Roundtable

Big Data and Transport Models

14-16 December 2020

Benefits of Cellular Telecommunication and Smart Card Data for Travel Behaviour Analysis

From a cross-sectional to a dynamic approach

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Research objectives

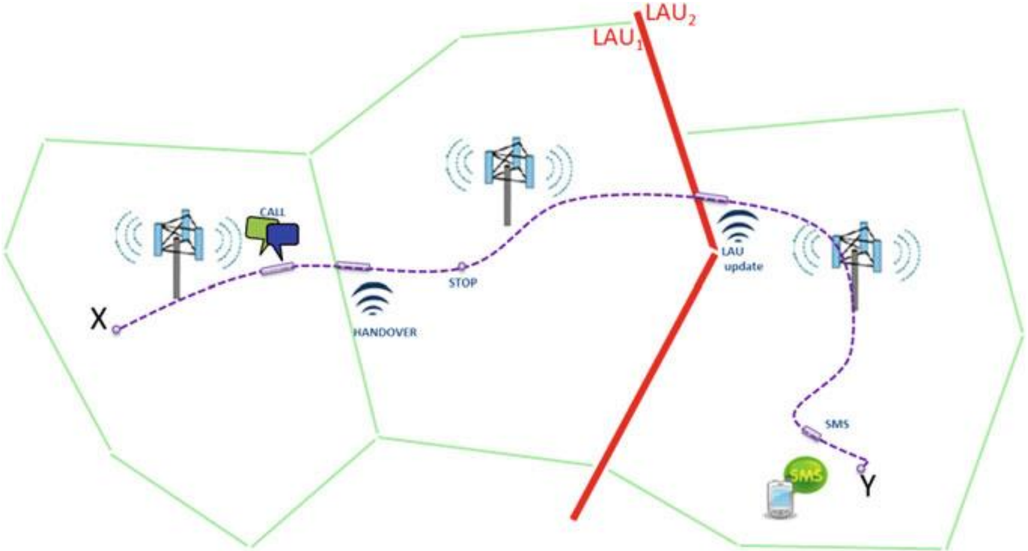
- Traditional travel surveys offer rich semantic data, but only one or few travel day every 5-10 years
- Road-side, cordon, origin-destination surveys might be more frequent but one trip only with limited semantic
- Long term aggregate dynamic possible using panel or pseudopanel analysis

- But short term dynamic analysis or intrapersonal variability analysis very limited

Continuous passive (big) data mean new perspectives for dynamic behavioral analysis: potentials and limits

Mobile phone probe data exploration

- Huge « passive » database with spatio-temporal information
- Possibility to identify individuals’ presence in time and space
- ORANGE probe data: richer than CDR (call detail record), less dependent to individual communication behavior (handover, Location area update, attach/detach events)



Mobile phone data filtering and expansion

- Maximum Inter-event Time (MIT) $\leq$ 180 minutes (a mobile switch on should have at least one LAU every 3 hours)
- Entropy (H) $\leq$ 0.9 (avoid machine-to-machine devices)
- Number of observations (NO) $\geq$ 4 (for trip identification)
- Household home location identification (for expansion to whole population, expansion factors 3.5-10)

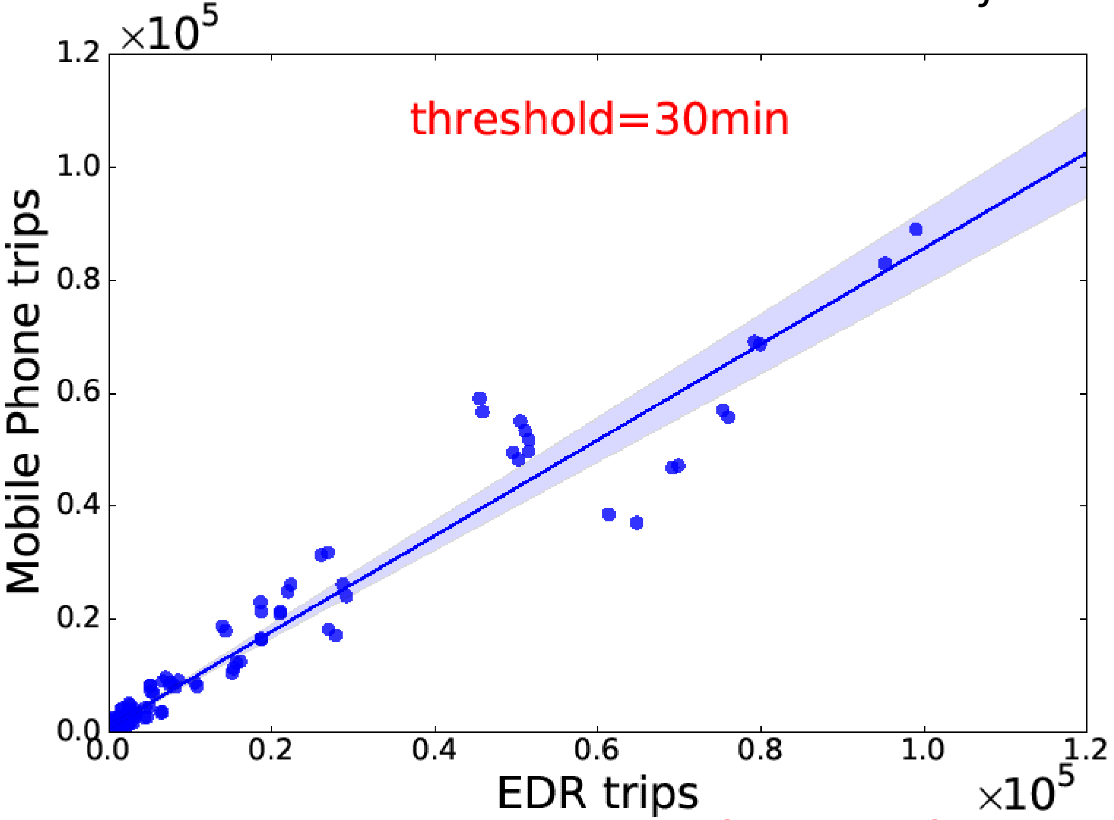
Data base represents 50% of initial mobile phone devices

