G7 ITALIA 2024

MOST

POLITECNICO MILANO 1863

G7 Transport Academic Workshop

Modeling approaches for resilient transport networks

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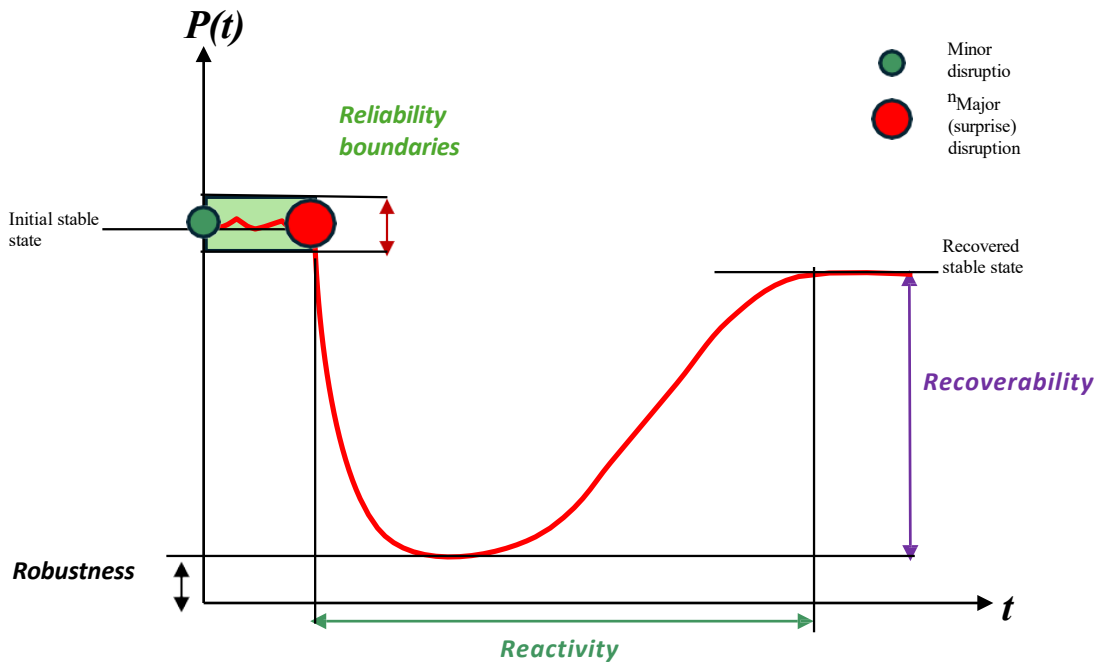
Université Gustave Eiffel

Wednesday, 10th April 2024 - Aula Magna "Carassa e Dadda"
Politecnico di Milano, Bovisa Campus, Milan (Italy)

