Cars and road traffic

Introduction on traffic flow

03-03-14

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Introduction: traffic simulation models

- Traffic jams: €1,5 bil/yr
- Capacity 3-5% too low
- Ex-ante testing of measures
- Zones 80 km/h:
  - Average speed check leads to different lane usage
  - Lower capacity
  - Models incorrect

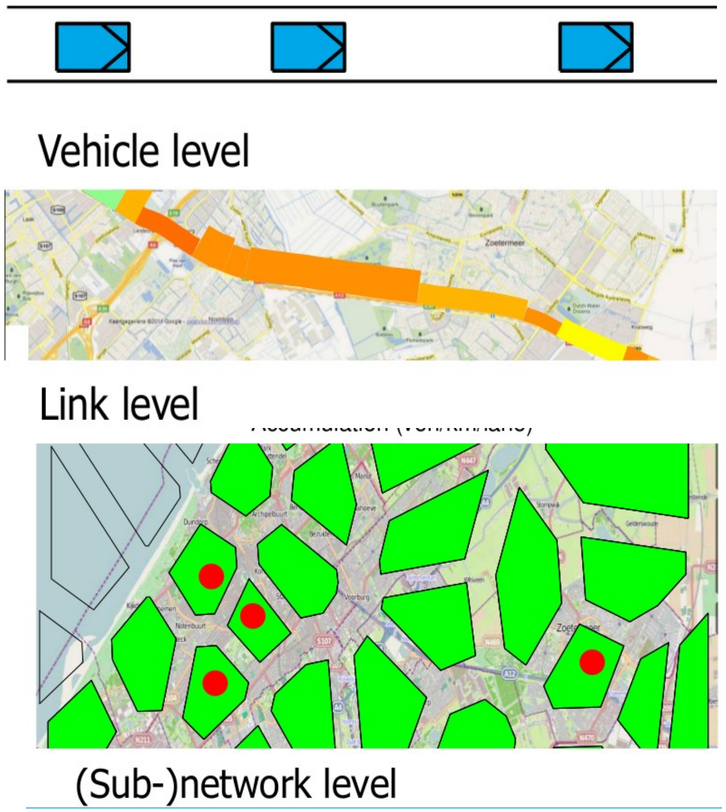
New communication allows to coordinate traffic control

Outline

- Explanation on scales
- Microscopic: motorway modelling
- Macroscopic: patterns
- Networks: a new aspect

Scales

- Microscopic: vehicle level
  www.traffic-simulation.de
- Macroscopic: link level
  www.traffic-states.com
- New level: network level
  http://victorknoop.eu/research/networktransmissionmodel/



Question

Traffic lights reduce the inflow of vehicles to the freeway. Why does this reduce the average delay?

A) Drivers keep shorter distances if they have not queued yet
B) In a specific time, cars on the freeway cover more distance than cars on the onramp
C) There are less cars delayed on the onramp

Nationale Wetenschapsquiz 2013

Vraag 5

Toeritdosering reguleert de instroom van auto's vanaf de toerit naar de snelweg. Waardoor zorgt toeritdosering per auto gemiddeld voor minder vertraging?

Antwoord:

A. Auto's houden minder afstand als ze nog niet in de file hebben gestaan

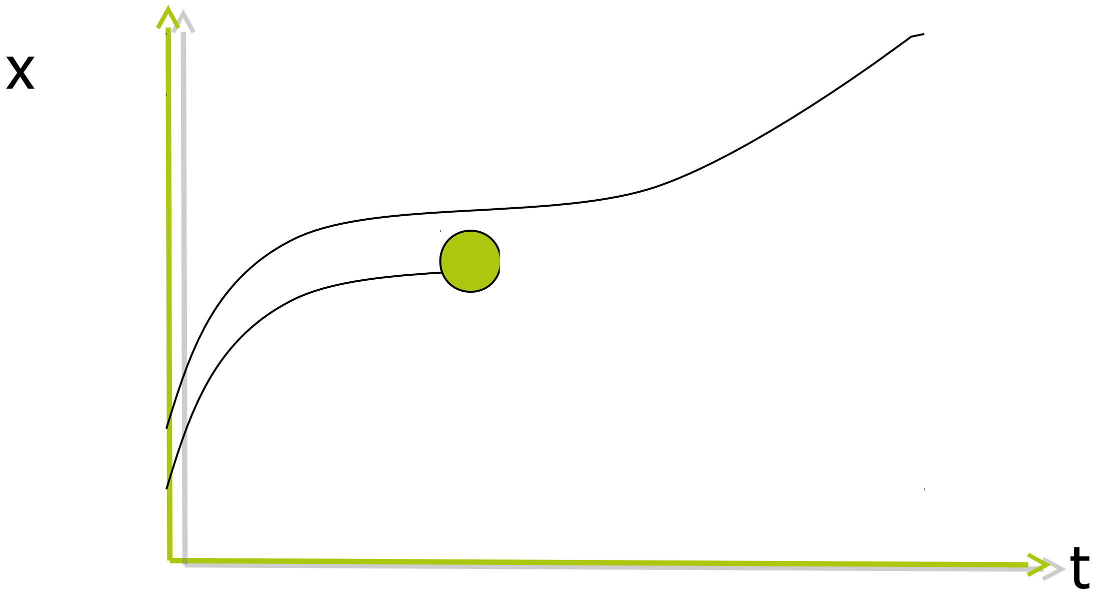
B. Binnen dezelfde tijd zal een auto op de snelweg meer afstand afleggen dan een auto op de toerit

C. Op de toerit lopen minder auto's vertraging op dan op de snelweg

Microscopic description

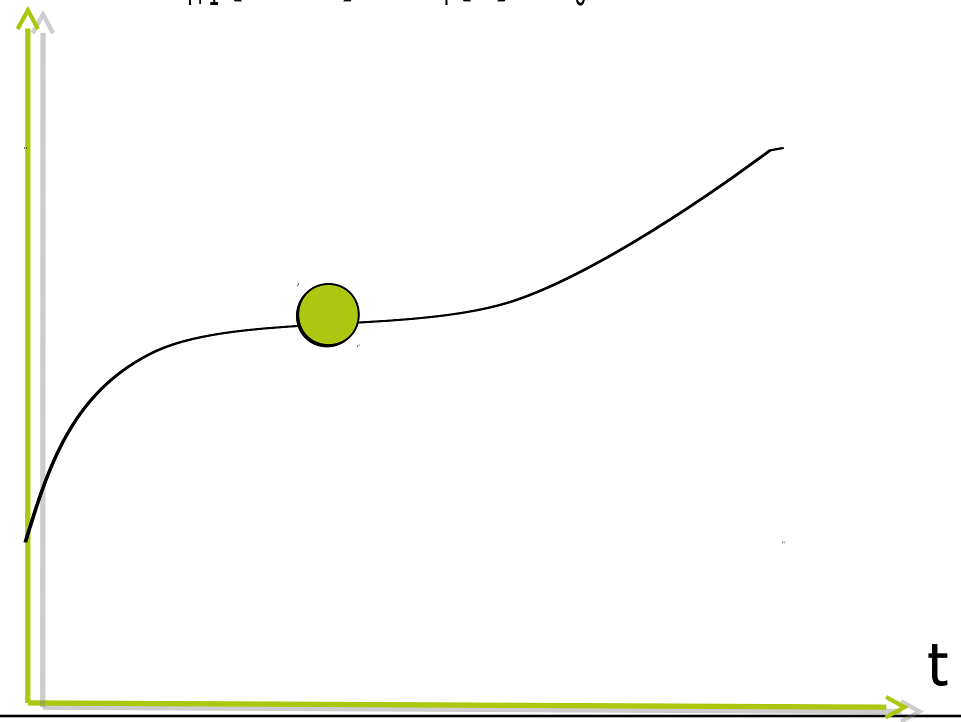
Car-following model

- Description of acceleration (or speed, or position?) of vehicle i as function of leader(s) parameters.
- a_i=… or v_i=… or x_i=…
- 2 minutes: build your own car-following model



