Metering with Traffic Signal Control

Development and evaluation of an algorithm

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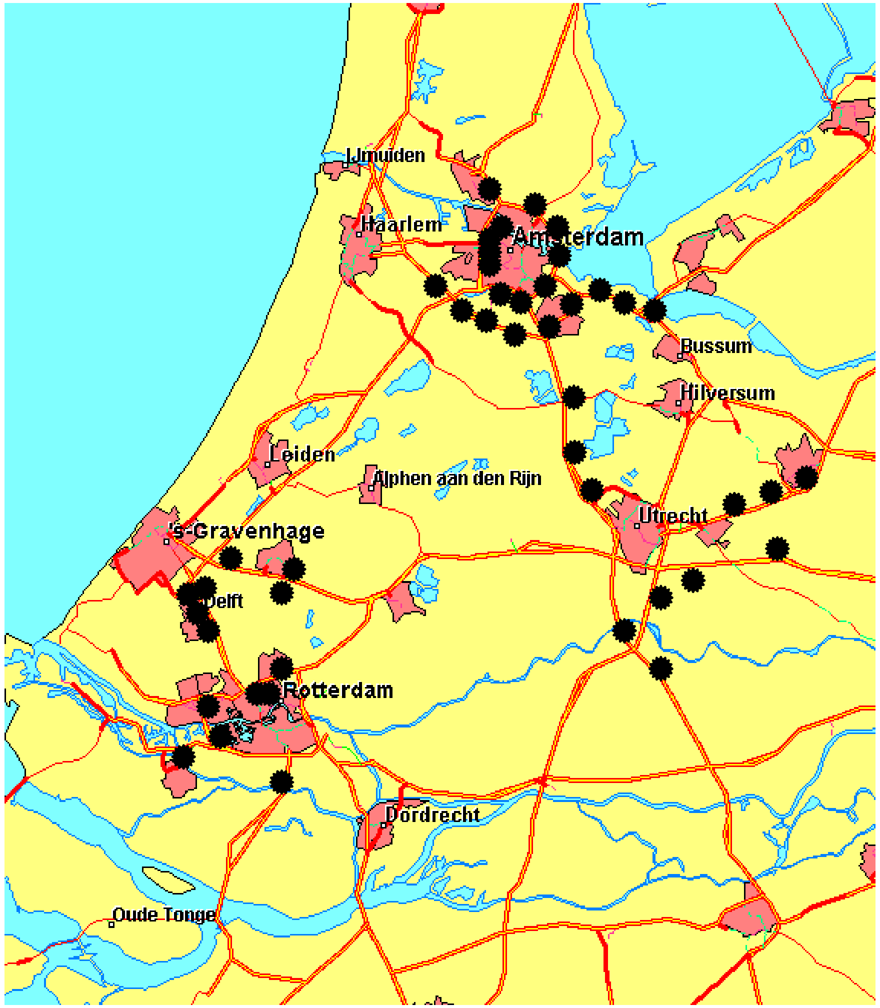
Ramp metering

Outline

- Ramp metering in The Netherlands
- Traffic Management Trial Amsterdam
- Control algorithms
- Simulations
- Results
- Conclusions

