Departure time choice modeling

an application to the Paris area

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Outline

- Definition of the problem
- Vickrey's model
- Simulation issues
- Integration into METROPOLIS
- Extensions
- Example of Paris
    - Data collection/survey
    - Input data sets
    - Results

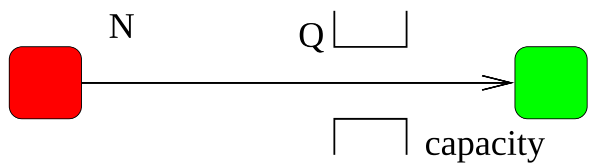
Definition of the problem

- Goal: extend dynamic traffic models by adding endogenous time of usage:
  - No arbitrary period
  - No time-dependent input data (i.e. dynamic O-D matrices)
- Time of usage depends on:
  - Sequence of daily activities
  - Availability of transport modes
  - Schedule of activities
- Assumptions:
  - Decision is individual to each single trip (no tours)
  - Single constraint (origin or destination)

Departure time choice-Literature

Vickrey, Small, Hendrickson, Plank, Bates, Mahmassani, de Palma, Arnott, Lindsey, Khattak, ...

Vickrey's model (1969)



- Choice variable: departure time t_d
- Congestion: $\tau(t_d) = \frac{Q(t_d)}{capacity}$
- Arrival time: $t_a(t_d) = t_d + \tau(t_d)$
- Cost specification:

$$C(t_d) = \alpha\tau(t_d) + \beta \max\{0, t^* - t_a(t_d)\} + \gamma \max\{0, t_a(t_d) - t^*\}$$

- α: monetary value of time
- β, γ: penalties for early/late arrivals
- t^*: desired arrival time

Vickrey's model - deterministic case

- (Nash) equilibrium for a single route exists
- Individual cost at equilibrum:

$$C^{eq} = \frac{N}{s}\frac{\beta\gamma}{\beta+\gamma}$$

- Independent of the value of time α
- Schedule delay costs accounts for one half of total cost
- Externality = individual cost
- Cost at the social optimum ($r(t) = s$):

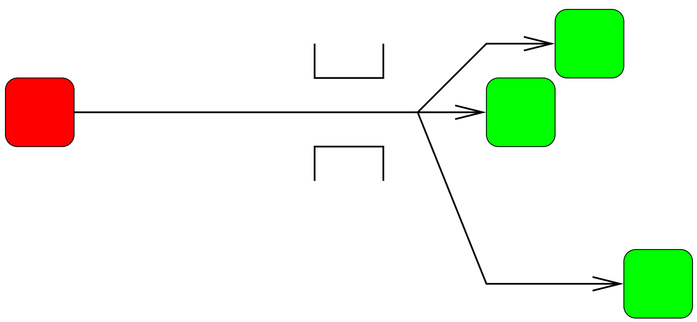
$$C^{min} = \frac{N}{2}\frac{N}{s}\frac{\beta\gamma}{\beta+\gamma}$$

Vickrey - Simulation issues

- Equilibrium not solved for general networks
- Cannot be embedded in a simulation as it is (no clue about the adjusment process)
- $\rightarrow$ random utility models to the rescue!
- $U(t_d) = -C_{vickrey}(t_d) + \mu\epsilon_{t_d}$
- Logit model: $\mathcal{P}(t < t_d \leq t + \Delta t) = \frac{\Delta t \exp \frac{-C(t)}{\mu}}{\int \exp \frac{-C(u)}{\mu} du}$
- Iterative procedure as follows:
  - compute travel costs $c(t_d)$
  - compute departure rates $r(t_d)$
  - compute travel times $\tau(t_d)$
- ... does it converge? -demo-

Simulation summary

- Unstable (reason=linear bottleneck)
- The logit model is not sufficient to stabilize the process for small capacities (i.e. the case where congestion is worth to study)
- Blending different desired arrival times is not sufficient



- Giving users some memory/inertia causes convergence
  Two equivalent techniques:
    Expected cost: $EC^{k+1} = (1-\lambda)EC^k + \lambda C^k$
    Refreshment rate (10% of users)

METROPOLIS - design philosophy

- Re-use existing static databases
- Small number of extra parameters
- Parameters should have a behavioral interpretation and can be estimated
- Transferable if possible
- Handle large-scale networks
- Straightforward comparison with simple models