Newell simple car-following model

1. Translate the trajectory in time
2. Translate the trajectory in space
   => $X_{i+1}(t+\tau)=x_i(t)-x_0$



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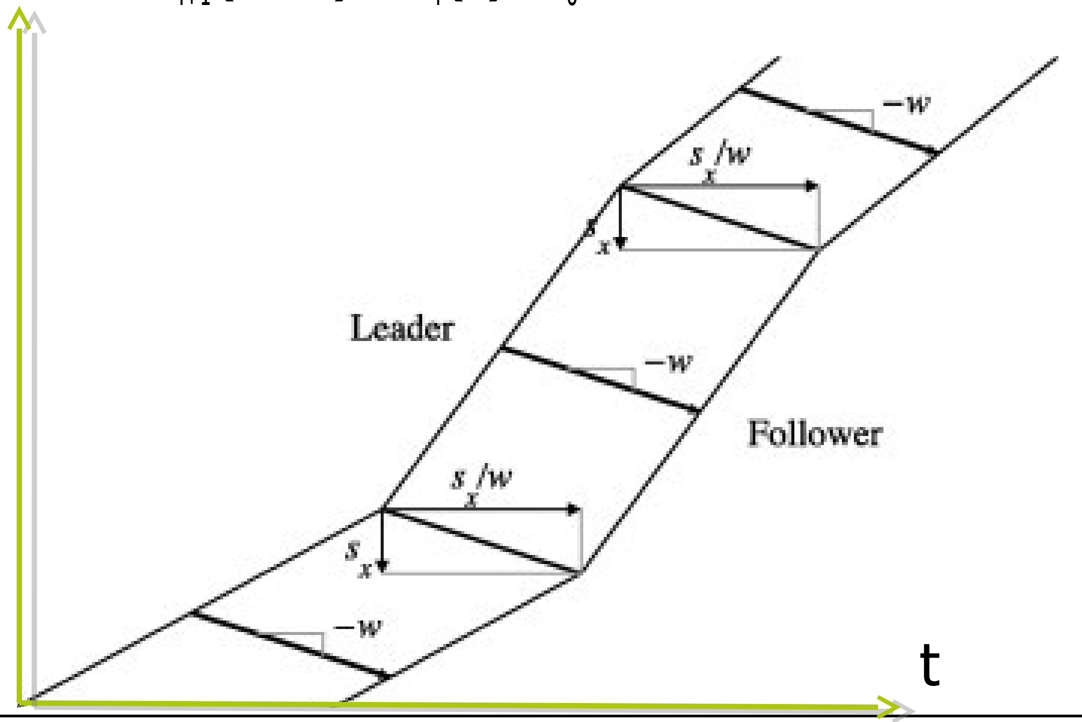

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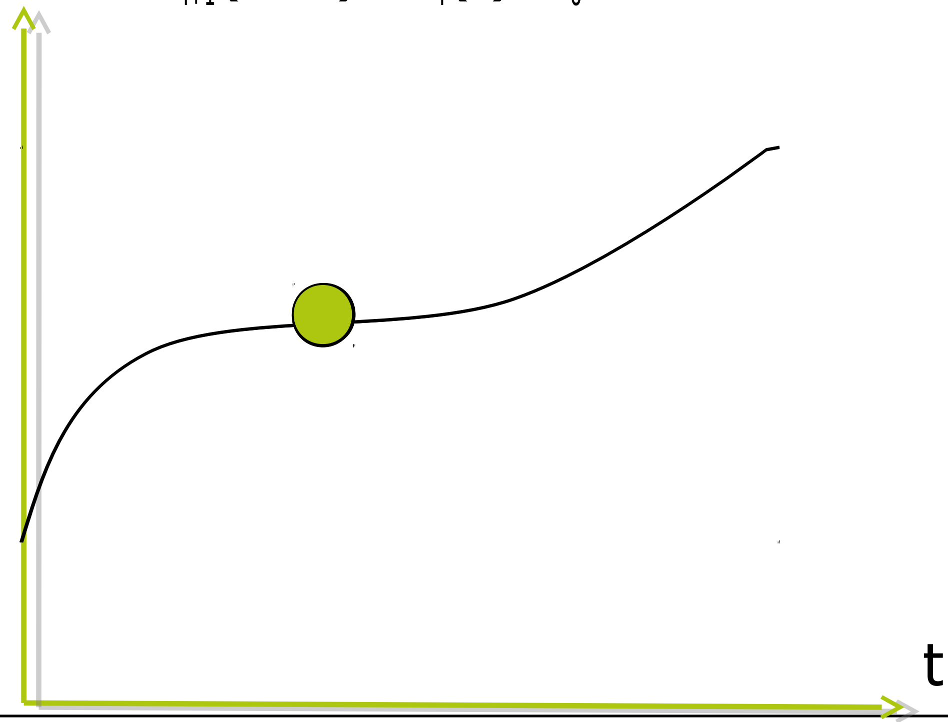
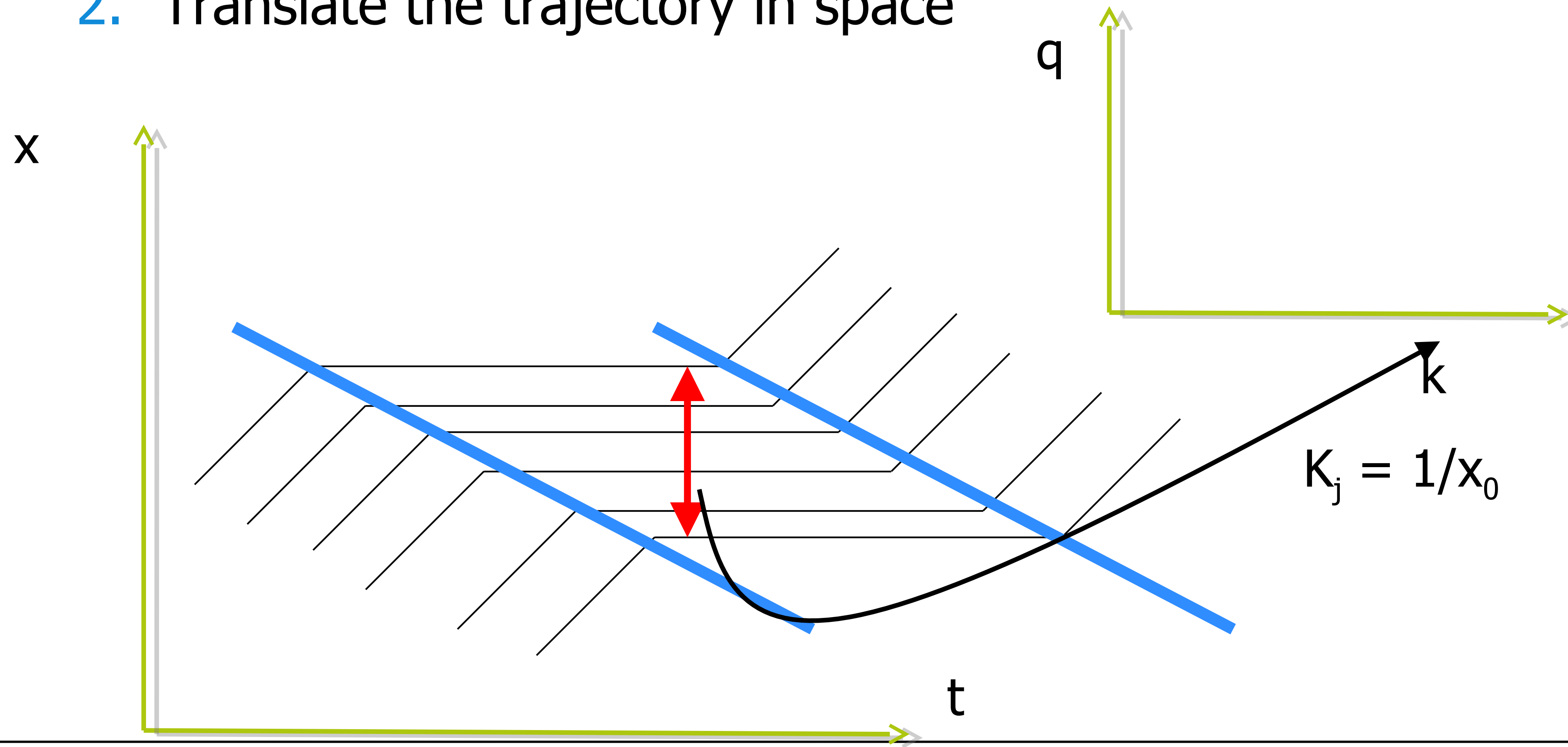


