MAGnUM

European Research Council
Established by the European Commission

European Commission

LICIT

Modeling traffic flow in large-scale networks

Guilhem Mariotte & Ludovic Leclercq

Univ Lyon, ENTPE, IFSTTAR, LICIT

June 19, 2017

SMRT, Grettia,
Marne-la-Vallée

UNIVERSITÉ DE LYON

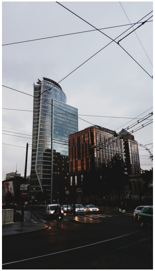
ENTPE
L'école de l'aménagement durable des territoires

IFSTTAR

About traffic flow modeling

Why modeling traffic flow?

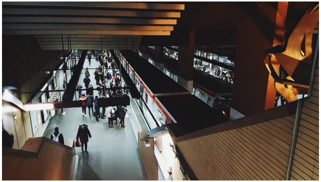
Urban planning



Traffic state estimation

Control

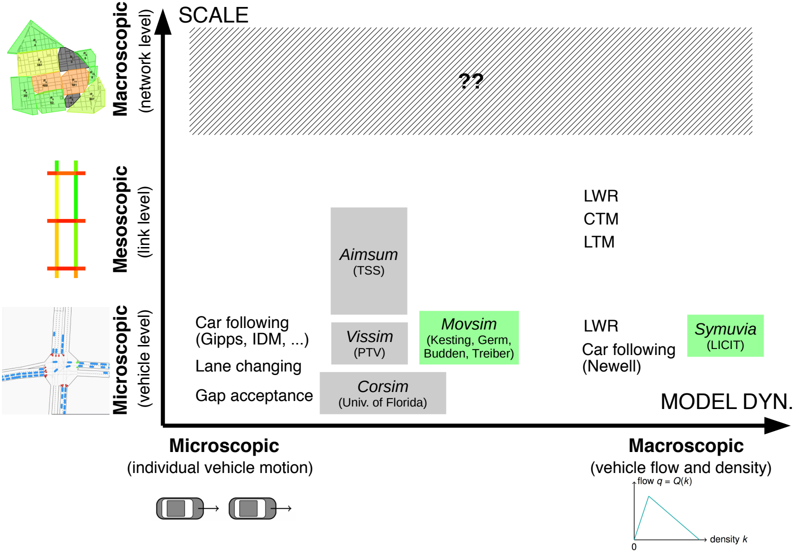
Public transports



Gas emissions

photo credits: Lucas Gallone, Hermes Rivera, Markus Spiske – unsplash.com

Brief overview of traffic flow models

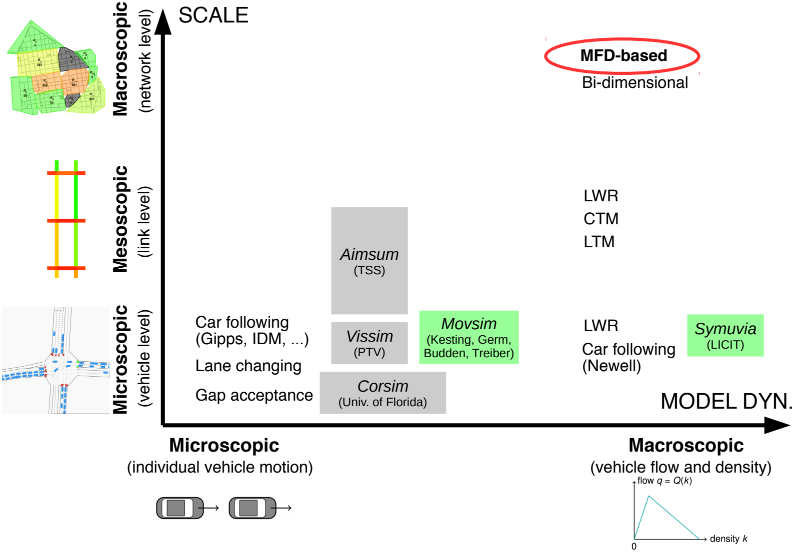


Limitations of these models at the network scale

- Computational complexity
- Real-time calculations almost impossible
- Large and detailed amount of information required (demand patterns, shortest paths, assignment, ...)

