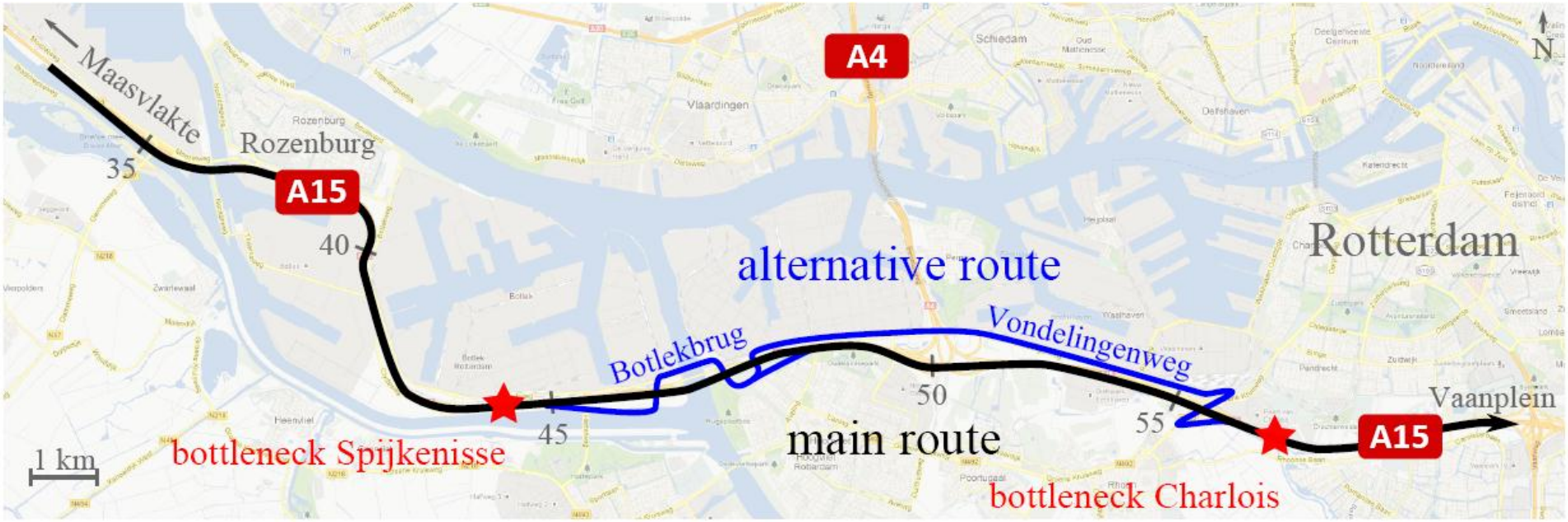
Een generieke aanpak voor DVM – Proactief regelen van de snelweg A15 in het havengebiet met BOS-HbR

Thomas Schreiter, Hans van Lint, Serge Hoogendoorn, Zlatan Muhurdarevic, Ernst Scheerder

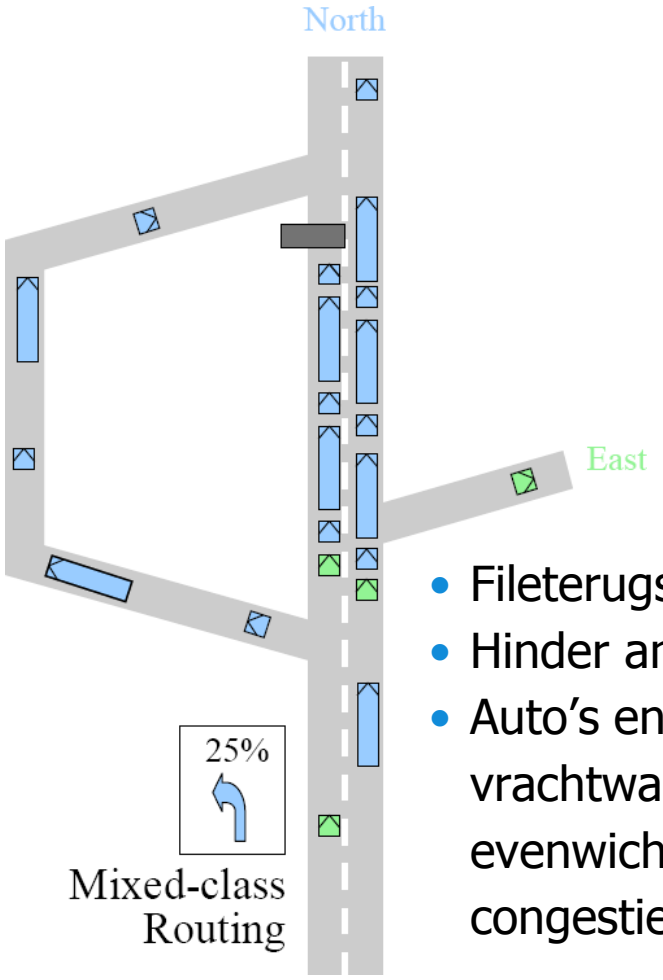


Motivatie

- Doel A15
  - Verbinden van haven met achterland
  - Vervoer met vrachtwagens
- Regelmatig congestie op A15
  - →Dynamisch Verkeersmanagement
- Verschillende voertuigklasses
  - Voertuiglengte, versnelling, emissie, tijdswaarde, …
- 2 Ideen:
  - klassespecifiek regelen
  - Proactief regelen

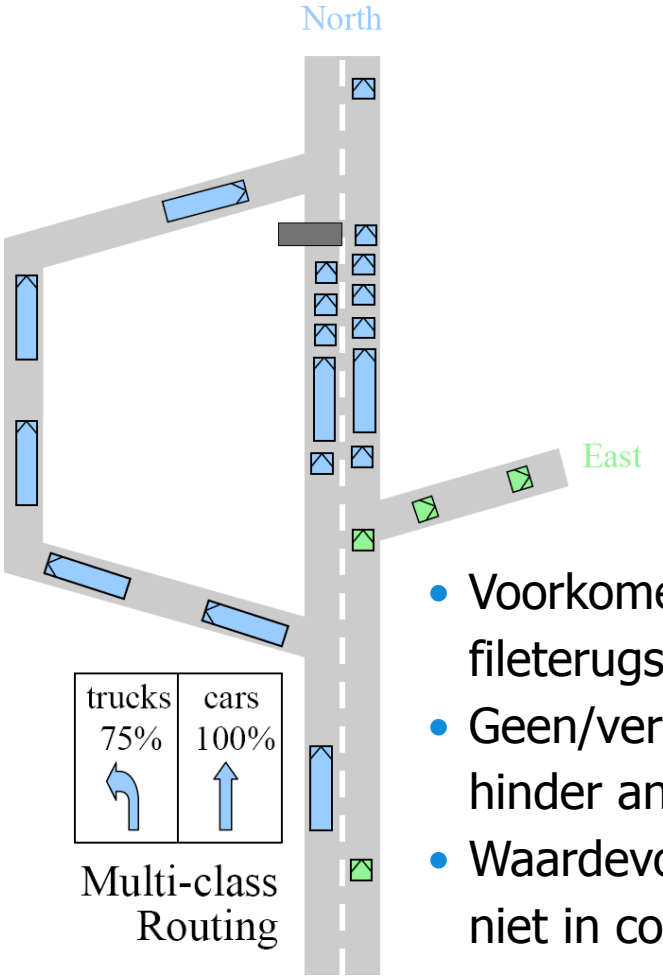
Voorbeeld Klassespecifieke Maatregel: Routering