Relation microscopic-macroscopic

1. Translate the trajectory in time
2. Translate the trajectory in space

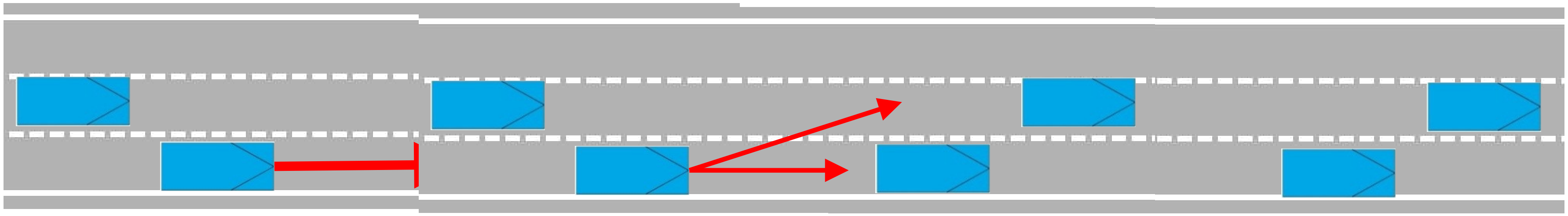


Impact of microscopic actions

Innovation 1: combine speed & lane

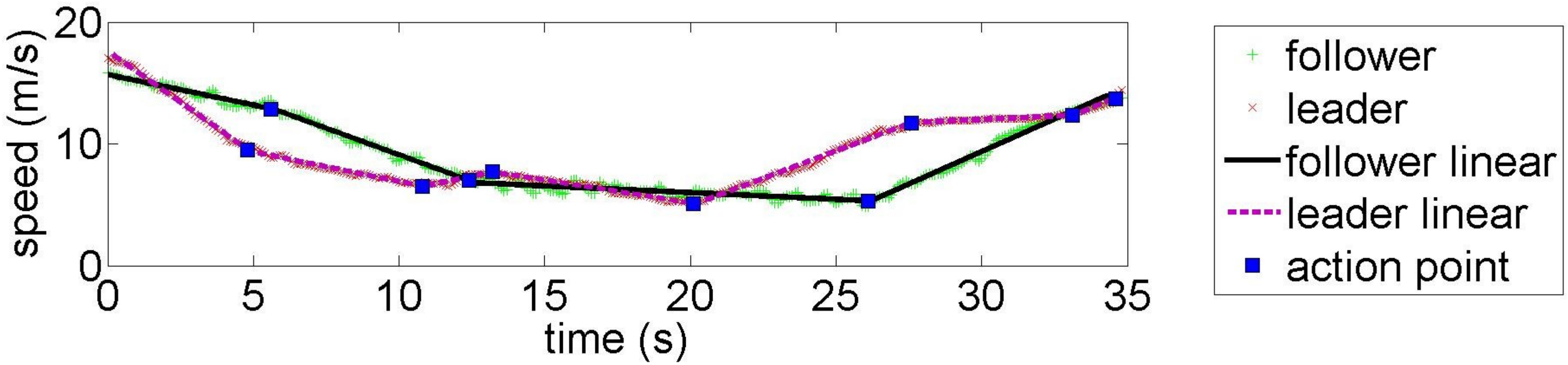
Motorway traffic simulation model

Couple acceleration and lane choice



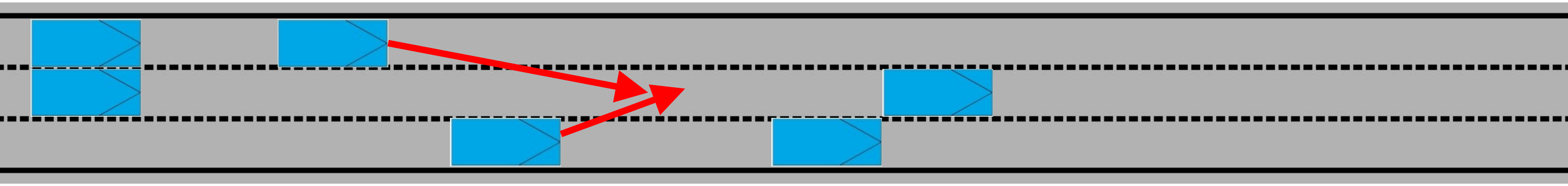
Innovation 2: action points

- Up to now: continuous adaptation acceleration
- In Veni: acceleration changes at action points (togeather with lane)



Innovation 3: Leaving space for others

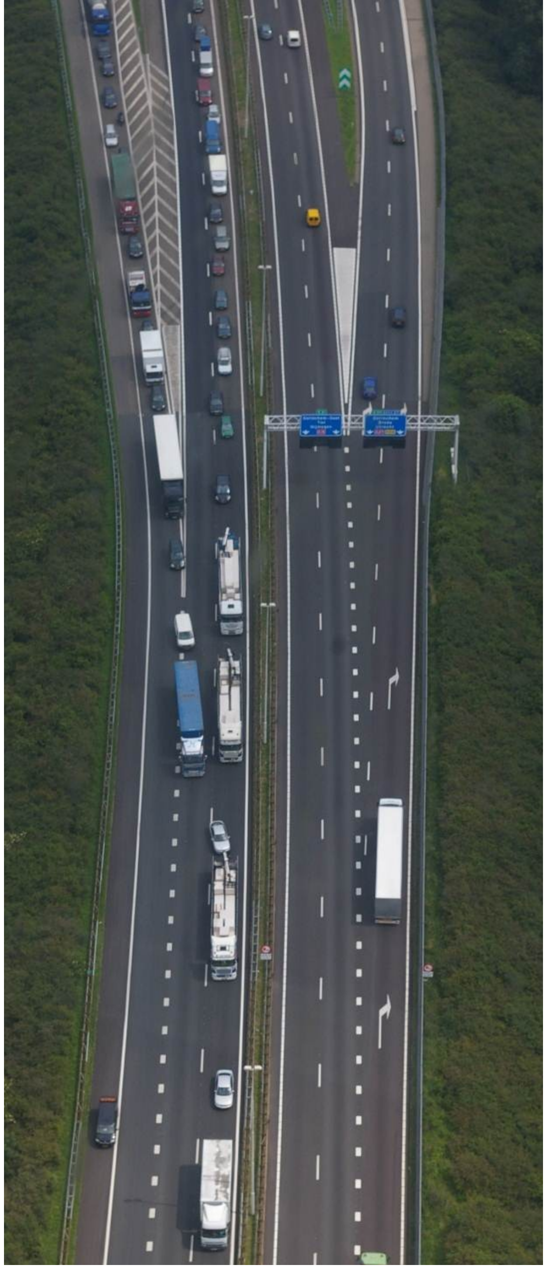
- State-of-the-art:
  One chooses its lane and the rest follows
- Model proposal:
  "Negotiate" on the space



Observations and calibration

- Individual vehicle data
  - 55 linked cameras (Rijkwaterstaat/TNO)
  - Helicopter: follow vehicle (nieuwe techniek)
- Driving simulator
  - Several test persons (required?)
  - Vary only one variable

