Activity-based dynamic traffic assignment on regional networks and aggregated traffic models

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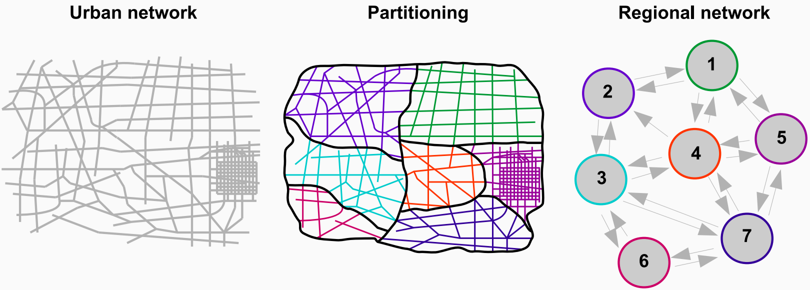
Introduction to MFD-based models

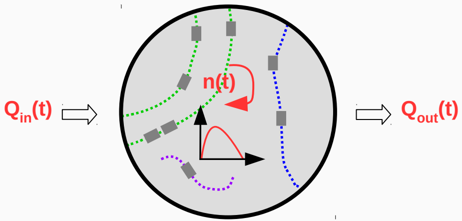
Scaling city into regional networks



* Saeedmanesh and Geroliminis 2016, 2017; Lopez et al., 2017; Ambuhl et al. (2019); Batista et al. (in prep.).

Aggregated traffic models based on the MFD

State variable: $n(t)$ – accumulation – number of circulating vehicles in a region.



Flow conservation equation *:

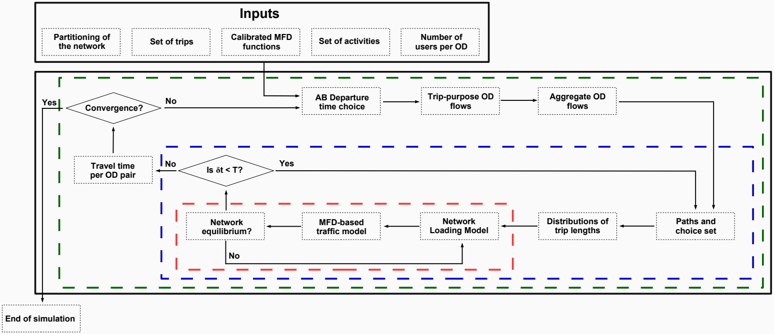
$$\frac{dn}{dt} = Q_{in}(t) - Q_{out}(t), t \geq 0 \qquad (1)$$

$Q_{in}(t)$: inflow [veh/s]
$Q_{out}(t)$: outflow [veh/s]

* Mariotte, G. and Leclercq, L. (2019), Flow exchanges in multi-reservoir systems with spillbacks. Transportation Research Part B: Methodological, 101:245–267, https://dx.doi.org/10.1016/j.trb.2019.02.014.

Activity-based DTA for regional networks and MFD models

General framework



Activity-based and Departure time choice

Utility-based DTA

The overall dis-utility of a user **n** doing an activity **a** knowing the departure time τ, transportation mode **m** and path **p** is:

$$U_n^{OD}(\tau, m, p) = \max_{\tau,m,r}(U_n^T(\tau, m, p) + U_n^A(\tau)), \forall n \in \mathrm{N} \wedge \forall(O, D) \in W \quad (2)$$

where O and D represent the Origin and Destination regions, respectively; N is the total number of users traveling on the OD pair; and W is the set of all OD pairs.

This network equilibrium can be formulated as a complementary problem:

$$\begin{cases} N(\tau,\mathrm{m},\mathrm{p}) \cdot (U_n(\tau,\mathrm{m},\mathrm{p})\text{-}\mathrm{U}^*) = 0 \\ N(\tau,\mathrm{m},\mathrm{p}) \geq 0,\ U_n(\tau,\mathrm{m},\mathrm{p})\text{-}\mathrm{U}^* \leq 0, \forall \tau,\ \mathrm{m},\ \mathrm{p} \end{cases}$$

where U^* is the maximum dis-utility.