gewone routering



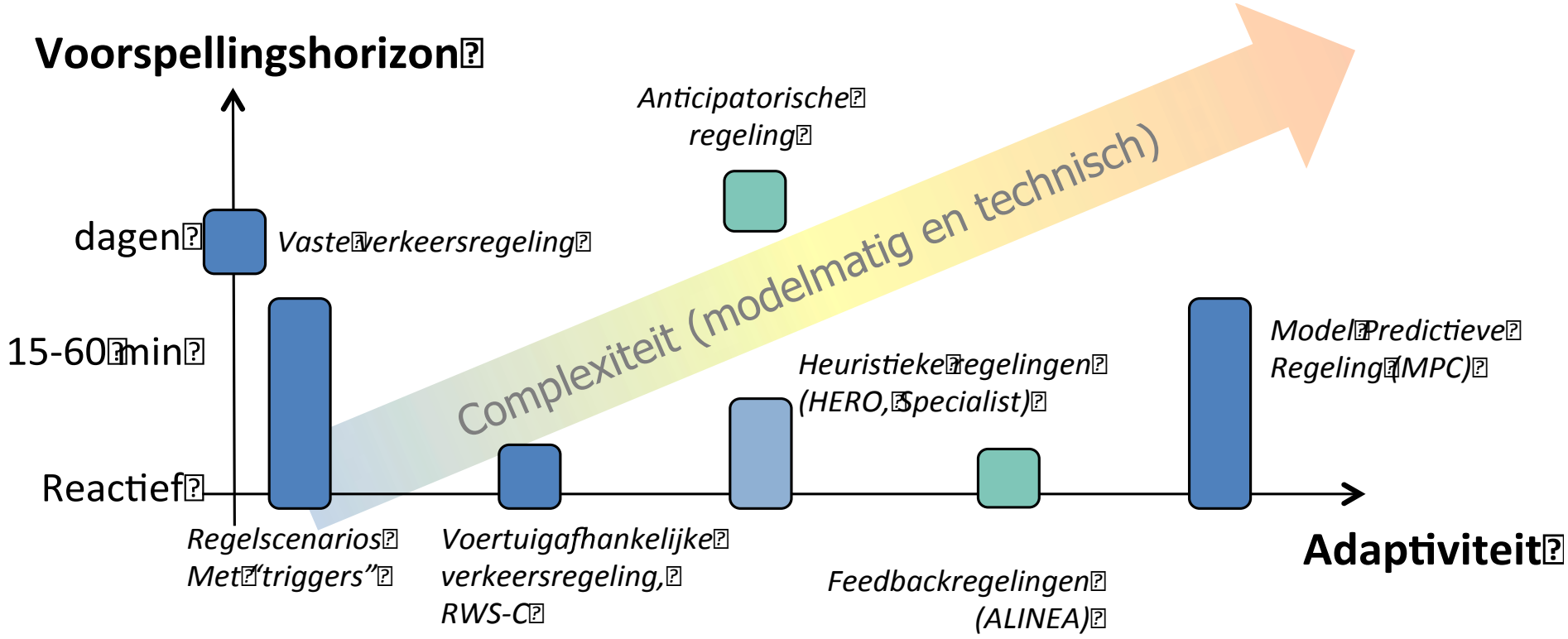
- Fileterugslag
- Hinder andere vtg
- Auto's en vrachtwagens evenwichtig in congestie

Klassespecifieke routering

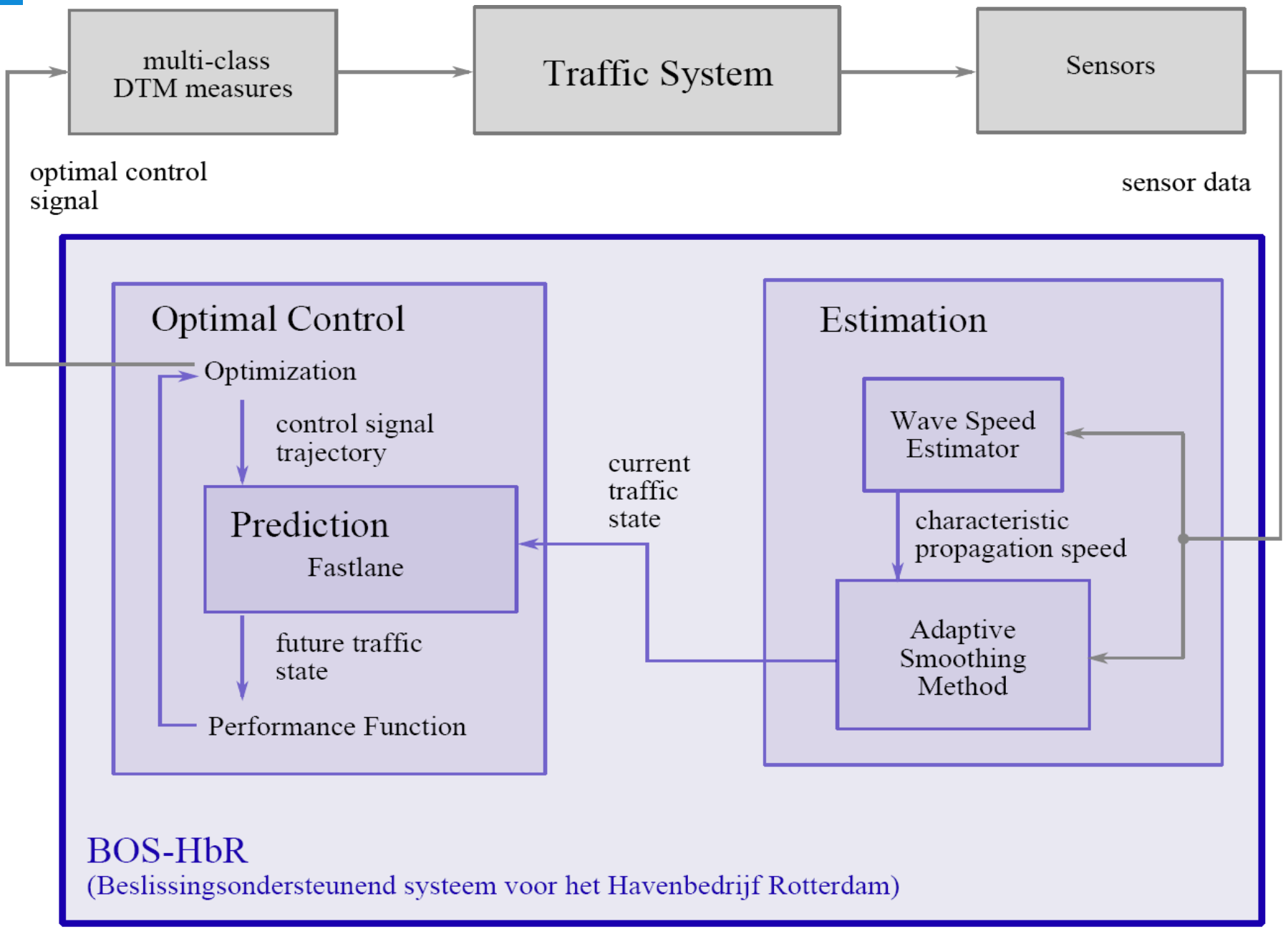


- Voorkomen van fileterugslag
- Geen/verdraagd hinder andere vtg
- Waardevolle vrw niet in congestie