=> Calibration of the model

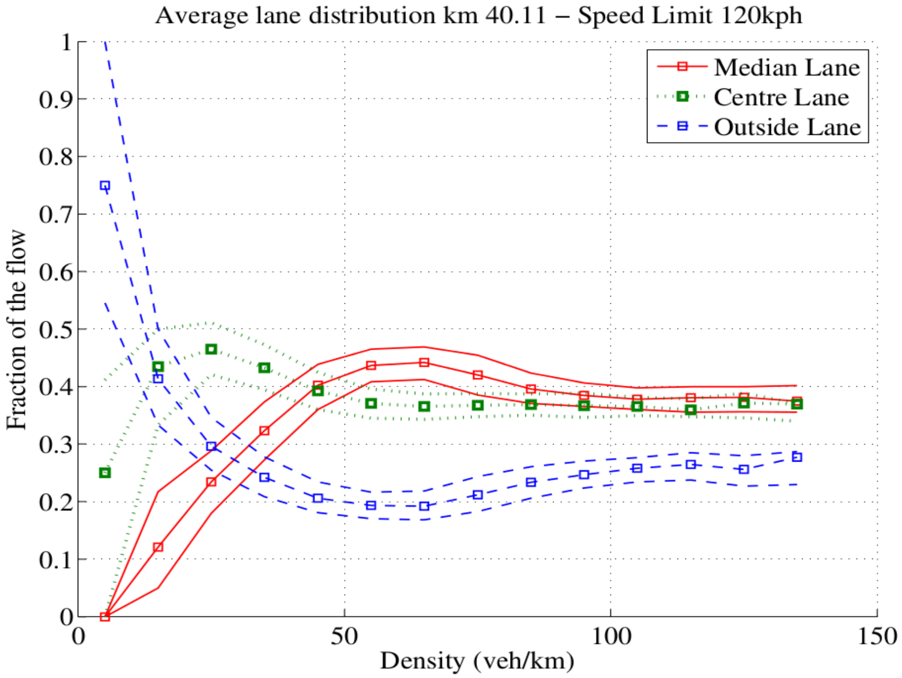


Apply on test case: average speed check

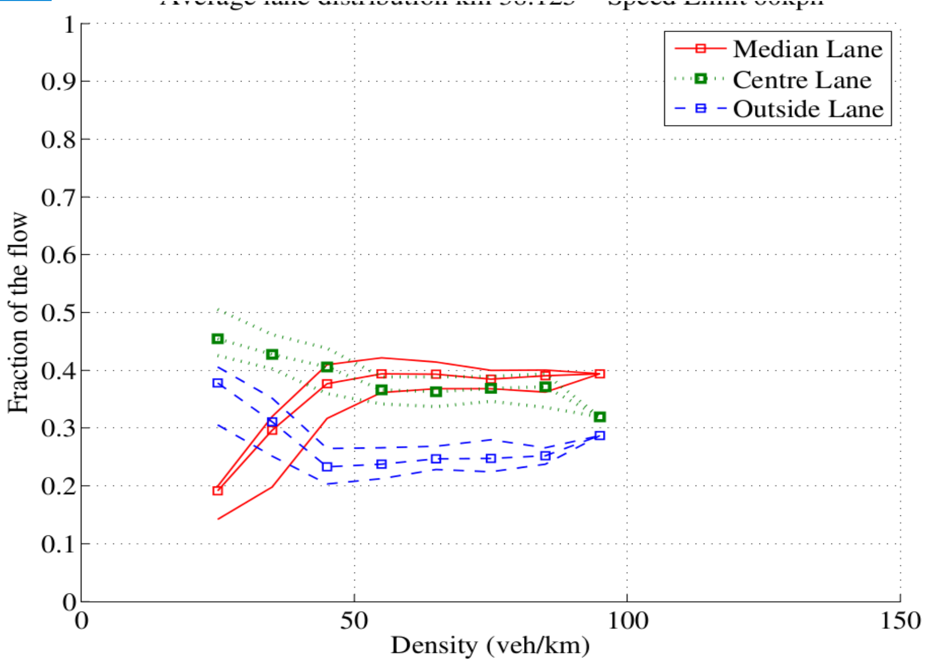
- Commercial simulation models require calibration
- Test: calculate effect without calibration (ex ante!)
- Compare to other models

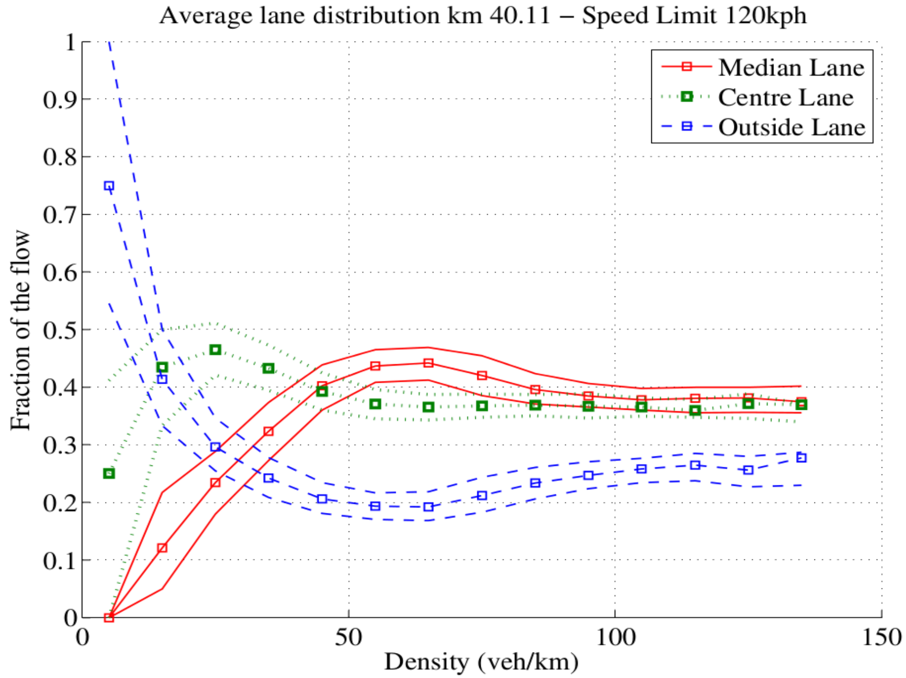
Where is underused road capacity

- Right lane heavily underused
- ITS measures to improve this
- Speed limit (and speed check) changes behavior



Where is underused road capacity





Calibration

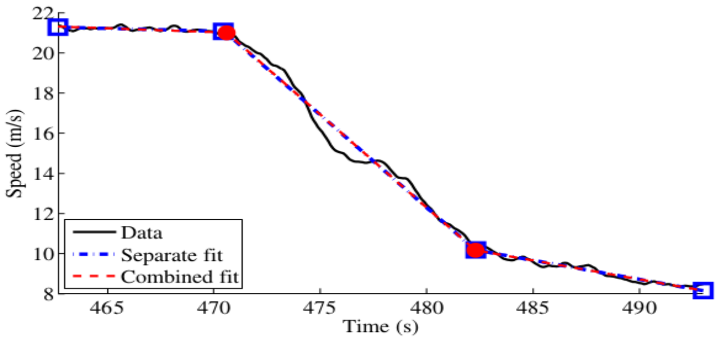
- Step 1: find action points (longitudinal/lateral)
  Difficulty: lane changes considered, but not performed

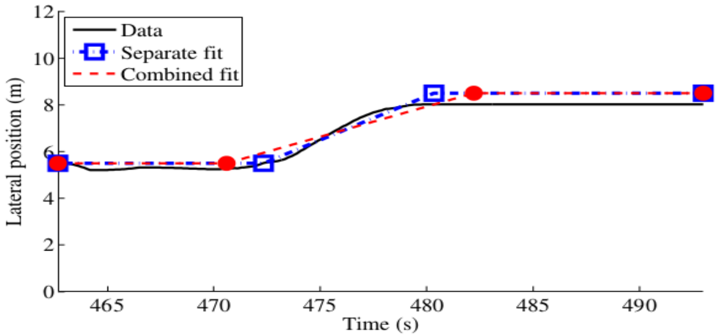
- Step 2: determine cost for all paths
  Running costs: acceleration, gain in time, not behind truck, lane change
  End costs: end speed, final lane, leader/follower
  Difficulty: not all individual costs are being observed

- Step 3: Model choice process
  Difficulty: every one is different, risk assessment?

Preliminary results

- How to quantify (and prove) correlation?





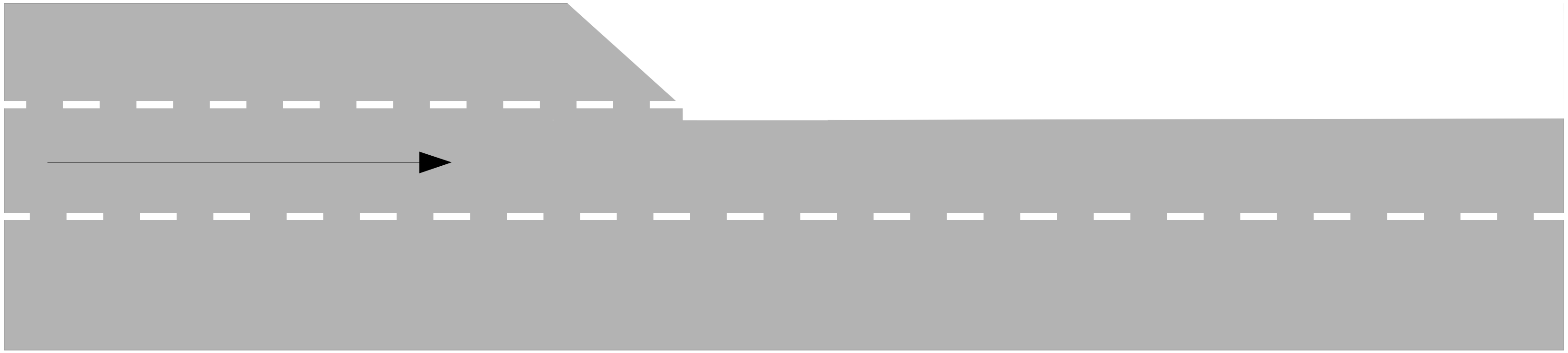
Questions...

- Could you describe your driving decisions?
- And are you willing to join experiments?