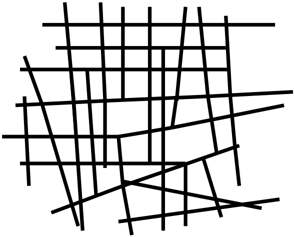
Road network of Lyon-Villeurbanne:
***27,000** links*
***1700** entries*
***1700** exits*

Brief overview of traffic flow models



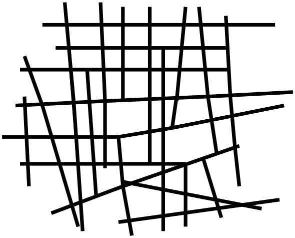
Macroscopic MFD-based models

Split the network into zones or “reservoirs”

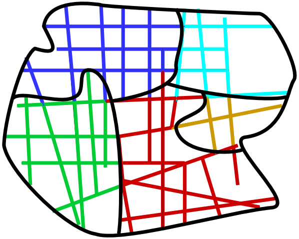


Real network

Split the network into zones or “reservoirs”

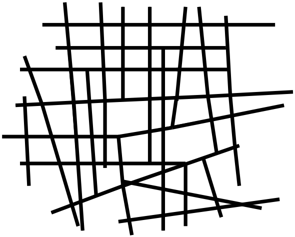


Real network

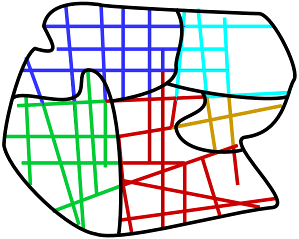


Clustering into zones or “reservoirs”

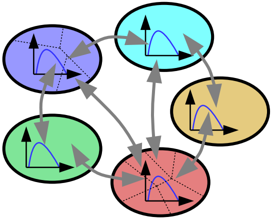
Split the network into zones or “reservoirs”



Real network

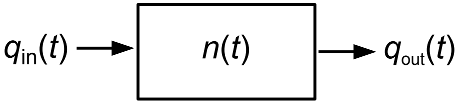


Clustering into zones or “reservoirs”



Modeling of flow exchanges between zones

Flow dynamics in one zone: the single reservoir or bathtub problem

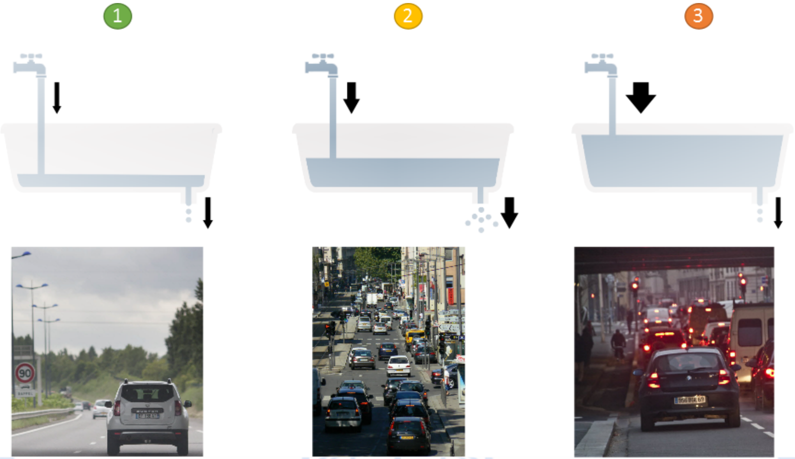


$q_{in}(t)$

$\updownarrow n(t)$

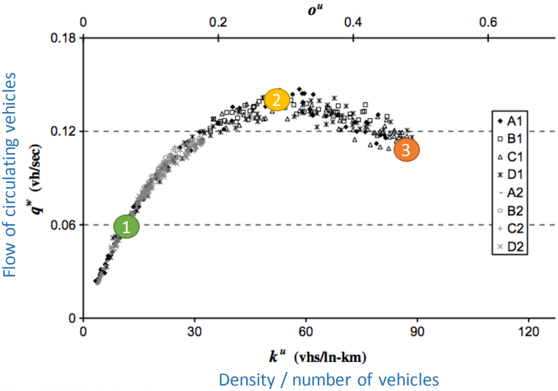
$q_{out}(t)$

Traffic regimes

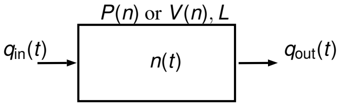


The Macroscopic or Network Fundamental Diagram (MFD or NFD)