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Integration into METROPOLIS

- $s \rightarrow$ network
- $N \rightarrow$ O-D matrix
- $tt_{OD}(t_d) = \arg\min_{p \in paths} tt_{OD}(p; t_d)$
- $\{\alpha, \beta, \gamma, \mu, t^*\} \rightarrow$*User Types*
- as many user types as needed to reproduce the segmentation of the travel demand
- all the parameters can be specified as a distribution in the same segment

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Extensions

- Flexible schedules:

$$C(t_d) = ... + \beta \max\{0, (t^* - \Delta) - t_a(t_d)\} + ...$$

- Evening (vs morning) peak: constraint at the departure

$$C(t_d) = ... + \gamma \max\{0, t^* - t_d\} + \beta \max\{0, t_d - t^*\}$$

Application to the Paris area

- Network and OD matrix for a morning peak hour provided by local agency (IAURIF) using DAVISUM
- Segmentation of the travel demand derived from a dedicated survey called MADDIF
  - Commuters
    - Going to Paris or the close suburbs
    - Going to the far suburbs
  - Non-commuters
- Estimation of the dynamic parameter set $\{\alpha, \beta, \gamma, \mu, t^*\}$ for each user type
- Calibration of a single parameter K to scale the overall demand

MADDIF survey

- Focused on primary travel purpose
- Description of travel conditions (constraint, modes, etc.)
- Scenarios proposed with trade-off between congestion and schedule delays
- Evaluation of the risk aversion of users
- About 4,000 successful interviews

MADDIF results

- (Value of time from external sources: $\alpha = 13\$/h$)
-

	$\beta[\$/h]$	$\gamma[\$/h]$	t^*	$\mu[\$]$
Com. (Paris/close)	6.0	7.5	N(08:30,60)	2.7
Com. (far suburbs)	8.3	17.4	N(08:24,50)	1.7
Other purposes	5.2	10.6	N(08:54,54)	2.4
			N(10:49,53)	

- Schedule delay costs =30% of travel costs

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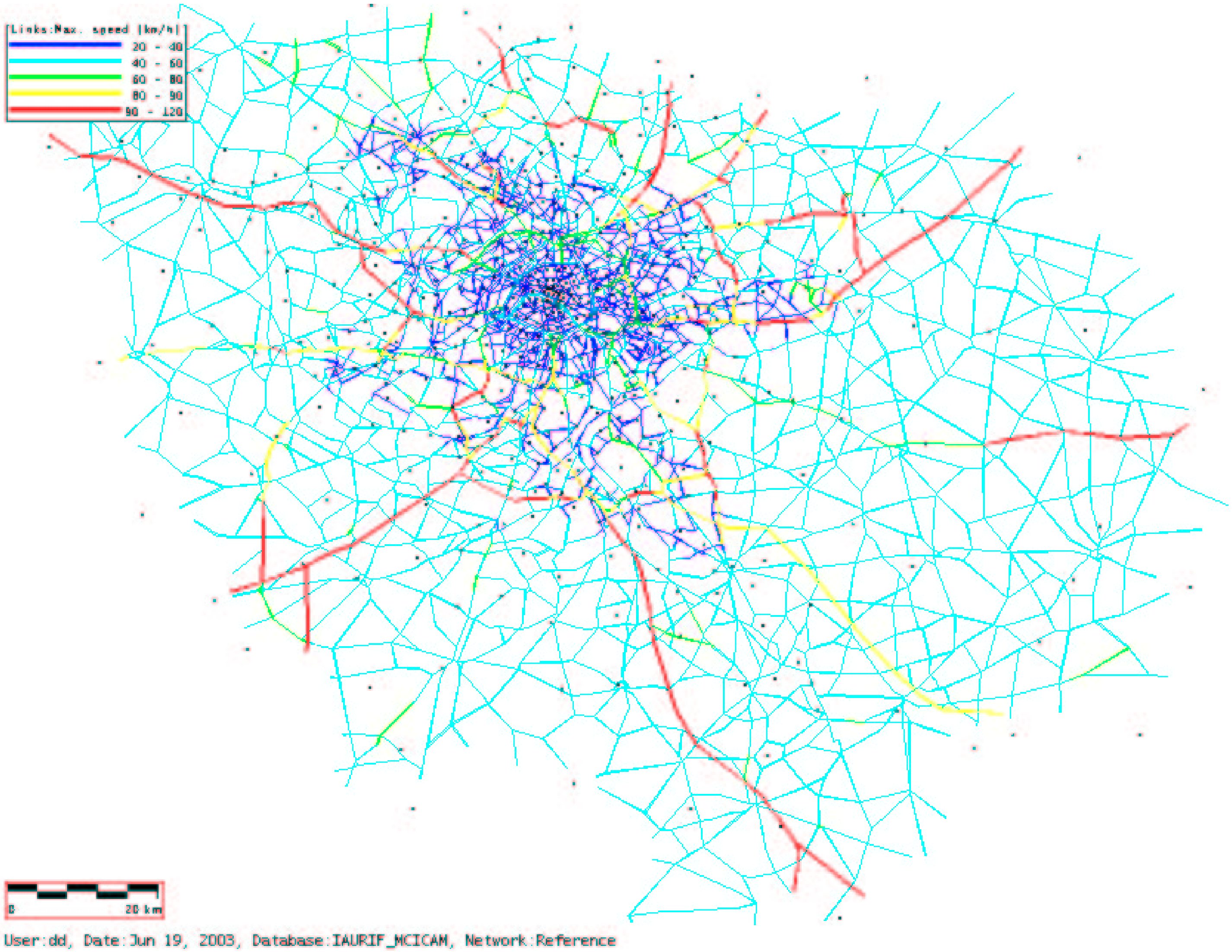
Regional database