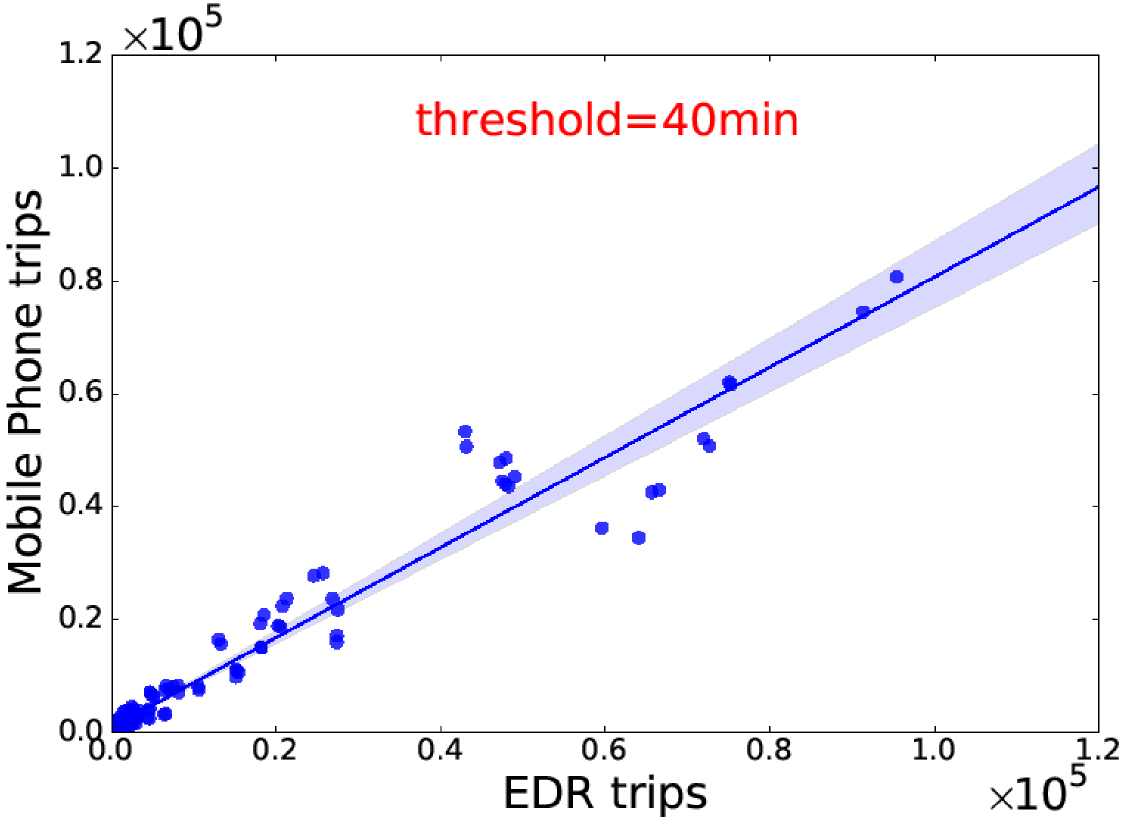
Mobile phone "ground truth" validation

Comparison with Rhône-Alpes travel survey

For 30 min: $y_{ij} = 0.85 \times x_{ij} + 877$ $R^2 = 0.95$

For 40 min: $y_{ij} = 0.80 \times x_{ij} + 788$ $R^2 = 0.95$

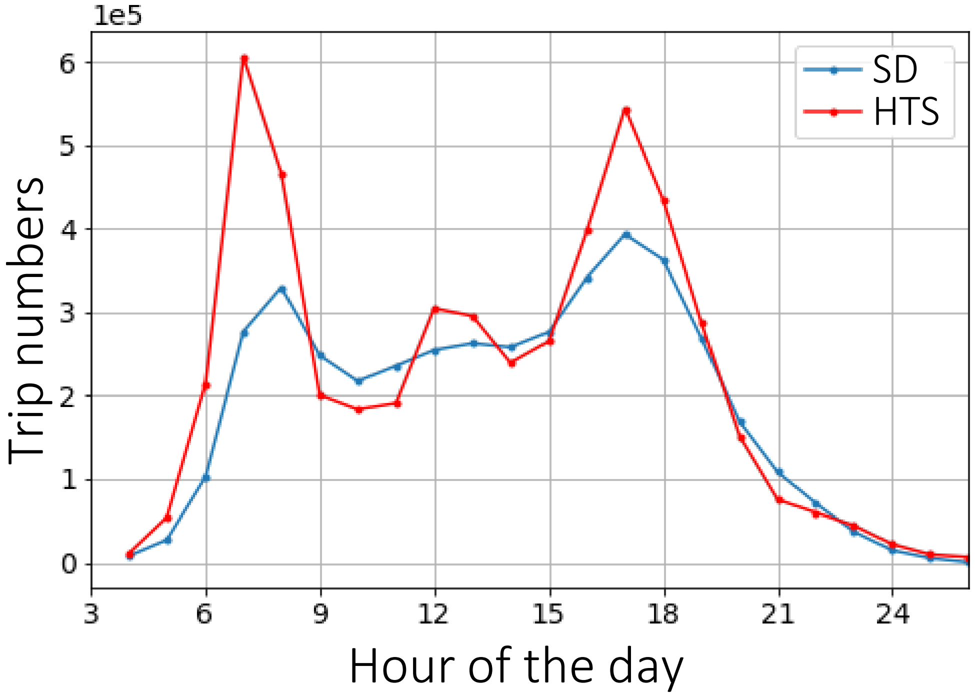




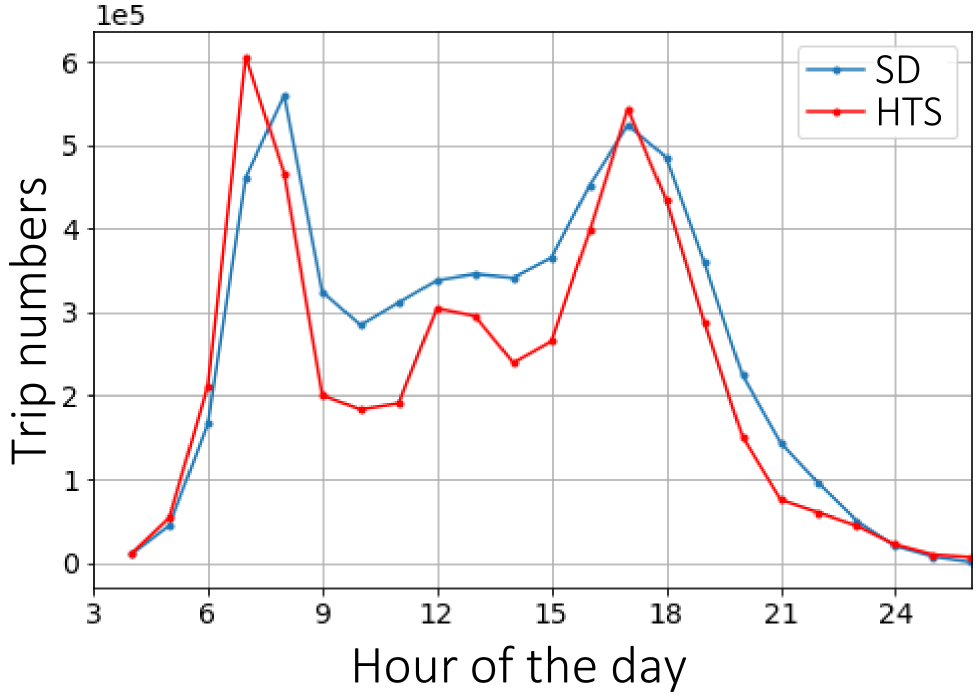
Slope close to 1 and constant to 0

Mobile phone/HTS temporal profile

Mobile phone temporal profile for whole Rhône-Alpes needs to be corrected (smaller peak especially in morning)



