

Investigating the Empirical Existence of Static User Equilibrium

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Traffic Modeling : User Equilibrium Frameworks

Equilibrium frameworks central in Transportation Research since Wardrop [Wardrop, 1952]

Diverse developments :

- Dynamic Stochastic User Equilibrium [Han, 2003]
- Restricted Stochastic User Equilibrium [Rasmussen et al., 2015] more realistic in alternatives
- Boundedly User Equilibrium [Mahmassani and Chang, 1987]
- Assignment techniques inspired from other fields such as Network Science [Puzis et al., 2013]

Validation and Practical Use

Static User Equilibrium lacks empirical validation in the literature

→ Some examples such as the behavioral study of user route choices (“Wardrop’s first principle”) in [Zhu and Levinson, 2010]

However still largely used

→ in theoretical literature, as for example [Leurent and Boujnah, 2014] : do refinements in the model such as adding parking cruising flows have a sense if the core is not validated ?

→ in real-world application, such as the MODUS model for Paris Metropolitan area : what are the implications of basing decision-making and traffic management on an unvalidated framework ?

Empirical Investigation of SUE Existence

Research Objective : *Investigate empirically the spatio-temporal stationarity of traffic flows, combining different complementary quantitative approaches*

→ Construction of a real-time dataset for major links of Paris region on 6 month by data crawling

→ Complementarity of approaches (Complex Systems general paradigm) :
Spatio-temporal data visualization, Network analysis, Spatial analysis

Dataset Construction

Difficulty to find Open Data on Transportation Systems
[Bouteiller and Berjoan, 2013]

→ Construction of an open historical travel time dataset for major links in the region of Paris, collecting in real time public traffic data from www.sytadin.fr

Data collection : Each two minutes, automated python script

- fetch raw webpage giving traffic information
- parse html code
- store in a sqlite database

Openly available (CC Licence) at

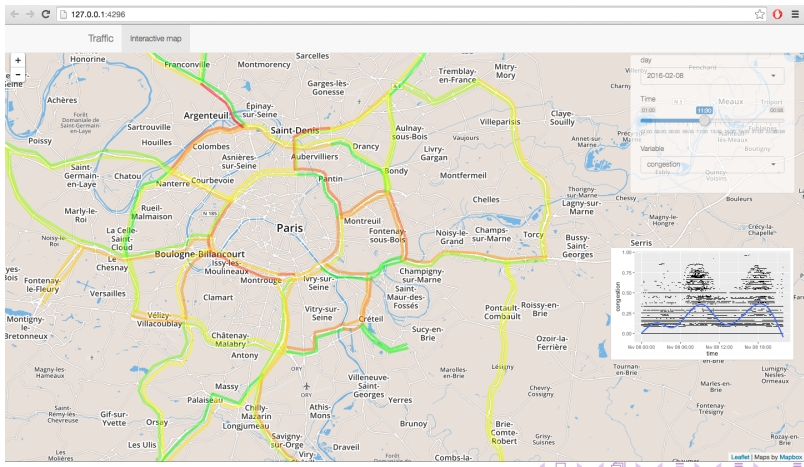
http://37.187.242.99/files/public/sytadin_latest.sqlite3

Data summary : 10 month (since Feb. 2016), 2min time granularity, effective travel time for 101 links (\simeq 10km spatial granularity)

Interactive Data Visualization

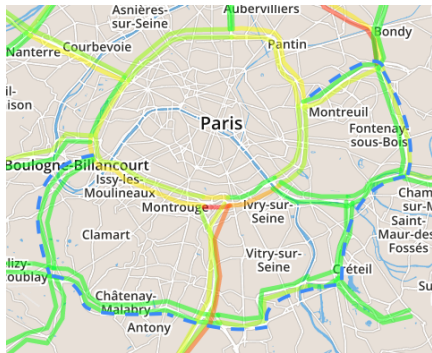
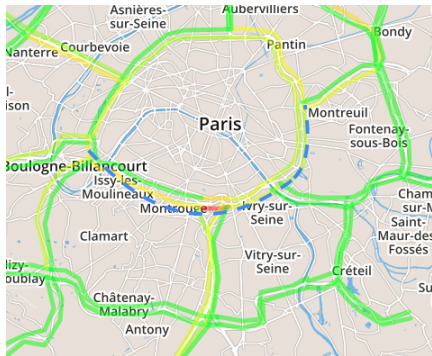
Interactive web-application for spatio-temporal exploration

<http://shiny.parisgeo.cnrs.fr/transportation>



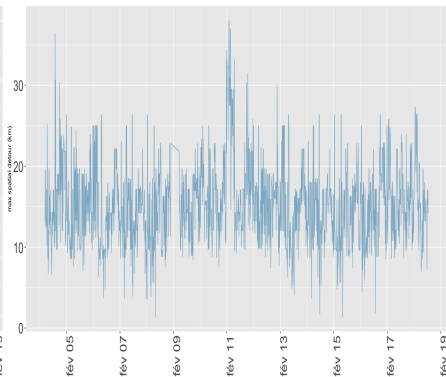
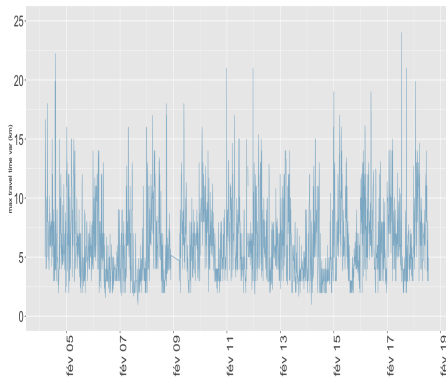
Spatio-temporal Variability : Example