Ramp Metering in The Netherlands

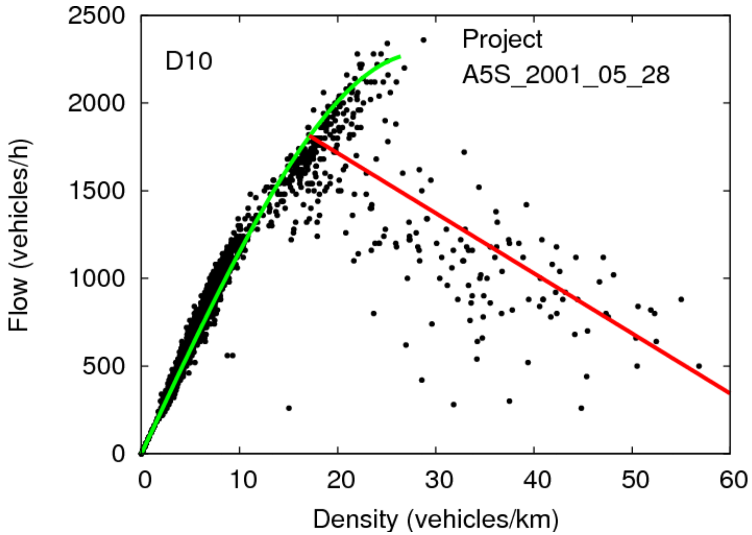


Function and goal

- 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

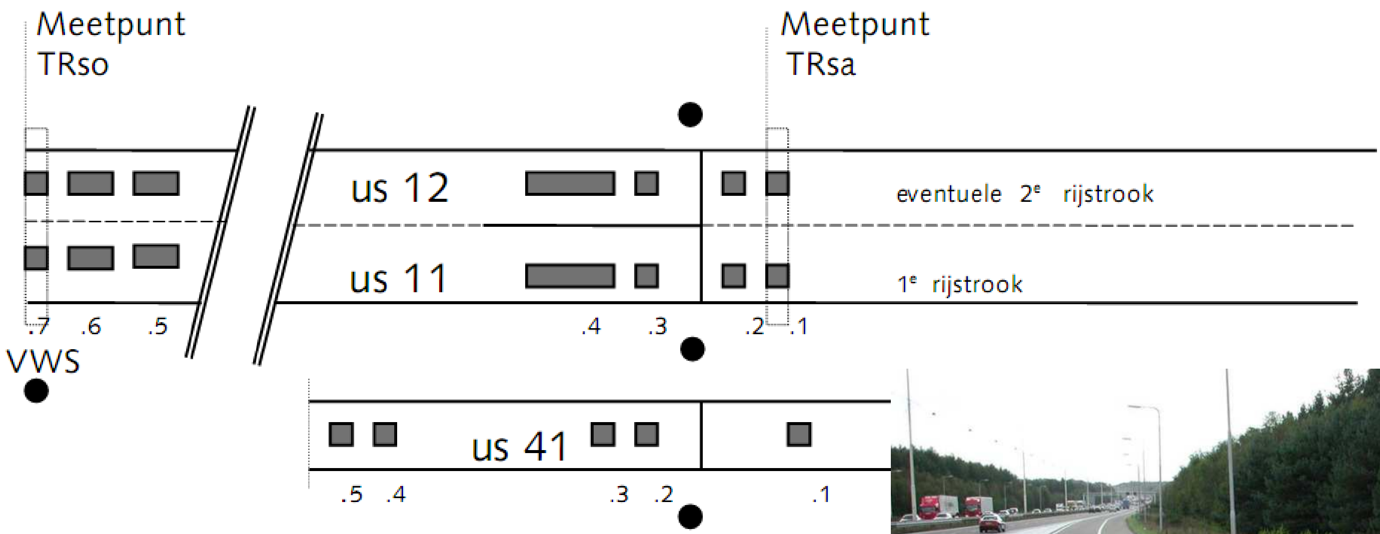
- Free flow cap > queue-discharge rate
- Dynamics in driving behaviour
  - in and out of congestion
  - drivers are more "relaxed" out of congestion
- Lane changing behaviour
- Heterogeneity: particularly bounded acceleration properties
- and there are more theories ...



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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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

	Average	Minimum	Maximum