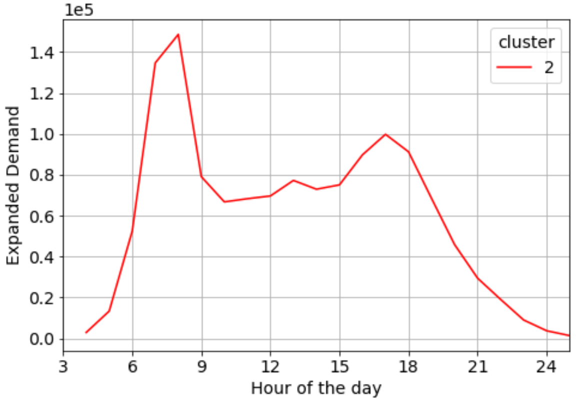
Initial profile



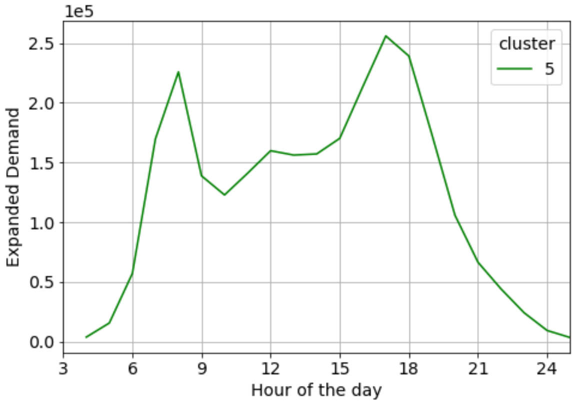
After debiasing process

Mobile phone – various temporal profile

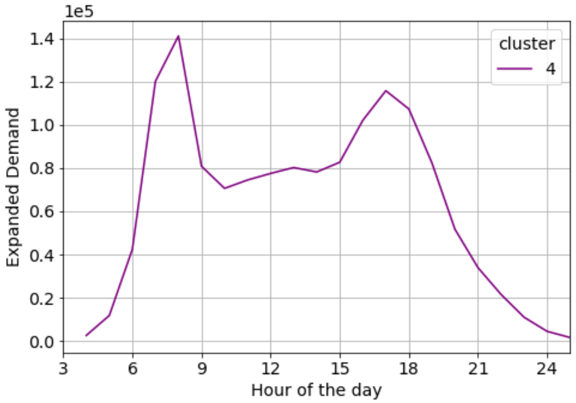
- Rhône-Alpes spatial clustering (77 zones) based on departure time distribution
- Profile based on origin (without intrazonal trips)



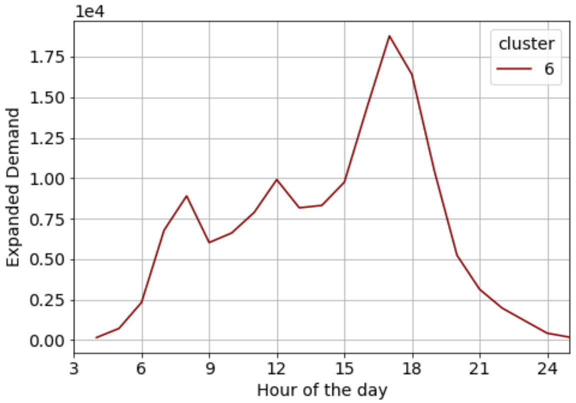
rural areas



urban areas



mix areas



very dense urban areas

Smart card data for Lyon conurbation

- Lyon conurbation (1.3 million inhabitants) transit network transaction only at vehicle boarding (including transfer)
  - Smart card (80% of validation, same Id over a long period)
  - Magnetic paper ticket (20% of validation, without Id)
- AVL (Automatic vehicle location)
- Automated passenger counting system (bus, tramway, subway)
- Origin-destination surveys (on board, all routes at least every 5 years)
- Household travel survey (every 10 years, nearly 1% stratified sampling, face-to-face)

Smart card data processing and expansion

Data correction and imputation

- Missing data imputation + deduplication
- Transfer identification to transform trip-legs into trips (rules from literature)
- Destination inference rules only for smart card data (same Id): 80.8% success
- Fraud (or non-validation) represents 21% of total transit trips

Data expansion

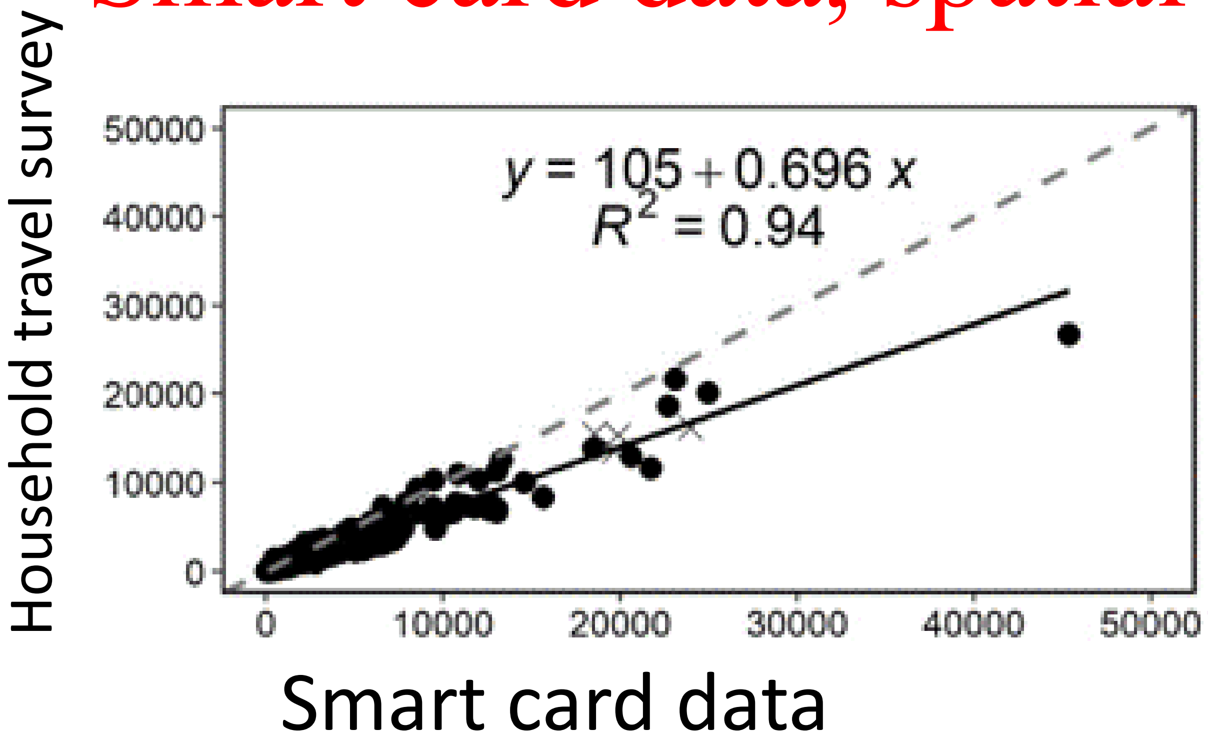
- Transit trips with alighting location: ≈ 50% of total transit trips
- Expansion with non uniform scaling factors based on route/subway station passenger counting (≈ 50k scaling factors)