Size: 120kmX120km, 500 zones, 18k links



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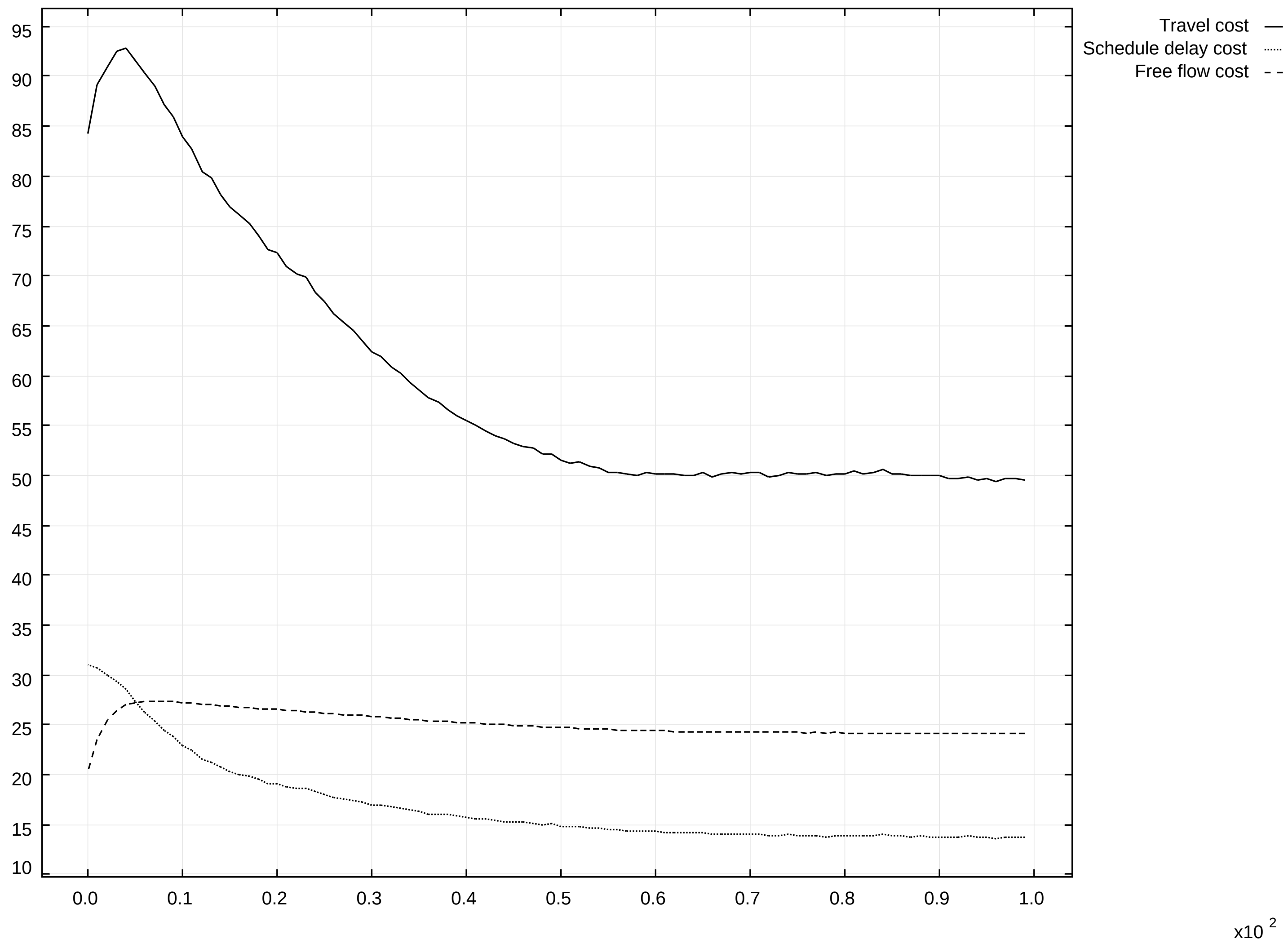
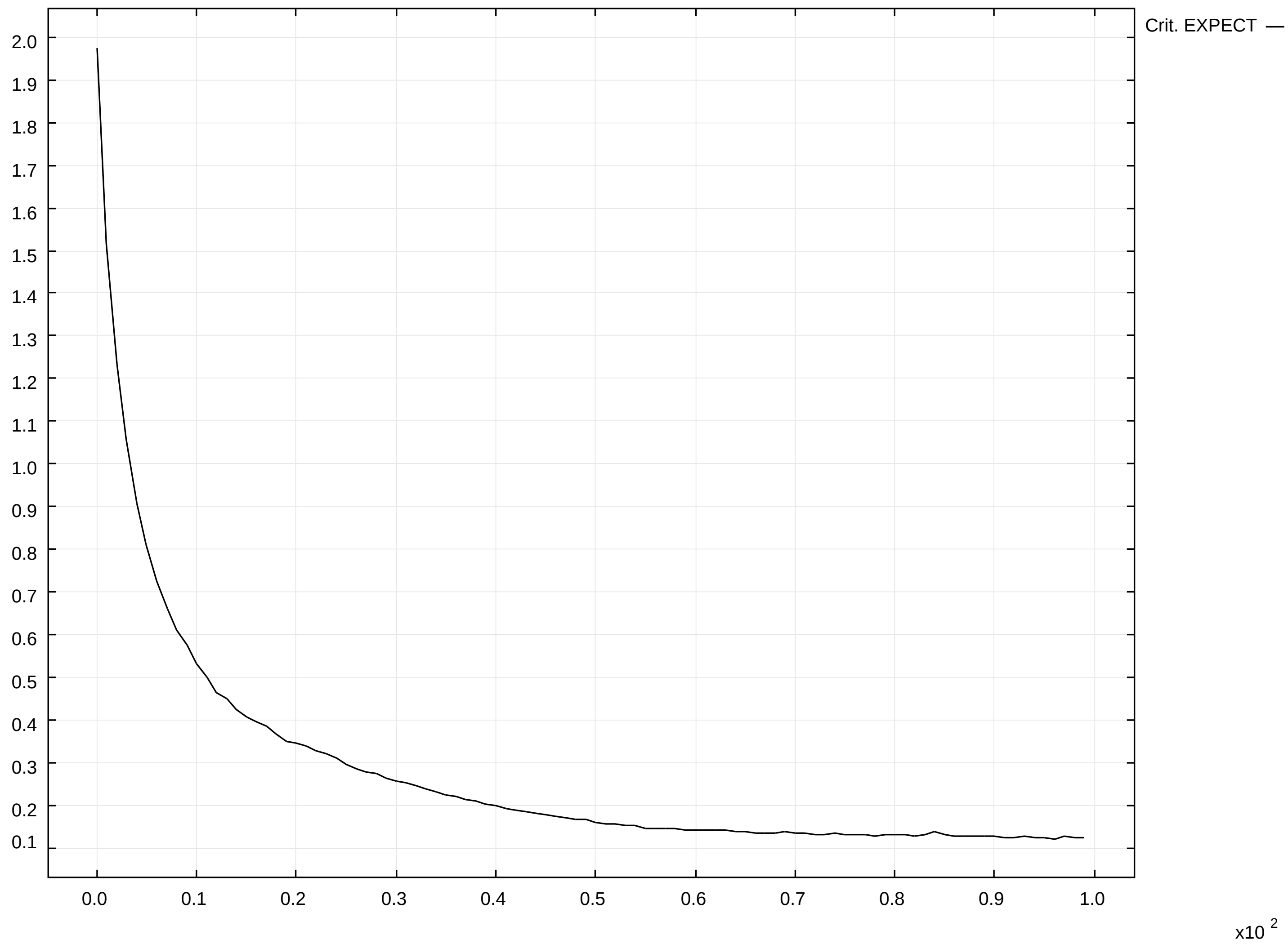
