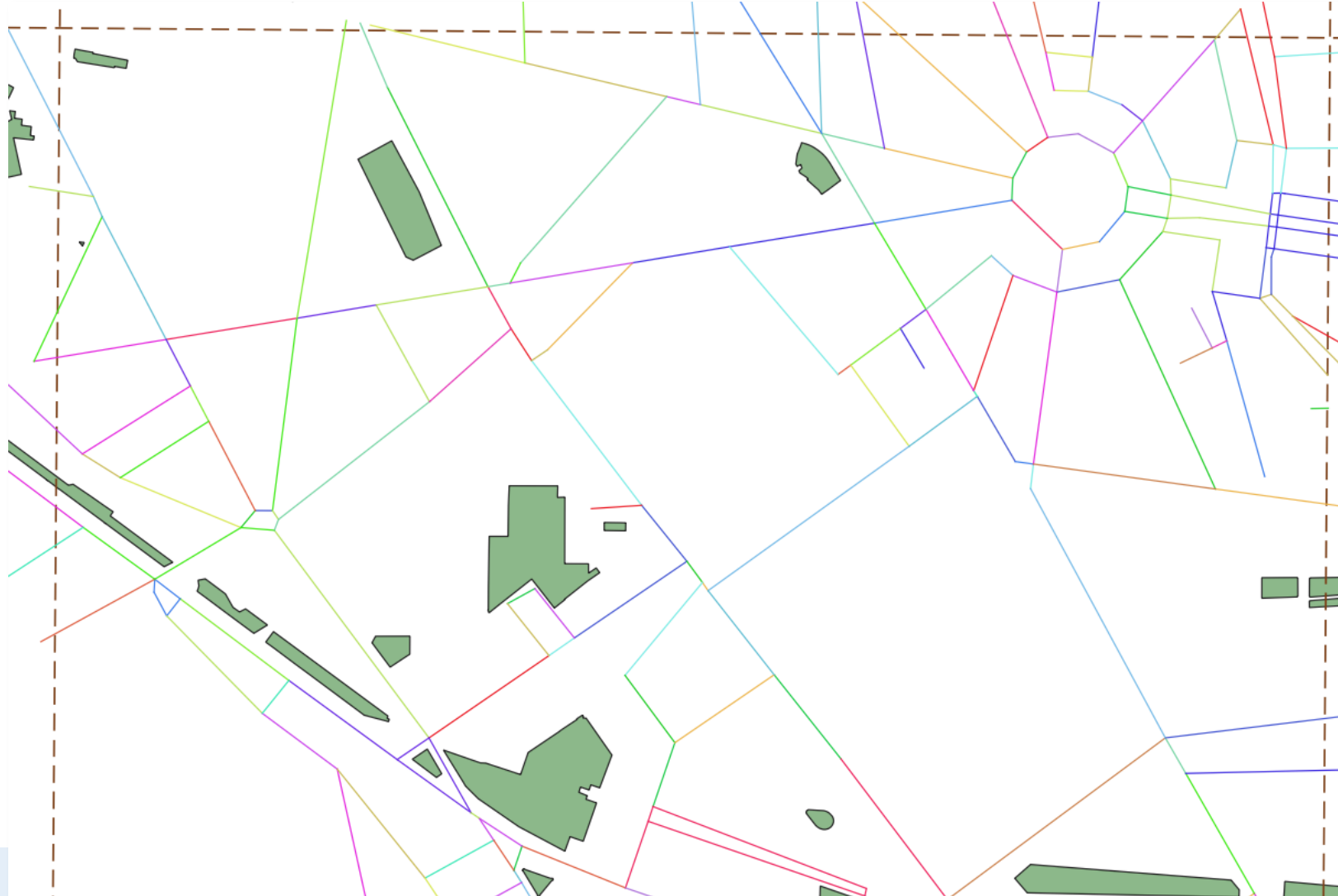## Car fleet synthesis
