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 *:

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

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

Activity-based DTA for regional networks and MFD models
General framework

End of simulation

Inputs

Partitioning of the network
Set of trips
Calibrated MFD functions
Set of activities
Number of users per OD

Convergence?

Travel time per OD pair

Is δt < T?

AB Departure time choice
Trip-purpose OD flows
Aggregate OD flows

Network equilibrium?

MFD-based traffic model
Network Loading Model
Distributions of trip lengths
Paths and choice set

End of simulation
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 $\tau$, transportation mode $m$ and path $p$ is:

$$U_{n}^{OD}(\tau, m, p) = \max_{\tau,m,r}(U_{n}^{T}(\tau, m, p) + U_{n}^{A}(\tau)), \forall n \in N \land \forall (O, D) \in W$$

(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:

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

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:

$$U_n^T(\tau, m, p) = \alpha^{OD}_a \cdot \overline{TT}^{OD} + \beta^{OD}_a \cdot EA + \gamma^{OD}_a \cdot LA$$  \hspace{1cm} (3)

where $\alpha^{OD}_a$, $\beta^{OD}_a$ and $\gamma^{OD}_a$ 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:

$$U_n^A(\tau, t^i_a, t^f_a) = \int_{t^i_a+1}^{t^f_a} U_n^A(t') \cdot \left( \frac{1}{(t' - t^i_a)} \right)^G \cdot dt'$$  \hspace{1cm} (4)

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


UE on regional networks
How to define paths on regional networks?

How to characterize the regional paths?

The trips describe different trip lengths inside the region. Distributions of trip lengths $L_1$, $L_2$. The trips describe different trip lengths inside the region.


How to define the regional network equilibrium?

Distributions of trip lengths for the regional paths crossing the region.

Traffic dynamics inside the regions: MFD.

The travel time $TT_{pOD}$ of a path is:

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

The travel time $TT_{pOD}$ 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:

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

SUE:

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

Quasi-static approach to calculate the network equilibrium

\[ N \delta t = T(N-1) \delta t(N-2) \delta t^2 \delta t \delta t^0 \]

Update regional paths and choice set

Warm-up period
Simulation period
General framework: an overview
Preliminary results
Test network and MFD functions
Demand scenario

Initial Demand Scenario

Final Demand Scenario
Accumulations and mean speeds in the regions

(a) Region 1
(b) Region 2
(c) Region 3
(d) Region 4

(e) Region 1
(f) Region 2
(g) Region 3
(h) Region 4
Outline
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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