Health mobility:
From a toy example to the Large-Scale network of Grenoble

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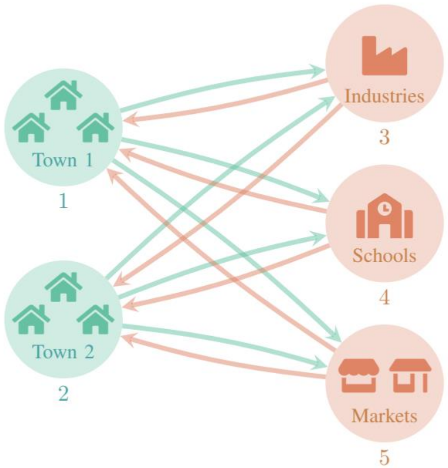
October 14, 2021
Inria Paris,
1st workshop “Epidemic: modeling, identification, control”



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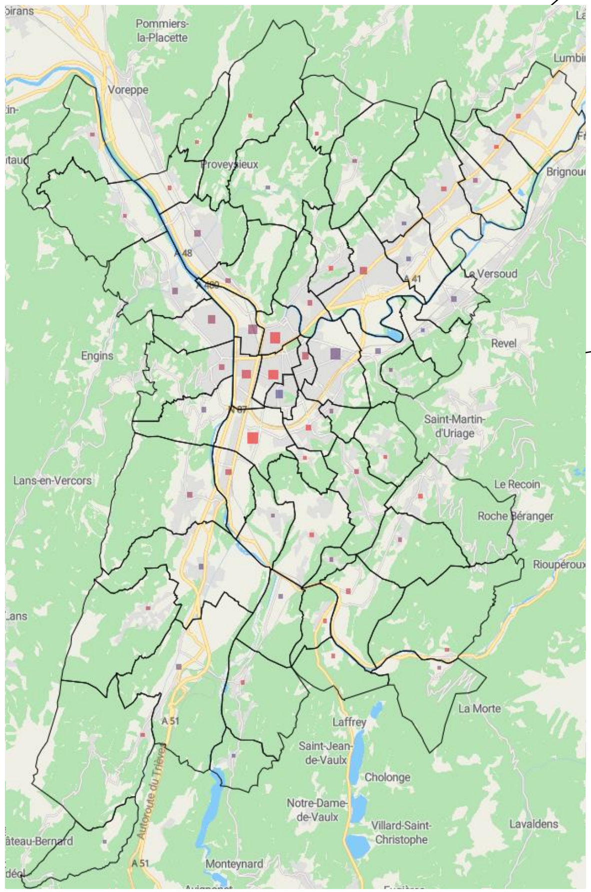
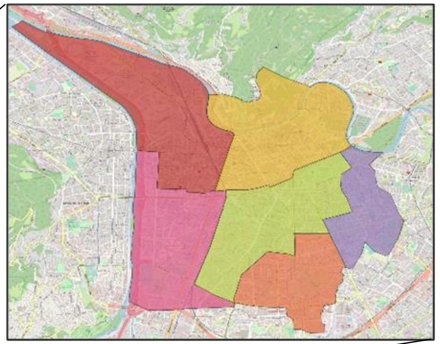
Main Ingredients to build the Grenoble network in the time-scale of hours

- Nodes (Location & Population/Capacity):
  - Origins
  - Destinations
- Origin/Destination matrix (WHW):
  - W: Where to go
  - H : How many
  - W: When to move

Region of study : Grenoble area

➤ Grenoble metropole and some communes of Gresivaudan





➤Origin nodes

- Communes and Grenoble sectors
  - Location: residential areas
  - Population
    - INSEE
    - Grenoble metropole
    - Population age groups (eg. 3-8, 8-11)

Places of interests: destination nodes

Schools
Primary schools
Middle schools
High Schools
Universities

Hospitals
CHU
Clinique mutualiste
Private clinics

Workplaces
Companies
Research centers
Microenterprises

Market
Malls
Supermarkets
Small shops

Leisure
Restaurants /bars
Parks
Stadiums
Theaters

➢ Location : sources and techniques

- Importing and filtering from **OpenStreetMap**
- Manually creating **GeoJSON*** files
- Manually locating them in **Google maps**