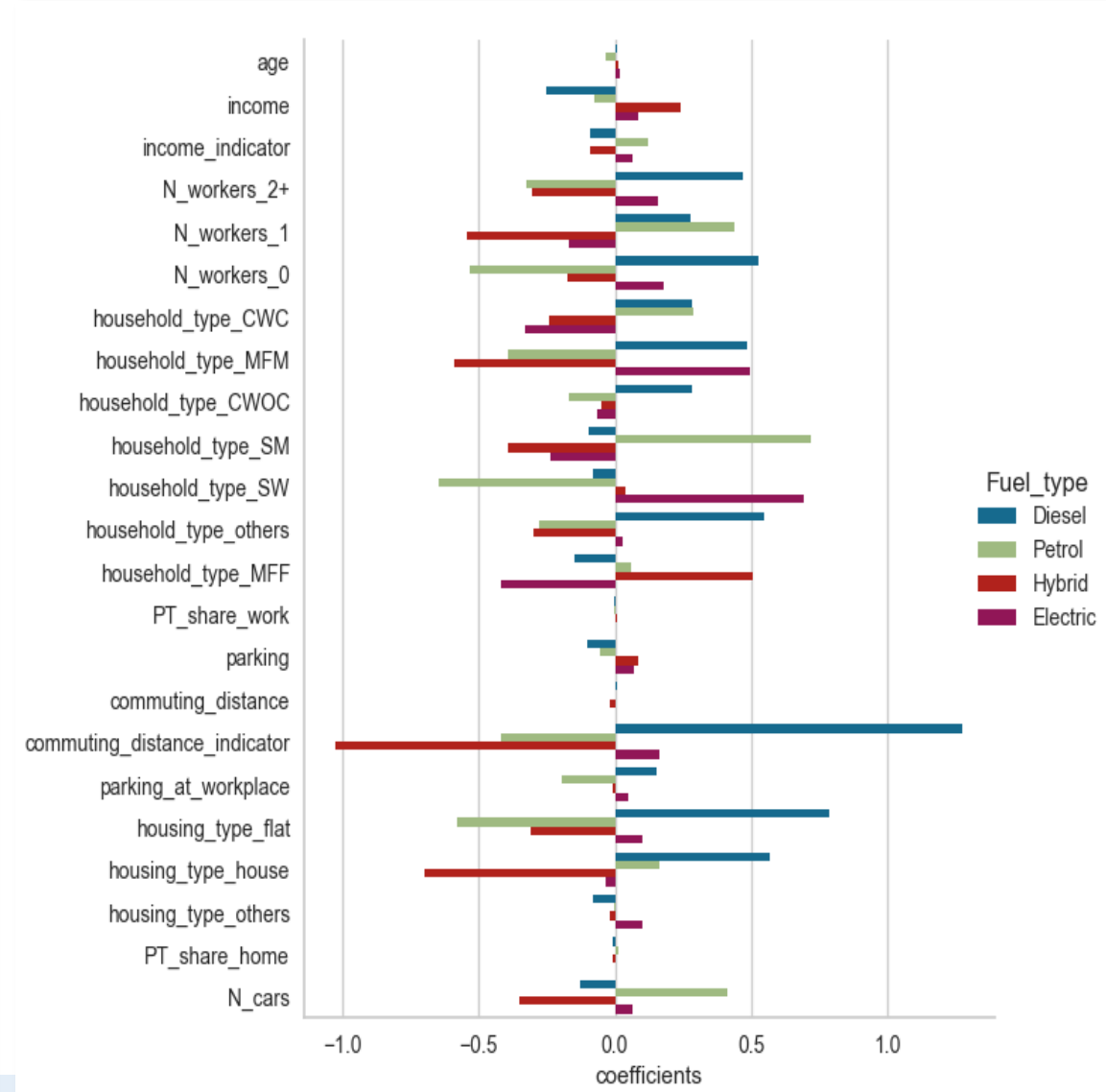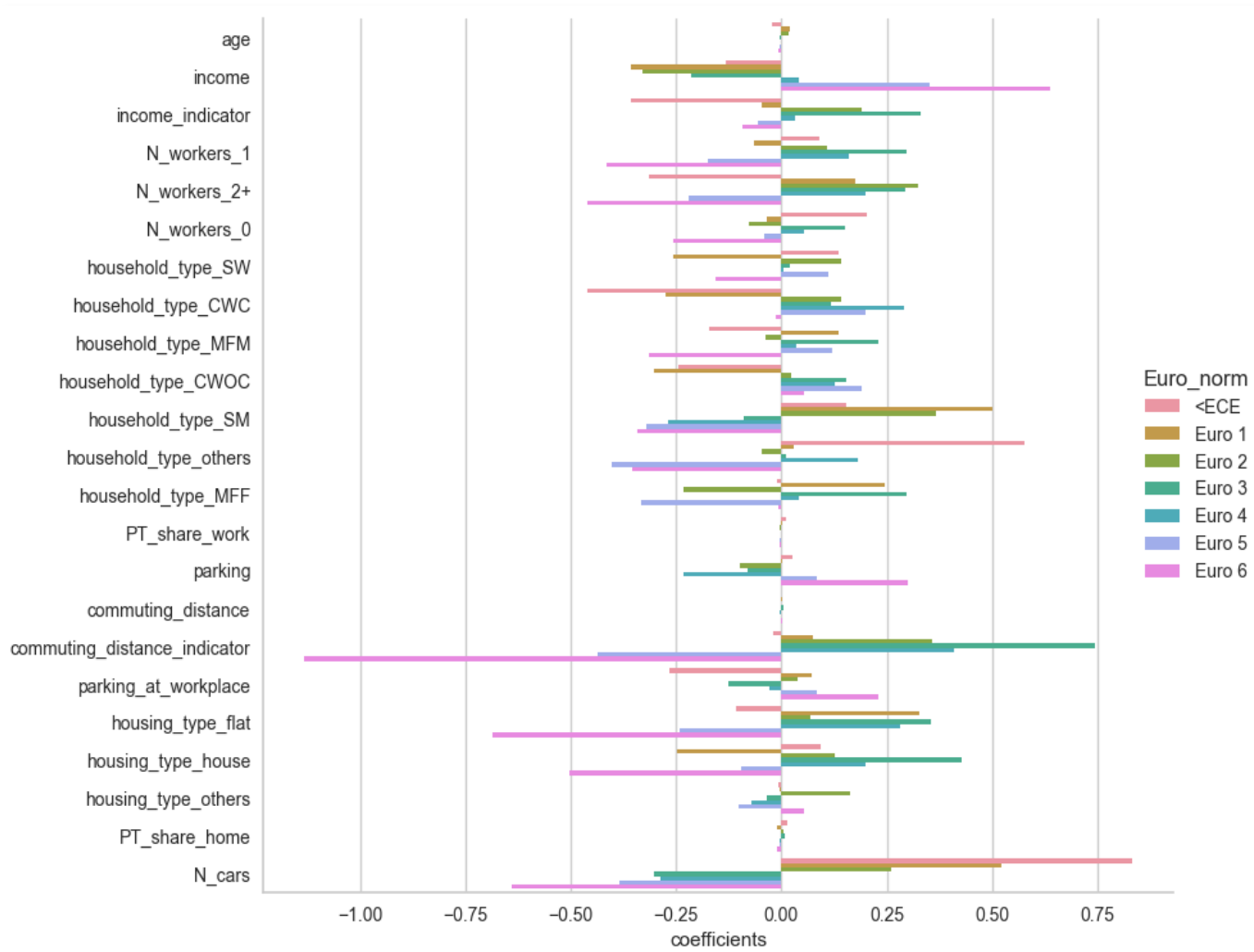
First results