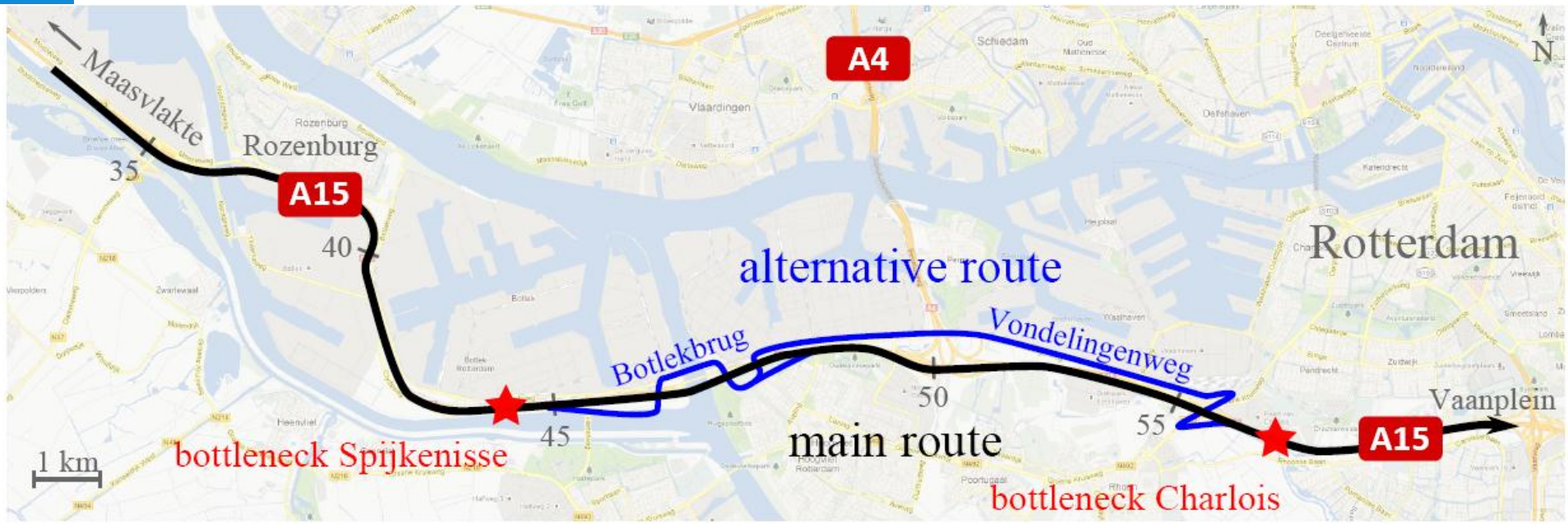
Regelmodellen DVM



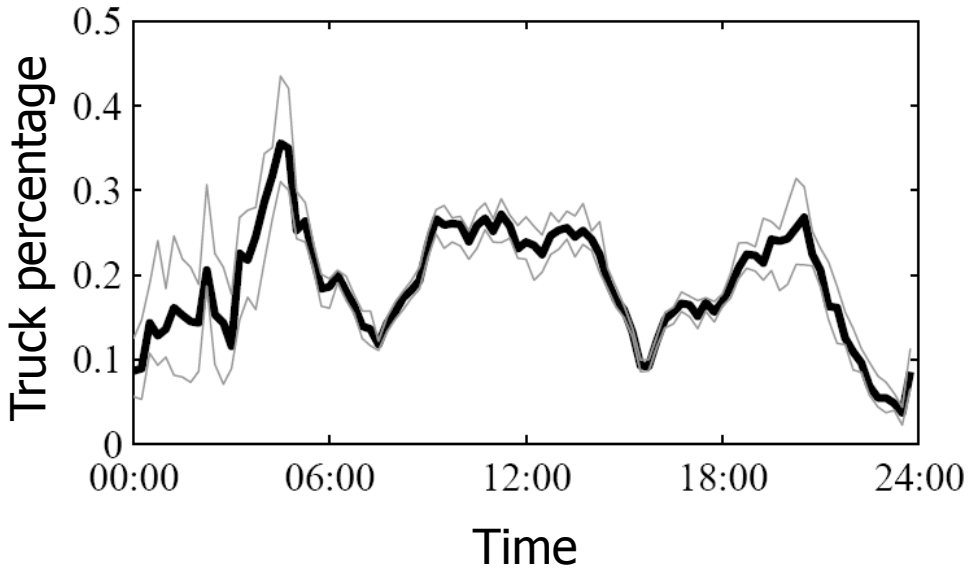
Regelcirkel klassespecifiek MPC



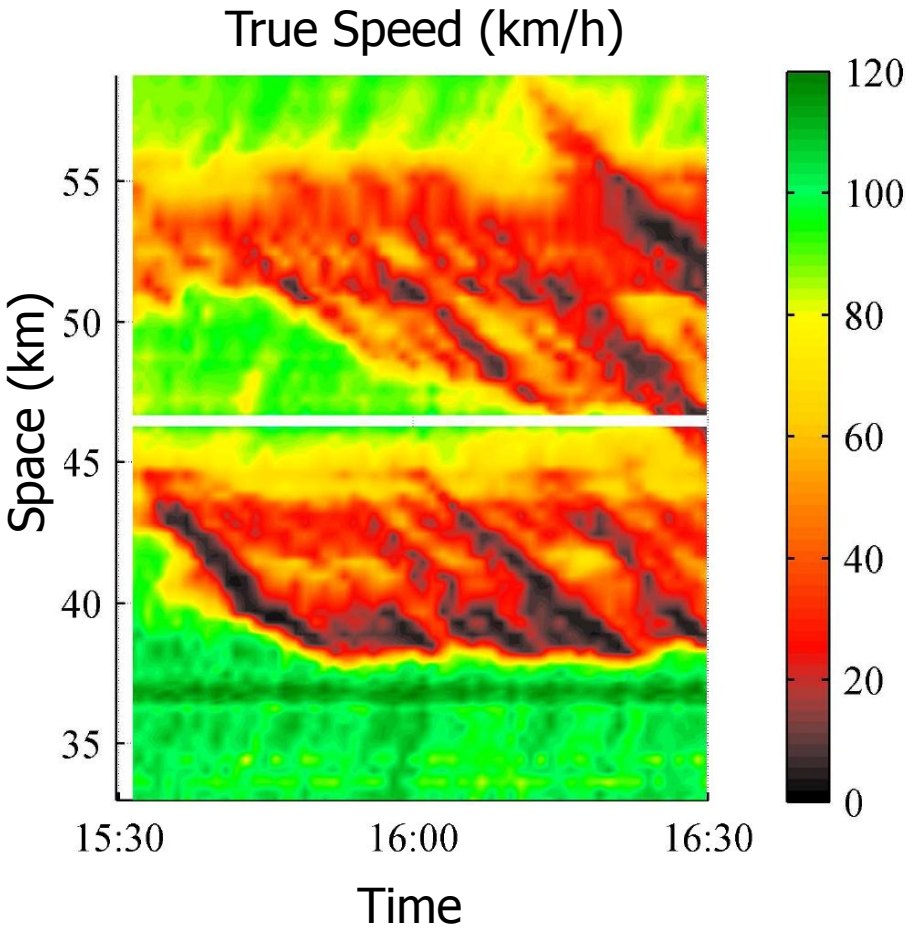
Case study A15

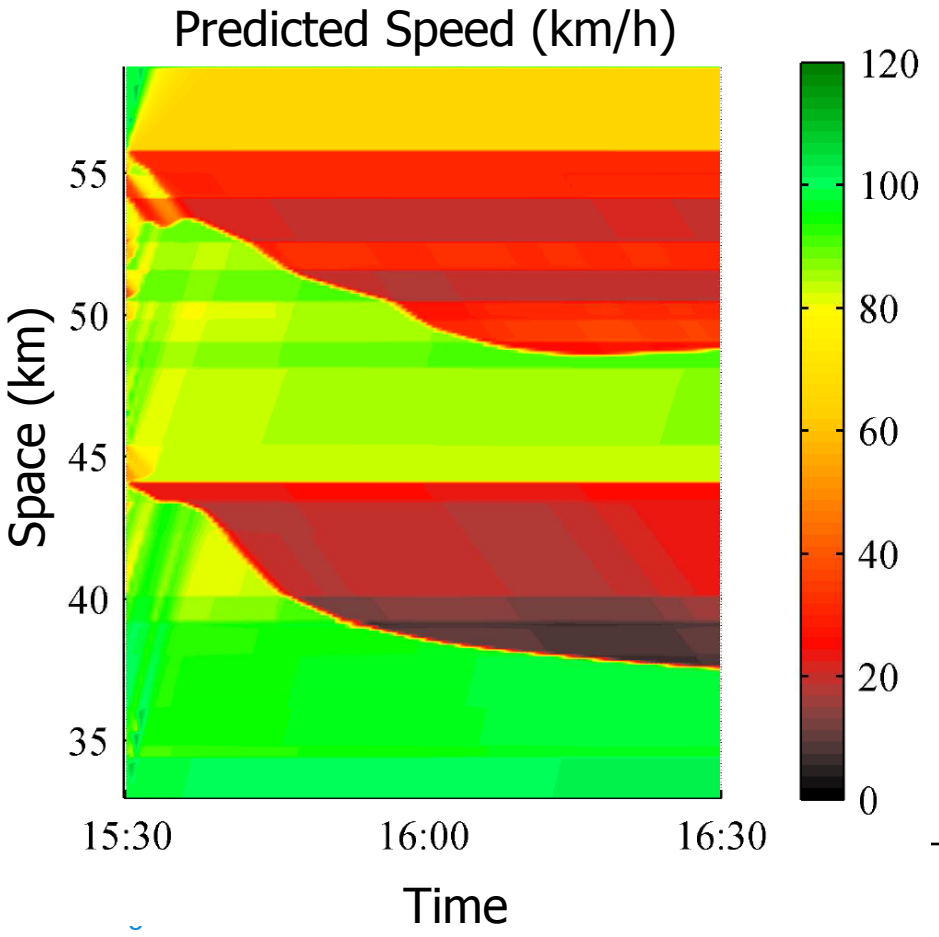


- 30 km snelweg + 1 alternatieve route
- Buitengewoon veel vrachtwagens