Data-driven approaches for assessing urban network resilience

A. Furno, ENTPE / Univ Eiffel

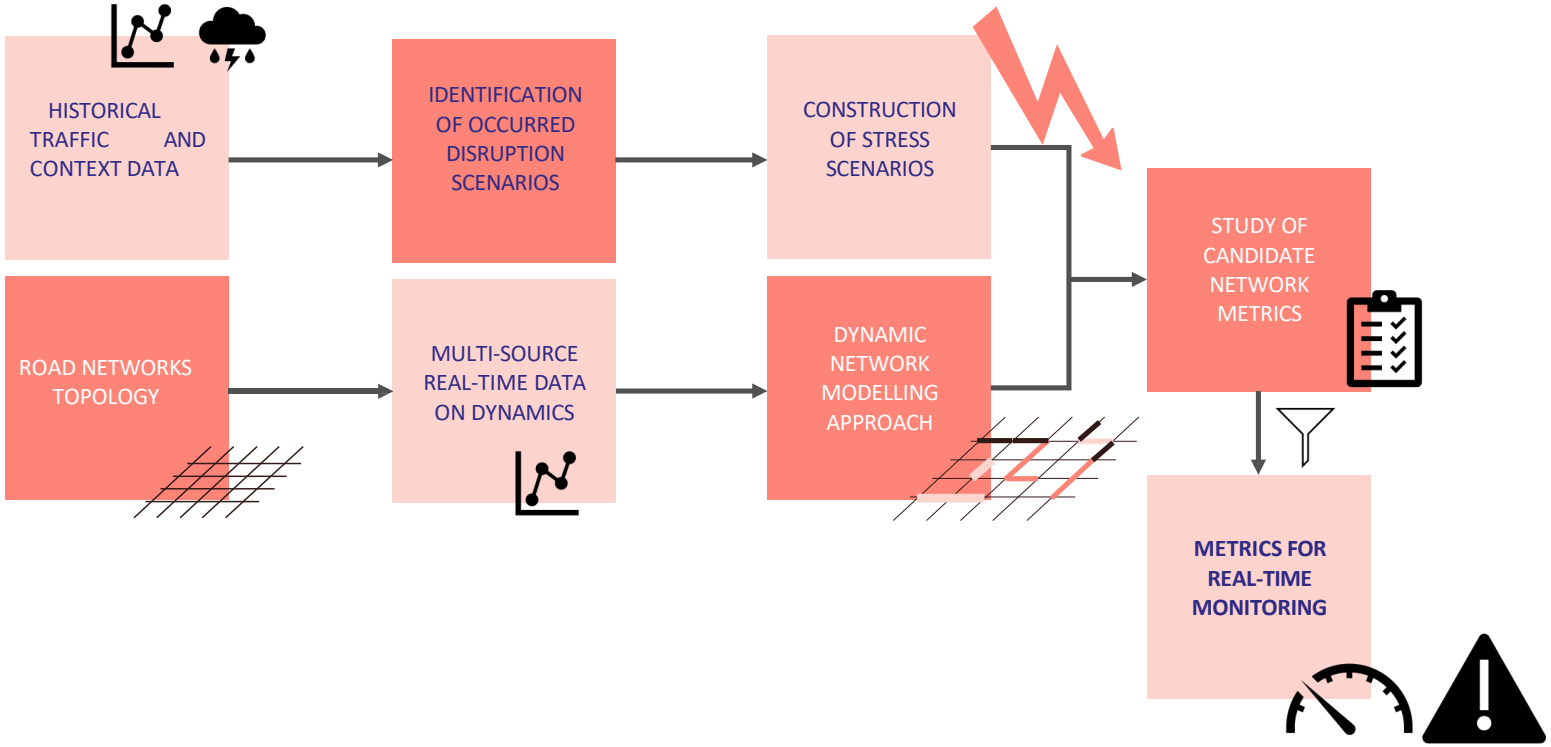
Resilience of transportation networks



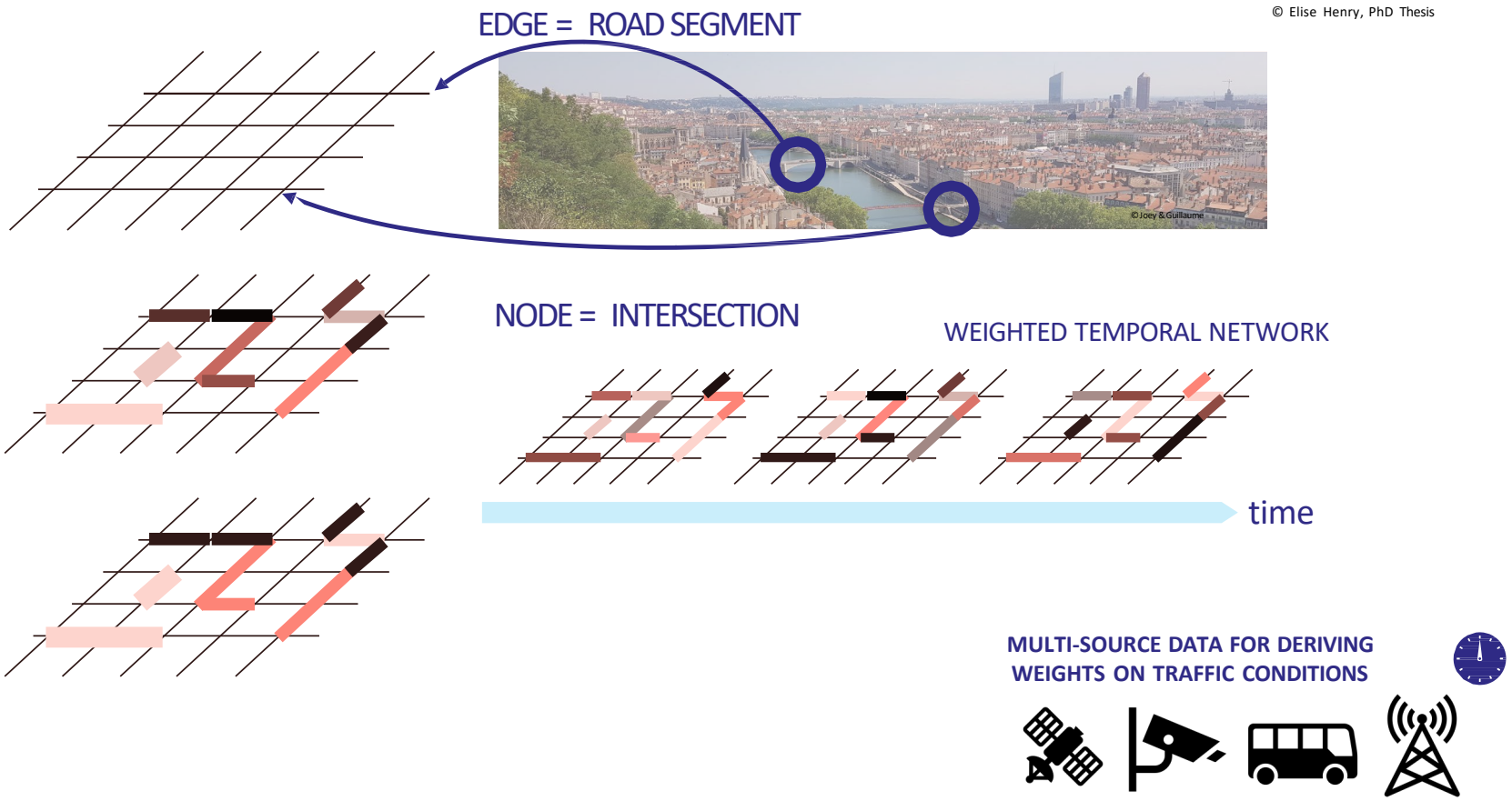
Resilience is a complex term

Mattsson and Jenelius, 2015: "Vulnerability and resilience of transport systems"

Metrics for real-time monitoring



Graph-based Modelling with Dynamic Urban Data



Metrics for Network-wide monitoring

WEIGHT(e) =
LEVEL OF SERVICE(e)
=
TT(e) / FFTT (e)

