Metering with Traffic Signal Control

Development and evaluation of an algorithm

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Ramp metering
Outline

- Ramp metering in The Netherlands
- Traffic Management Trial Amsterdam
- Control algorithms
- Simulations
- Results
- Conclusions
Ramp Metering in The Netherlands
Function and goal

- Function:
  control flow to the motorway, based on the road conditions and traffic conditions on the motorway and the on-ramp

- Goal:
  improvement of the traffic conditions on the motorway by preventing or postponing capacity drop

- Taking into account:
  conditions on the on-ramp and connecting roads and junctions

- Cooperation with local road authorities needed:
  - Queuing and blocking back
  - Alternative routes
  - Coordination with traffic signals
Capacity drop

- Free flow cap > queue-discharge rate
- Dynamics in driving behaviour
  - in and out of congestion
  - drivers are more “relaxed” out of congestion
- Lane changing behaviour
- Heterogeneity: particularly bounded acceleration properties
- and there are more theories ...
Design

- Differences with normal traffic signal control
  - signals are put close to the road user
  - square, yellow background shields
  - control per lane
  - One or two car per green
- But same legal status
- Detection on the motorway:
  - speed, flow and occupancy
- Short cycle time: maximum of 12 seconds
- Algorithm: demand-capacity or ALINEA
Detection
Compliance

• At first compliance not so good
  • Sometimes goal was not so clear for the road users
  • Red light running of 10-15%
• Introduction of red light cameras
  • Red light running about 5%
Effects of ramp metering

- Effects based on 29 evaluation studies between 1989 and 2009

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>+105 veh/hr (2.1%)</td>
<td>-116 veh/hr</td>
<td>+350 veh/hr</td>
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<tr>
<td>Flow on-ramp</td>
<td>-70 veh/hr (-6.3%)</td>
<td>-964 veh/hr</td>
<td>+217 veh/hr</td>
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<tr>
<td>Speed motorway</td>
<td>+2.8 km/hr (3.7%)</td>
<td>-10.2 km/hr</td>
<td>+19.1 km/hr</td>
</tr>
<tr>
<td>Travel time</td>
<td>-0.3 min (-3.5%)</td>
<td>-3.3 min</td>
<td>0.9 min</td>
</tr>
<tr>
<td>Total delay</td>
<td>-11.3%</td>
<td>-1357 veh.hrs</td>
<td>243 veh.hrs.</td>
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</tbody>
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Traffic Management Trial A’dam

- Traffic Management Trial Amsterdam is a Dutch project to show benefits of integrated and coordinated, network-wide traffic management
- Goal: optimize network throughput and reliability, respecting road functions, priorities (and also livability, safety)
- Ramp metering is essential part of the trial
- Phase 1 development and implementation of algorithms to
  - Coordinate ramp meters with each other
  - Coordinate ramp meters with traffic signal control
- In phase 2 using FCD data
- In phase 3 integration with in-car systems
- Phase 1 is evaluated at this moment
Network TMTA
Control principles

- Manage locally if possible
- Use coordination if the problem cannot be solved otherwise
- Anticipate rather than react
  - Freeway conditions
  - Queue lengths
- Use graceful degradation of (parts of) the network, if the overall network throughput can be improved (considering the priorities in the network)
  - Use spare capacity in the network (buffers)
Two examples
Buffer locations A10 network
Control strategy with ramp metering
Research

- Sometimes on-ramp too short for ramp-metering
- Can traffic signal controllers be used to meter traffic?
- Develop a control algorithm
- Test the algorithm in a simulation environment
Control strategy
without ramp metering

1. Determine the set of available buffers
2. Determine the available effective buffer space
3. Determine if metering traffic is necessary
4. Calculate the metering rate with AD-ALINEA
5. Determine if the use of buffers is needed, based on the (estimated) queue length on the on-ramp
6. Determine how much traffic has to be stored in the buffers
7. Distribute the surplus of traffic among the available buffers
8. Calculate the adjustment for the green times
9. Communicate the green time adjustments to the local controllers and start the next cycle
Algorithms

- AD-ALINEA

\[ q_{rm}(t + 1) = q_{rm}(t) + K \cdot [\rho_{crit}(t) - \rho_m(t)] \]

- Distribution of traffic

\[ b_j(t) = b_j(t - 1) + b_r(t) \frac{s_j^{eff}(t)}{\Sigma_j s_j^{eff}(t)} \]

- Calculation of green time adjustment

\[ \Delta g_m^n(t) = \frac{b_j(t) c^n(t)}{u^n_m(t)} \]
Network and demand
Calibration

- Capacity drop
- Weaving behaviour
Scenarios

- Base situation
  - without ramp metering
  - with local (fixed-time) signal control for the intersections
- Local ramp metering
  - with ramp metering on the on-ramps
  - local signal control
- Dummy ramp metering
  - no ramp metering on the on-ramps
  - traffic signal controllers are used to meter traffic
- Scenarios simulated with VISSIM for 6 different random seeds
Results

Total distance travelled

![Graph showing total distance travelled for different demand profiles and scenarios.](image)
Results

Total time spent

- Demand profile 1
- Demand profile 2

**Results**

**Total time spent**

- Base
- LRM
- Dummy RM
Results

Average delay

![Bar chart showing average delay for demand profiles 1 and 2 with different scenarios.](chart.png)
Results

Delay different network parts

![Bar chart showing total delay in vehicle hours for Motorway and Urban network for Base, LRM, and Dummy RM]
Results

Capacity drop

![Graph showing cumulative flow (veh) vs control interval (min) for different scenarios: Base, RM, Dummy RM.](image-url)
Summary

- Metering with traffic signal control is promising
  - Less effective than normal ramp metering
  - Better than no metering at all
- Metering with traffic signal control postpones capacity drop, but to a lesser extent than normal ramp metering
- Further research
  - Distance to on-ramp
  - Platooning
  - Other traffic control strategies (e.g. vehicle actuated)
  - Metering algorithm
Contact

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