Street network

Source: Google Earth

Road graph from OpenStreetMap

0   100   200 m

Marjolaine LANNES
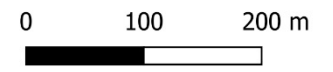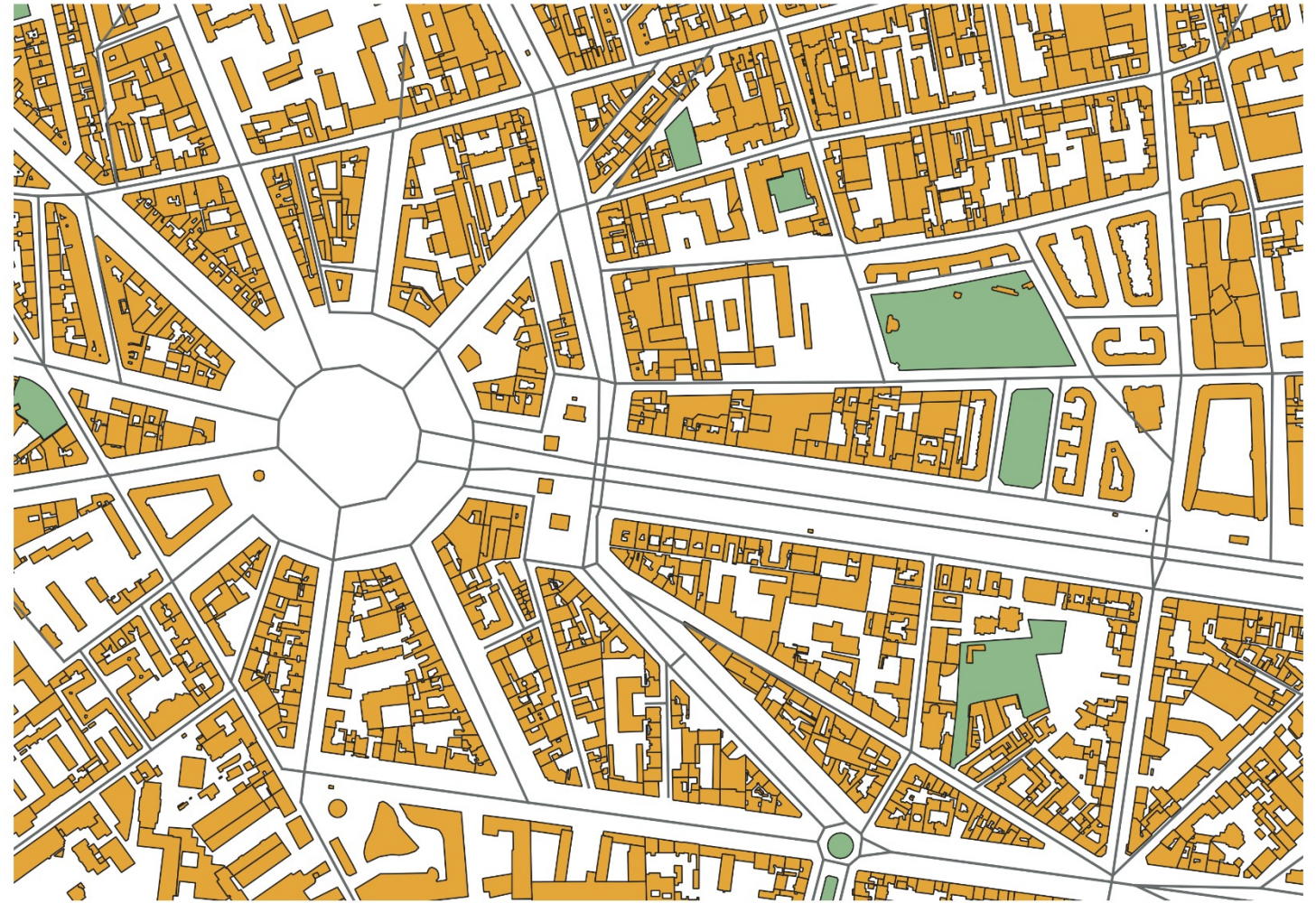
First results