DENSITY:
AVERAGE DEGREE

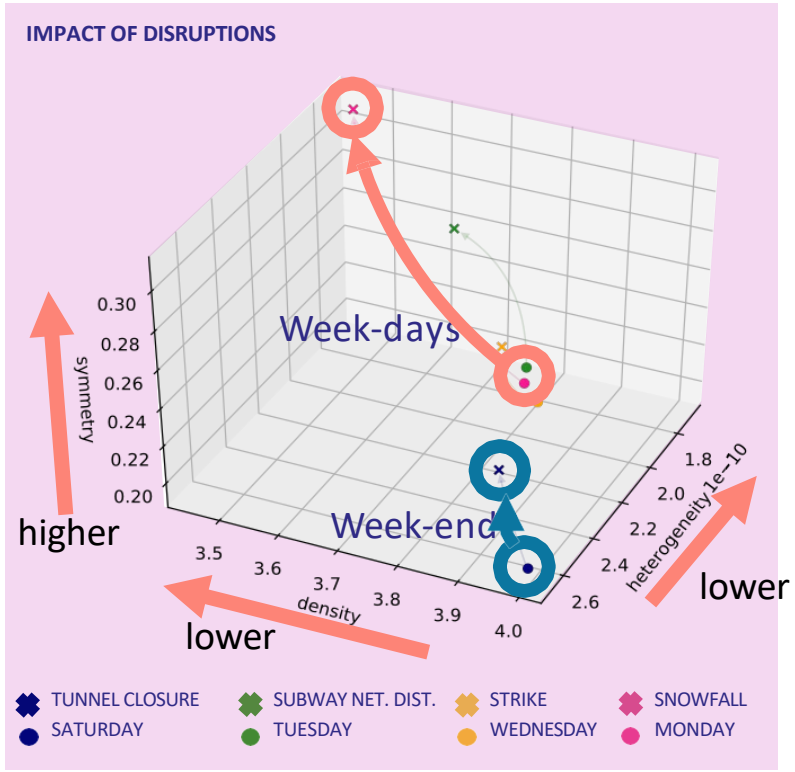
$$\langle k \rangle$$

HETEROGENEITY:

$$h = \frac{\sigma_{in}\sigma_{out}}{\langle k \rangle}$$

SYMMETRY:
CORRELATION COEFFICIENT
IN-DEGREE & OUT-DEGREE

$$S = \frac{\langle k_{in}k_{out} \rangle - \langle k_{in} \rangle \langle k_{out} \rangle}{\sigma_{in}\sigma_{out}}$$



© Elise Henry, PhD Thesis

A new modeling framework for multimodal transport systems

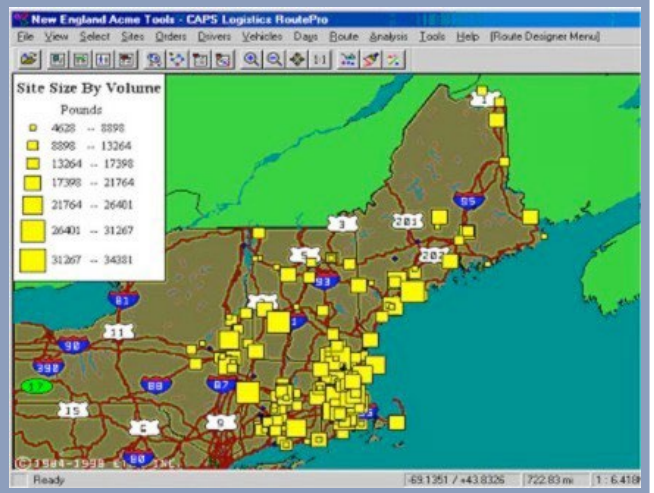
Transportation models

Local traffic dynamics

Open simulation plateform (Symuvia)

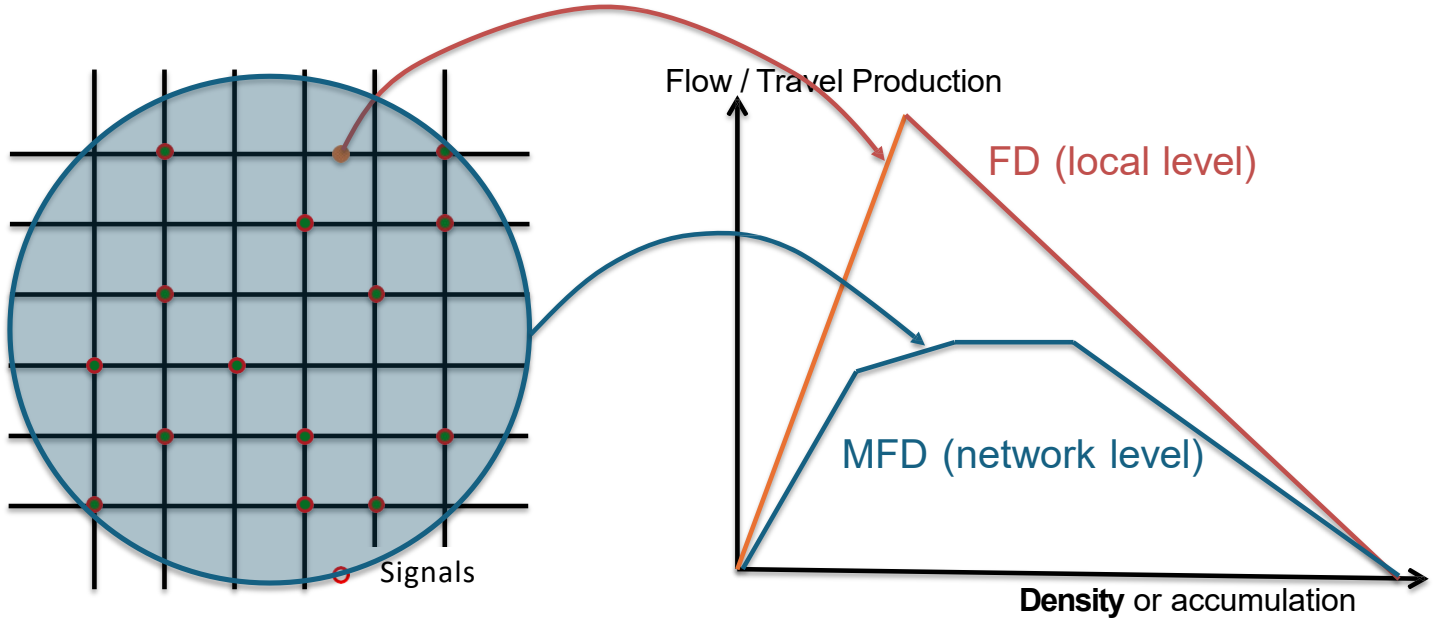
(Leclercq et *al*, 2009-2015)

