Modeling impacts of congestion pricing using simulation-based dynamic traffic assignment

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1.1 Overview of DTA

Dynamic Traffic Assignment

- Dynamic (time-varying) version of the static traffic assignment problem
- Wardrop conditions for user-equilibrium (UE) on experienced travel time

Wardrop conditions (UE)

- No driver can improve travel time by unilaterally changing paths

Path travel time

- Average (experienced) path travel time for vehicles leaving the origin during a discrete time-interval
1.2 Iterative solution framework

- travel times generated with detailed traffic simulation model
- assignment in space of path flows
- MSA-based algorithm (no derivatives)
1.3 Simulation-based DTA

Model behaviour

- Models produce ``reasonable`` outputs given reasonable inputs
  - Converge to a stable solution with relative gaps $\approx 1 \rightarrow 5\%$
  - Solutions appear to be unique for practical purposes

- As congestion increases, solutions become more unstable
  - Under extreme congestion, model fails to converge: no meaningful solution
1.4 Simulation-based DTA

Current challenge:

- General assumption is that higher-fidelity in the traffic model increases instabilities related to congestion
  - Gridlock in the simulation is another phenomenon which can undermine solution stability
- At the same time, traffic management schemes are becoming increasingly **complex** and **dynamic** in nature:
  - E.g., adaptive pricing on HOT (high-occupancy toll) lanes that changes in real time according to congestion levels

- **Question:** how to practically solve large models with the necessary realism?
Contents

1. Background
2. Experiment
3. Numerical results
4. Conclusions
2.1 Experiment

Impact of traffic model fidelity

- How does the level of detail of the traffic simulation model impact model solution (e.g. link flows and speeds)?
  - Is all of the detail we build into these models really necessary… does it have a significant impact on results?
- Basically, what would happen if we simplified the traffic simulation model?
- First, a quick overview of traffic congestion effects…
2.2 Congestion effects

1 - Spillback effect (upstream)

Capacities: 1800 1800 1800 1200 1800

1500 demand

link speed

link flow
2.3 Congestion effects

2 - Choke effect (downstream)

Capacities: 1800 1200 1200 1200 1800

1500 demand

link speed
link flow
2.4 Congestion effects

3 – Spill-over effect (lateral – across lanes)
2.5 Experiment

Impact of traffic model fidelity

- What would happen if we simplified the traffic simulation model?
- **Experiment**: replace traffic model with lane-based uncapacitated point queues
  - Removes spill-back effect (upstream)
  - Maintains choking effect (downstream)
  - Removes lateral spill-over effect
- Node (intersection) model: remains unchanged
  - Traffic signals, driver interactions, identical in both models
2.6 Test Network

Notre-Corridor in Montreal

- 2848 links, 986 nodes
- 444 signalized intersections
- 3 hour demand: 200,000 vehicles

- Hypothetical toll added to both directions of the freeway tunnel through CBD
  - Realistic value of time parameters
- Both models run to acceptable convergence
1. Background
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3.1 Flow and Speed differences (north)

simplified model minus regular traffic model
(bar width indicates average link flow)

flow differences  speed differences
3.2 Flow and Speed differences (south)

simplified model minus regular traffic model
(bar width indicates average link flow)

flow differences

speed differences
3.3 Toll links

SW direction

NE direction
3.4 Main O-D for NE toll link

Average flows and speeds: 8:00 – 9:00

Regular model

Simplified model
3.5 Main O-D for SW toll link

Average flows and speeds: 8:00 – 9:00

Regular model

Simplified model
3.6 O-D Travel Times (2 gate origins)

6:00 – 6:15
7:30 – 7:45
8:45 – 9:00
3.7 O-D Travel Times (all O-D pairs)

6:00 – 6:15
7:30 – 7:45
8:45 – 9:00

All paths
Delay > 10 min
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4.1 Conclusions

- Level of detail can have a dramatic effect on the model solution:
  - Link flows and speeds: particularly where congestion effects are acute (e.g. spillback + spillover)
- These differences in turn can have a major impact on O-D travel times
  - Differences increase rapidly as network congestion increases
- This raises some interesting + challenging questions with regards to modeling increasingly detailed traffic management schemes in increasingly congested networks.