METROPOLIS: an Applied Dynamic Discrete-Choice Transport Network Model

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METROPOLIS Users Meeting 2010 - ETHZ

Part I: Dynamic congestion models Part II: METROPOLIS: a tutorial

Outline of Part I



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Part I: Dynamic congestion models Part II: METROPOLIS: a tutorial

Outline of Part I



Motivations

2 Modelling

- Demand side departure time choice
- Supply side linear bottleneck
- Equilibrium
- System optimum
- Day-to-day adjustment process

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Outline of Part II (Fabrice Marchal)

3 Design philosophy of METROPOLIS

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Outlines Par

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Outline of Part II (Fabrice Marchal)

- 3 Design philosophy of METROPOLIS
- 🕘 Data issues
 - Demand static O-D matrices and parameters
 - Network parameters

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- 5 Simulation isssues
 - Convergence properties
 - Peak and off-peak demand

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 - Road pricing
 - Peak spread measures
 - Capacity expansion
 - Varying levels of demand

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7 FAQs

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Part I

Dynamic congestion models

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Focus

Transp. systems

- Public transport
- Private modes
 - Car traffic

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Focus

Transp. systems

- Public transport
- Private modes
 - Car traffic

Reasons for time-dependent models

- Innovative policies
- Technology (ITS)

Time-dependent context



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Time-dependent context



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Demand side - departure time choice Supply side - linear bottleneck Equilibrium System optimum Day-to-day

Travel choices considered

- Mode choice
- Route choice
- Departure time choice

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Departure time choice - Vickrey's model (1969)

Cost specification:

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

- departure time: t_d
- travel time: $\tau(t_d)$
- arrival time: $t_a(t_d) = t_d + \tau(t_d)$
- α: monetary value of time
- β, γ : penalties for early/late arrivals
- t*: desired arrival time

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Trade-off between travel time and schedule delay costs



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Typical parameter values

Linear estimations

	β [\$/h]	γ [\$/h]	t^*	μ [\$]
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)	

(value of time from external sources: $\alpha = 13$ \$/*h*; sources: MADDIF, estimations on Paris area)

Non-linear estimations

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Linear queue for a single O-D pair



Congestion:

$$\tau(t_d) = \frac{Q(t_d)}{\kappa}$$

Dynamics:

$$\frac{dQ}{dt} = r(t) - \kappa \text{ if } Q > 0$$

- N: total number of users
- κ : road capacity
- r(t): entry flow

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Taking spill-over effects into account

Extension: space limitations and blocking back



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Equilibrium - deterministic case

- Cournot-Nash equilibrium condition: $\frac{dC}{dt} = 0$
- individual cost at eq.:

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

- departure rate: $r(t) = \kappa \frac{\alpha}{\alpha \beta}$ (early), $r(t) = \kappa \frac{\alpha}{\alpha + \gamma}$ (late)
- independent of value of time (α)
- schedule delay costs = half of travel cost
- externality = individual cost

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System(social) optimum

• condition:

$$r^{so} = \arg\min_{r(t)} C_{TOTAL}$$

$$C_{TOTAL} = \int_{-\infty}^{+\infty} C(t) dt$$

• solution:

$$r^{so}(t) = \kappa$$
 if $t \in T$

• total cost at sys. optimum:

$$C_{TOTAL}^{so} = \frac{NC^{eq}}{2}$$

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Equilibrium and sys. optimum departure rates

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Day-to-day adjustment process

Extension: general networks , heterogenous demand

- no closed form available for the equilibrium
- heuristics procedures to adjust decisions iteratively (departure/route/mode)
- for instance, inspired by R.U.M.: $U(t_d) = -C(t_d) + \mu \epsilon_{t_d}$

• If
$$\epsilon_{t_d}$$
 are assumed Gumbel i.i.d \rightarrow logit:
 $\mathcal{P}(t < t_d \leq t + \Delta t) = \frac{\Delta t \exp\left(\frac{-C(t)}{\mu}\right)}{\int_T \exp\left(\frac{-C(t)}{\mu}\right) du}$
• $\tau_H^{k+1}(t) = \lambda \tau_H^k(t) + (1 - \lambda) \tau_S^k(t)$

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Logit adjustment - instabilities - case $\lambda = 0$



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Logit adjustment - instabilities - case $\lambda = 0.9$



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Part II

METROPOLIS: a tutorial

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Design philosophy

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Demand Network



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Convergence Travel purposes

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Convergence

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Convergence Travel purposes

Travel purposes - peak/off-peak

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Road pricing Peak spread measures Capacity expansion Varying levels of demand



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Road pricing Peak spread measures Capacity expansion Varying levels of demand

Road pricing

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Peak spread measures

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Capacity expansion

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Varying level of demand

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Questions

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