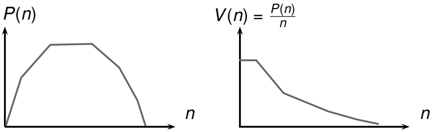
N. Geroliminis, C.F. Daganzo / Transportation Research Part B 42 (2008) 759–770



Traffic flow dynamics: two approaches



single reservoir



production and speed MFD

$$\frac{dn}{dt} = q_{in}(t) - q_{out}(t)$$

$q_{in}(t)$: defined by demand

$q_{out}(t)$: ?? $\rightarrow$ two modeling approaches

No spatial extension in a reservoir!!

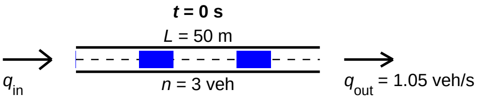
$\rightarrow$ need to define a trip length

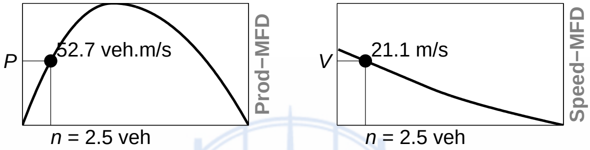
Accumulation-based model

(Daganzo, 2007, Geroliminis & Daganzo, 2007)

Use the principle of the queuing formula of Little (1961):

$$q_{\text{out}}(t) = \frac{n}{T} = n\frac{V}{L} = \frac{P}{L}$$



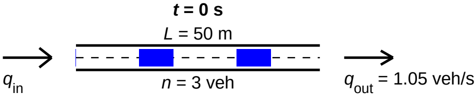


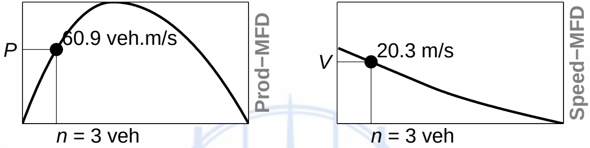
Trip-based model

(Arnott, 2013)

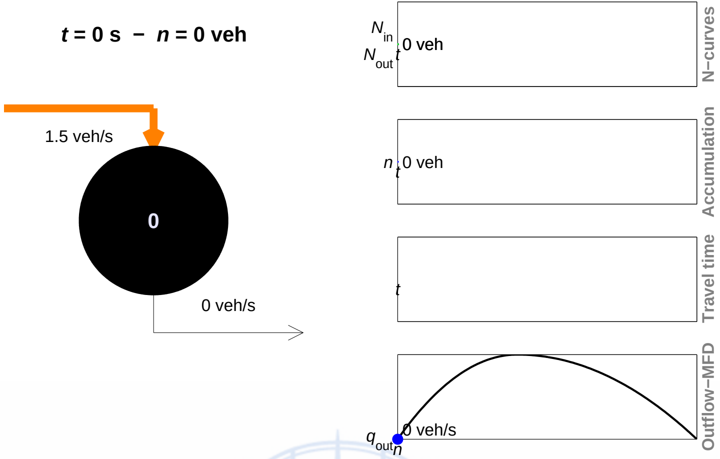
Explicit formulation of the trip length L:

$$L = \int_{t-T(t)}^{t} V(n(s))ds \iff q_{out}(t) = q_{in}(t - T(t))\frac{V(n(t))}{V(n(t - T(t)))}$$