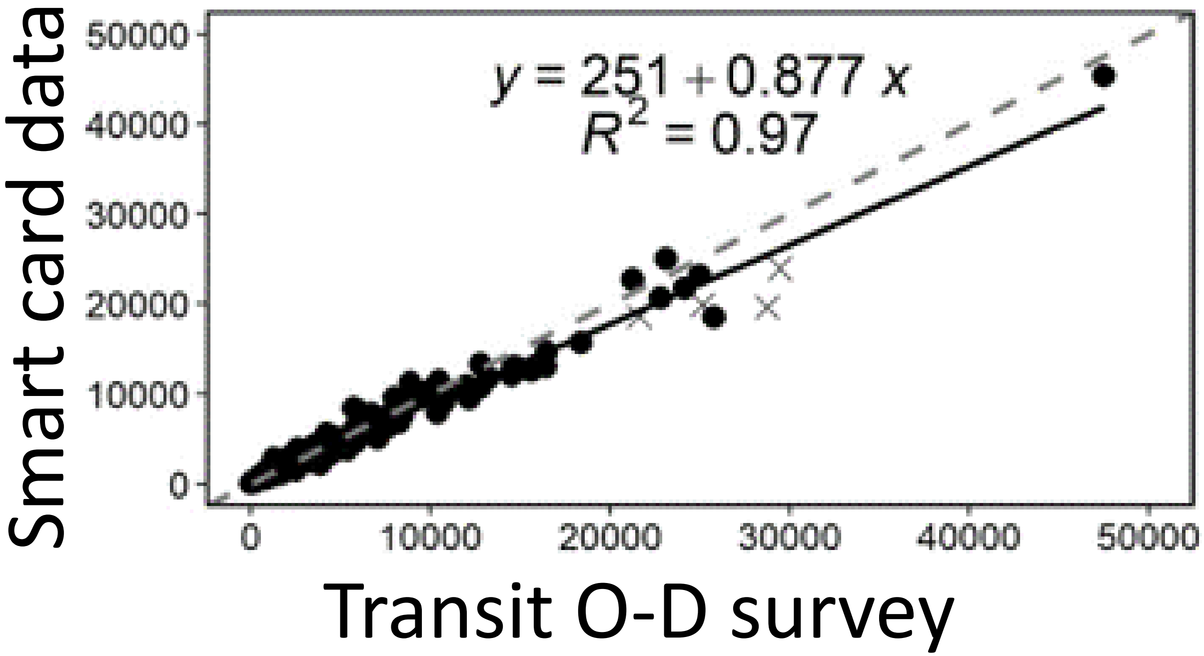
Smart card data “ground truth” validation

	Smart card data	Public transport origin-destination survey	Household travel survey (HTS)
Trip legs (million)	1.56	1.51	1.11
Trips (million)	1.10	1.16	0.80
Bus trip legs (%)	41	39	43
Tramway trip legs (%)	23	22	21
Subway trip legs (%)	37	39	36

- Much less trip-legs and trips in household survey compared to smart card data and O-D survey which appears much more coherent

Smart card data, spatial "ground truth" validation

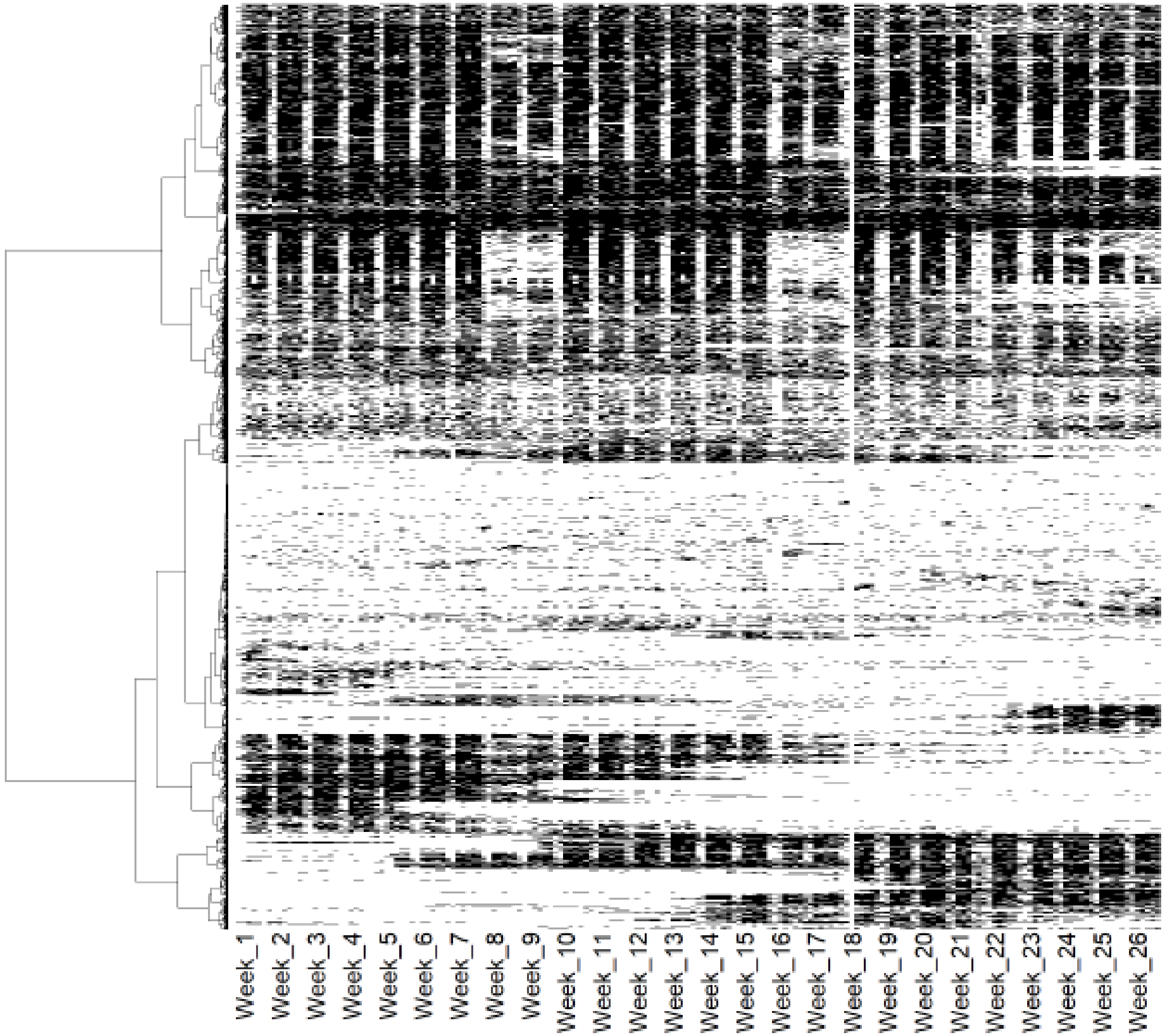




- Spatial comparison at O-D level (18 zones)
- Smart card data are much more coherent with transit O-D survey, than with household travel survey