Capacity	+105 veh/hr (2,1%)	-116 veh/hr	+350 veh/hr
Flow on-ramp	-70 veh/hr (-6,3%)	-964 veh/hr	+217 veh/hr
Speed motorway	+2.8 km/hr (3.7%)	-10.2 km/hr	+19.1 km/hr
Travel time	-0.3 min (-3,5%)	-3.3 min	0.9 min
Total delay	-11,3%	-1357 veh.hrs	243 veh.hrs.

Traffic Management Trial A'dam

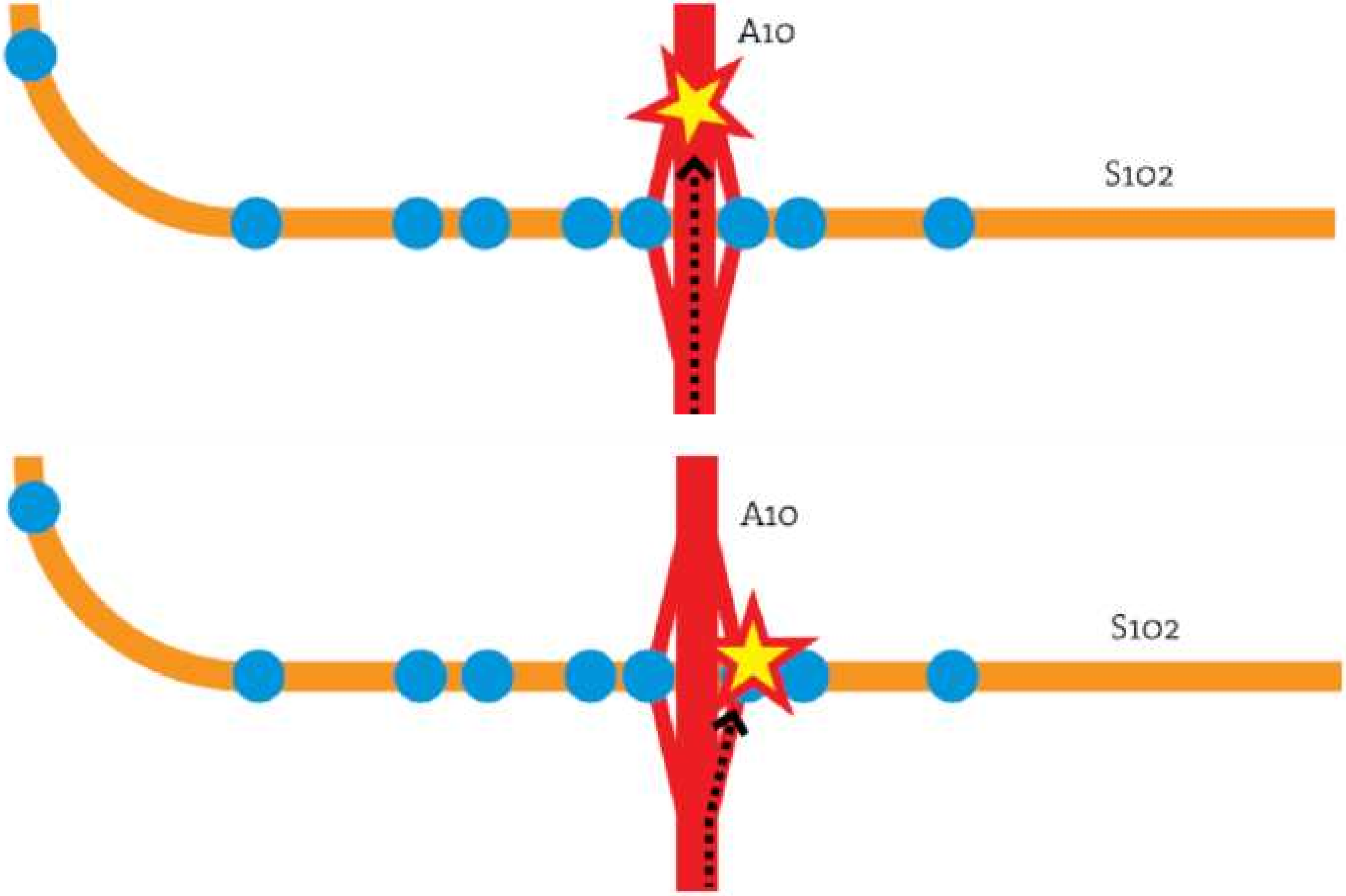
- Traffic Management Trial Amsterdam is a Dutch project to show benefits of integrated and coordinated, network-wide traffic management
- Goal: optimize network throughput and reliability, respecting road functions, priorities (and also livability, safety)
- Ramp metering is essential part of the trial
- 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