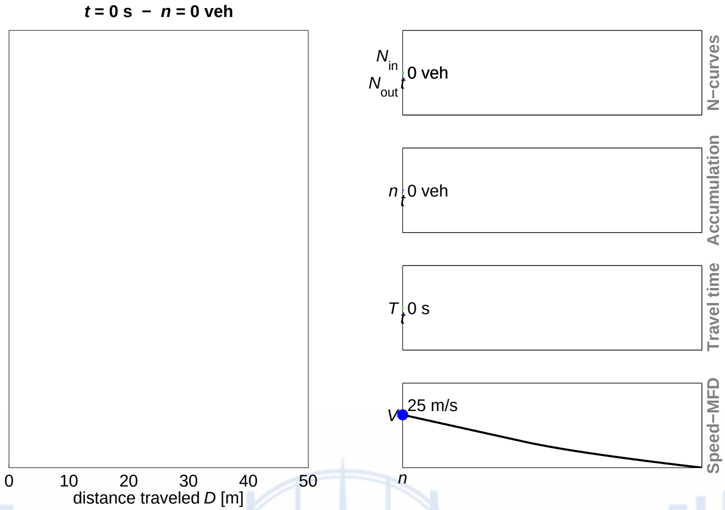




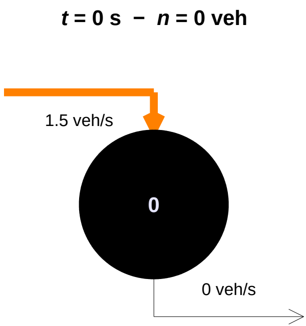
Accumulation-based (free-flow conditions)

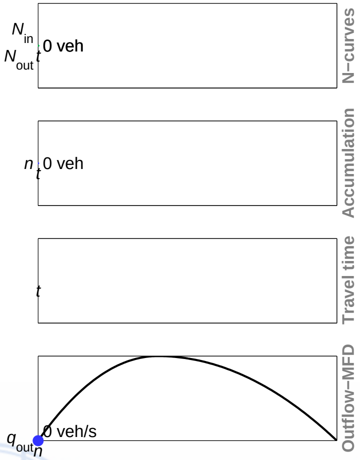


Trip-based (free-flow conditions)

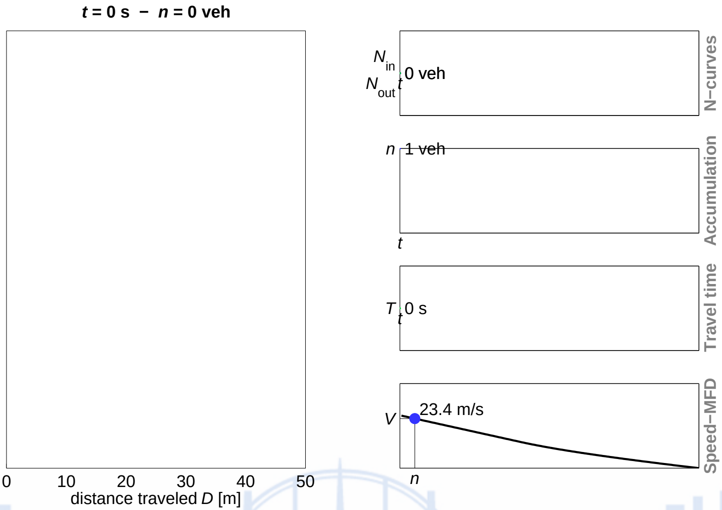


Accumulation-based (congested conditions)





Trip-based (congested conditions)



Major differences

Accumulation-based:

Trip-based:

Major differences

Accumulation-based:

- flow exchange management at the reservoir borders

Trip-based:

- track of individual vehicles

Major differences

Accumulation-based:

- flow exchange management at the reservoir borders
- outflow demand explicitly defined by the formula of Little (1961)

Trip-based:

- track of individual vehicles
- outflow demand implicitly defined: result of the vehicles traveling at the reservoir mean speed

Major differences

Accumulation-based:

- flow exchange management at the reservoir borders
- outflow demand explicitly defined by the formula of Little (1961)
- smooth and continuous evolution of flow

Trip-based:

- track of individual vehicles
- outflow demand implicitly defined: result of the vehicles traveling at the reservoir mean speed
- irregular and discontinuous representation of flow (stochasticity)

Major differences

Accumulation-based:

