Modeling complex urban systems

FTOC

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Urban Transport Systems Laboratory
The effect of parking

Congestion pricing
Part II: Modeling complex urban systems with an MFD representation

The effect of parking

Congestion pricing
Cruising parking

- Important source of congestion
- Delays ↑
- Output ↓

- Moving
- Cruising
- Parked
Parking Dynamics

Outer region 2

Diagram:

- Local dest.: $n_m$ with $O_m$ and $n_s$ searching.
- External dest.: $n_o$ with $O_o$ and $n_p$ parked.
- Transition rates: $q_{R \rightarrow R}$.
Parking Dynamics

The output for sub-reservoirs $m, s, o$, is (Little’s formula):

$$O_x (n_x, n) = \frac{n_x P(n)}{l_x}, \quad x \in \{m, s, o\}$$

Dynamic equations:

$$\frac{dn_m}{dt} = q_{R'\rightarrow R} + q_{R\rightarrow R} - O_m (n_m, n)$$

$$\frac{dn_s}{dt} = O_m (n_m, n) - O_s (n_s, n)$$

$$\frac{dn_o}{dt} = q_{R'\rightarrow R'} + q_{R\rightarrow R'} - O_o (n_o, n)$$

$$\frac{dn_p}{dt} = O_s (n_s, n) - q_{R\rightarrow R'} - q_{R\rightarrow R'}$$
A “Cruising for Parking” Simulation

PARKING AVAILABILITY

TOTAL # OF VEHICLES

TOTAL # OF TRIPS ENDED

# OF VEHICLES SEARCHING

HORIZONTAL AXES : TIME
Interesting observations

- The marginal cost of an additional user with external destination is smaller than that of a user who will cruise for parking.
- An additional user with internal destination, causes more delays in the non-cruising vehicles, than the cruising ones.
- The delay for vehicles with outer destinations can be a significant part of the delay.
Area-Based Pricing vs. On-Street Parking Pricing

CASE 1: $f_{in} = 1.04, f_{ex} = 1.46$; CASE 2: $f_{in} = 1.1, f_{ex} = 1.1$
Congestion pricing

Nikolas Geroliminis
• Macroscopic Fundamental Diagram (the MFD) and agent-based model (ABM): concepts and motivations
• Investigation of the existence of the MFD in ABM MATSim: case studies and results
• Investigation of the effectiveness of different congestion pricing schemes: case studies and results (ongoing)
Introduction

Ultimate goal:
• Cordon/Area-based Congestion Pricing with Macroscopic Models

Problems:

• Modeling demand
  i. Demand elasticity (fixed demand in traffic microscopic models)
  ii. Utility heterogeneity (deterministic for users in pricing models)

• Modeling traffic state (supply)
  Requirement of a well-defined curve (macroscopic vs. microscopic)
On demand modeling:

• **Agent-based models (ABM)**
  
  i. Modelling individual components (Meister et al. (2010) etc.)
  
  ii. Modelling individual heterogeneity (Axhausen (2008) etc.)
  
  iii. Modelling interactions between components (Zhang et al. (2008) etc.)
The ABM

Tool: Multi-agent simulator MATSim (www.matsim.org)
• Activity-based demand generation
• Random utility plan generation
• Demand generation is integrated with traffic
Motivation

• The MFD is a proper macroscopic tool for describing network dynamics
• ABM is a proper tool for representing travelers’ individual heterogeneity and elasticity

• Does the output of ABM represent macroscopic traffic flow dynamics as this expressed by the MFD?
• Can one combine ABM with MFD to develop efficient pricing schemes?
Investigation

Perspectives
• The existence and the rationale of the μFD
• The existence and the rationale of the MFD

Scenarios (Zurich)
• Scenario 1, 10% real demand, general network
• Scenario 2, 25% real demand, navigational network
• Scenario 3, 25% real demand, navigational network v/c ratio lower than Scenario 2

Simulator: MATSim (ETHZ & TU Berlin)
Investigations

- The existence and the rationale of the μFD
- The existence and the rationale of the MFD
Case Studies and Results

The μFDs and Spill-back Effect in MATSim
Case Studies and Results

The MFD

Scenario 1

Scenario 2

Scenario 3
The MFD and the hysteresis
Case Studies and Results

• MATSim results are consistent with the physics of traffic on both microscopic (spillback) and macroscopic (the MFD and hysteresis) levels

• Developing MFD controlled strategy in ABM has great potential (for congestion pricing)
Investigation

• Different congestion schemes

Figure 1 (left) An area-based pricing (the green links), example cities are Singapore and New York
Figure 1 (right) A cordon-based pricing (the blue cordon line), example cities are London and Stockholm
Figure 1 (right) A corridor pricing (the orange line), example cities are Rome and Oslo
The role of the MFD
• The role of the MFD
Investigation

• Control Strategies: “Feedback” Control

Initial pricing

Agents update plans

Plan execution (ith iteration)

Equilibrium?

Update pricing

For p1, PRICE(i+1) = PRICE(i) + k(O1-Ocr);
For p2, PRICE(i+1) = PRICE(i) + k(O2-Ocr);
......

Network density below critical density Ocr

In period p1, p2... network density exceeds Ocr

Obtain MFD (ith iteration)
• Advantage of “Feedback” Control

i. Flexible pricing charges and duration
ii. Generate better travel condition
iii. May help simulation reach equilibrium faster
Case studies and Results
The resulting MFD (a) of the cordon area (b) of the suburb area
The resulting behavioral change of (c) work-related and (d) the other activities (arrows indicate shifts of activity starting time)
### Summary of results

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<thead>
<tr>
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<th>Before Pricing</th>
<th>After Pricing</th>
<th>Effectiveness Ratio</th>
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<tbody>
<tr>
<td><strong>Total Travel Savings (In cordon)</strong></td>
<td>6356 veh-hours</td>
<td>-4541 veh-hours</td>
<td>1.5</td>
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<tr>
<td><strong>Total Travel Savings (Out cordon)</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Effectiveness Ratio</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Travel Savings per Km Travelled per trip (In Cordon)</strong></td>
<td>0.94 minutes</td>
<td>-0.13 minutes</td>
<td>7</td>
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<tr>
<td><strong>Travel Savings per Km Travelled per trip (Out Cordon)</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Disaggregated Social Gain</strong></td>
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Problems and ongoing work

- Scale
- “Feedback” sensitivity analysis $K (no)$
- Go on the same analysis to the other congestion pricing schemes
- Advantage of the “feedback” control by other indicators
- Especially evaluate equity issues (thank to the heterogeneity of agents)