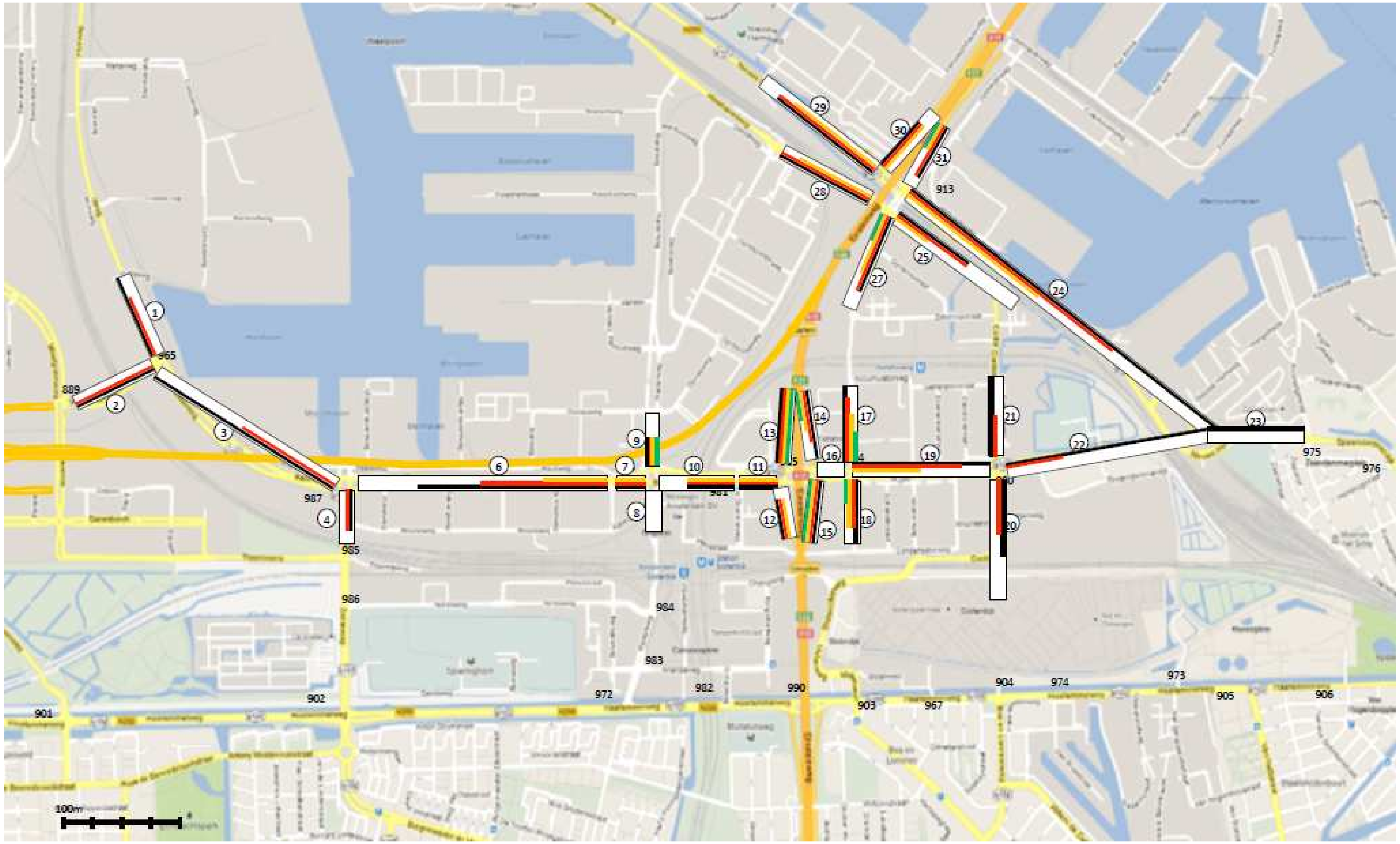
Control principles

- 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)