Macroscopic description

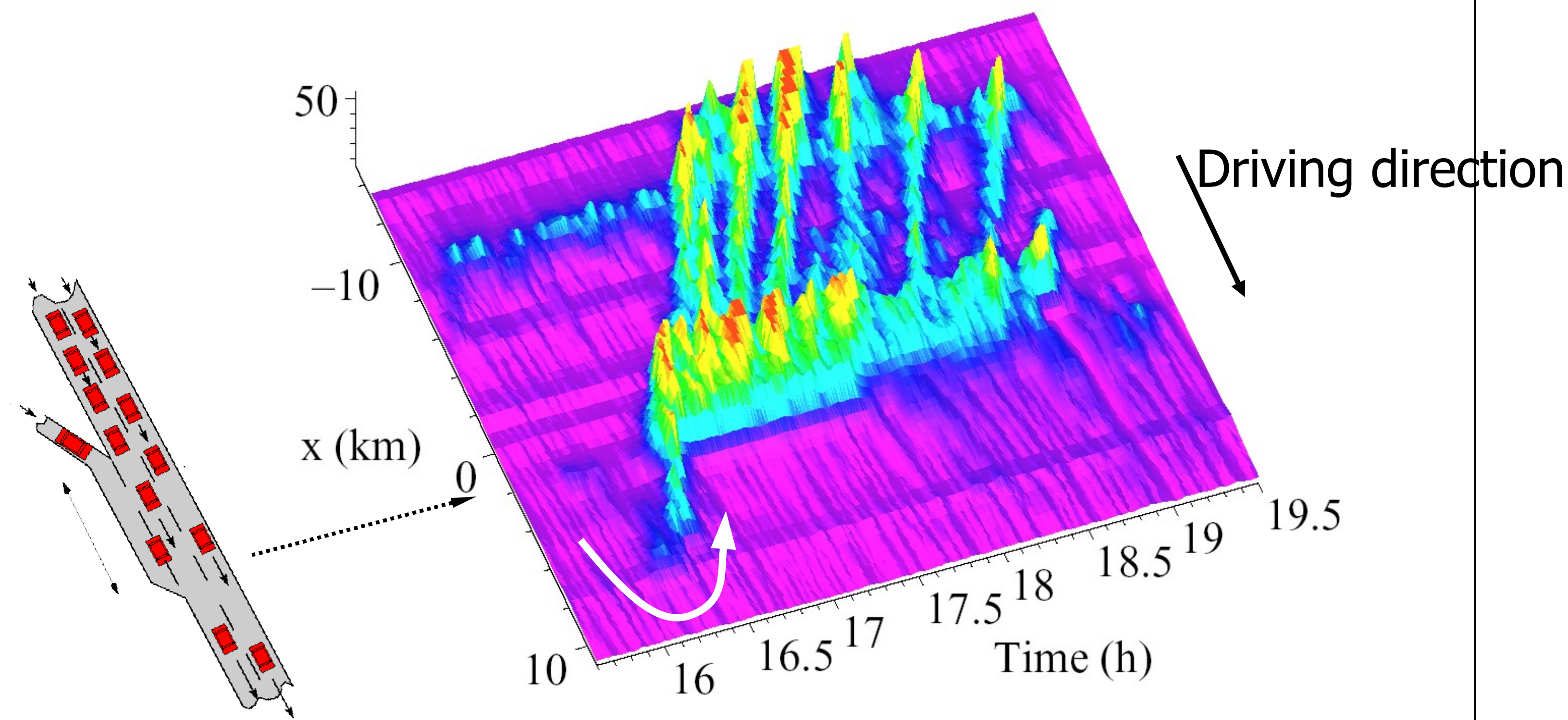
Stable and unstable parts

- What do you expect on this road?



Boomerang effect

- speed



What could we see?

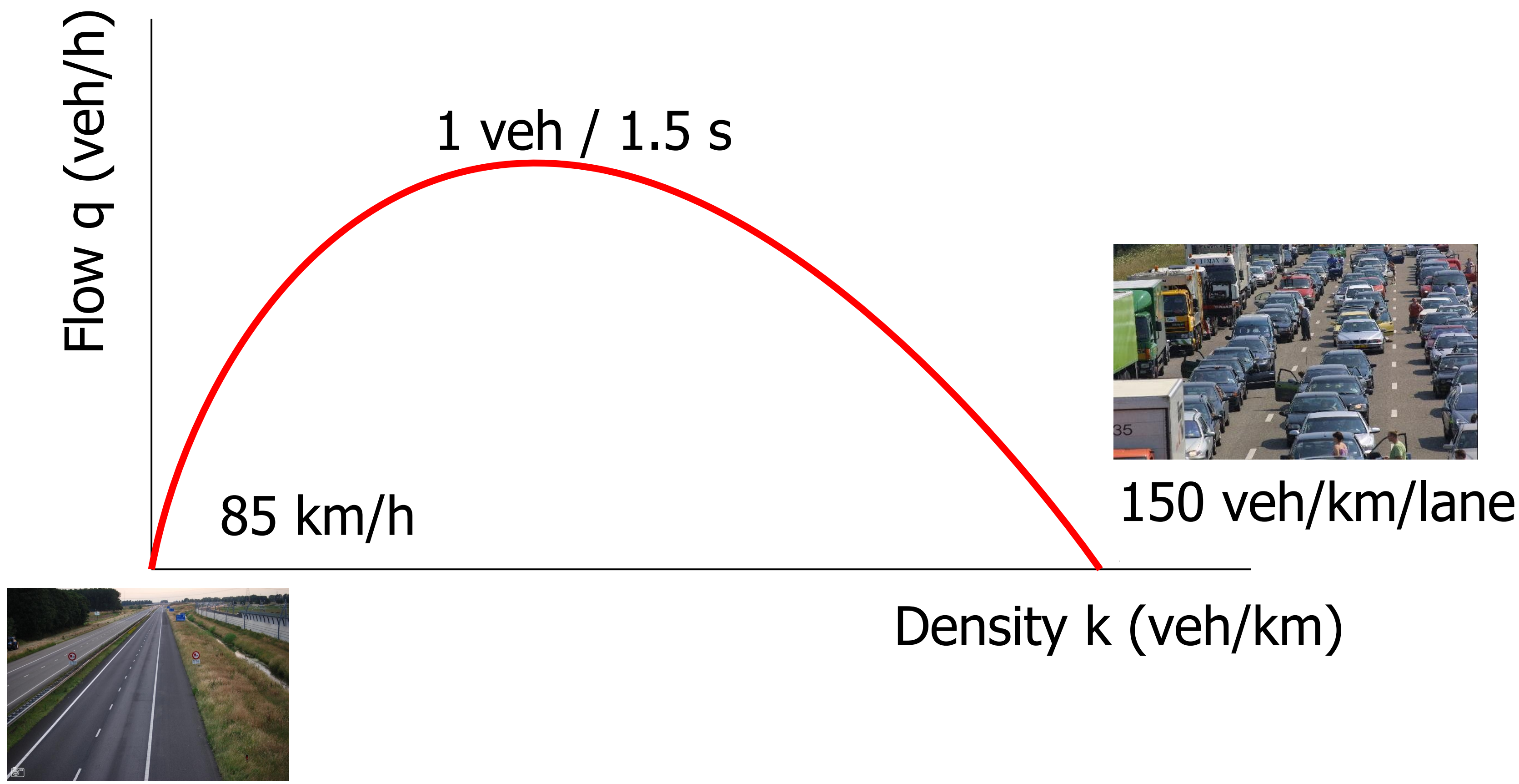
- temporary acceptance (or occurrence!) of small headways
- Jam starts inside or downstream bottleneck and moves upstream
- Also note instability of congested flow

Capacity and capacity drop

- One law and one relationship in modelling

Fundamental diagram

Flow=density*speed



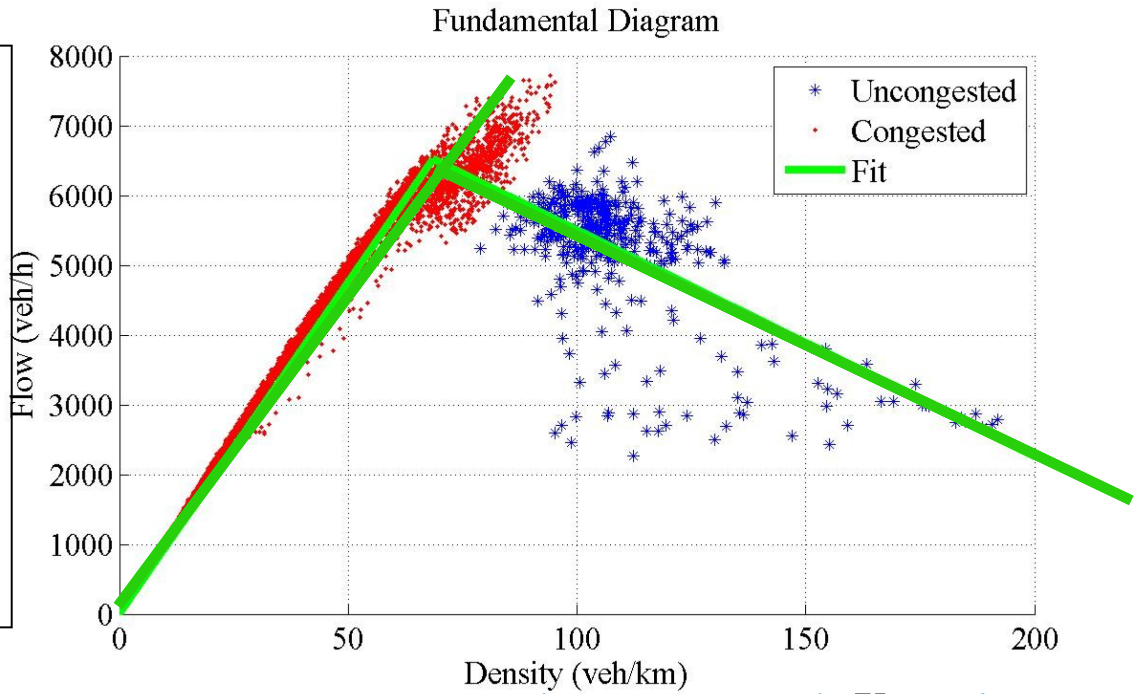
Now, the real world

- Stochasticity
- (and capacity drop)

Capactiy drop!