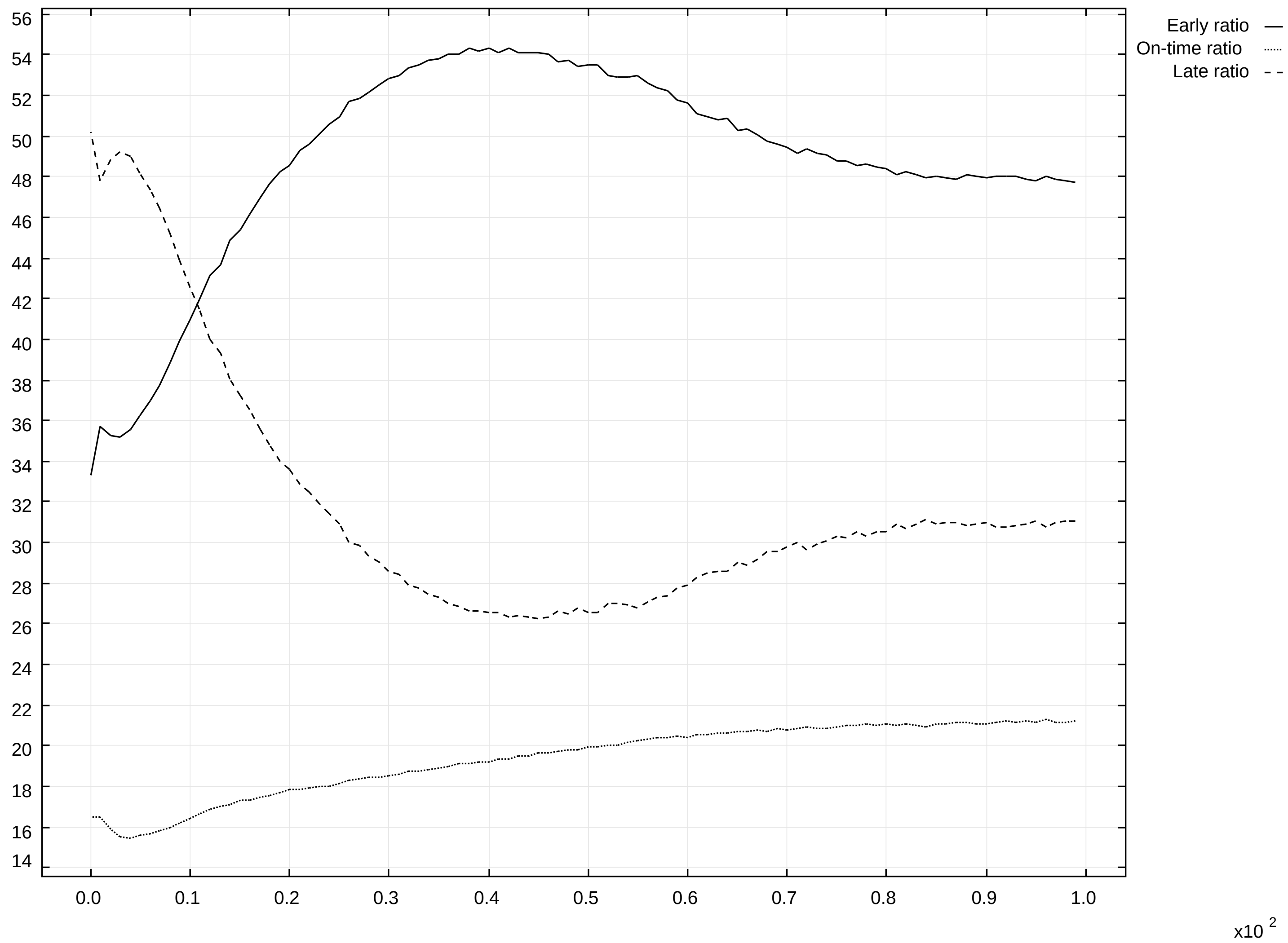
Results - Convergence