Street network

Source: Google Earth

First results

Street network

Marjolaine LANNES

First results

Street network

Marjolaine LANNES
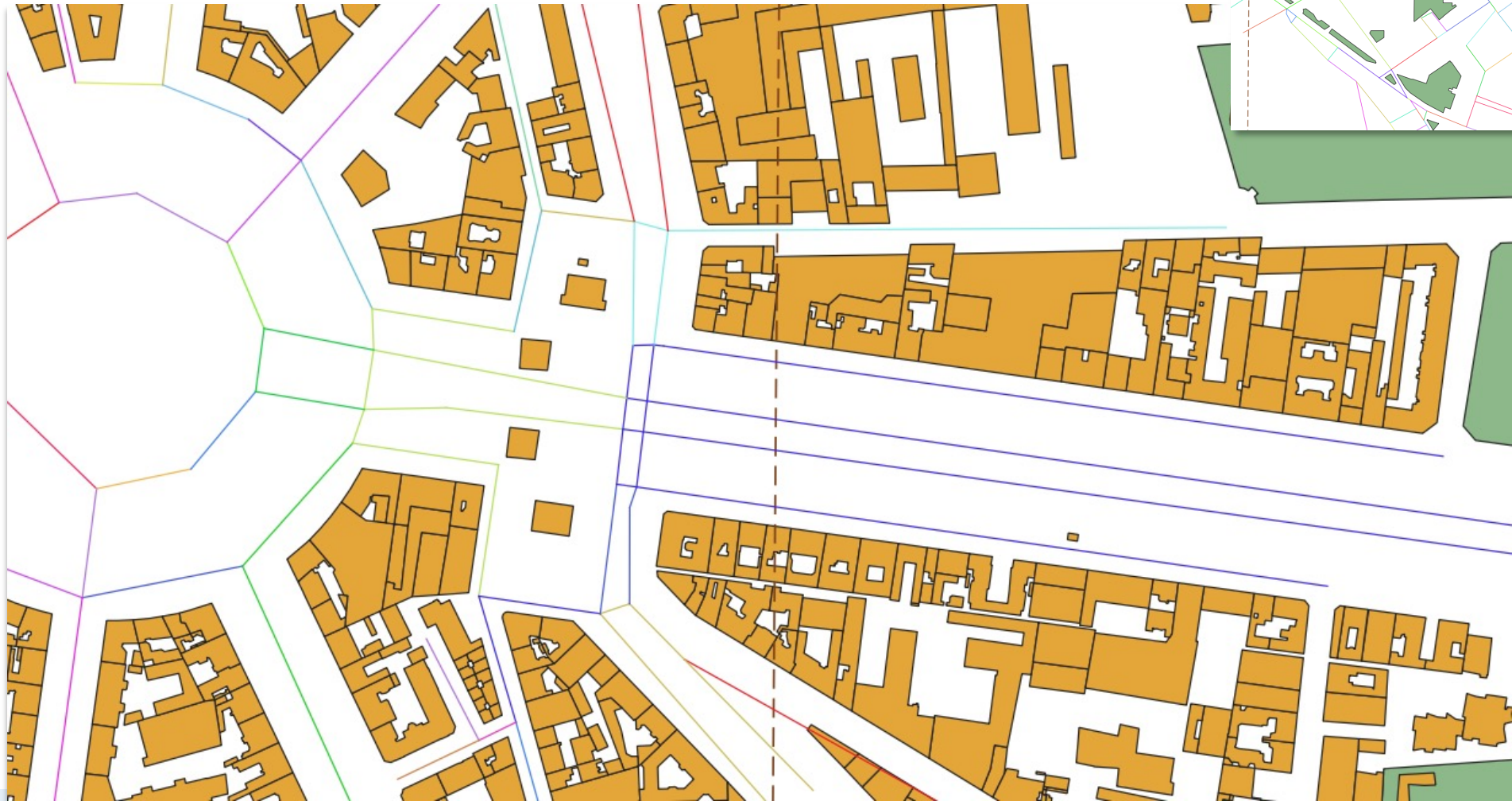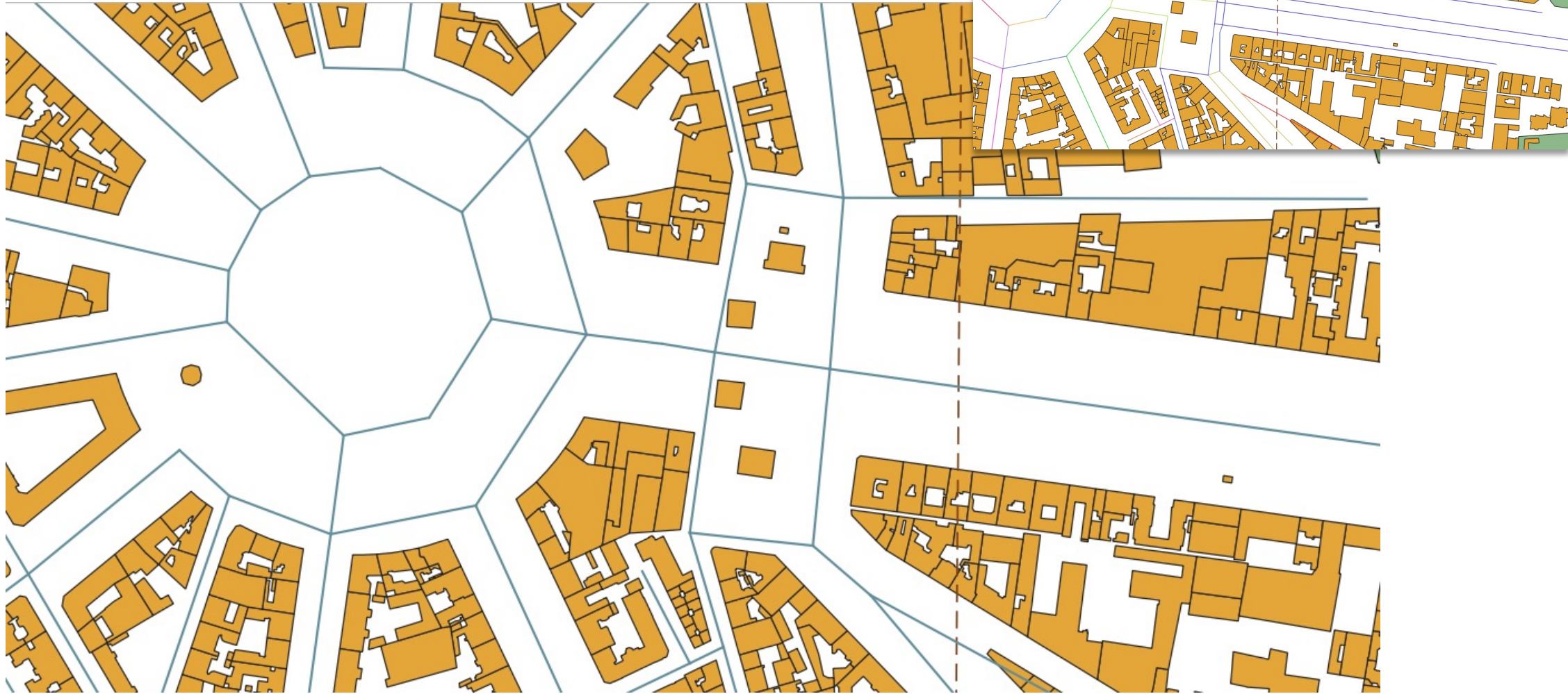
Results
Street network
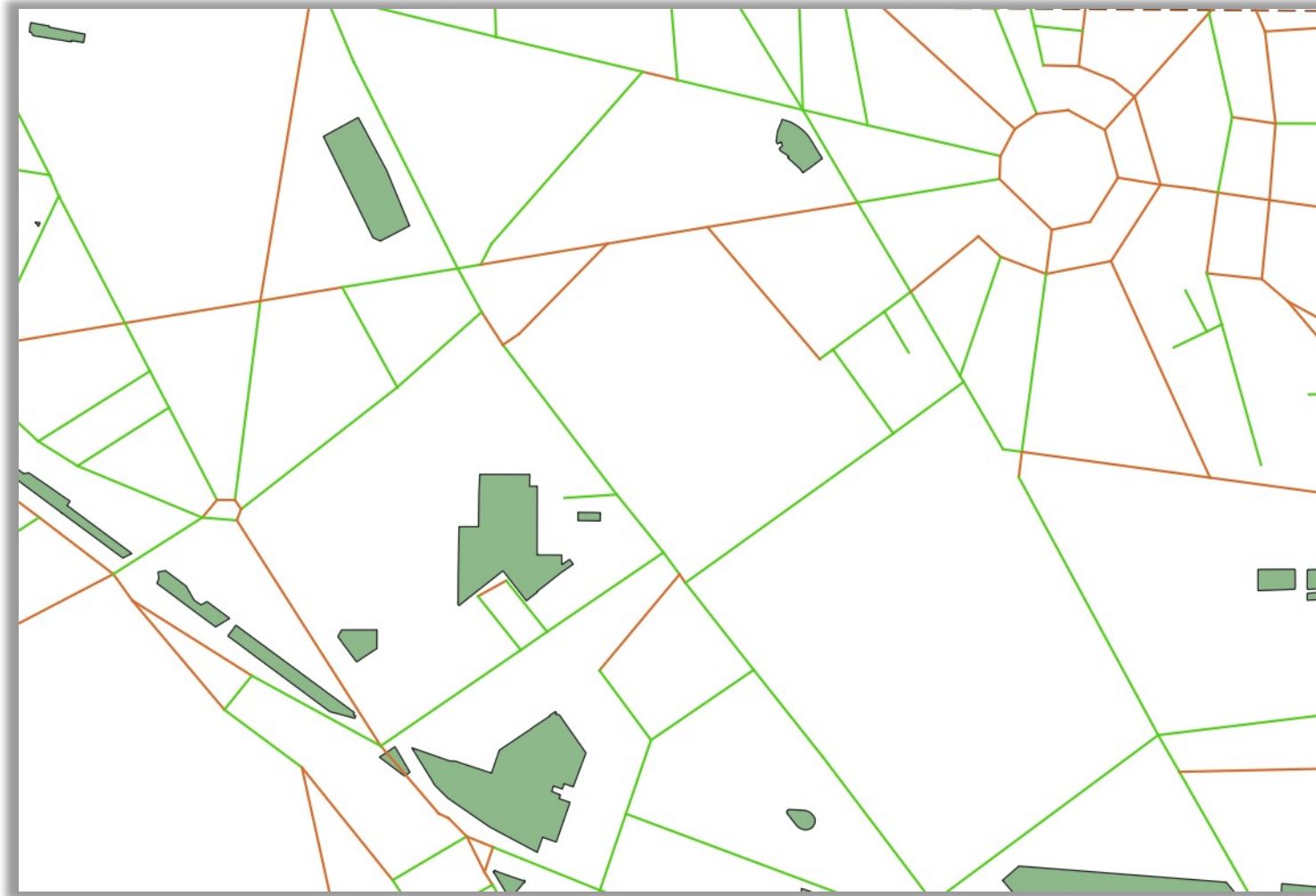
R = Height / width
$$R_{lim} = 1/3$$