Static model for planing



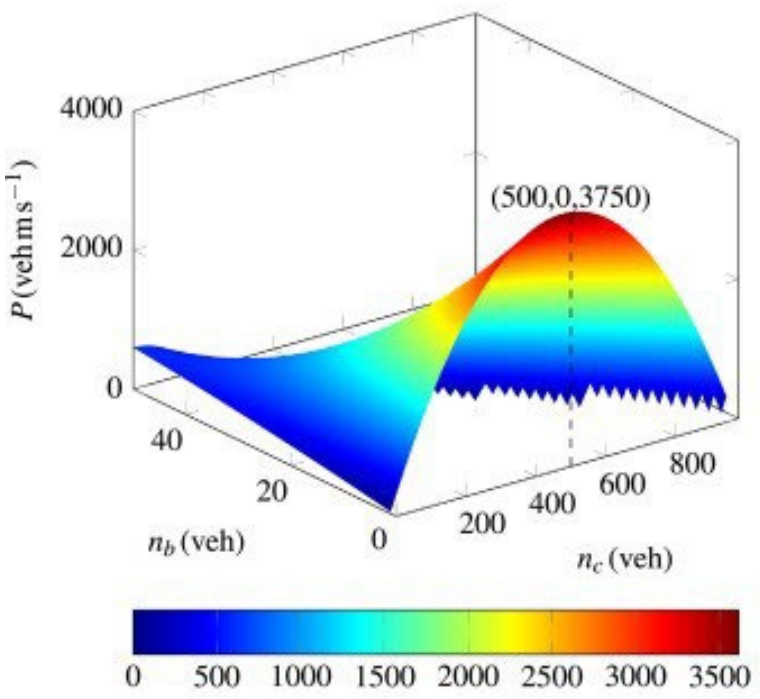
Room for large-scale dynamic models

The Macroscopic Fundamental Diagram

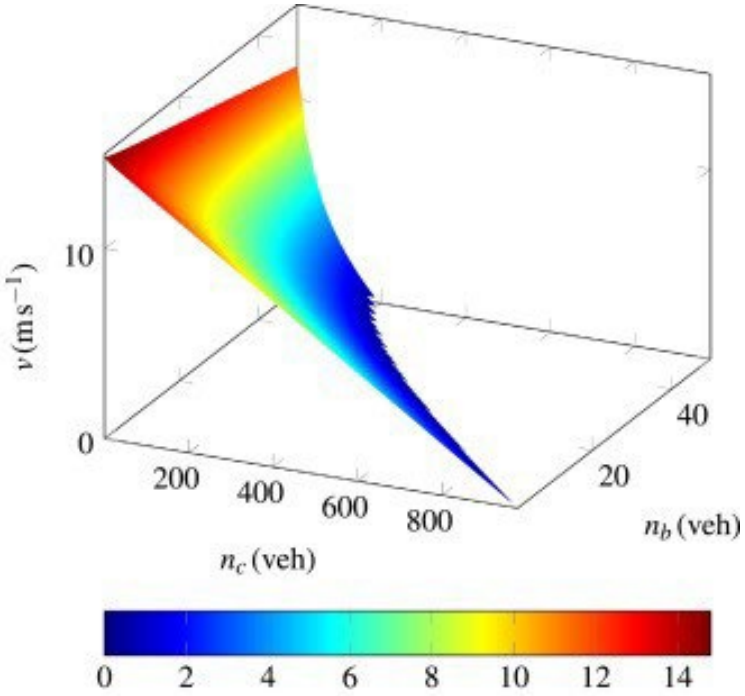


FD + Network structure (topology / signal timings) + Route choices = MFD

Multimodal MFD extension



(a) Production MFD surface.