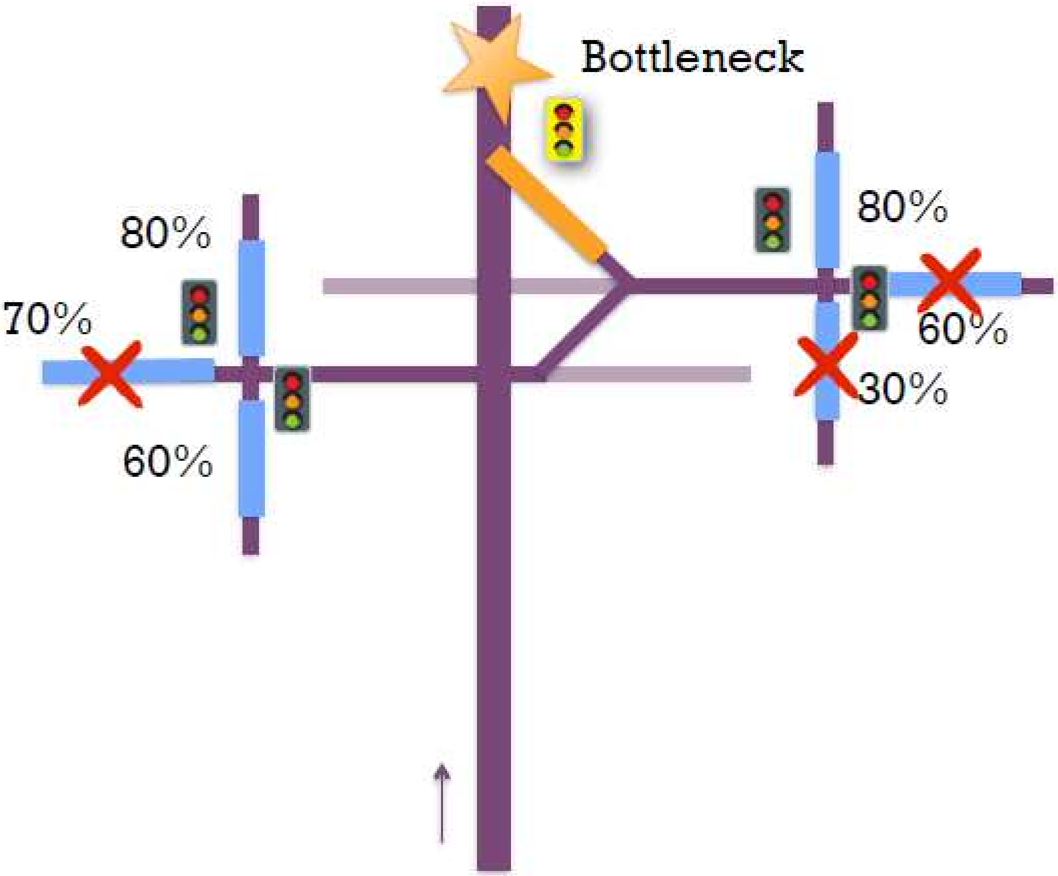
Two examples



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

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

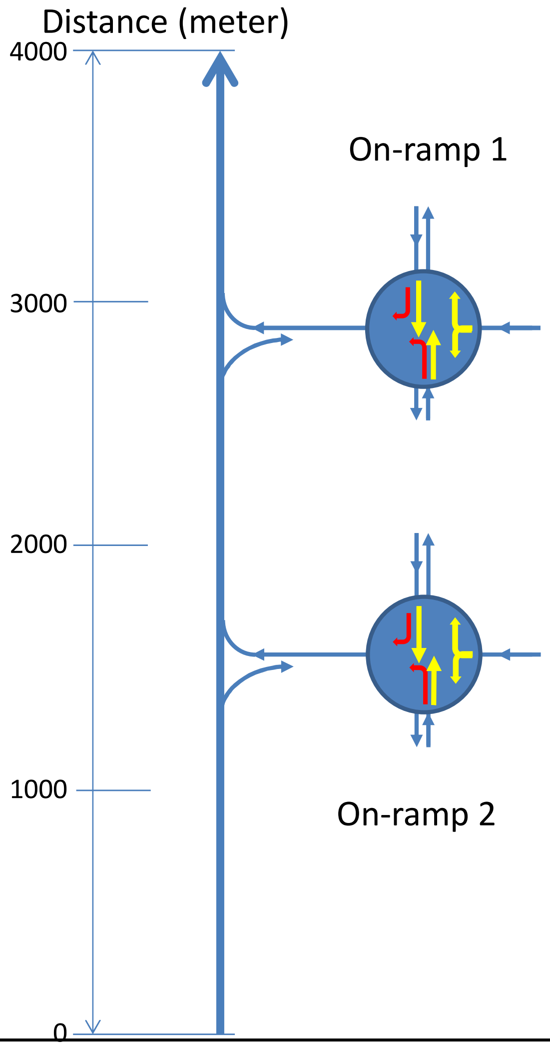
- Distribution of traffic

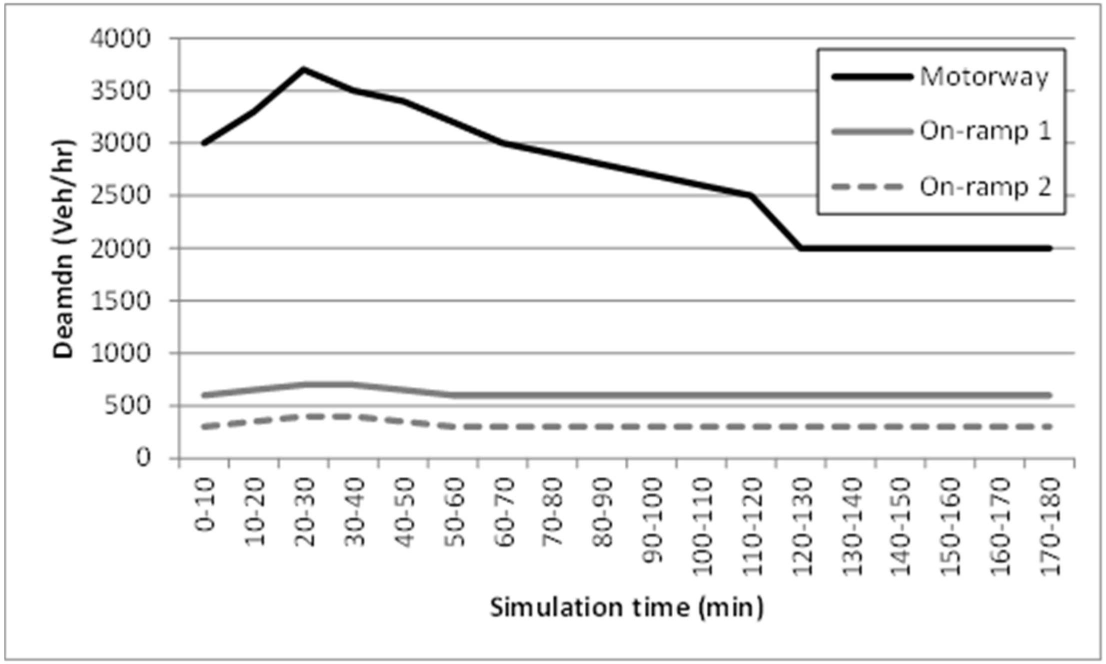
$$b_j(t) = b_j(t-1) + b_r(t)\frac{s_j^{eff}(t)}{\sum_j s_j^{eff}(t)}$$