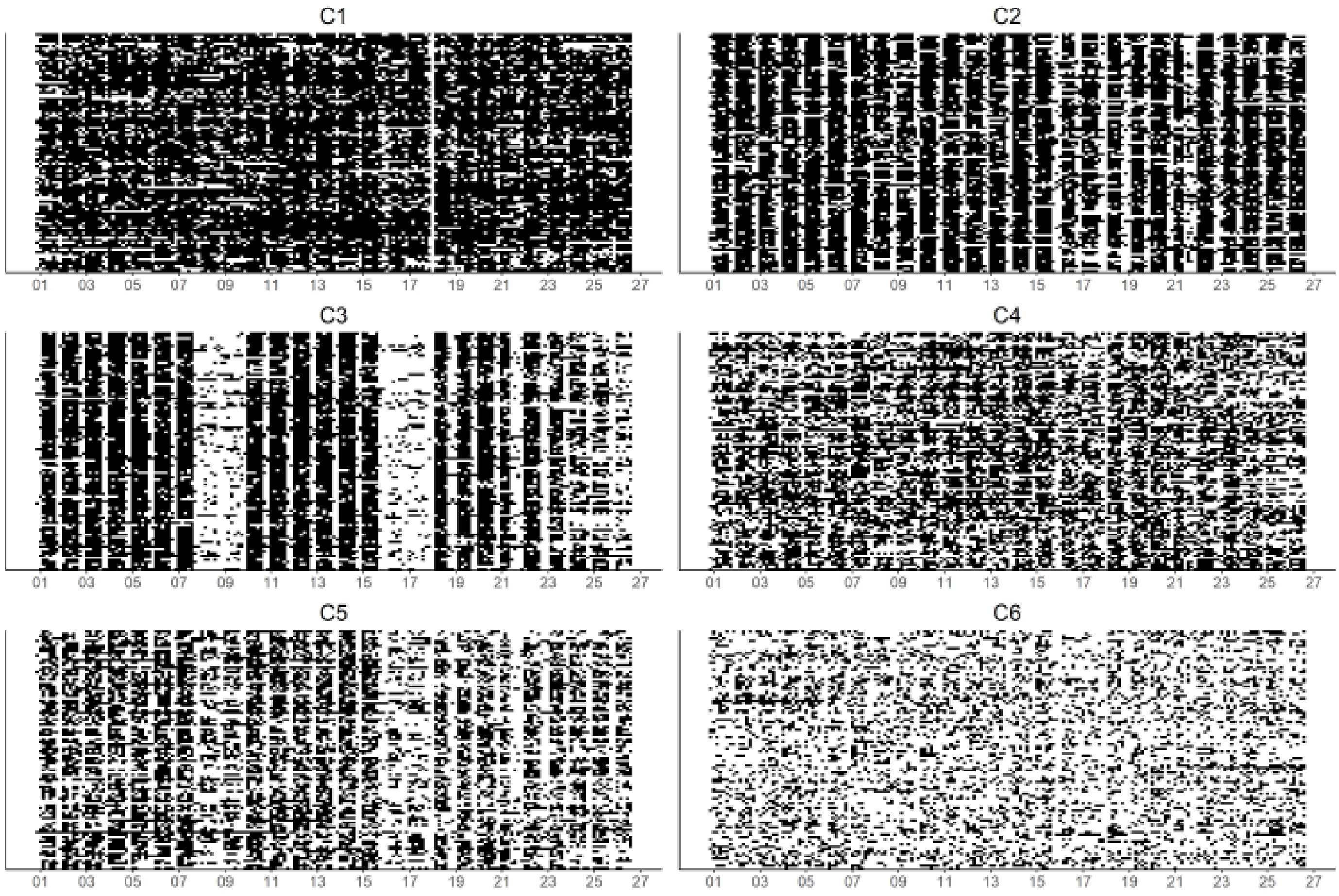
Smart card analysis over 6 months

- Clustering on vector day with/without trip
- We can identify 3 groups:
  - Consistent transit users (regular user, top dendrogram) 45% of users, 69% of trips
  - Low frequency users (middle dendrogram) 14% - 1%
  - Intermittent transit users (bottom of dendrogram) 41% - 30%
- Day-to-day regularity does not mean individual regularity



Smart card analysis over 6 months – among regular users

- Cluster 1 very high transit use even WE, no calendar effect
- Cluster 2 high use in week-days, lower WE, no calendar
- Cluster 3 WE + calendar (holidays) effects
- Cluster 4 regular use without clear effect of WE and calendar
- Cluster 5 calendar and WE effects with lower use (than C3)
- Cluster 6 sparse use but somewhat regular without clear structure



Big data base are not error free

- Mobile phone data need filtering process for example to suppress machine-to-machine devices, or devices with too few data
- Smart card data need correction for example deduplication
- Data imputation is often required for missing information

Big data base need expansion factors

- Even if big, data base are not exhaustive and do not represent whole population
- Individuals might have no/several devices

- Expansion factors are required with spatio-temporal scaling factors
- External sources improve scaling quality

Big data base require « ground truth » validation

- Passive big data sources evolve continuously
- Passive big data might be context-dependant

- Regular ground truth validation is recommended using external information not used in data processing

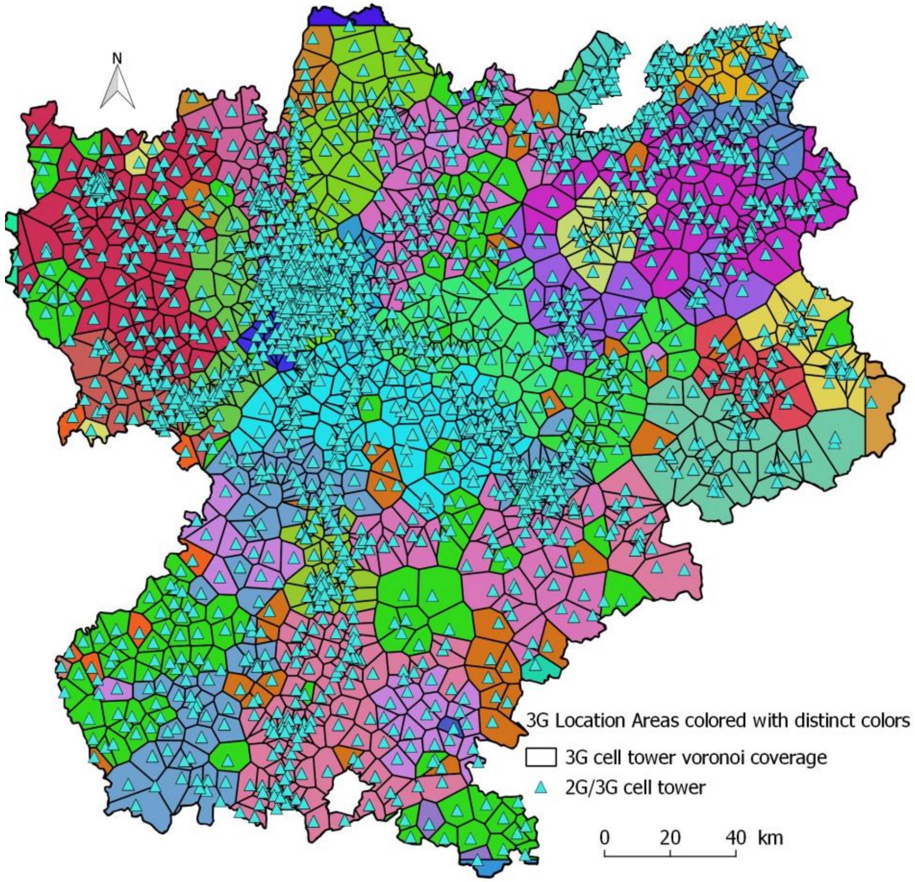
But big data present a high potential for dynamic analysis even at disaggregate level