- 2 klassespecifieke routering
- 1 klassespecifieke TDI



Case study –
Validatie van Verkeersmodel





Case study –
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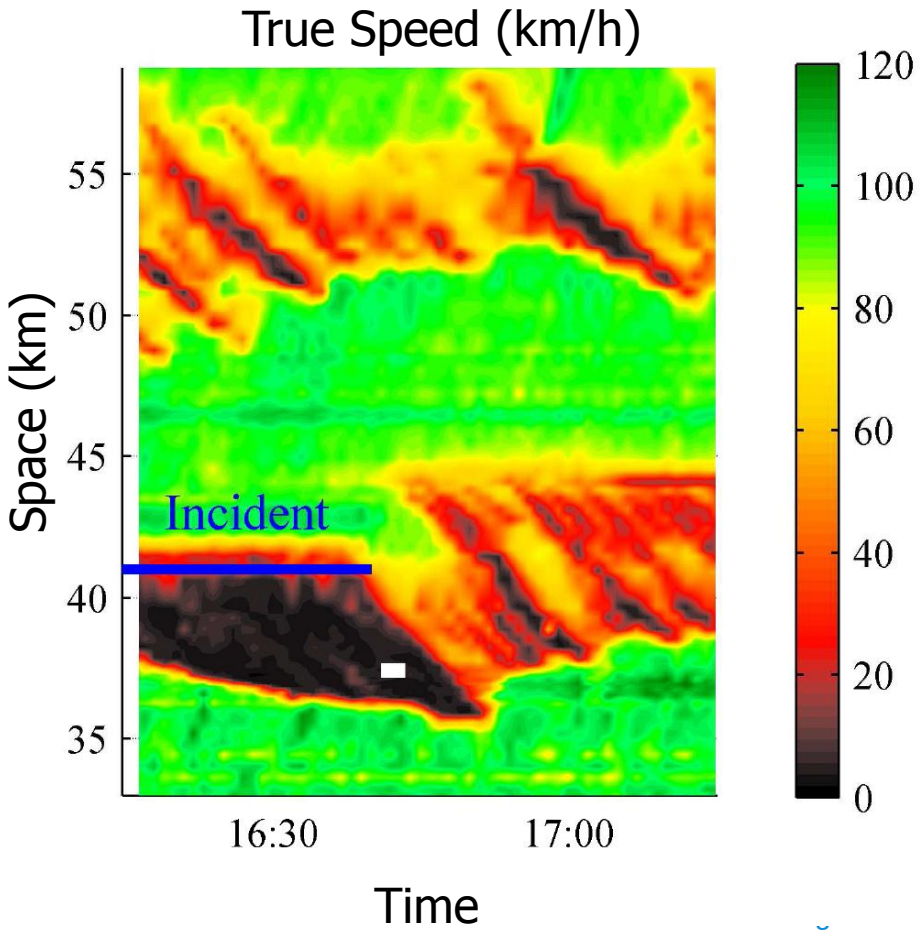
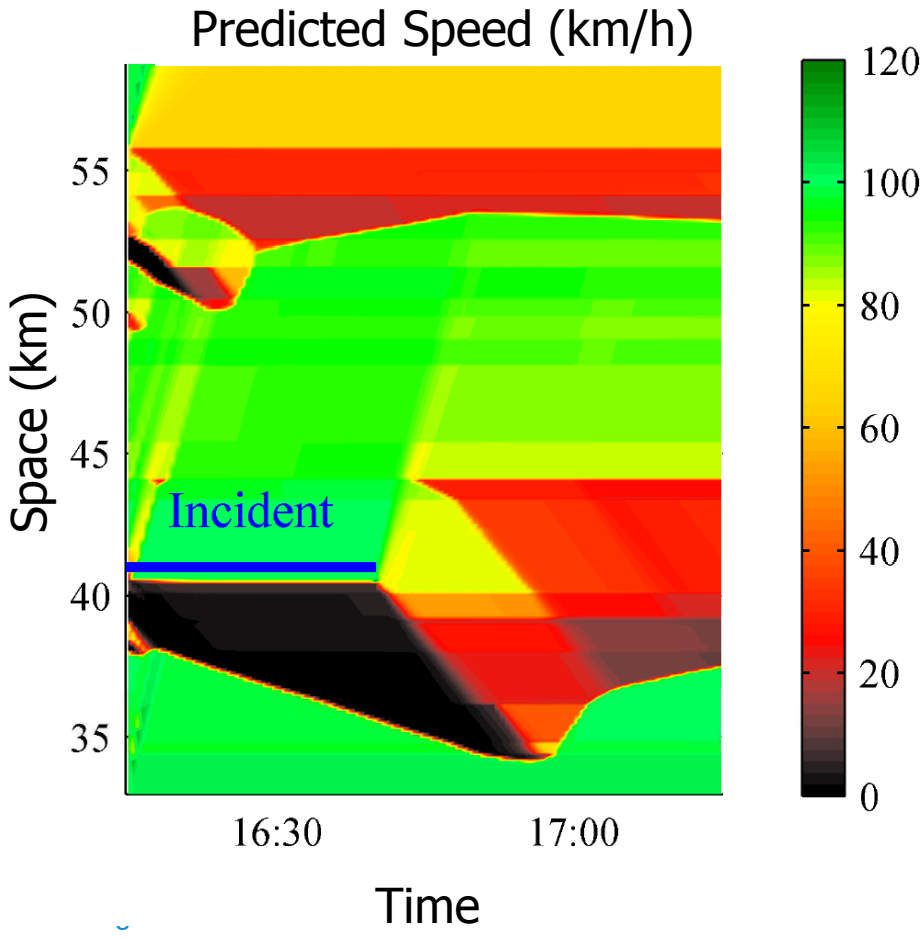
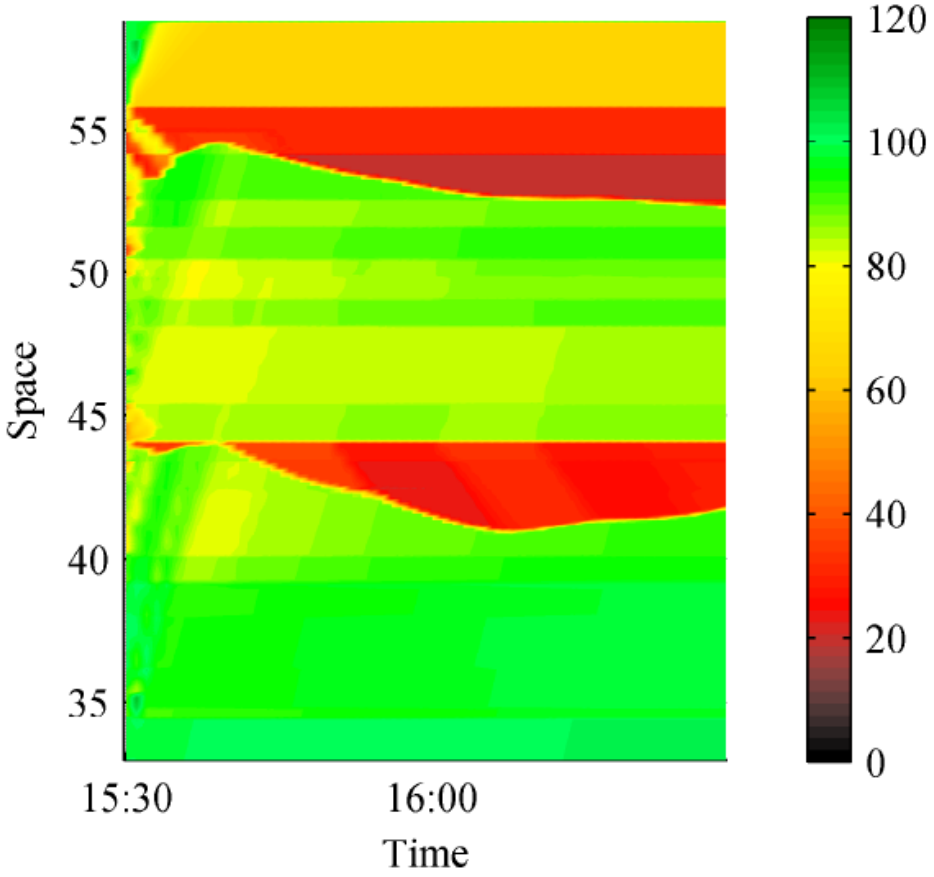
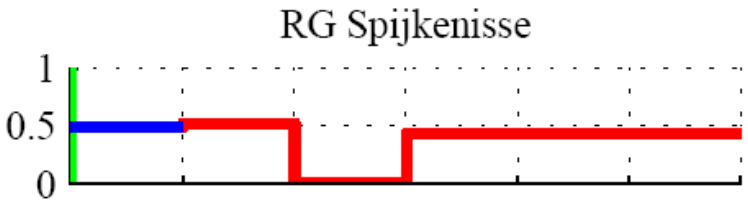