- Calculation of green time adjustment

$$\Delta g_m^n(t) = \frac{b_j(t)C^n(t)}{u_m^n(t)}$$

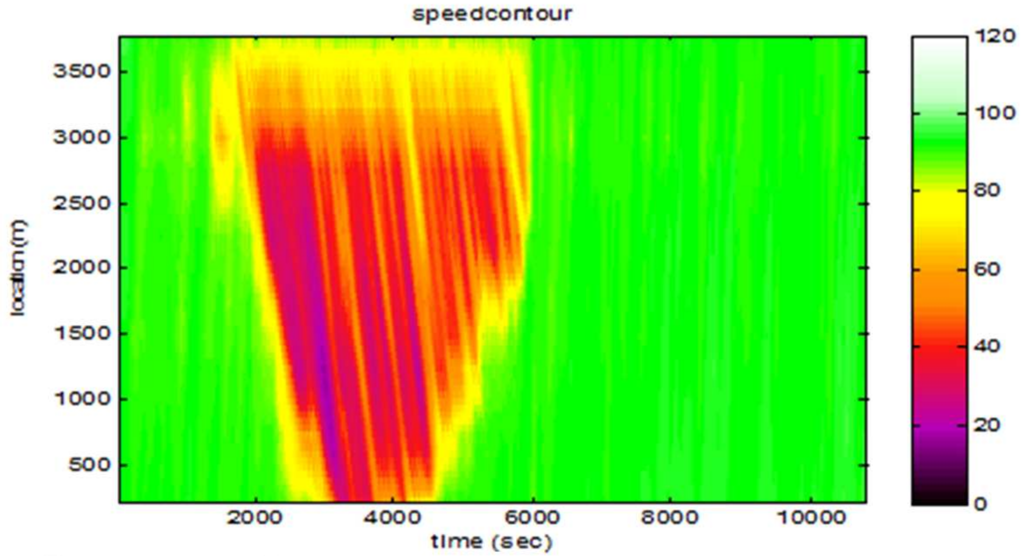
Network and demand

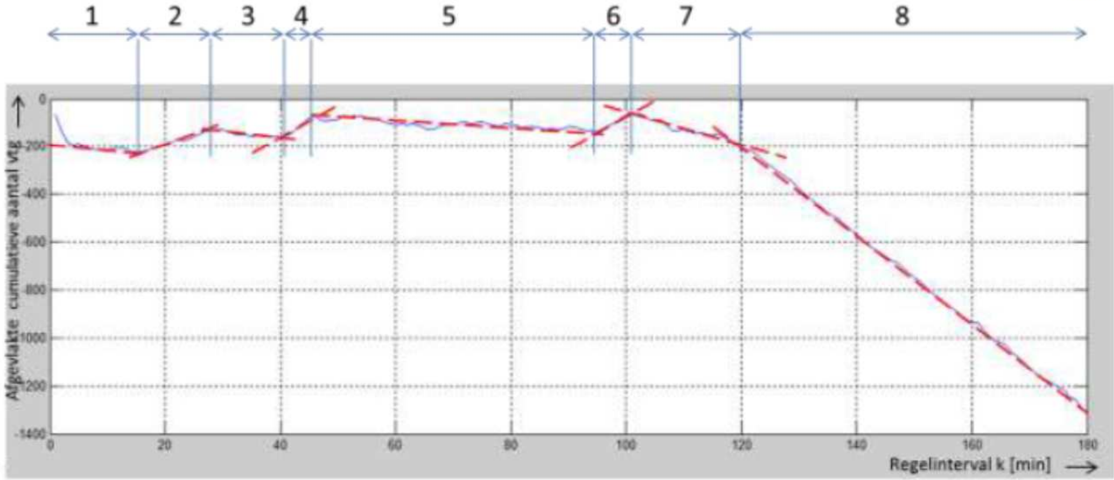




Calibration

- Capacity drop
- Weaving behaviour