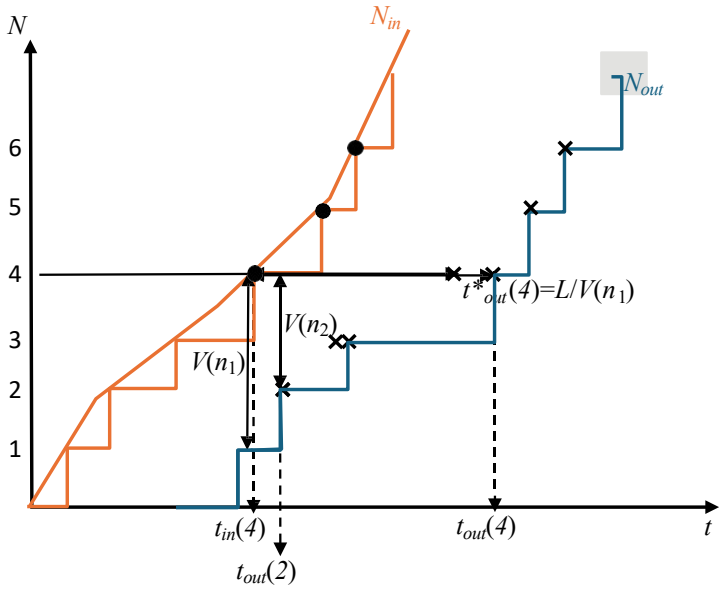


(b) Velocity MFD surface.

Trip-based model: event-based formulation

$$\int_{t-T(N_{out}(t))}^{t} V(n(s))ds = L$$

(Arnott, 2013)
(Lamotte & Geroliminis, 2016)
(Mariotte & Leclercq, 2017)



An event-based numerical scheme

Advantages

- Direct access to entry and exit times for all individual vehicles
- Efficient numerical scheme as only the next vehicle to exit should be updated in practice at each event
- Straightforward extension to account for heterogeneous travel distances

(Leclercq et *al*, TRptB, 2017)

Hybrid trip-based model concept

Motion is based on regional speed given by the MFD

Trip calculation are made on the real (multimodal) network

MAGnUM
Multiscale and Multimodal Traffic Modelling Approach for Sustainable Management of Urban Mobility

European Research Council

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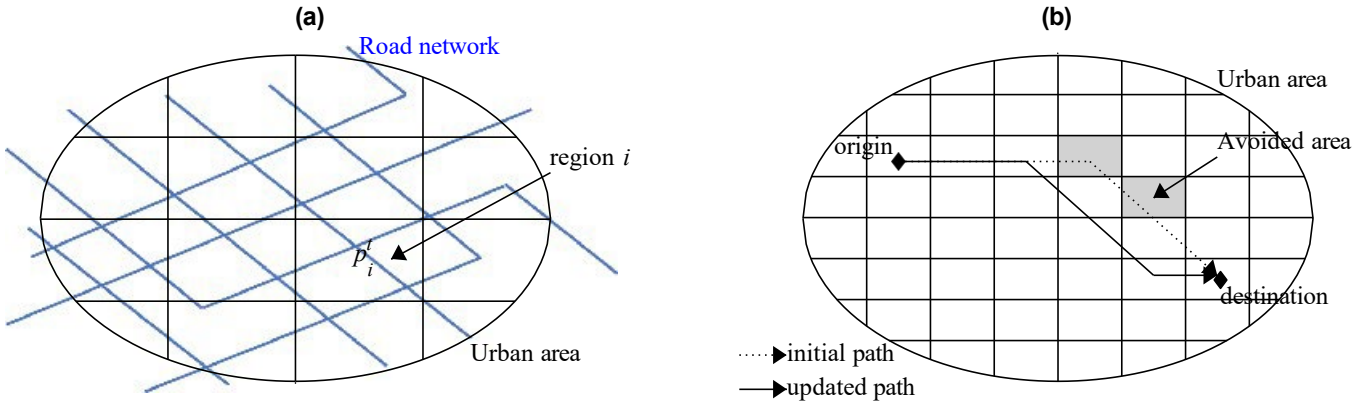
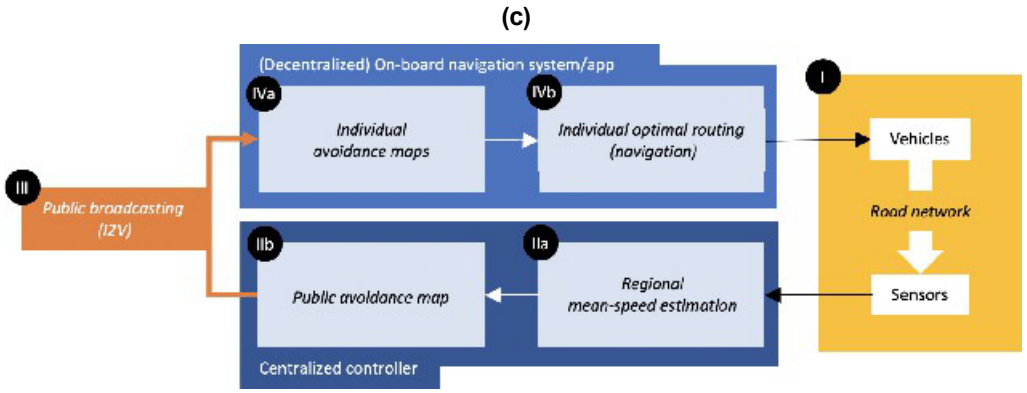
Applications to resilient urban traffic management

An optimal route guidance strategy based on avoidance maps

(Leclercq, L., Ladino, A., Becarie, C., 2021. Enforcing Optimal Routing Through Dynamic Avoidance Maps. *Transportation Research part B*,)