After correction, debiasing process, expansion and validation continuous big volume data is available allowing:

- Aggregate and disaggregate regularity/variability analysis
- Detailed spatio-temporal analysis including O-D matrix analysis at fine grain level
- Intrapersonal variability when same Id is available over time

Mobile phone data

- 2G et 3G signaling data collected during June 2017
- From « Orange » mobile phone operator
- For all Rhone-Alps Region
- More than 2 millions users and 300M data per day
- Each trace is anonymized and with timestamp. Mobile ID is changed every day



Timestamp	IMSI (ID)	LAC	ID cellule	évènement
2017-06-01 11:53:33	201803567834	104	20865	CALL

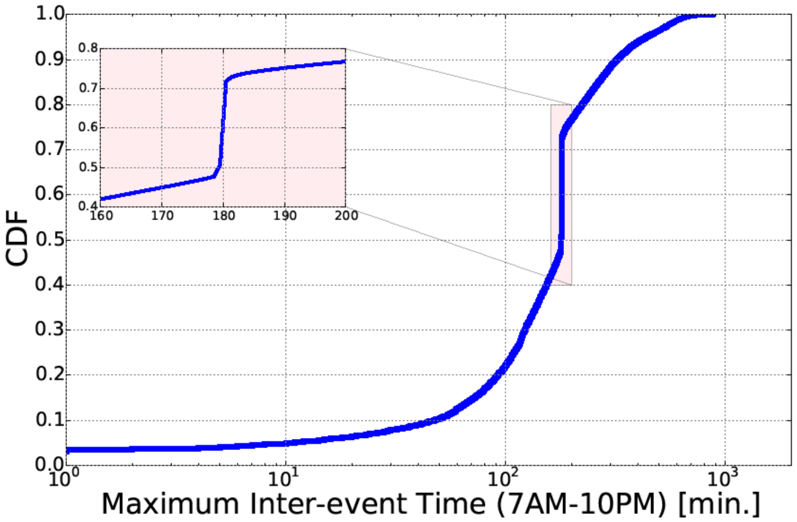
Localisation = Location Area Code (LAC)+ ID cellule

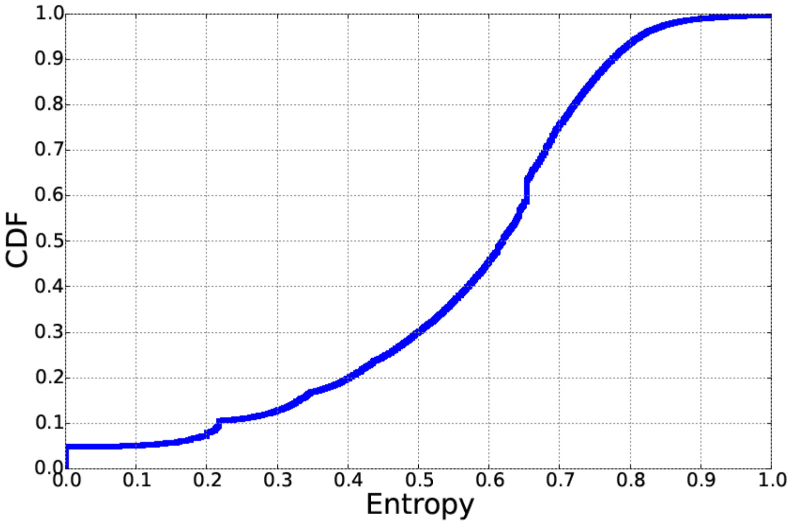
EDR Rhône-Alpes data

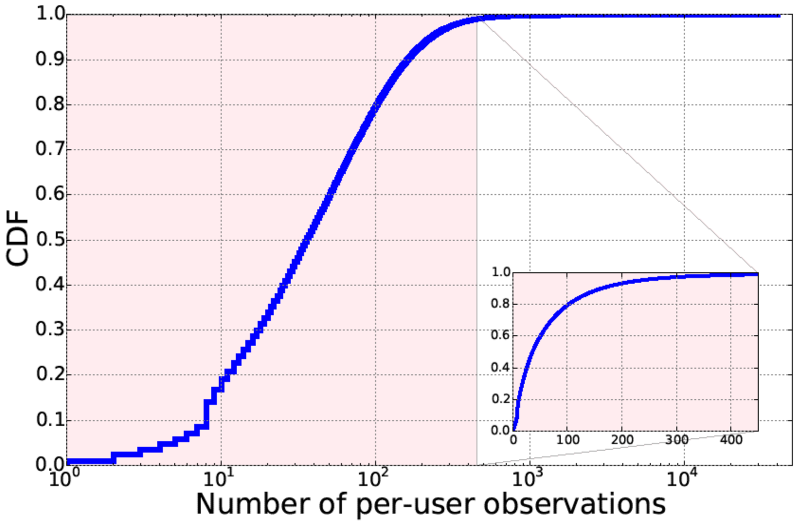
- Regional travel survey (EDR)
- Conducted between 2012 and 2015 on all Rhone-Alps region
- 38 000 individuals above 11 years old, 143 000 trips
- Territory zoning: 77 sampling sectors, aggregated in 14 macro zones

Cell phone activity: Indicators-based filtering

- Maximum Inter-event Time (MIT) [7am-10pm] ≤ 180min (presence)
- Entropy (H) ≤ 0.9 ; $H(X) = -\sum_{i=1}^{n} p(x_i)\log(p(x_i))$ (uniformity)
- Number of observations (NO) ≥ 4 (frequency should be ≥ 8 with LAU)
- ➢ Filtering of outlier, uniform and machine-generated behaviors