Softwares: QGIS/ python/ Matlab/ OSM maps

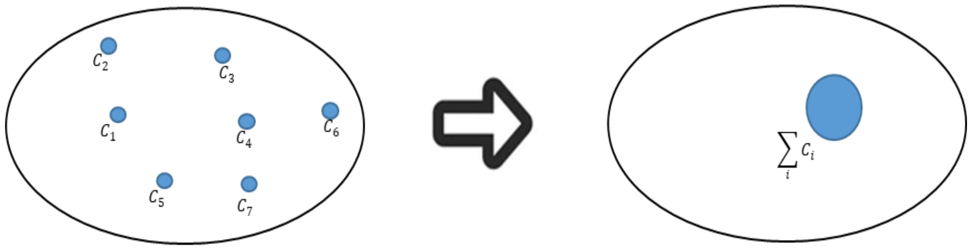
➢ Capacities: sources and techniques

- Academie de Grenoble: number of students
- Fire department rules: persons/square meters
- Destinations/Booking websites
- Manually using data fitting and/or imputation

Softwares: QGIS/ Matlab/ python

➢ Aggregation:

- ➢ **All nodes** in one region are **aggregated**
  - ➢ Capacity : sum of capacities
  - ➢ Location: barycenter of all the nodes



* File type containing node location and different information used in online maps

OD Connections: origins to where?

- **Primary schools**
  - Connected to the same origin node
- **Lycee**
  - Govt. assigned Lycee according to ones address
- **College**
  - Govt. assigned sectors for each college
- **Universities/ Hospitals**
  - Connected to every origin node

- **Work place / Market /Leisure**
  - Attraction based laws depending on road distance

Rules: attraction based laws

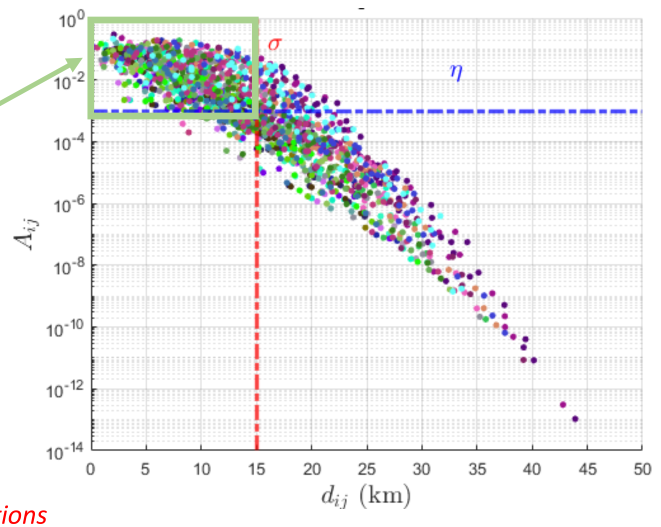
- If $d_{ij} = road\ distance^{*}$ between i and j, then attraction between them

$$Q_{ij} = P_i C_j e^{-|\ln(1-\nu)|\left(\frac{d_{ij}}{\sigma_j}\right)^2}$$

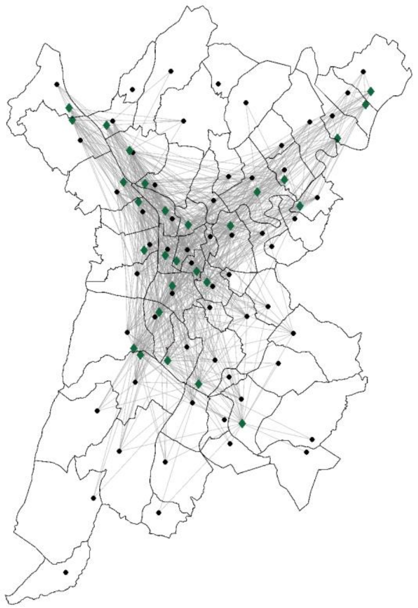
- Normalized attraction

$$A_{ij} = \frac{Q_{ij}}{\sum_h Q_{hj}} \quad \text{and} \quad O_{ij} = \begin{cases} 1 \;\; if \;\; d_{ij} \le \sigma_j \text{ and } A_{ij} \ge \eta \\ 0 \;\; o/w \end{cases}$$

σ_j = maximum distance that ν % of the people travel daily to j.
η = threshold on attraction between i and j.