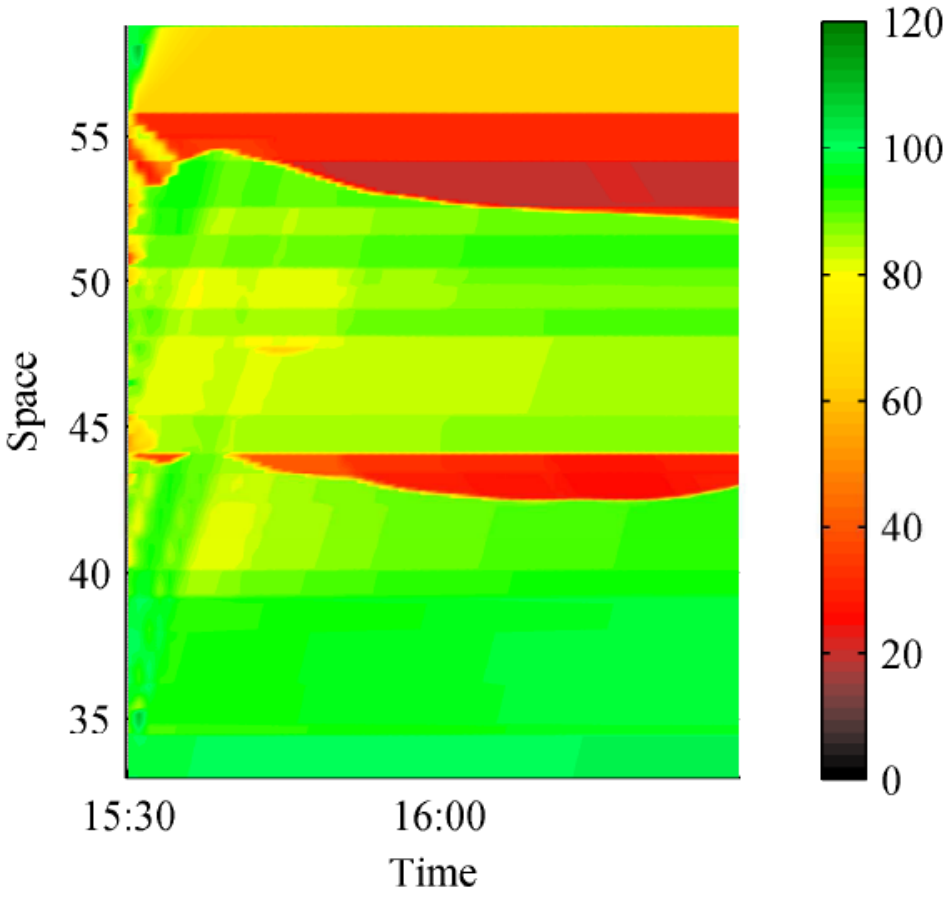
Case Study – Mixed-class regeling tijdens spits

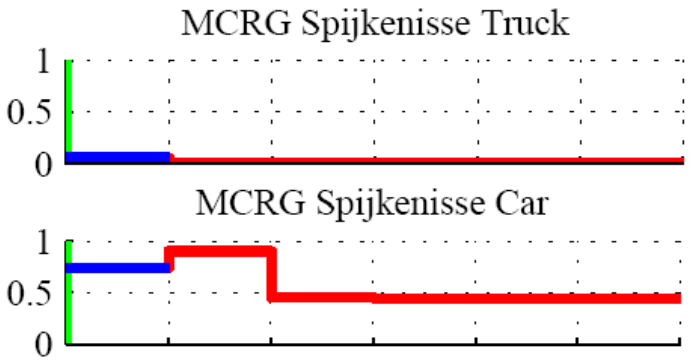




- Herroutering via alternatieve route

Case Study – Multi-class regeling tijdens spits





- Herroutering van auto's
- Minder file voor vrachtwagens

Case Study – Netwerkprestatie (totale kosten)

	Regular Conditions	Incident Conditions
Multi-class Control	44 000 €	39 800 €
Single-class Control	44 700 €	40 000 €
No Control	47 900 €	45 500 €

Conclusies

- Proactief Dynamisch Verkeersmanagement
  - Gebruik gevalideerd verkeersmodel
  - Voorspellen van verkeersituatie
    - Effecten van incidenten
    - Effecten van maatregelen
  - Optimale oplossing om doelfunctie te minimaliseren
- Klassespecifieke regeling
  - Uitnutten van klassespecifieke eigenschappen
  - Voertuiglengte, tijdswaarde, snelheid, …
- Prototype: www.regiolab-delft.nl/boshbr

Bedankt

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Case Study – Control Setup

- Goal: compare multi-class vs. mixed-class vs. no control

- Optimal Control
  - Prediction Horizon: 60 hour
  - Control Horizon: 40 min
  - Control Interval: 10 min
  - Objective: Minimize Total Cost

- 2 vehicle classes:
  - Cars: short, fast, 15 EUR/vehh
  - Trucks: long, slow, 45 EUR/vehh