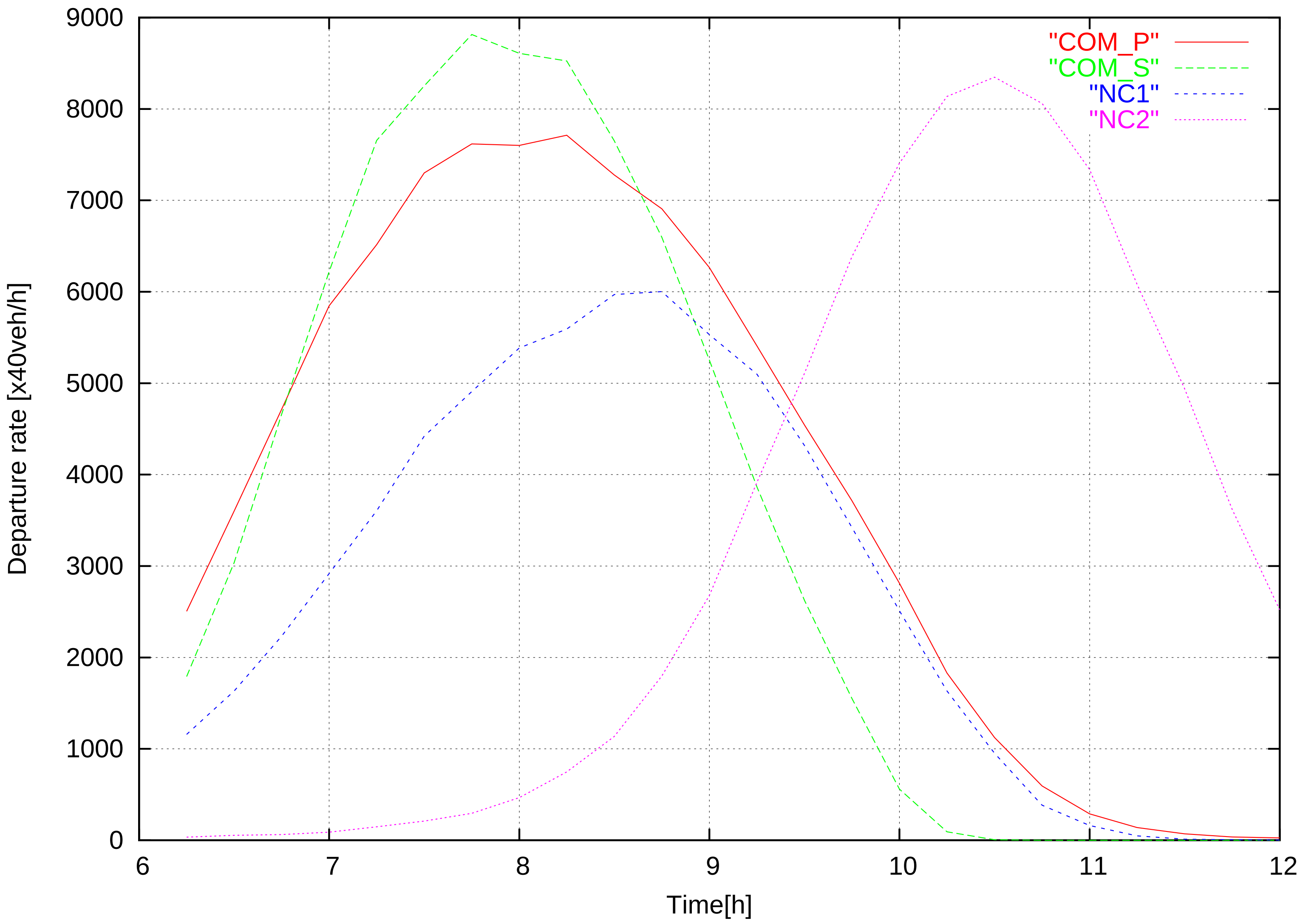
Results - Expected travel time



Results - Adjustment process



Results - Departure rates (1)