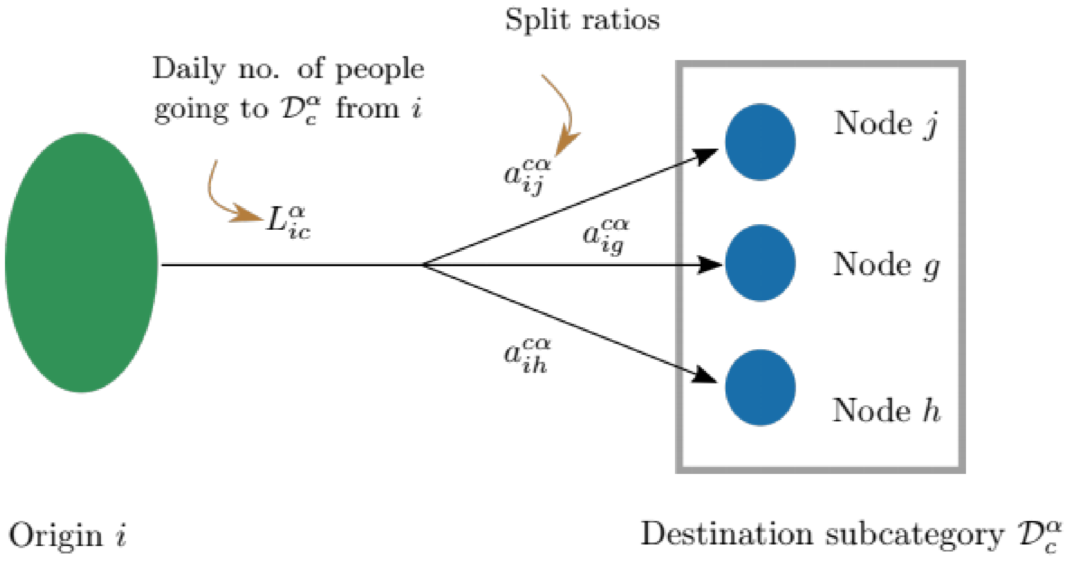
Companies



* *real minimum road distance computed using the road network between all possible origins and destinations*

Boeing, G. 2017. "OSMnx: New Methods for Acquiring, Constructing, Analyzing, and Visualizing Complex Street Networks." *Computers, Environment and Urban Systems*.

Connection weights:
How many people from origin to destinations?



$$L_{ic}^{\alpha} \propto \textbf{Population of } i * \sum_{k \in \mathcal{N}_i} c_k$$

$$a_{ik}^{c\alpha} \propto \textbf{Capacity of } k$$

$$\sum_k a_{ik}^{c\alpha} = 1$$

Daily number of people going from i to k:

$$M_{ik} = L_{ic}^{\alpha} a_{ik}^{c\alpha}$$

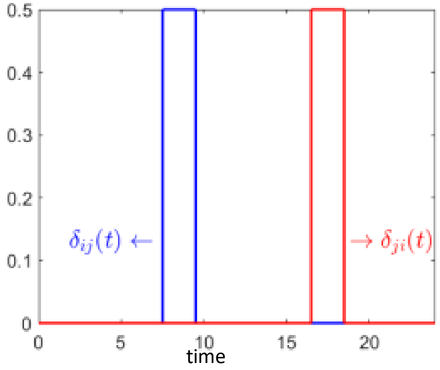
Time schedules and mobility patterns: When does mobility happen?

- Scheduling variables:
  - opening times, closing times and average time spent
    - Different sources for different subcategories
      - Académie de Grenoble
      - Openstreetmap / Google maps
      - Destination / booking websites

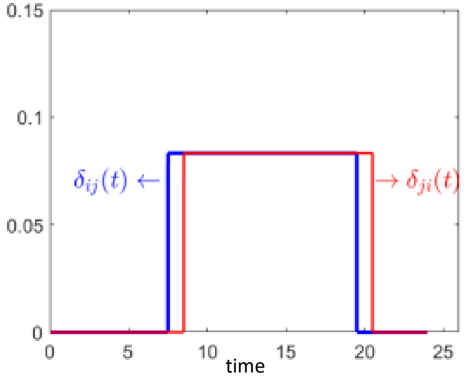
	Opening	Closing	Average time
Malls	10:00	20:00	2h
Supermarkets	7:30	22:00	45min
Small shops	9:00	19:00	20min