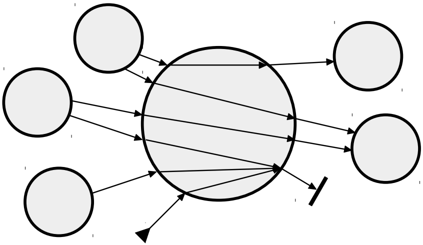
- flow exchange management at the reservoir borders
- outflow demand explicitly defined by the formula of Little (1961)
- smooth and continuous evolution of flow
- algorithm complexity depending on the number of reservoirs and the time step choice (fast)

Trip-based:

- track of individual vehicles
- outflow demand implicitly defined: result of the vehicles traveling at the reservoir mean speed
- irregular and discontinuous representation of flow (stochasticity)
- algorithm complexity depending on the number of reservoirs and the number of vehicles (slower)

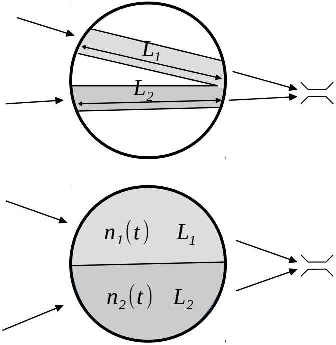
Multi-routes in a reservoir

Inner dynamics of a reservoir

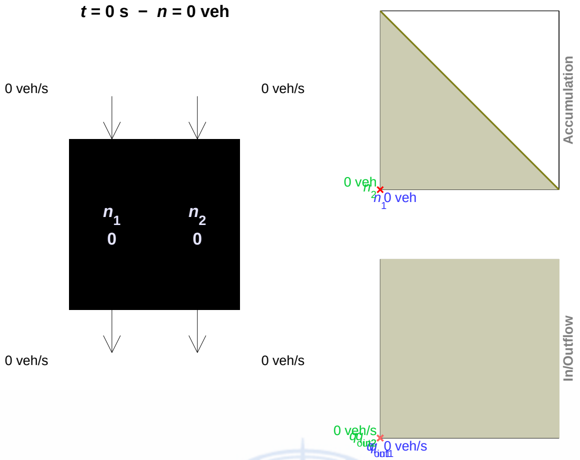


We may define different travel distances inside the same reservoir, but all users/flows experience the same mean speed
→ Outflows from each different trips are all inter-dependent!!

Case of two routes

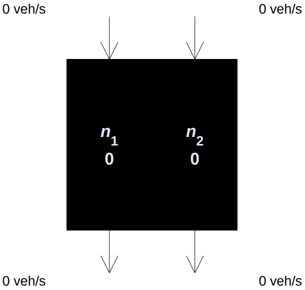


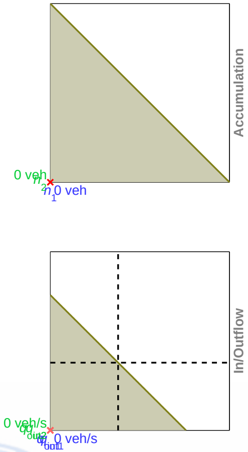
Accumulation-based, two routes, (free-flow)



Accumulation-based, two routes, (congestion)

t = 0 s – n = 0 veh

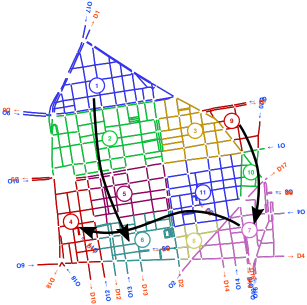




Application on a real network

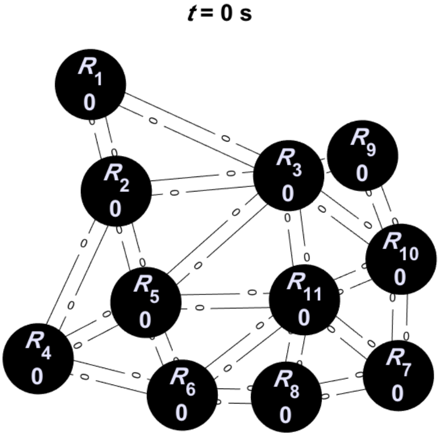
Application example on the network of Lyon 6