Results

NO2 Emissions from 6 pm to 7 pm
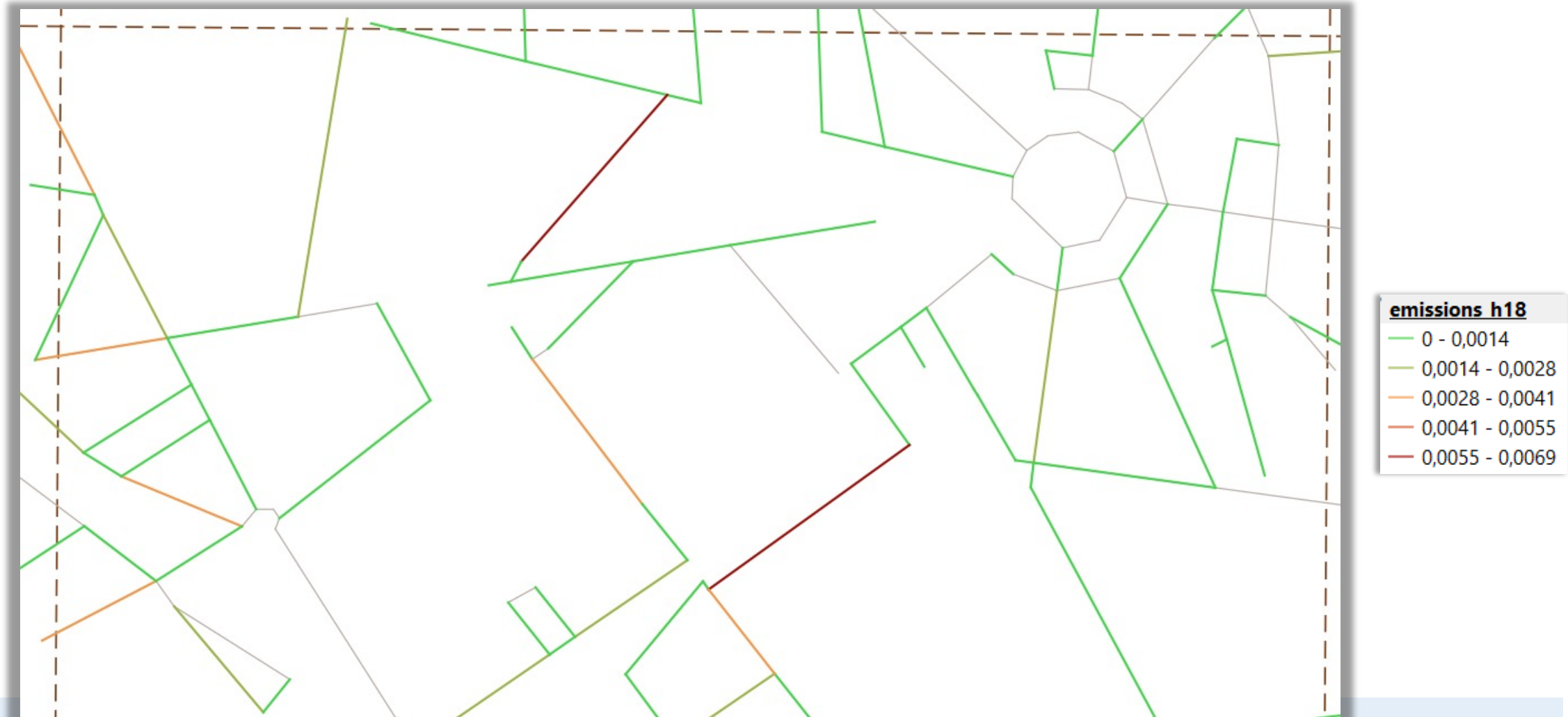
emissions_h18
- 0 - 0,0014
- 0,0014 - 0,0028
- 0,0028 - 0,0041
- 0,0041 - 0,0055
- 0,0055 - 0,0069