Dis-utilities of traveling and performing an activity

The dis-utility of traveling $U_n^T(\tau, m, p)$ is:

$$U_n^T(\tau, m, p) = \alpha_a^{OD} \cdot \overline{TT}^{OD} + \beta_a^{OD} \cdot EA + \gamma_a^{OD} \cdot LA \tag{3}$$

where α_a^{OD}, β_a^{OD} and γ_a^{OD} are the cost of traveling, early arrival and late arrival, respectively; EA is the scheduling delay; LA is the penalty of late arrival; and $\overline{TT}^{OD}$ is the average travel time of the regional OD pair.

The dis-utility of performing an activity $U_n^A(\tau)$ (Cantelmo and Viti, 2018; 2019) is:

$$U_n^A(\tau, t_a^i, t_a^f) = \int_{t_a^i+1}^{t_a^f} U_n^A(t') \cdot \left(\frac{1}{(t' - t_a^i)}\right)^G \cdot dt' \tag{4}$$

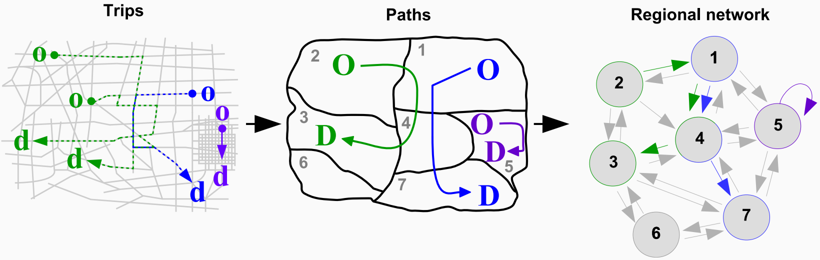
where $G \in [0, 1]$ is an hyper-parameter of the model; t_a^i and t_a^f represent the starting and ending times of the activity. The dis-utility $U_n^A(t')$ is given in Ettema and Timmermans (2003).

Cantelmo, G. and Viti, F. (2019), *A utility-based dynamic demand estimation model that explicitly accounts for activity scheduling and duration*, Transportation Research Part A, 114, 303-320, https://doi.org/10.1016/j.tra.2018.01.039.

Cantelmo, G. and Viti, F. (2019), *Incorporating activity duration and scheduling utility into equilibrium-based Dynamic Traffic Assignment*, Transportation Research Part B, 126, 365-390, https://doi.org/10.1016/j.trb.2018.08.006.

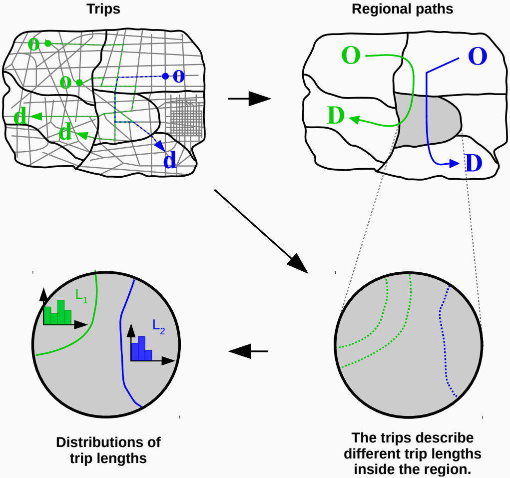
UE on regional networks

How to define paths on regional networks?



S. F. A. Batista, M. Seppecher and L. Leclercq (2021). *On the identification and characterization of paths on regional networks for MFD-based applications*, Transportation Research Part C: Emerging Technologies, 127, 102953, `https://doi.org/10.1016/j.trc.2020.102953`.

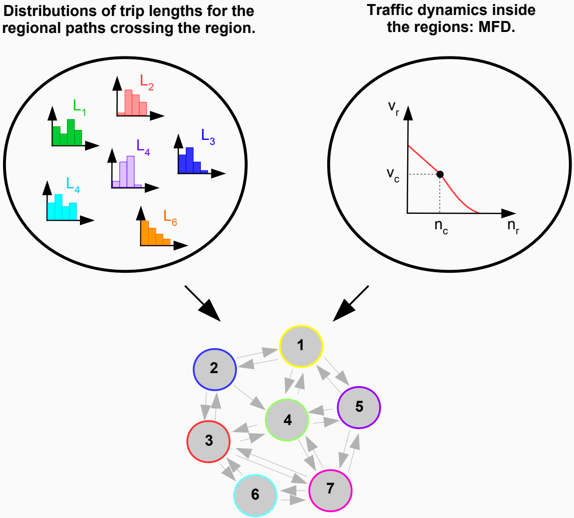
How to characterize the regional paths?