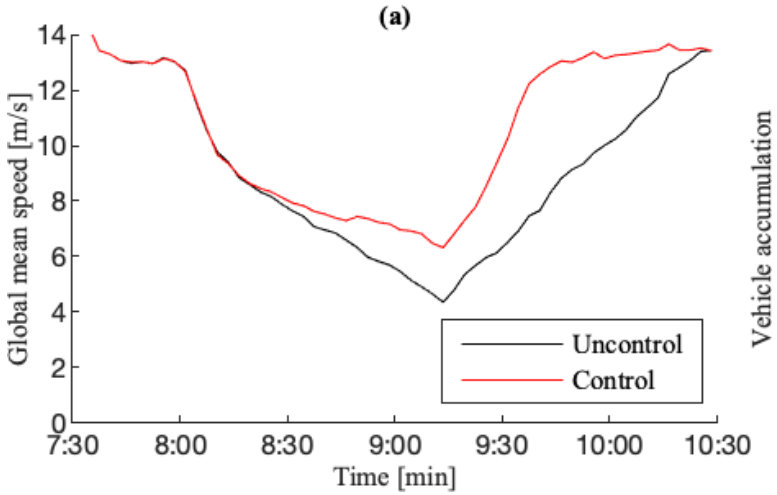
Route guidance based on avoidance maps





Simulation studies on a real network

Northern Lyon network

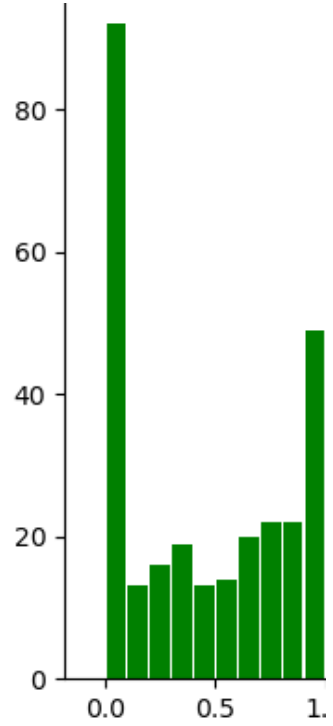


Proof of concept – Lyon city

ERC PoC MAGnUM+
(prototype and first field tests)