Conclusions
Developments

1 – Car fleet synthesis	• Based on households characteristics • Pollutant emissions-related typology
2 – Street network synthesis	• Based on OSM road network • Street network adapted for air quality modelling
3 – Emissions modelling	• HBEFA module in MATSim • Spatiotemporal aggregation (hour and link resolution) • Pollutants speciation

Conclusions
Developments

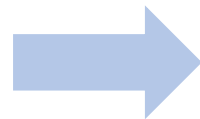|	
1 – Car fleet synthesis	• Based on households characteristics • Pollutant emissions-related typology
2 – Street network synthesis	• Based on OSM road network • Street network adapted for air quality modelling
3 – Emissions modelling	• HBEFA module in MATSim • Spatiotemporal aggregation (hour and link resolution) • Pollutants speciation

Next step : simulation of **concentrations** in the streets

Marjolaine LANNES
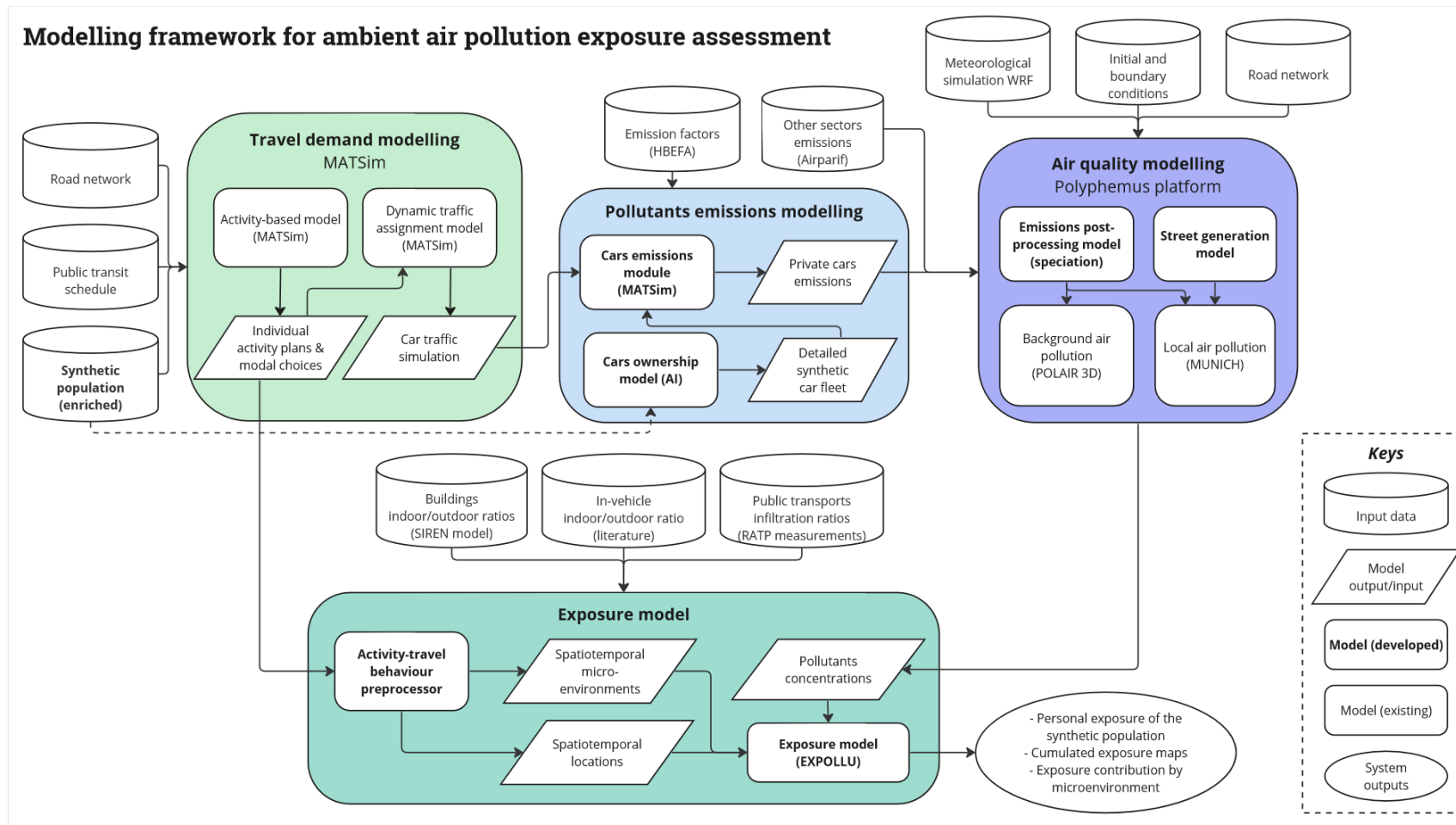
Conclusions

Towards exposure assessment