S. F. A. Batista, L. Leclercq and N. Geroliminis (2019). *Estimation of regional trip length distributions for the calibration of the aggregated network traffic models*, Transportation Research Part B, 122, 192-217, `https://doi.org/10.1016/j.trb.2019.02.009`.

S. F. A. Batista, L. Leclercq and M. Menéndez (2021). *Dynamic Traffic Assignment for regional networks with traffic-dependent trip lengths and regional paths*, Transportation Research Part C: Emerging Technologies, 127, 103076, `https://doi.org/10.1016/j.trc.2021.103076`.

How to define the regional network equilibrium?



S. F. A. Batista and L. Leclercq (2019). *Regional dynamic traffic assignment framework for macroscopic fundamental diagram multi-regions models*, Transportation Science, 53 (6), 1563-1590, https://doi.org/10.1287/trsc.2019.0921.

Travel time of a path in a regional network

The travel time TT_p^{OD} of a path is:

$$TT_p^{OD} = \sum_{r \in X} \left(\frac{L_{rp}}{v_r(n_r)} \right) \delta_{rp}, \forall p \in \Omega^{OD} \wedge \forall (O,D) \in W \tag{5}$$

The travel time TT_p^{OD} depends on:

- the sets of trip lengths $\{L_{rp}\}$ for all regions r that define path p.
- the speed-MFD $v_r(n_r)$ inside region r that defines path p.

DUE:

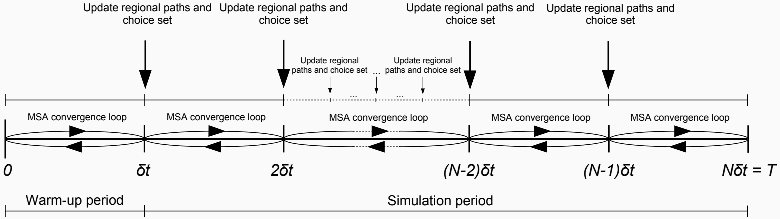
$$U_p^{OD} = \sum_{r \in X} \left(\frac{\overline{L}_{rp}}{\overline{v}_r} \right) \delta_{rp}, \forall p \in \Omega^{OD} \wedge \forall (O,D) \in W \tag{6}$$

SUE:

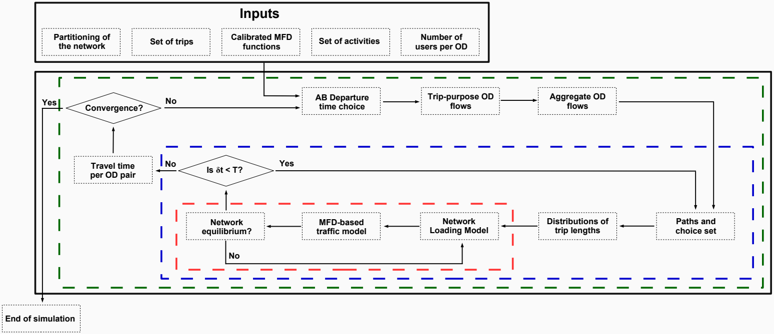
$$U_p^{OD} = \sum_{r \in X} \left(\frac{\overline{L}_{rp}}{\overline{v}_r} + \frac{L_{rp}}{\overline{v}_r} - \frac{\overline{L}_{rp} v_r}{\overline{v}_r^2} \right) \delta_{rp}, \forall p \in \Omega^{OD} \wedge \forall (O,D) \in W \tag{7}$$

S. F. A. Batista and L. Leclercq (2019). *Regional dynamic traffic assignment framework for macroscopic fundamental diagram multi-regions models*, Transportation Science, 53 (6), 1563-1590, https://doi.org/10.1287/trsc.2019.0921.