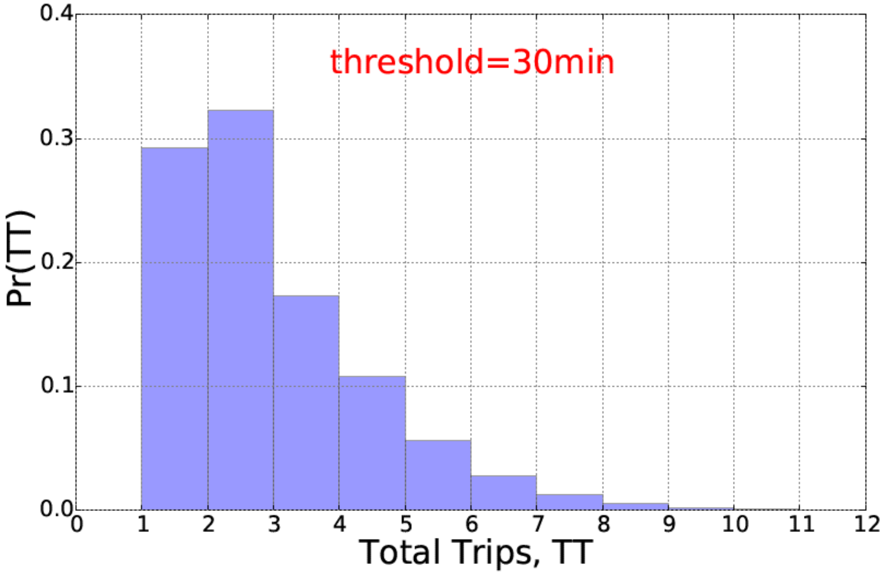


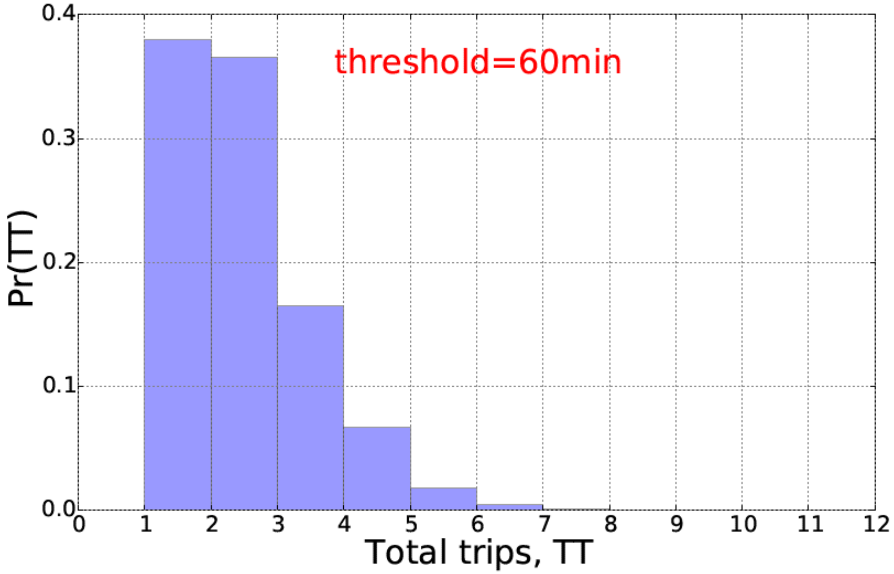




Stationary threshold choice

Stationary activity time threshold	60 minutes	50 minutes	40 minutes	30 minutes
Trips number EDR (in thousand)	2,211	2,260	2,344	2,448
Trips number Orange (in thousand)	1,607	1,743	1,905	2,108



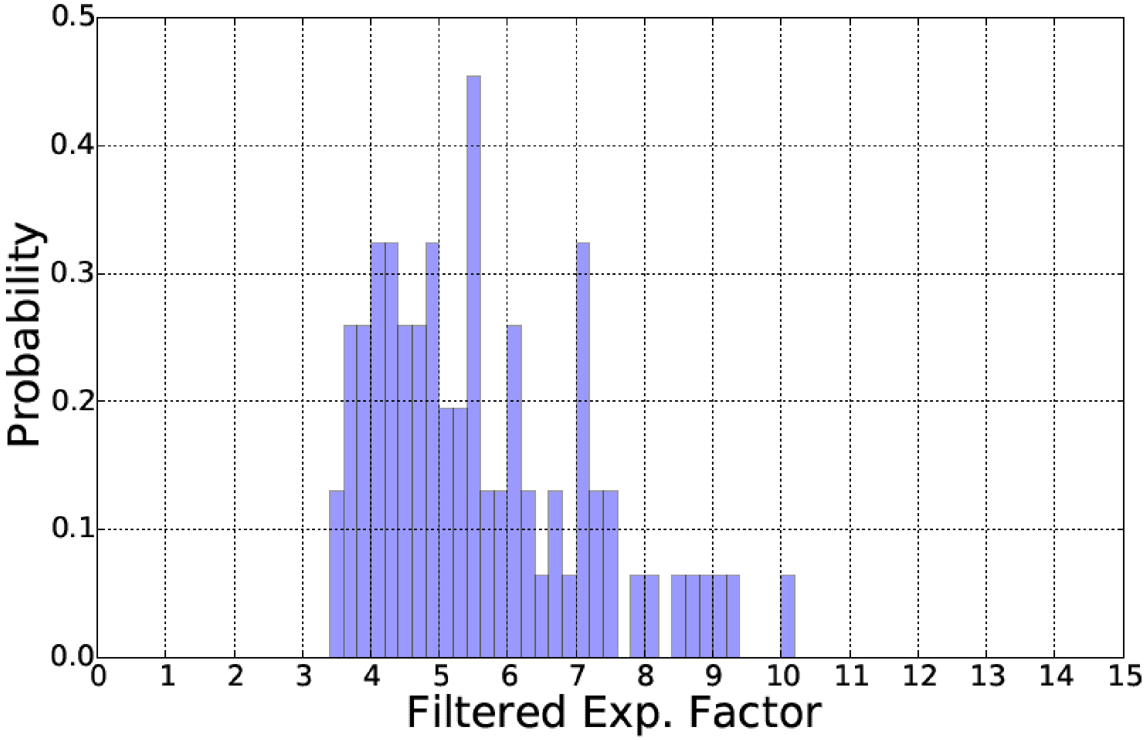


Probability distribution of total trips per user with a threshold 30min and 60min

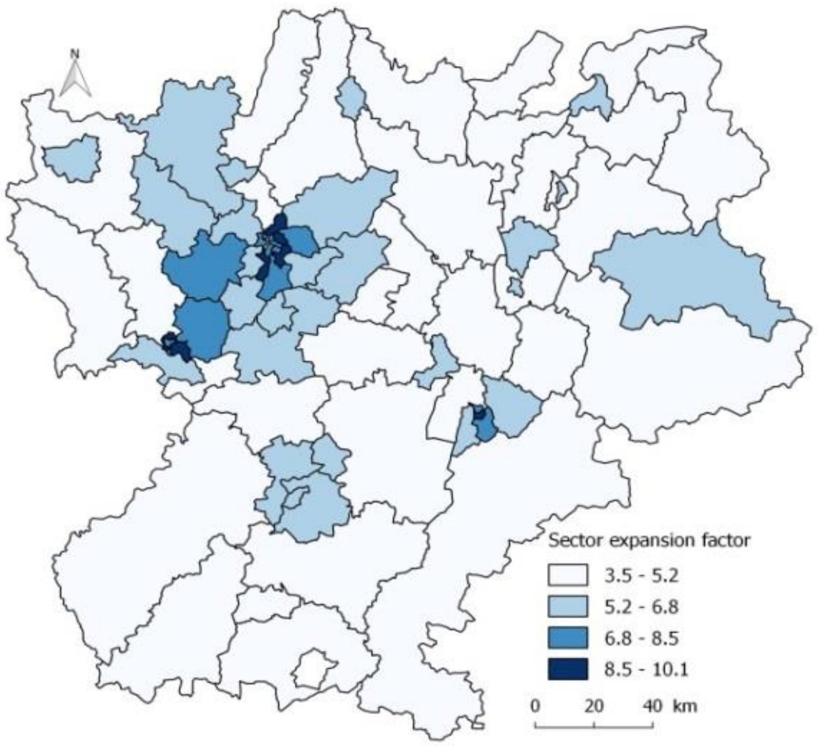
We keep 30-40 minutes threshold which seems reasonable regarding sector size and gives the best results in comparison to EDR