Demand gating functions: $\delta_{ij}(t)$

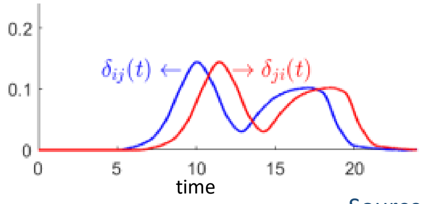
Schools/Workplaces



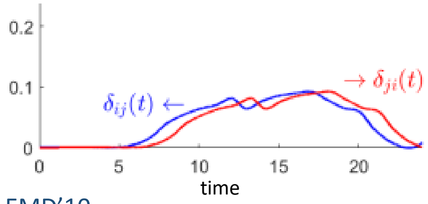
Hospitals



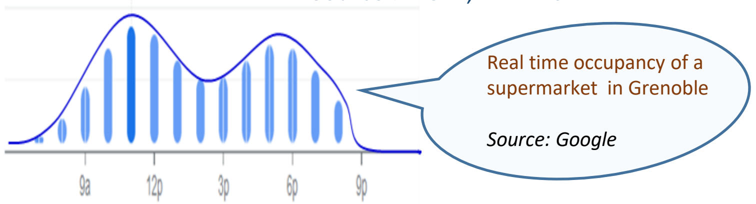
Shopping



Leisure



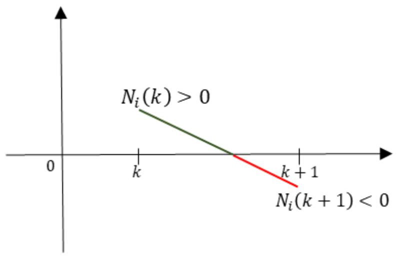
Source : INSEE, EMD'10



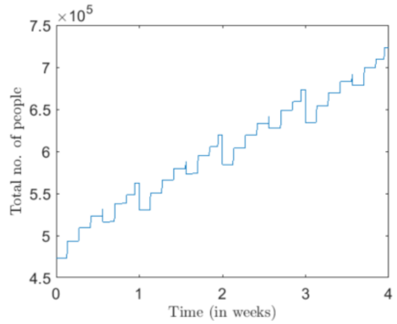
Application challenges: continuous to discrete

Issues with simple discretization techniques

- Loss of non-negativity for some i: $N_i < 0$



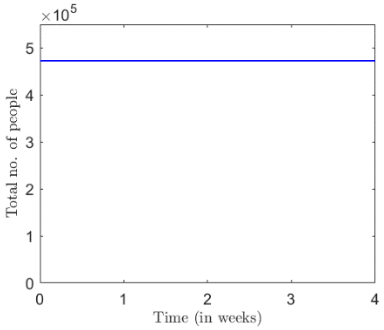
- Loss of mass conservation: $N_\infty \neq N_0$

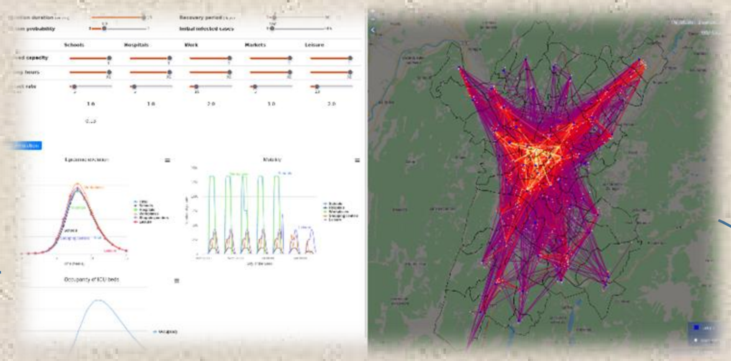


- Loss of boundedness in full model for some i: $S_i + I_i + R_i \neq N_i$

Solution techniques

- Redefining the flows in discrete–time to ensure non-negativity of N_i in the mobility model (anti-wind up)
- Non-local non-standard discretization of SIR-mobility model





Questions? Comments?