*Very high spatial variability on 10min time interval, here on 11/02/2016
00:06-00:16*



Spatio-temporal Variability

Maximal travel time and spatial variabilities on a two week sample



Stability of Network Measures

Network Betweenness Centrality

$$b_i = \frac{1}{N(N-1)} \cdot \sum_{o \neq d \in V} \mathbb{1}_{i \in p(o \rightarrow d)} \quad (1)$$

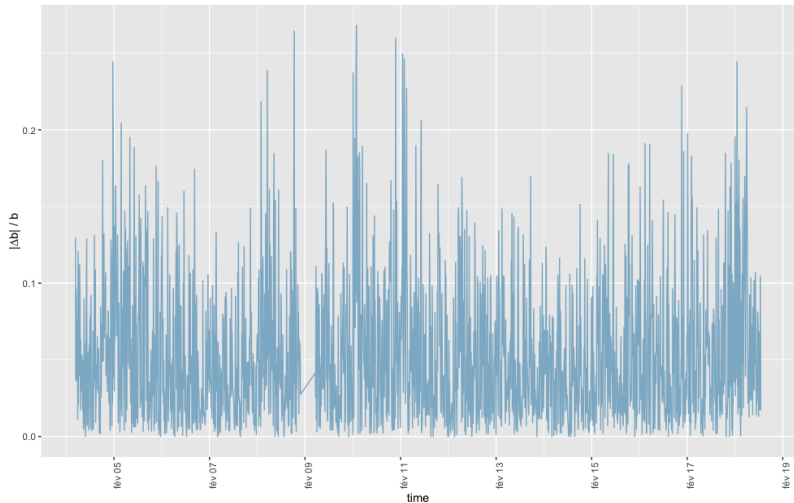
Temporal Maximal Betweenness Variability

$$\Delta b(t) = \frac{|\max_i(b_i(t + \Delta t)) - \max_i(b_i(t))|}{\max_i(b_i(t))} \quad (2)$$

→ Reveals either a proportion of rerouted travels (negative variation) or a minimal proportion of load increase for a single node (positive variation)

Stability of Network Measures

Temporal maximal betweenness variability on a two weeks period



Spatial Heterogeneity

Spatial Autocorrelation as an index of spatial variability, for link i

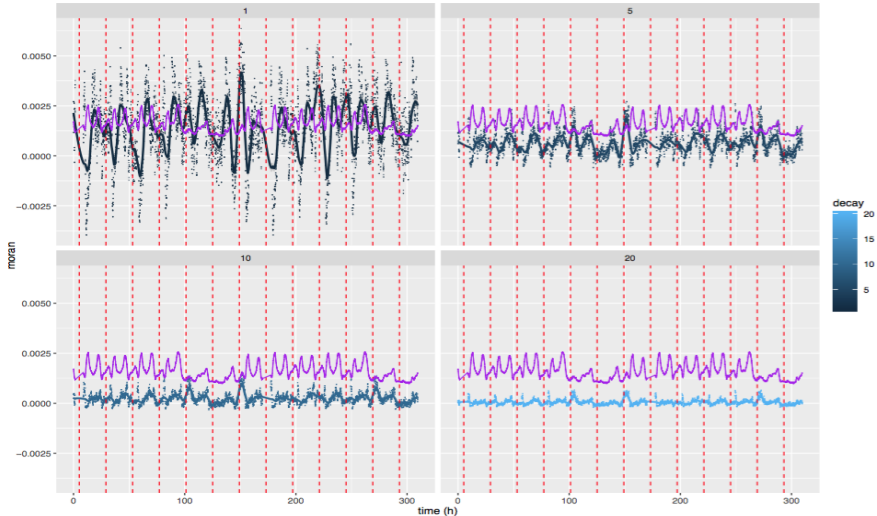
$$\rho_i = \frac{1}{K} \cdot \sum_{i \neq j} w_{ij} \cdot (c_i - \bar{c})(c_j - \bar{c}) \quad (3)$$

with spatial weights $w_{ij} = \exp\left(\frac{-d_{ij}}{d_0}\right)$

→ *Indirect measure of the spatial stationarity of flows : a decreasing correlation implies a chaotic system*

Spatial Heterogeneity

Spatial autocorrelation on a two weeks period for different decays



Theoretical and Practical Implications

Theoretical Implications

- Need for more systematic comparison of framework validity ([Kryvobokov et al., 2013] compares two LUTI models e.g.)
- Can still be used e.g. for integration within more complex models

Practical Implications

- Difficulty of transferring academic results to real-world engineering, that can be tied to habits, myths, political interests, etc. [Commenges, 2013] ; [Offner, 1993]

Possible Developments

1. Further assessment of chaotic nature of traffic flows

→ Study of spatio-temporal properties of Liapounov exponents [Goldhirsch et al., 1987], recently used in transportation research [Tordeux and Lassarre, 2016]

→ Additional features for spatio-temporal data exploration : Kernel smoothing for wave visualization, localized plots, etc.

2. Systematization of empirical assessment ; generic benchmarks for frameworks/model

→ Similar use of a web-application for users to crowd-source their model/data as e.g. [Cottineau, 2016]




Conclusion

- Simple but necessary empirical insights into SUE spatio-temporal stationarity
 - Construction of an open dataset : need for more openness, transparency, reproducibility
 - Strong need for more integrated research : theoretical-empirical, between disciplines, between approaches and objectives, between models (multi-modeling)
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- All code available at <https://github.com/JusteRaimbault/TransportationEquilibrium>
 - Paper preprint available at <http://arxiv.org/abs/1608.05266>




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