Satellite view of Lyon, France (© Google Maps)

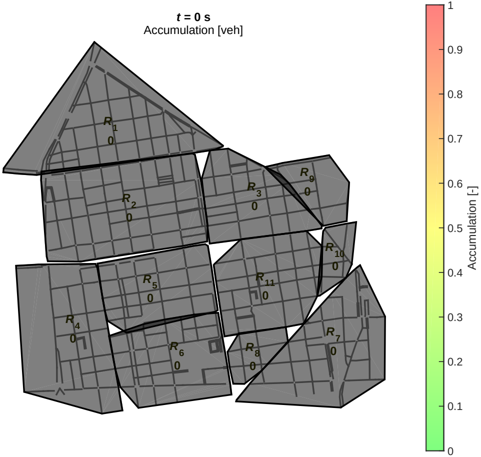


www.ifsttar.fr

Application example on the network of Lyon 6

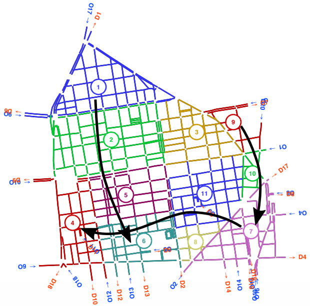


Application example on the network of Lyon 6

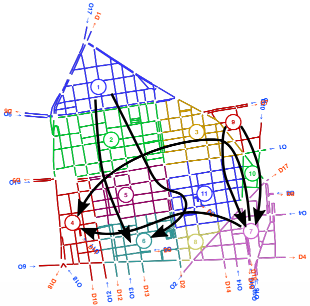


Application example on the network of Lyon 6

We can achieve a better distribution of trips among the reservoirs through assignment schemes (Probit here)

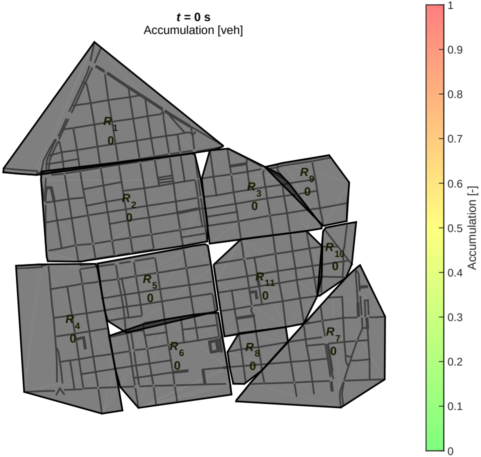


3 OD, 3 macro-routes



3 OD, 6 macro-routes

Application example on the network of Lyon 6



Current research questions & further work

With real networks and data:

- MFD definition and estimation
- Network clustering
- Trip length definition and estimation

Theoretical issues:

- Flow merging problems between reservoirs
- Congestion propagation within multi route frameworks

Acknowledgements

This project has received funding from the European Research Council (ERC) under the European Unions Horizon 2020 research and innovation programme (grant agreement No 646592 – MAGnUM project).

Thank you for your attention

Guilhem Mariotte & Ludovic Leclercq

@ guilhem.mariotte@ifsttar.fr
www.guilhemmariotte.com

Univ Lyon, ENTPE, IFSTTAR, LICIT
UMR _T 9401, F-69518, LYON, France

Rue Maurice Audin
69518 Vaulx-en-Velin Cedex
France
+33 (0)4 72 04 77 69

www.entpe.fr | www.ifsttar.fr | www.licit-lyon.eu | magnum.ifsttar.fr

www.ifsttar.fr

References

Arnott, R. (2013). A bathtub model of downtown traffic congestion. *Journal of Urban Economics*, 76:110–121.

Daganzo, C. F. (2007). Urban gridlock: Macroscopic modeling and mitigation approaches. *Transportation Research Part B: Methodological*, 41(1):49–62.

Geroliminis, N. & Daganzo, C. F. (2007). Macroscopic modeling of traffic in cities. In *Transportation Research Board 86th Annual Meeting*, 07-0413. Washington DC.

Little, J. D. C. (1961). A proof for the queuing formula. *Operations Research*, 9(3):383–387.