- Prediction with Fastlane
  - Cell length: ~100 m
  - Time step length: 2.7 sec

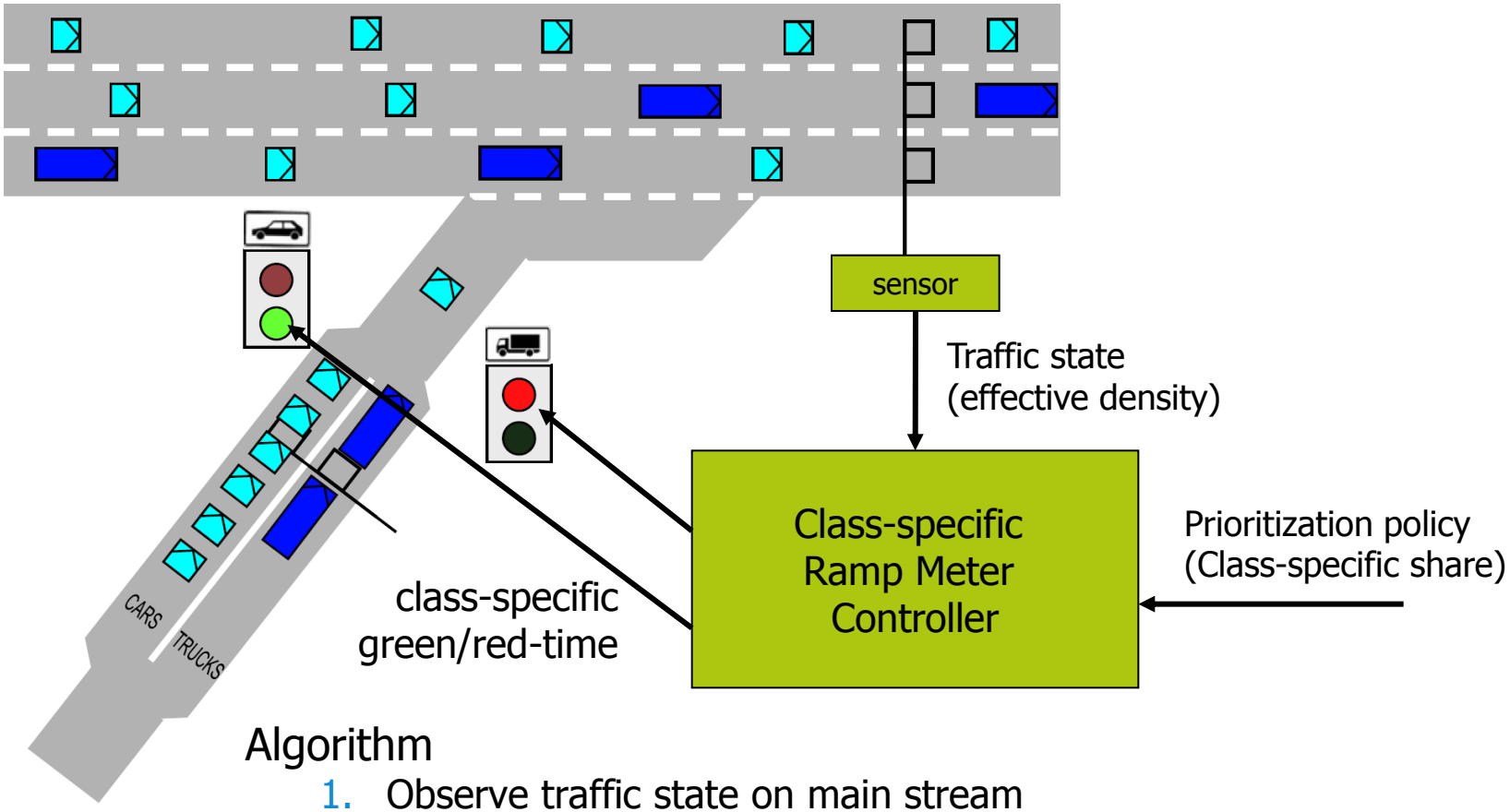
Multi-class Ramp Metering – Summary of Results

- Policy of prioritizing trucks leads to
  - Short waiting queues
  - Low total cost

- Policy of prioritizing cars leads to
  - High ramp flow
  - Few vehicles queued
  - Low Total Delay

➔Class-specific ramp metering enables a goal-specific prioritization

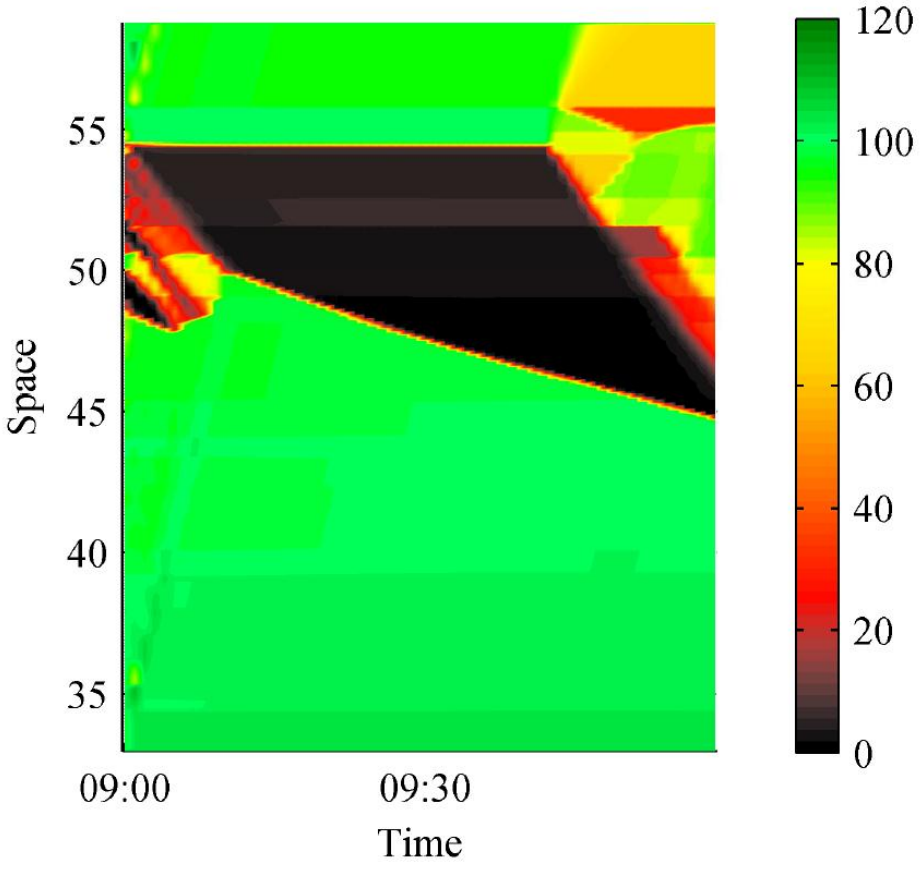
Layout of Multi-class Ramp Metering



Algorithm

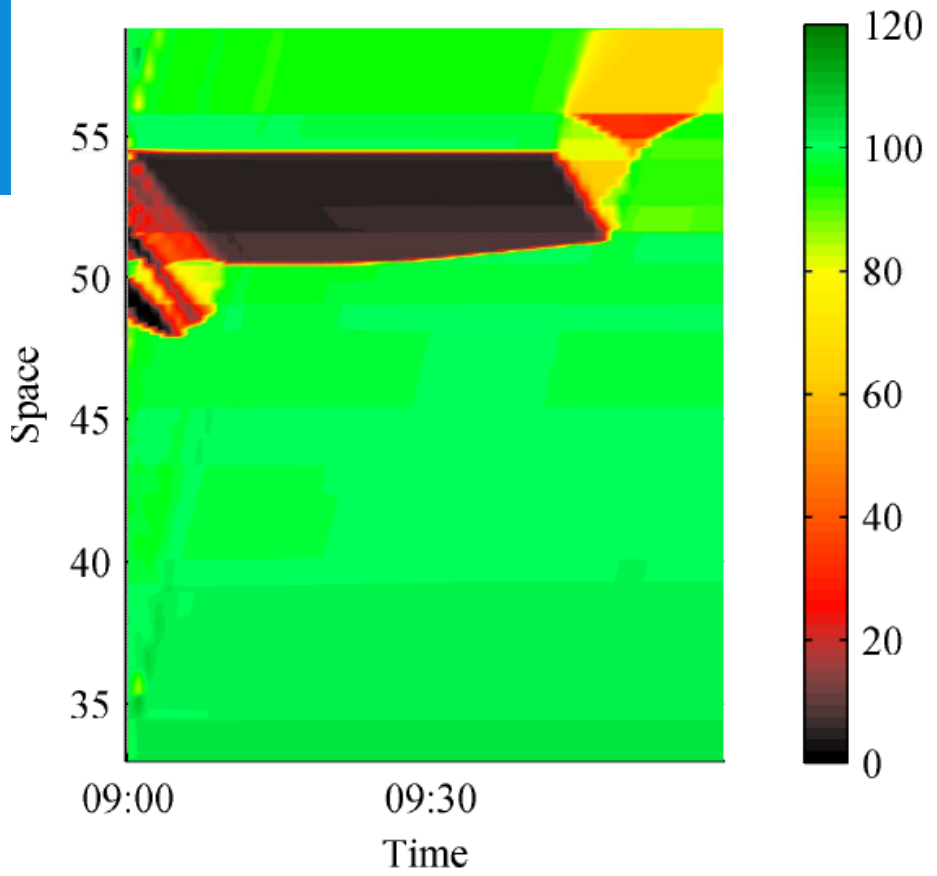
1. Observe traffic state on main stream
2. Calculate total effective ramp flow (in pce/h)
3. Distribute to waiting queues according to prioritization policy