Lyon city has been partitioned in about 430 regions

Behavioral observations



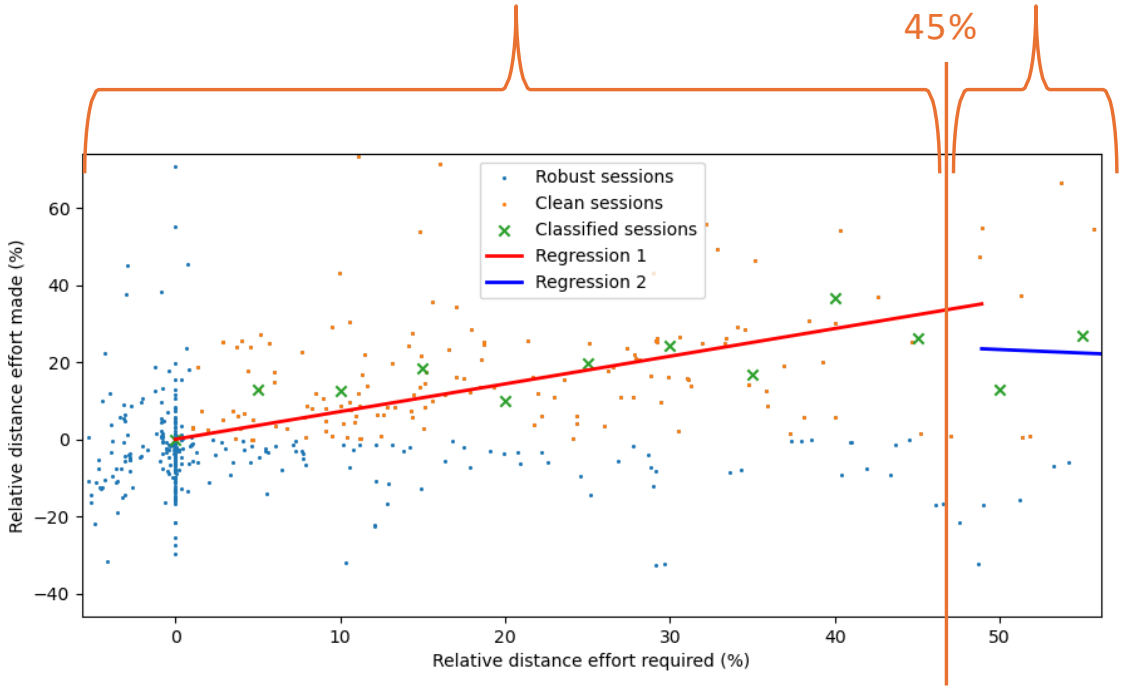
Individual compliance rate

Threshold is 45% of relative effort or about 10km

Partial compliance about 70% of the requested extra distance

Drop in compliance

45%

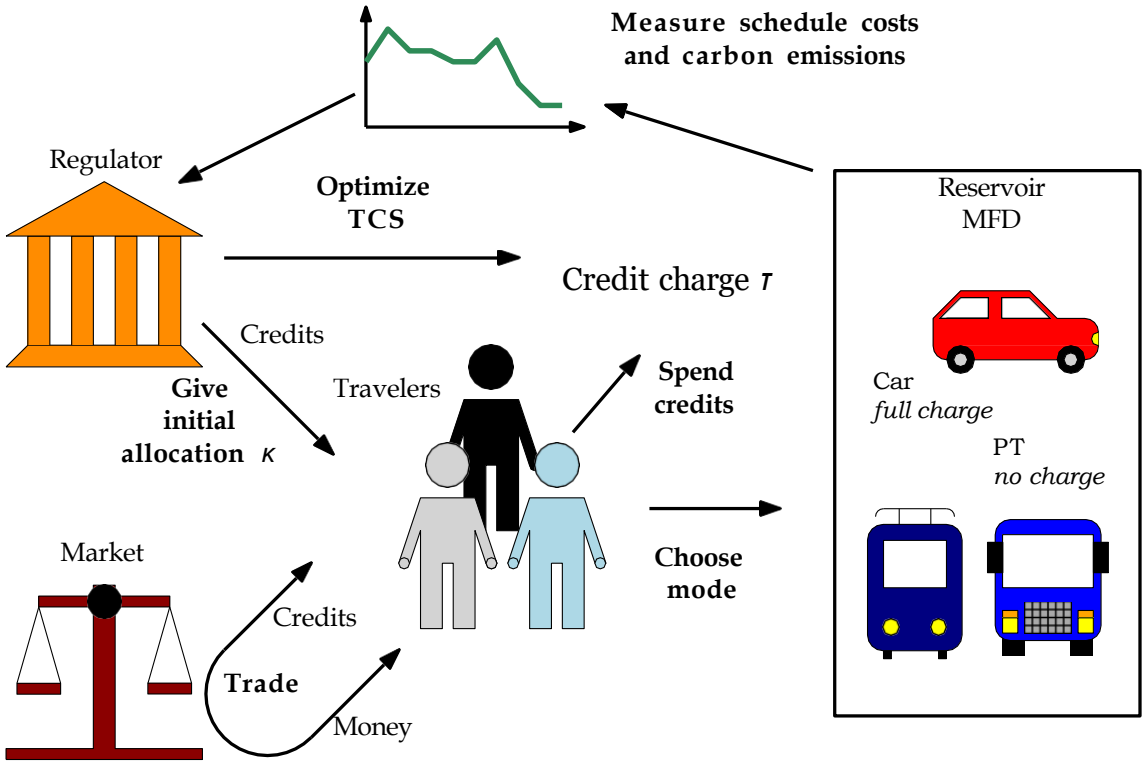


Overall distance in banned regions is reduced by 30% compared to the non-control case

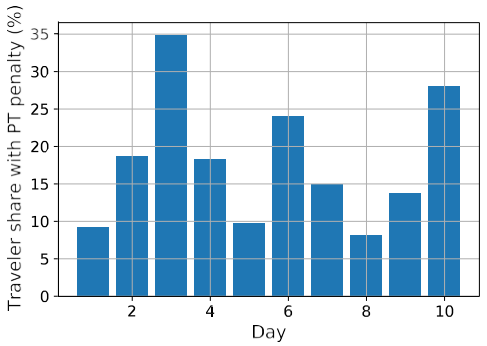
Managing demand with tradable credits

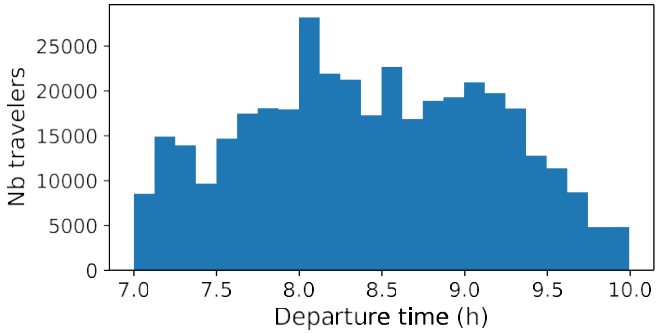
Balzer, L., Leclercq, L., 2022. Modal dynamic equilibrium under different demand management schemes *Transportation*.
Balzer, L., Leclercq, L., 2022. Modal equilibrium of a tradable credit scheme with a trip-based MFD and logit-based decision-making. *Transportation Research part C*, 139:103642

Tradable Credit Scheme Concept

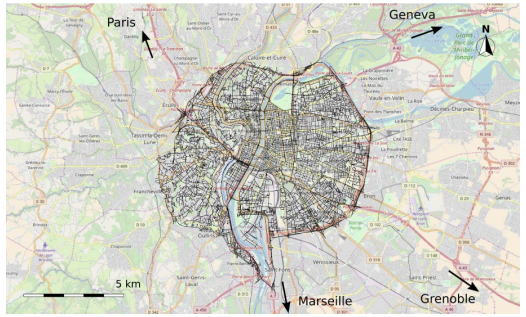


Simulation settings





Mariotte et al. (2018)



- Lyon Metropolis
- Morning commute 7:00 to 10:00
- Look over 10 days
- Credits **valid** two weeks
- No car on needed day ➔ 10 EUR **penalty** (VoT = 10.8 EUR)