O-D expansion: expansion factor (2)

- **Expansion Factor** definition on sector level (77 sectors):
- $$F_{exp}(sector_i) = \frac{Population\ of\ sector_i\ (over\ 11\ years)}{Nb\ of\ home\ locations\ detected\ in\ sector_i}$$



Expansion factor probability distribution

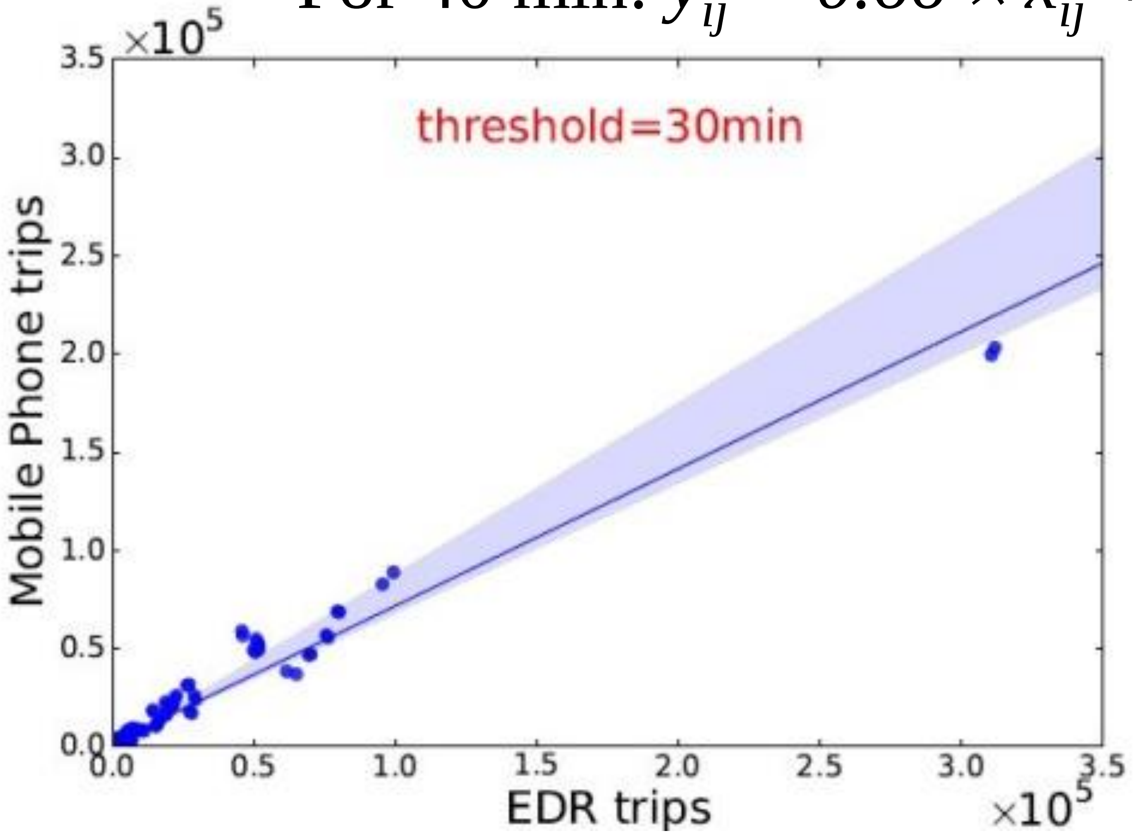


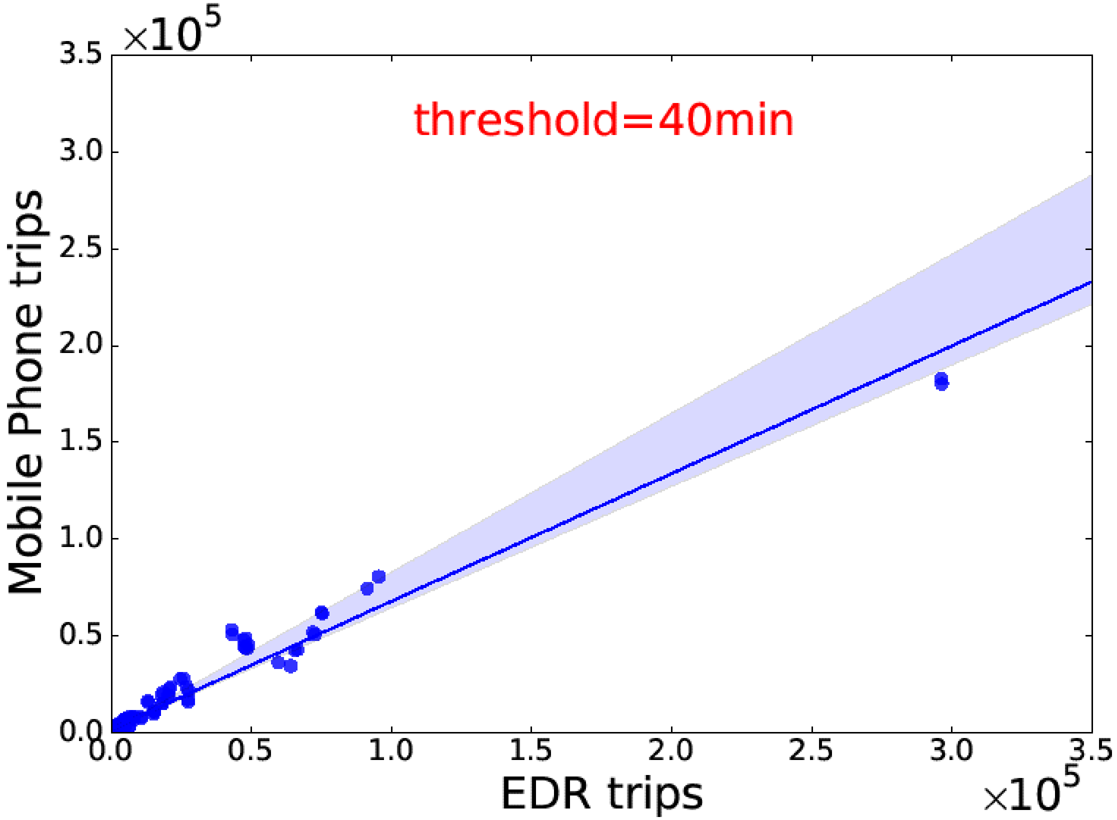
Spatial distribution of sector expansion factors in the Rhône-Alpes region after user filtering

EDR – Orange comparison (2)

For 30 min: $y_{ij} = 0.70 \times x_{ij} + 2{,}193$ $R^2 = 0.96$

For 40 min: $y_{ij} = 0.66 \times x_{ij} + 1{,}964$ $R^2 = 0.96$





O-D pairs between the two Lyon sectors are badly estimated and strongly impact slope

Signaling mobile phone data

- Entropy formula

$$H(X) = -\sum_{i=1}^{n} p(x_i) \log(p(x_i))$$

The entropy measures the randomness of a system or on the opposite its regularity. High measure of entropy corresponds to very regular signals like those generated by machine-to-machine communications or IOT (Internet of Things).