Adaptive Ramp Control
The Gardiner Expressway Case Study

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Congestion Solutions
Intelligence for managing both supply and demand

Less Demand

More Supply
Control Approach Characteristics

1. “Pacing” Beats “Rushing”
2. Real Time: Closed Loop Optimal Control
3. Role for Artificial Intelligence
2. Closed Loop Optimal Control

- Always measuring and mapping system state to optimal actions
- Better chance to be on top of changes
- But:
  - How to get the optimal control policy

Possibly let the controller learn it: Machine Learning and AI

3. Artificial Intelligence:
Self-Learning the Optimal Control Law
AI: Reinforcement Learning

RL: Illustrative Demo

Source: https://www.youtube.com/watch?v=DCjbk4m1G6I
RL: Another Illustrative Demo

Ramp Metering

- Why Ramp Metering?
  1. Pacing demand: avoid congestion due to demand exceeding capacity and resulting capacity breakdown
  2. Avoid blockage of exit ramps
  3. Influence route choice behavior
  4. Enhance traffic safety:
     - less congestion
     - safer merging
Congestion Avoidance

Off Ramp Blockage

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Impacting Route Choice

Summary of Today’s Status Quo

- **Under-utilization** of freeway corridors and networks due to recurrent and non-recurrent congestion:
  - high demand creates flow breakdown and congestion causing loss of capacity
  - downstream of congestion (empty stretch ahead)
  - off-ramp blockage (stuck on the freeway)
  - suboptimal utilization parallel arterial
  - reduced safety
  - increased pollution
Ramp Metering Benefits in the Literature

- 30% more vehicles served during rush hours
- Improved service for all users
- Reduced urban network load
- > 50% reduction of total time spent
- Efficient response to incidents
- Increased traffic safety
- Decreased fuel consumption and environmental pollution

Why NOT RM?

- Fallacy:
  - RM benefits people on the freeway at the expense of those entering from the ramp
  - RM causes traffic to use the surface street, i.e. benefit freeway at the expense of surface streets

- Fact:
  - ramp queues do not mean dis-benefit to surface streets. As the overall throughput of the freeway is improved, more surface street traffic can now use the freeway, i.e. benefit both.
  - Coordinated RM does not penalize later entries (see Gardiner case)
Ramp Metering Categories

- Fixed Time Metering:
  - Mainly off line
  - Based on historical demand
  - Not responsive to real time traffic dynamics

- Traffic Responsive:
  - Realtime
  - Regulator Approach:
    - e.g. ALINEA
  - Optimal Control Metering
    - e.g. RL

Control of Multiple On-ramps
Ramp Metering the Gardiner

Scenarios
- Base Case
- RLRM-I: Isolated
- RLRM-IwQO: Isolated with queue override
- RLRM-C: Coordinated
- ALINEAwLC: ALINEA with linked control

Gardiner Expressway westbound in Toronto from DVP to Humber Bay

Network Total Travel Time

<table>
<thead>
<tr>
<th>Scenario</th>
<th>TTT</th>
<th>TTTml</th>
<th>Total Time Spent on Network (Veh.hr)</th>
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</thead>
<tbody>
<tr>
<td>BaseCase</td>
<td>10276</td>
<td>6998</td>
<td>48%</td>
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<tr>
<td>RLRM-I</td>
<td>5360</td>
<td>4147</td>
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<td>RLRM-C</td>
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<tr>
<td>ALINEAwLC</td>
<td>6660</td>
<td>6660</td>
<td></td>
</tr>
</tbody>
</table>
Downtown Origins Travel Times

Travel time from different origins to west end of network

Local vs. Coordinated
Conclusion

Least overall TTT

Best overall travel times from all ramps

Reduced and balanced queueing

Thank You!