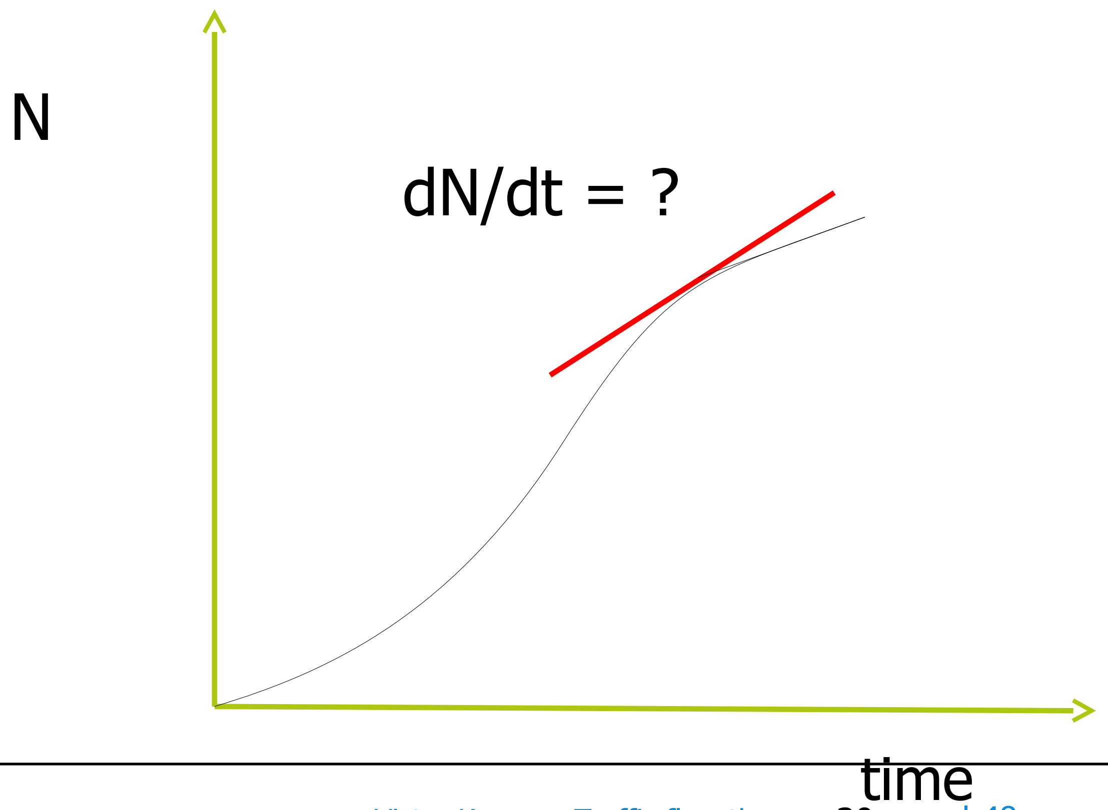
free flow capacity
is higher than
congested capacity

Inverse-lamda
fundamental diagram



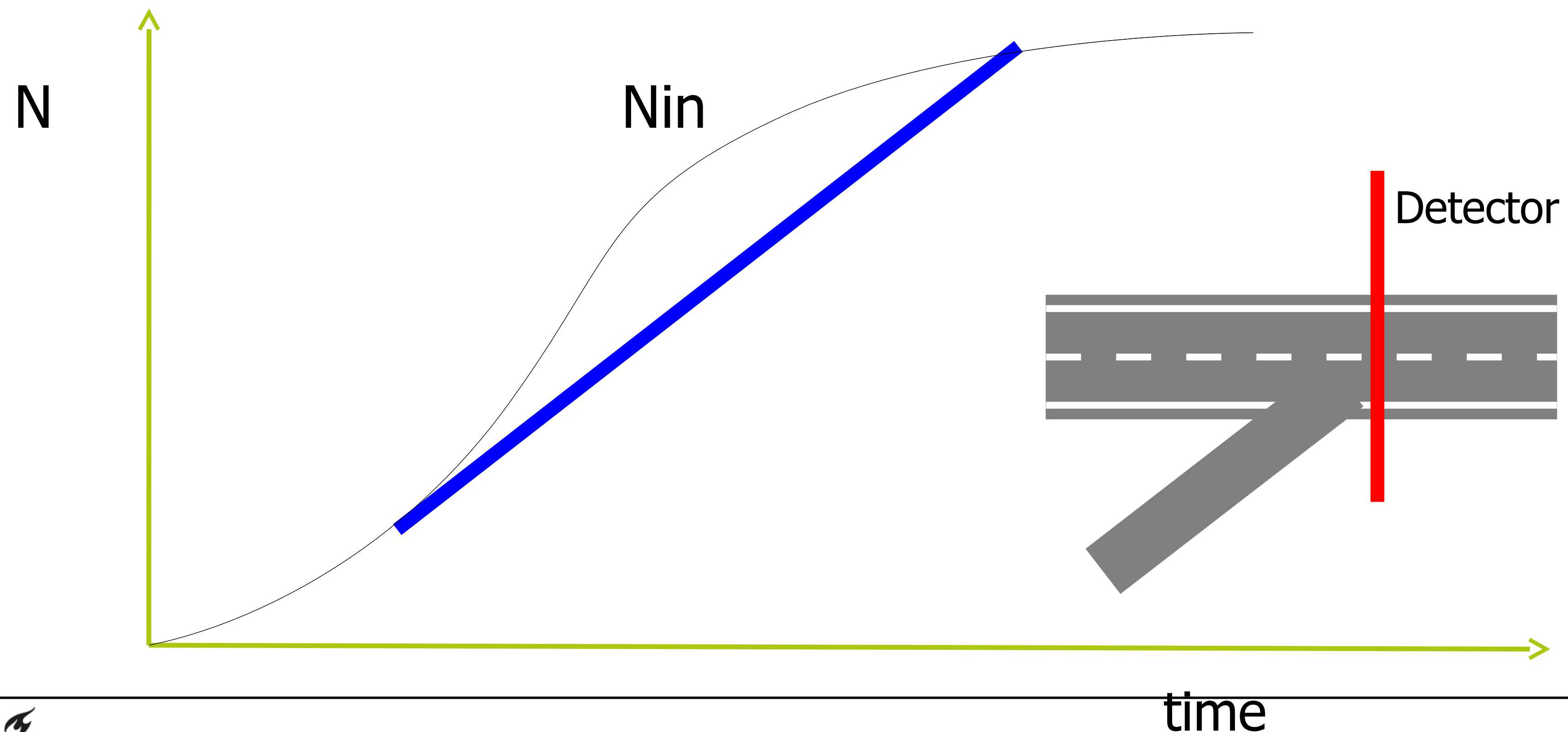
Intermezzo: calculate delays

- Consider cumulative curves, i.e. how many cars passed(N)?
- Restrictions for curve



Intermezzo: calculate delays

- One for demand (Nin) and one for outflow (Nout)