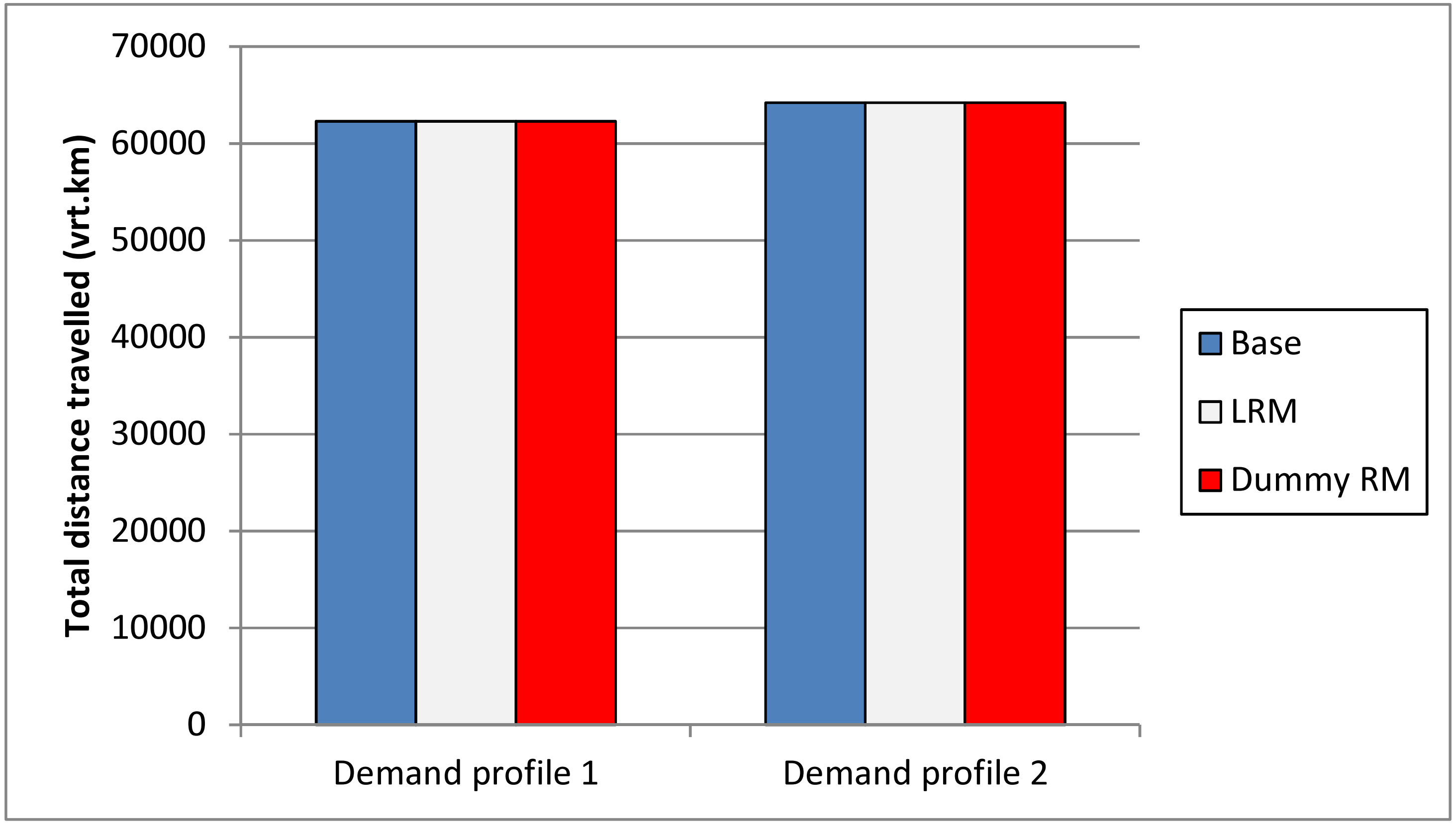


Scenarios

- 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

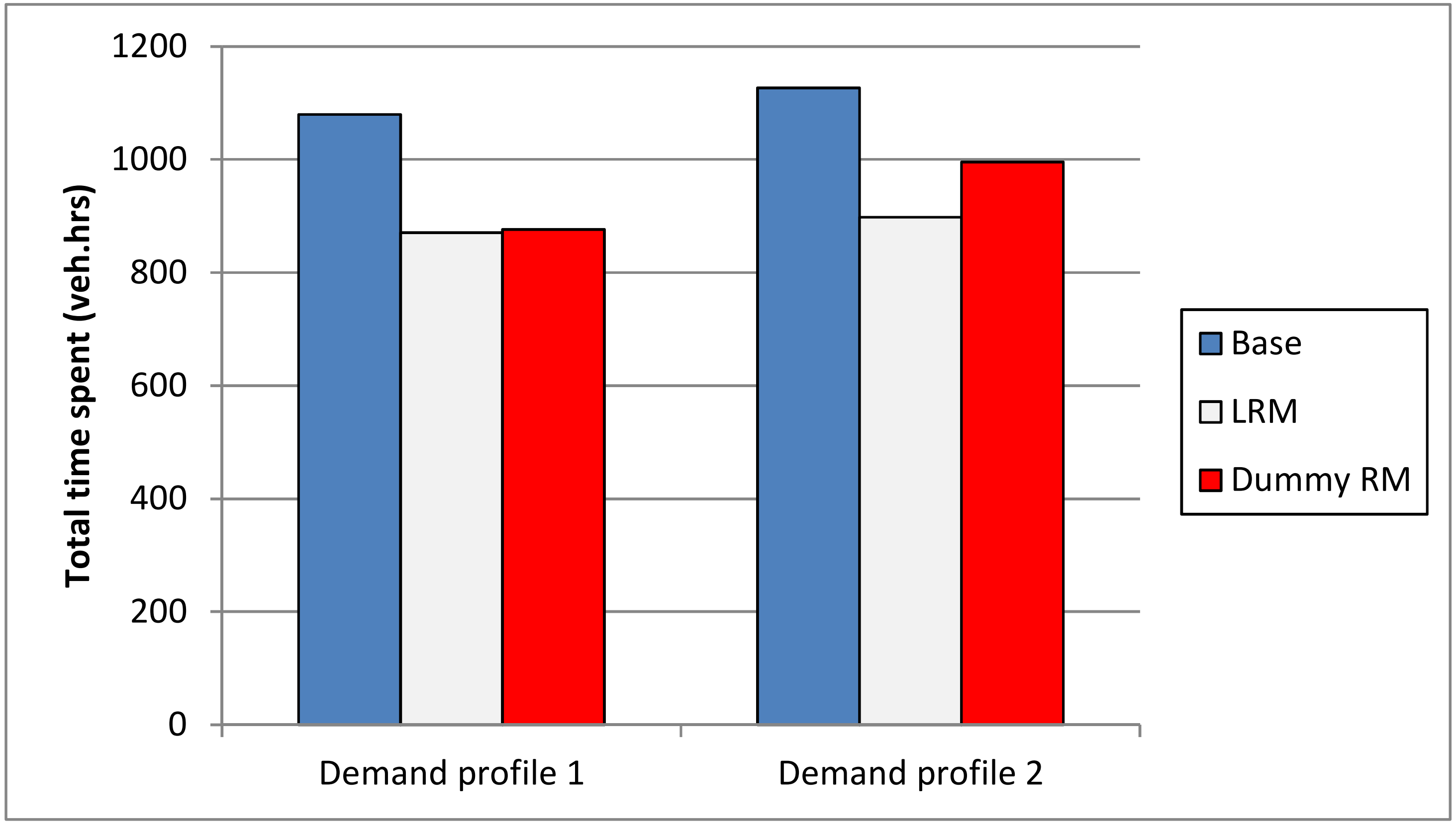
Results

Total distance travelled



Results

Total time spent

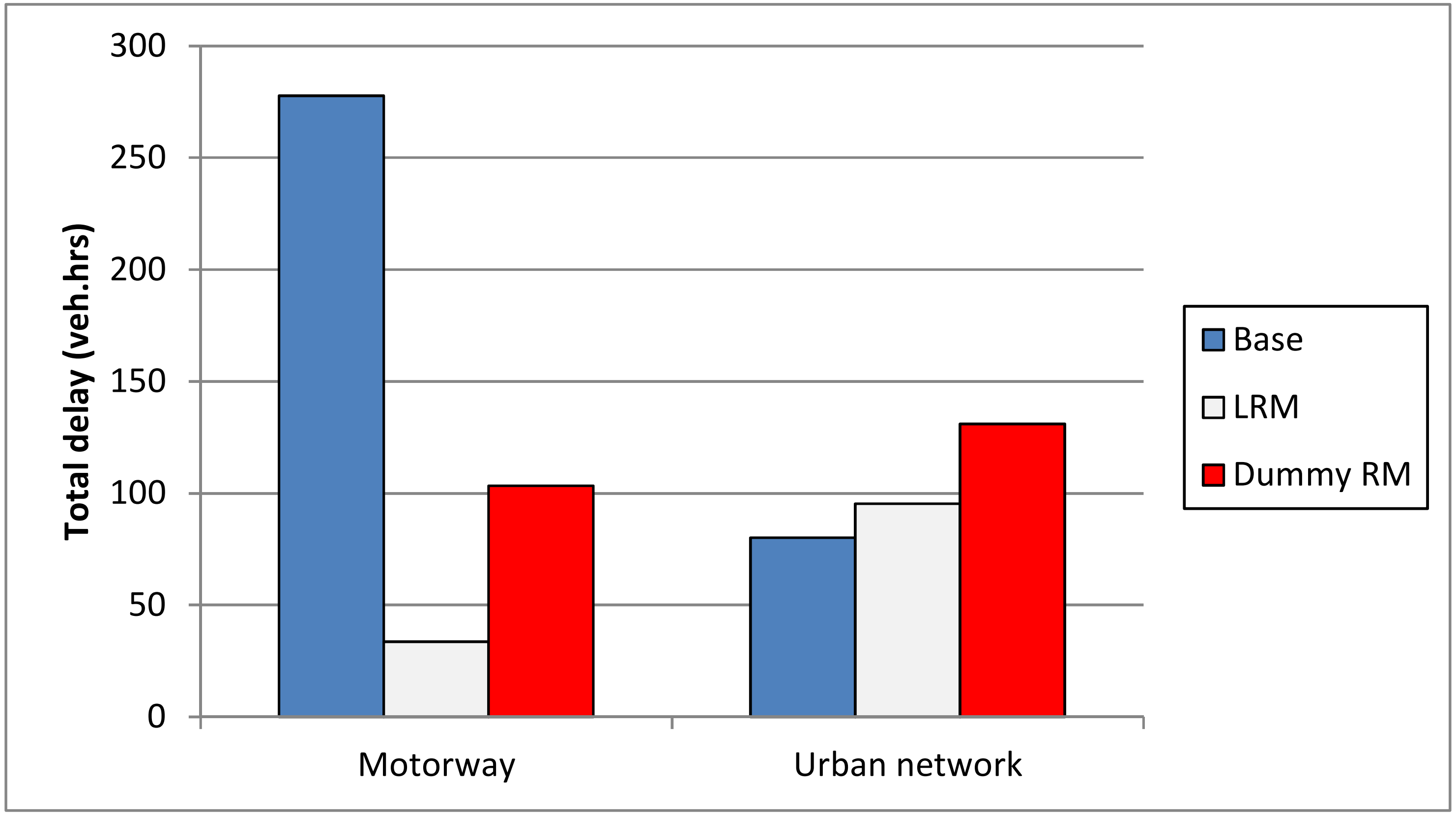