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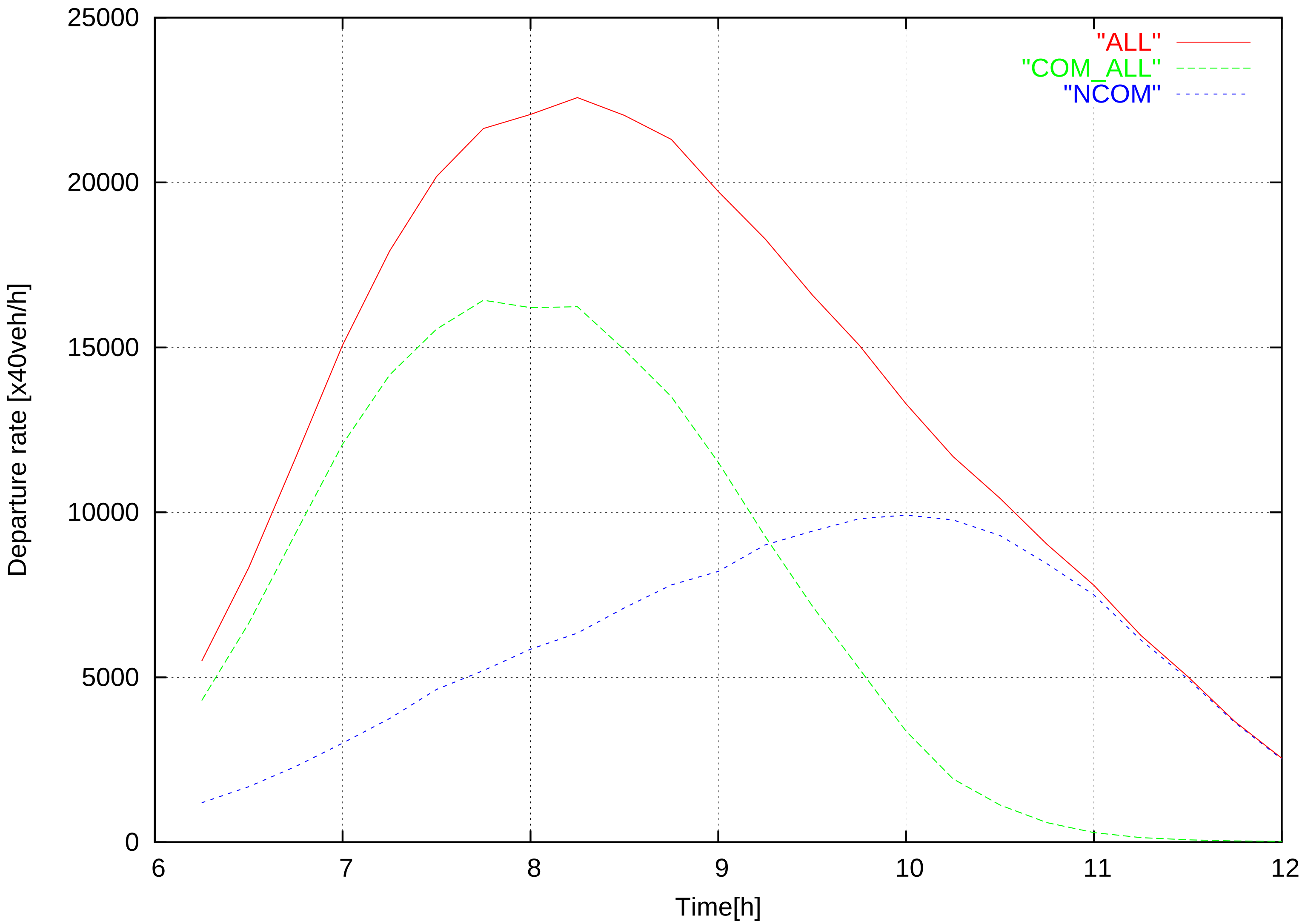

Conclusions

- Tractable approach to simulate departure time choice in equilibrium models, for large-scale systems
- Low data requirements
- Valid comparison with theory and empirical values
- Future directions:
  - Add pre-trip information provision (e.g. radio broadcast)
  - Integrate risk aversion ($\sigma(\tau(t))$)
  - Link with complete activity models / trip chaining