Quasi-static approach to calculate the network equilibrium

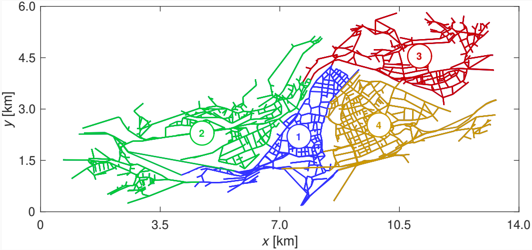


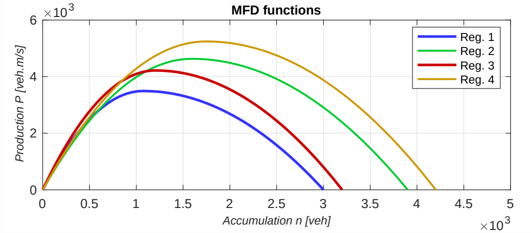
General framework: an overview



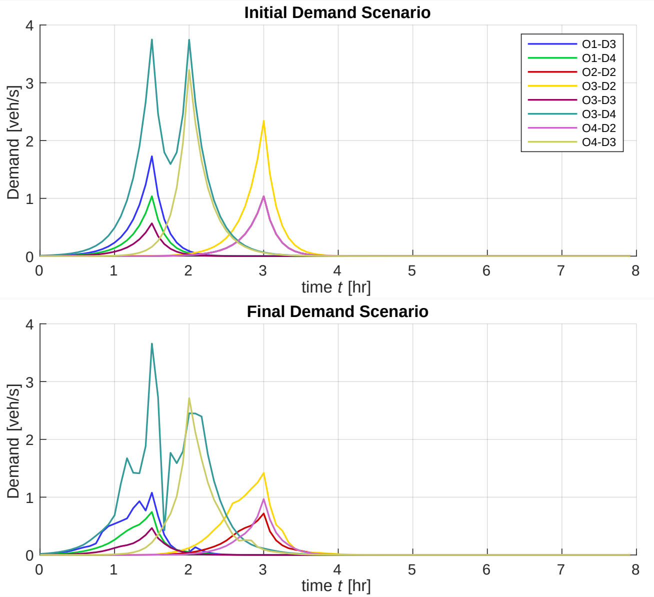
Preliminary results

Test network and MFD functions

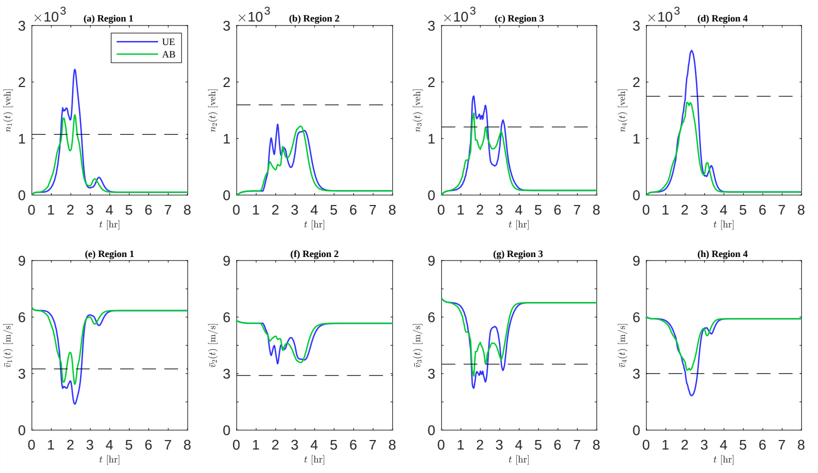




Demand scenario



Accumulations and mean speeds in the regions



Outline

Outline and future research directions

In this work, we:

- designed an Utility-based Dynamic Traffic Assignment model (which includes departure time and path choice) for regional networks and aggregated traffic models based on the MFD;
- discussed an example of application on the network of Innsbruck (Austria), partitioned into 4 regions, and considering three activities home-work;
- the dynamic choice of departure time flattens congestion around the peak hours.

As the next steps, we will:

- design a framework that does the departure time, mode and path choice simultaneously and propose a solution algorithm;
- introduce more realistic utility functions able to reproduce more complex mobility patterns;
- analyze the effect of special events on traffic patterns;
- show and discuss the importance of this activity-based DTA and MFD framework for applications of congestion pricing, environmental pricing and route guidance and perimeter control.

Thank you for your attention.

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