Results

Average delay

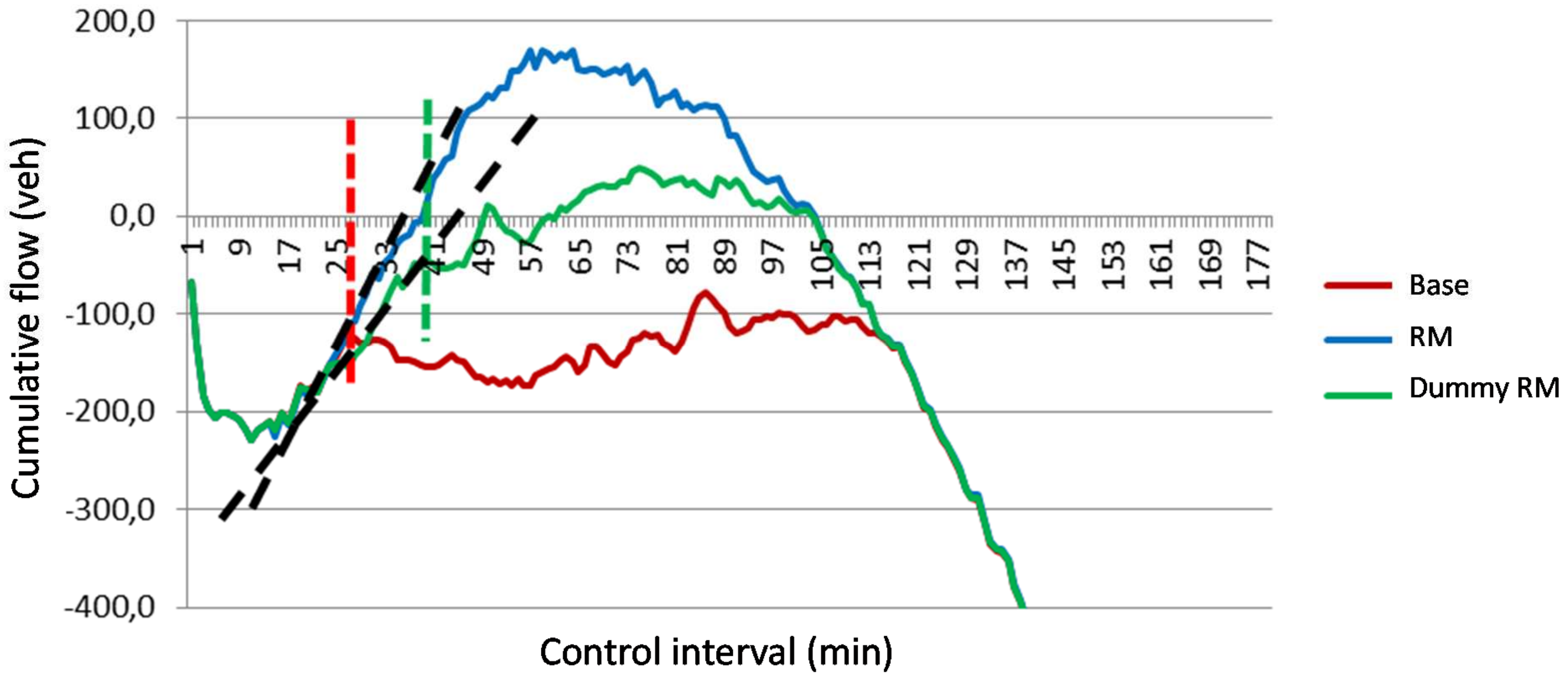
Results

Delay different network parts



Results

Capacity drop



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

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