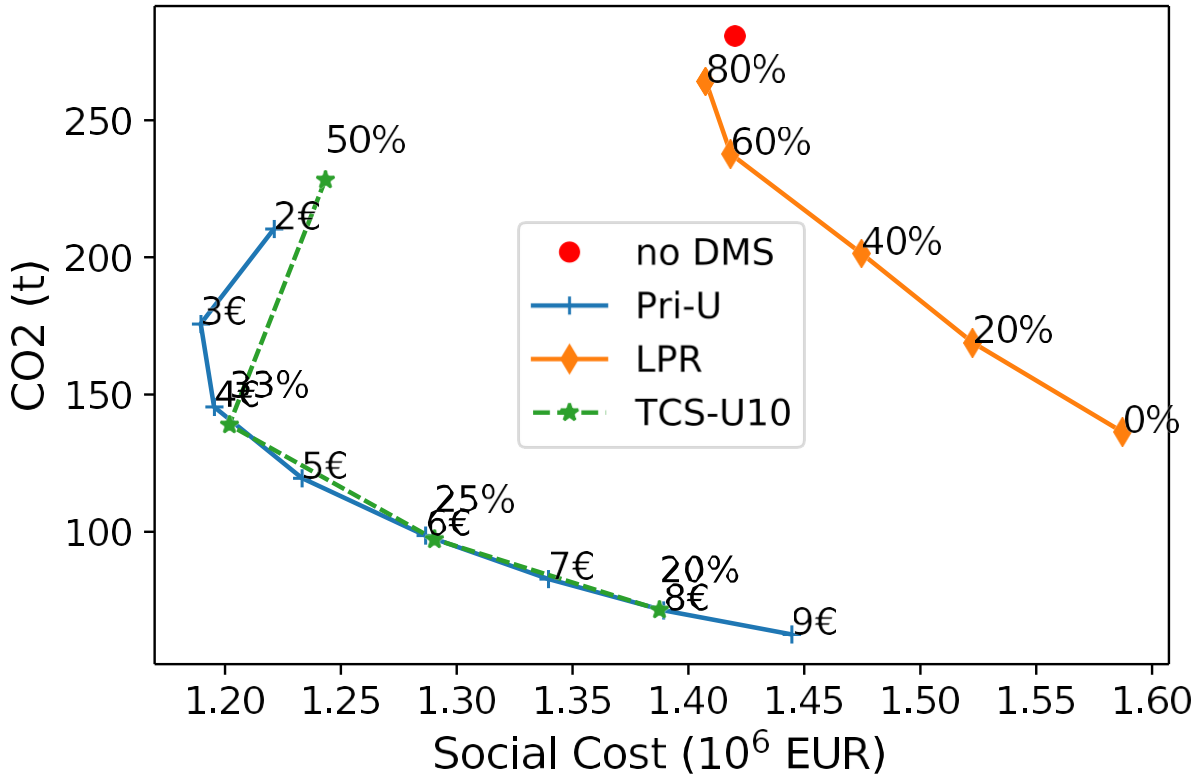
Assessing different policies by simulation

- **License plate rationing**: every traveler is allowed to drive its car every two days, depending on the plate number (odd or even).

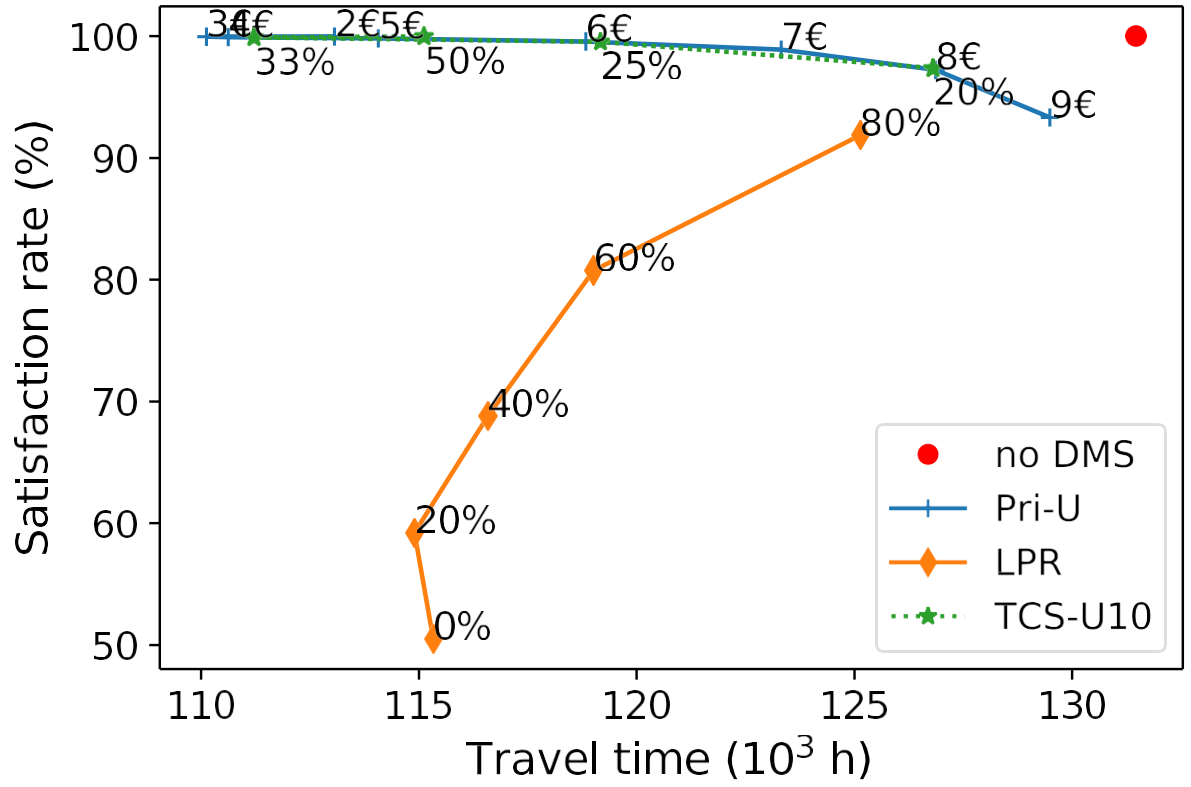
- **Congestion pricing**: additional price set by the regulator to drive a car.

- **Tradable credit scheme**: credits are required to travel by cars

Pollution and congestion reduction for TCS, LPR, and pricing



Satisfaction vs congestion reduction for TCS, LPR, and pricing



Thank you for your attention