Case Study – No Control During Incident

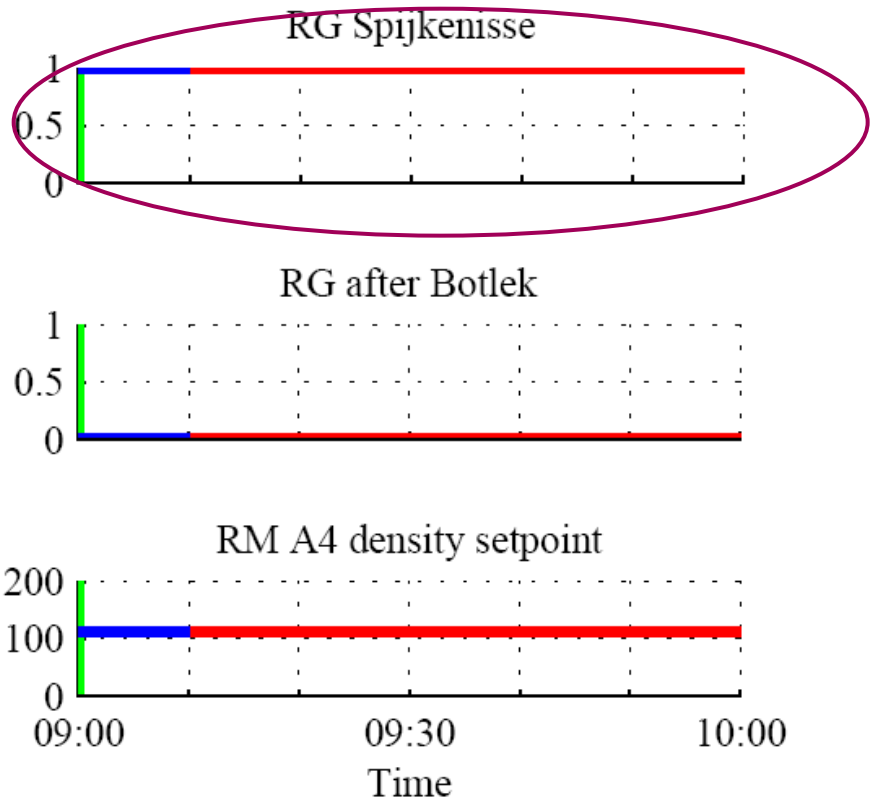


- Long spillback
- Congestion prevalent after incident clearance

Case Study – Mixed-class Control During Incident



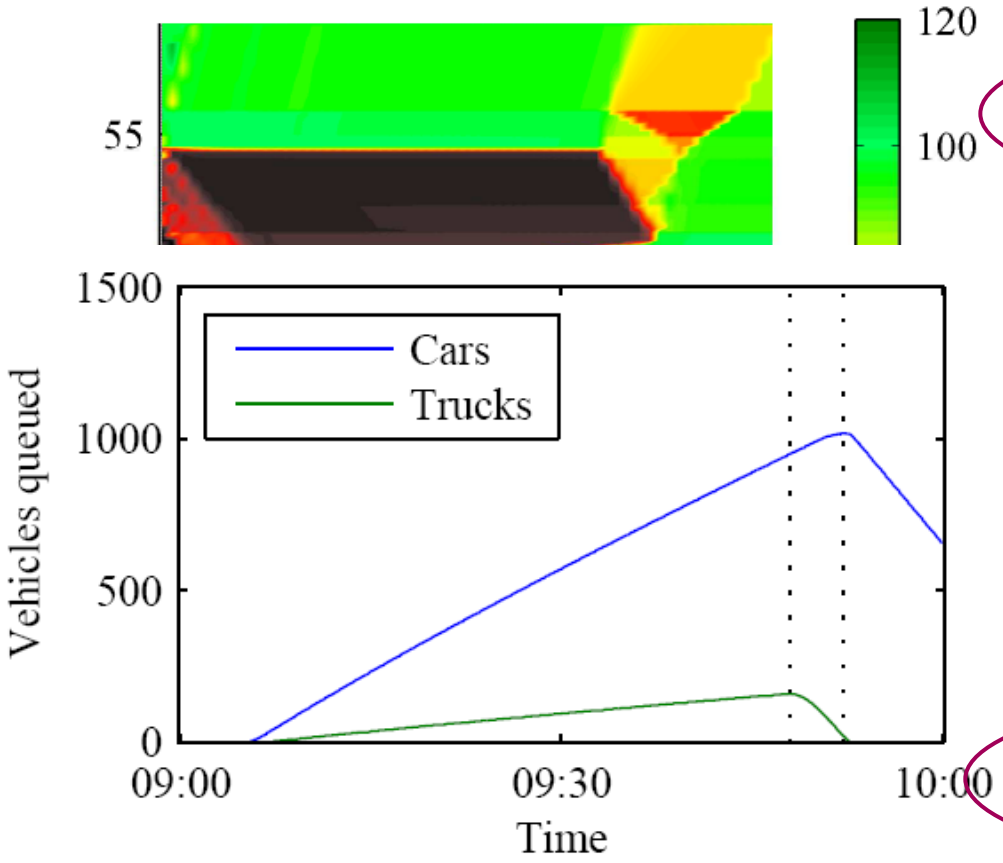
(a) Spatiotemporal Speed Prediction



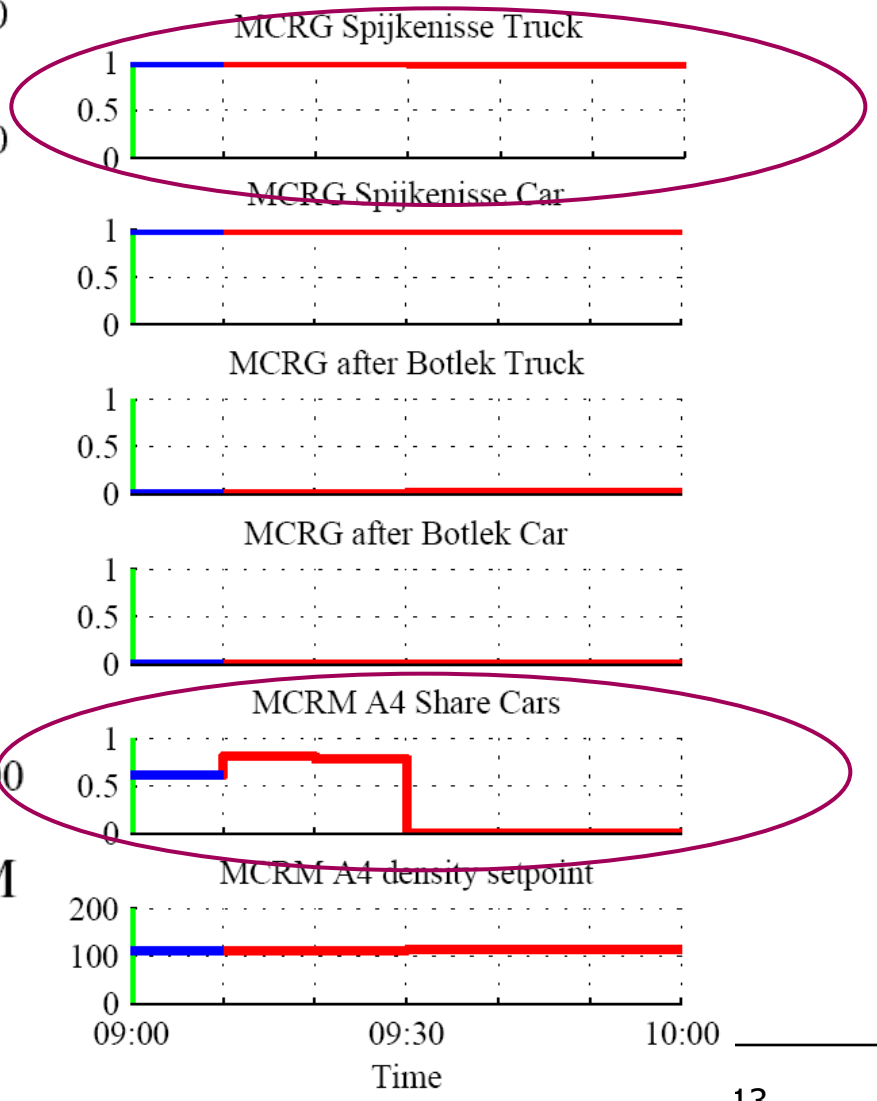
(b) Control Signals

- Rerouting + Ramp Metering
- Prevention of long spillback

Case Study – Multi-class Control During Incident



(c) Number of queued vehicles at MCRM



- Rerouting + Ramp Metering
- Trucks are released first
- Prevention of long spillback

Multi-class Traffic Flow Analysis (Chapter 5)

- Goal:
  - model multi-class phenomena: dynamic spacing, different maximum speed
  - Model multi-class DTM measures
  - Evaluate traffic performance class-specifically (different VOT)

- ➔ use traffic flow model: "Fastlane"

- Overview:
  - Generalization of LWR / CTM to multiple vehicle classes
  - Vehicle-class properties: pce function π_u, maximum speed
  - Convert vehicular quantities to effective quantities by pce value π_u
  - E.g.: vehicular density k_u (in veh/km) to effective density K_u (in pce/km)

$$K_u = \pi_u k_u$$

  - Similarly: demand, supply, flow, etc.

Fastlane: equations and basic ideas

- Class-specific conservation of vehicles equation

$$\frac{\partial k_u}{\partial t} + \frac{\partial q_u}{\partial x} = 0$$

$$q_u = k_u v_u$$

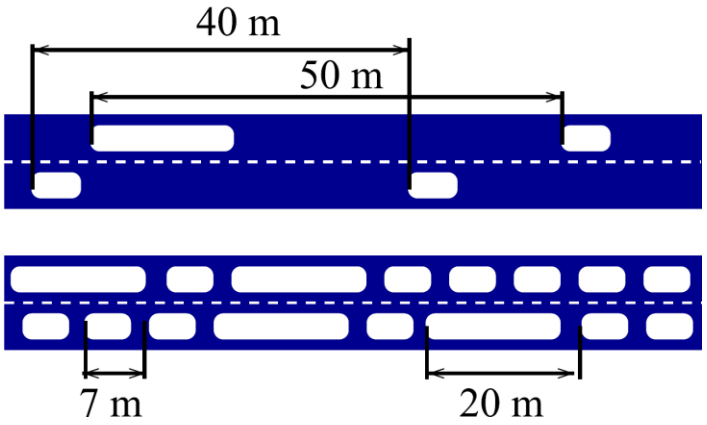
- Class specific equilibrium relation – in Fastlane function of *effective* density in pce

$$v_u = V_u(K),$$

$$K = \sum_u \pi_u k_u$$