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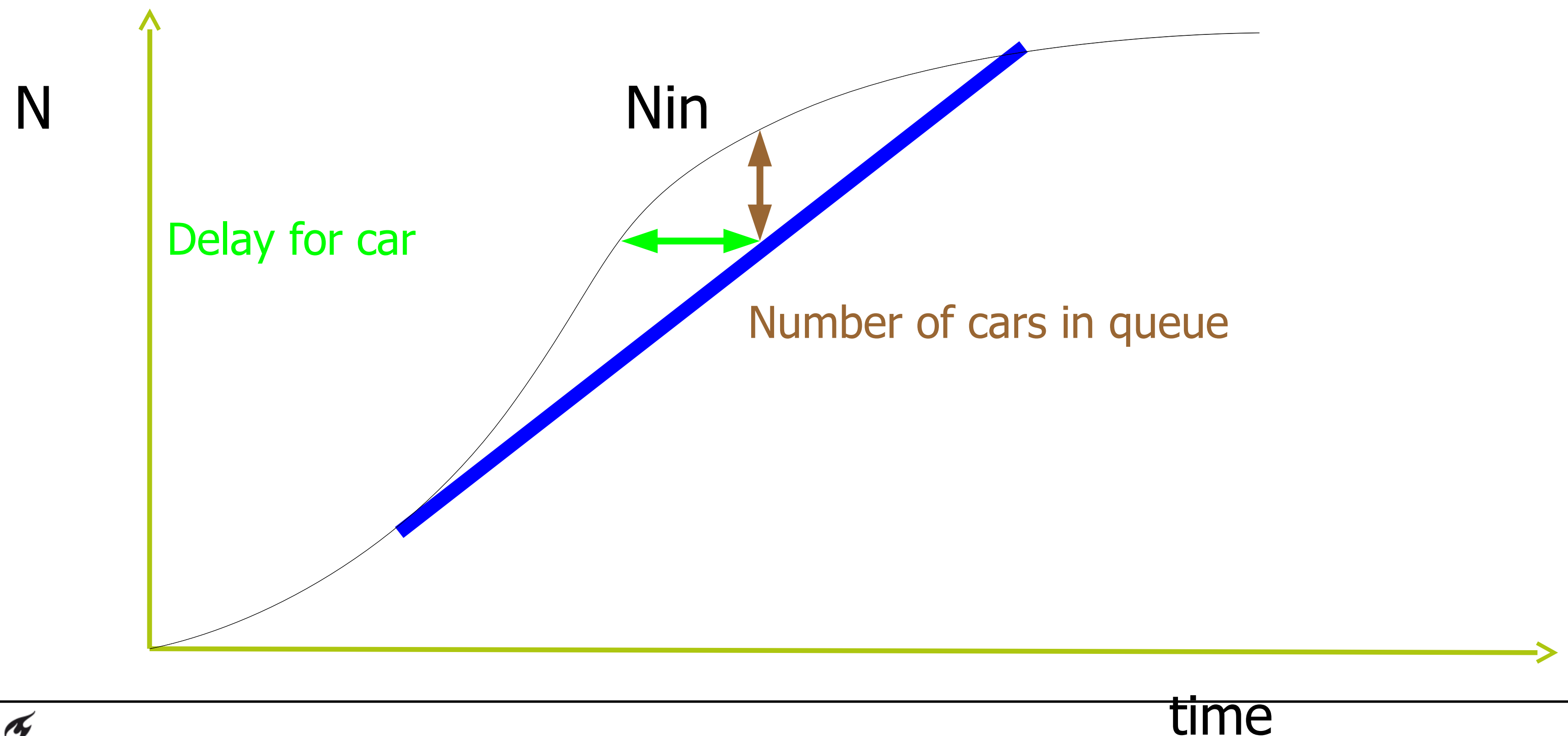
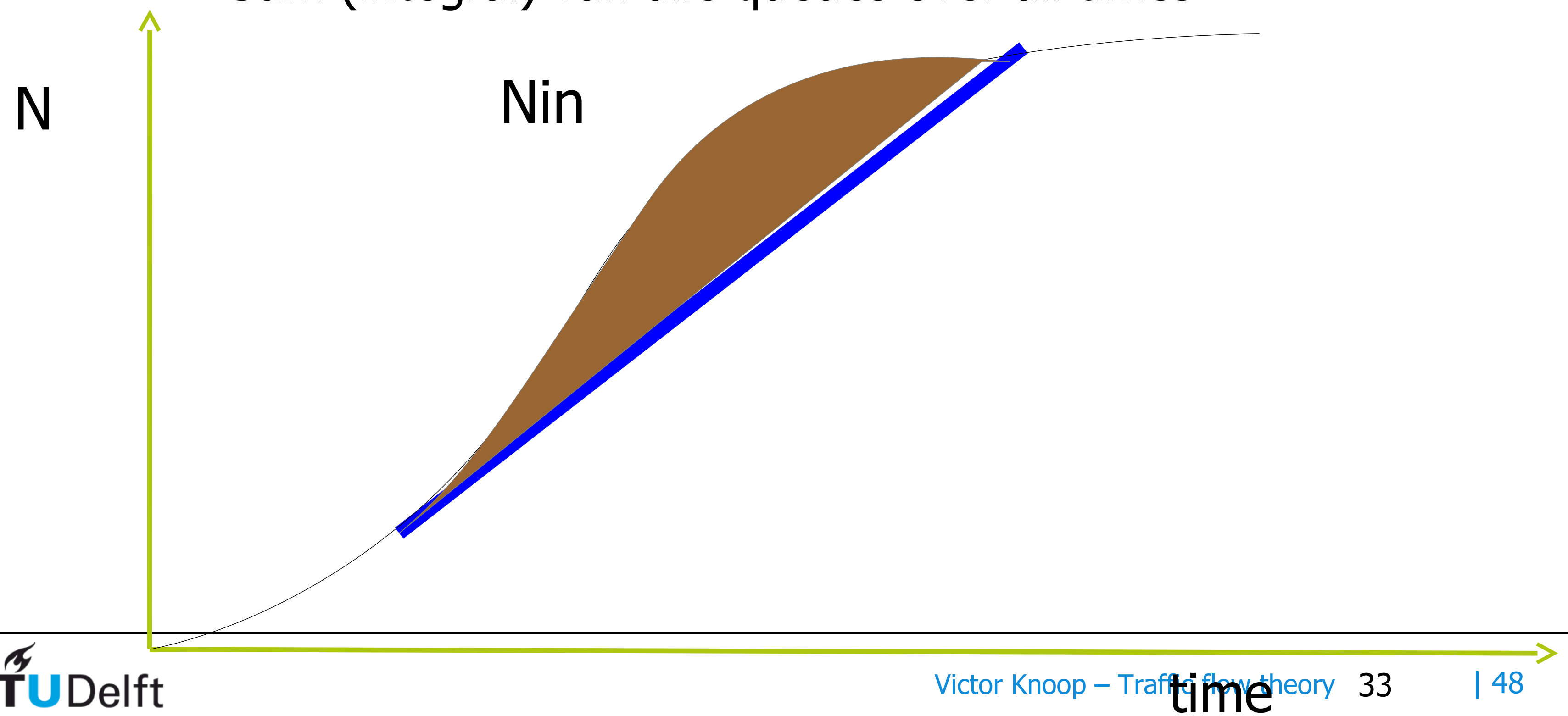


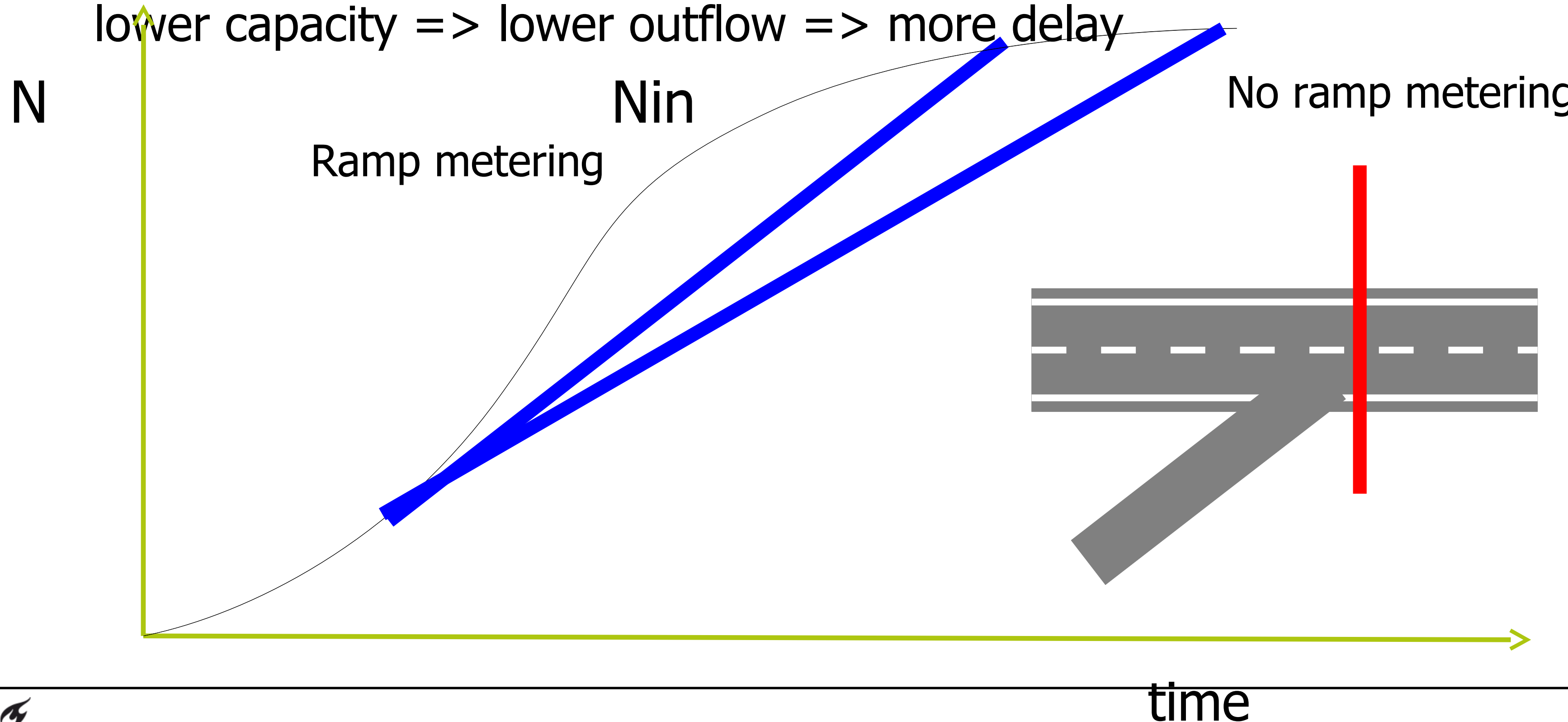
Intermezzo: calculate delays

- Total delay:
  - sum (integral) of delays over all vehicles
  - Sum (integral) van alle queues over all times