travel demand - emissions - air quality modelling chain

Conclusions
Towards exposure assessment

Modelling framework for ambient air pollution exposure assessment

Marjolaine LANNES
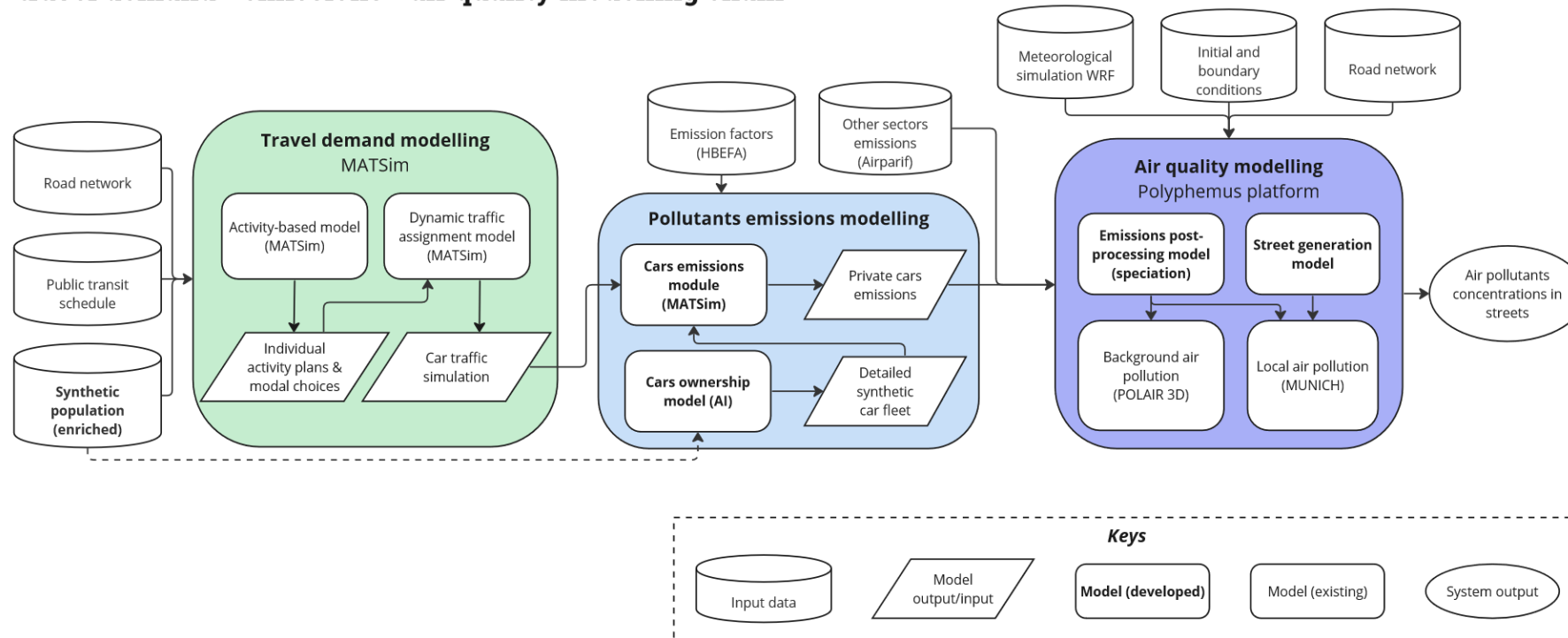
Bibliography

[1] Gurram, Sashikanth, Amy Lynette Stuart, and Abdul Rawoof Pinjari. 2019. 'Agent-Based Modeling to Estimate Exposures to Urban Air Pollution from Transportation: Exposure Disparities and Impacts of High-Resolution Data'. *Computers, Environment and Urban Systems* 75: 22–34.

[2] Hörl, Sebastian, and Milos Balac. 2021. 'Synthetic Population and Travel Demand for Paris and Île-de-France Based on Open and Publicly Available Data'. *Transportation Research Part C: Emerging Technologies* 130: 103291.

[3] Lugon Lya, 2021. 'Modélisation de la qualité de l'air dans les rues de Paris'. https://www.theses.fr/2021ENPC0011

Marjolaine LANNES

Thank you for your attention !

Contact : marjolaine.lannes@enpc.fr

Marjolaine LANNES