- Pce function:

$$\pi_u(t,x) = \frac{s_u + T_u \cdot v_u(t,x)}{s_0 + T_0 \cdot v_0(t,x)}$$



x space	u vehicle class
t time	V fundamental diagram
k density	π pce function
K effective density	s minimum spacing
q flow	T minimum headway
v speed	

Fastlane: Fundamental Diagram

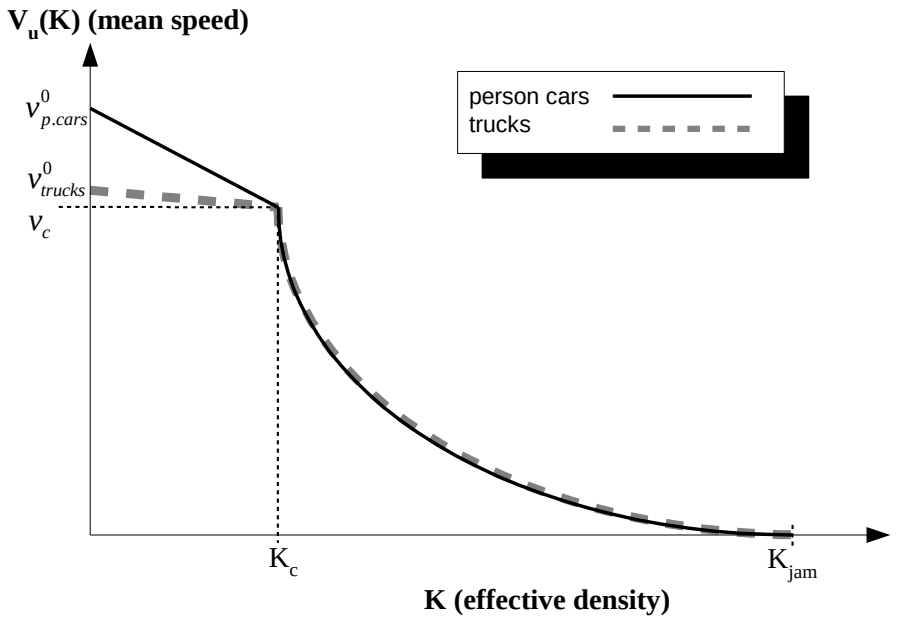
$$V_u(K) = \begin{cases} v_u^0 - K\dfrac{(v_u^0 - v_c)}{K_c} & \text{for } K < K_c \\ \dfrac{v_c K_c}{K}\left(1 - \dfrac{K - K_c}{K_{jam} - K_c}\right) & \text{for } K \geq K_c \end{cases}$$

Class specific mean speeds

- Different in free-flow branch
- Same average speed under congestion

Note

- Average speeds may be equal under congestion, but class-specific space occupancy is still dynamic!



Recommendations for Practice

- Estimate whole traffic state
  - Install working sensors
  - Use ASM or Localized EKF for fast Traffic state Estimation
- Use a (multi-class) traffic flow model to anticipate traffic state, especially under irregular conditions
- Move from reactive scenarios to predictive scenarios
- Simulate optimal controller and compare with scenarios
- Implement MPC
- Expand DTM measures to multiple vehicle classes

- Result: Proactive Multi-class network-wide DTM

Multi-class Ramp Metering – Simple Example

Let:

- 2 classes: 50% cars, 50% trucks
  - In free-flow: 1 truck = 2 pce
  - By definition: 1 car = 1 pce
- In congestion: 1 truck = 6 pce
- Total effective ramp flow = 6 pce / time unit

Then:

Prioritization Policy	*Number of Vehicles served*	*Queue Length served*
1) Prio trucks		
2) Prio cars		
3) 50 : 50		