Effect ramp metering

- No ramp metering: queuing
- After queue:
  lower capacity => lower outflow => more delay



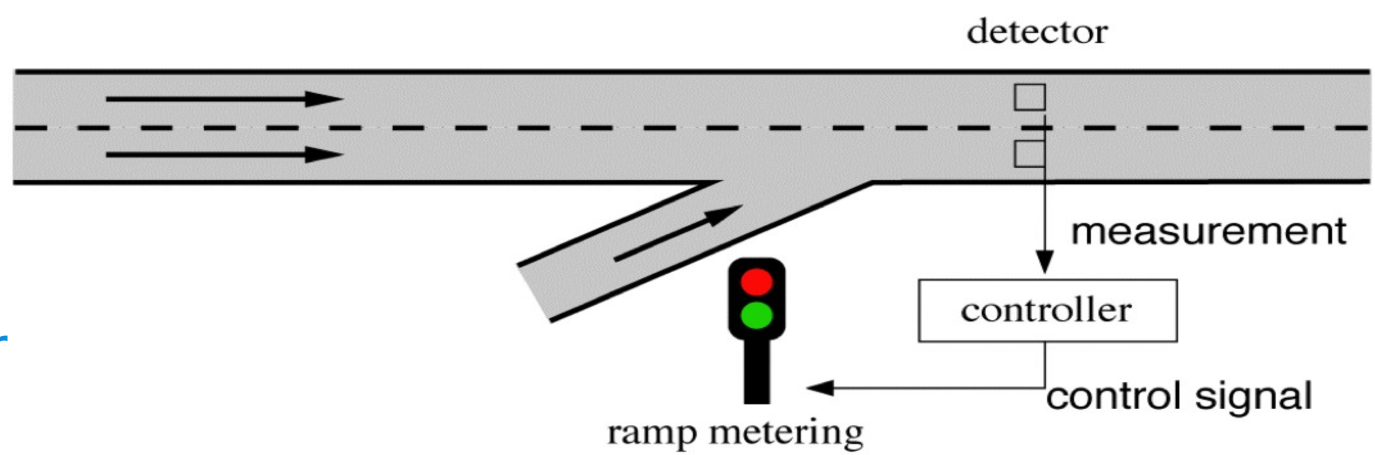
Ramp metering

- **Avoid capacity drop at motorways**

Restriction:
Queuing at underlying road network cannot exceed the available space

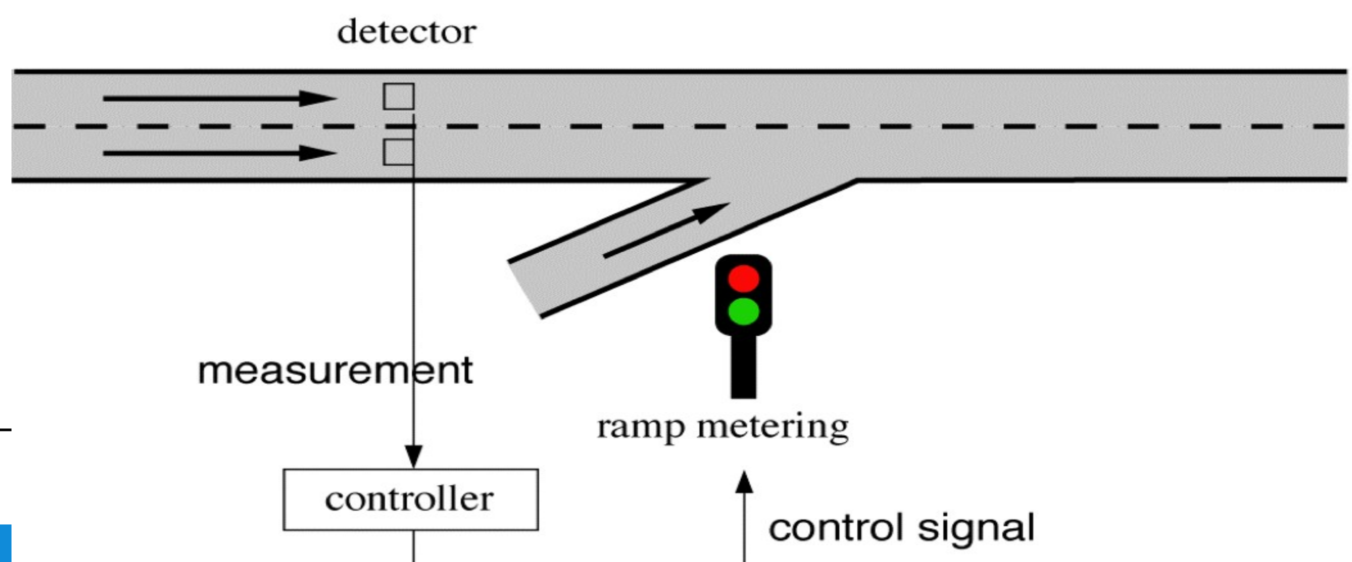
Ramp metering: avoid congestion

ALINEA algorithm



(a) TDI gebaseerd op feedback control

RWS algorithm (in NL)



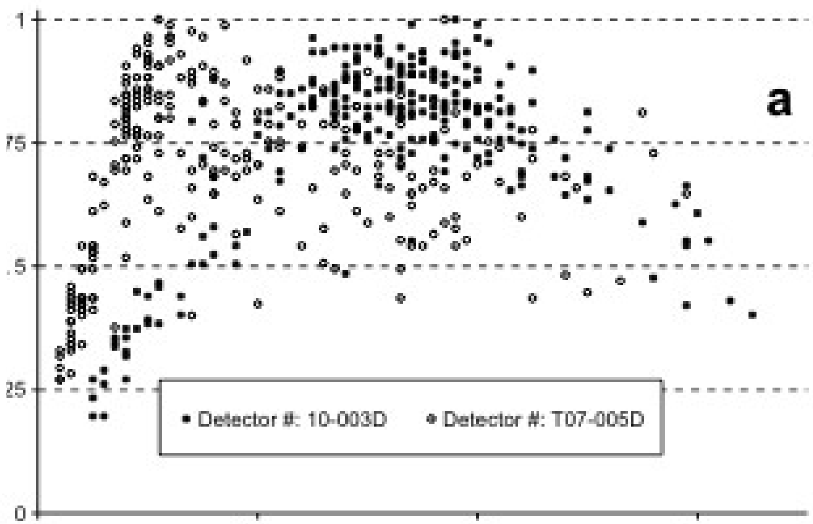
(b) TDI gebaseerd op feedforward control

Network Fundamental Diagram

Fundamental diagram

- Network Fundamental Diagram
- Average fundamental digram for an area

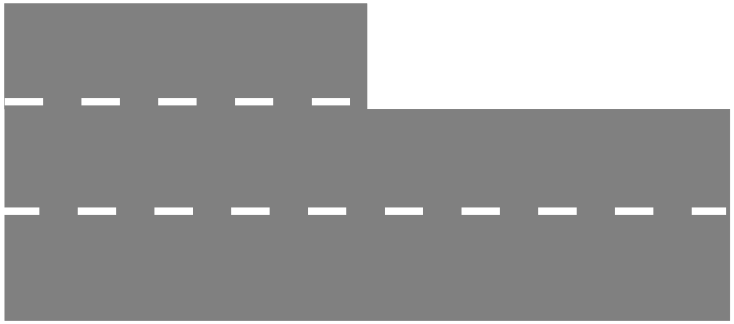
- Flow



Density

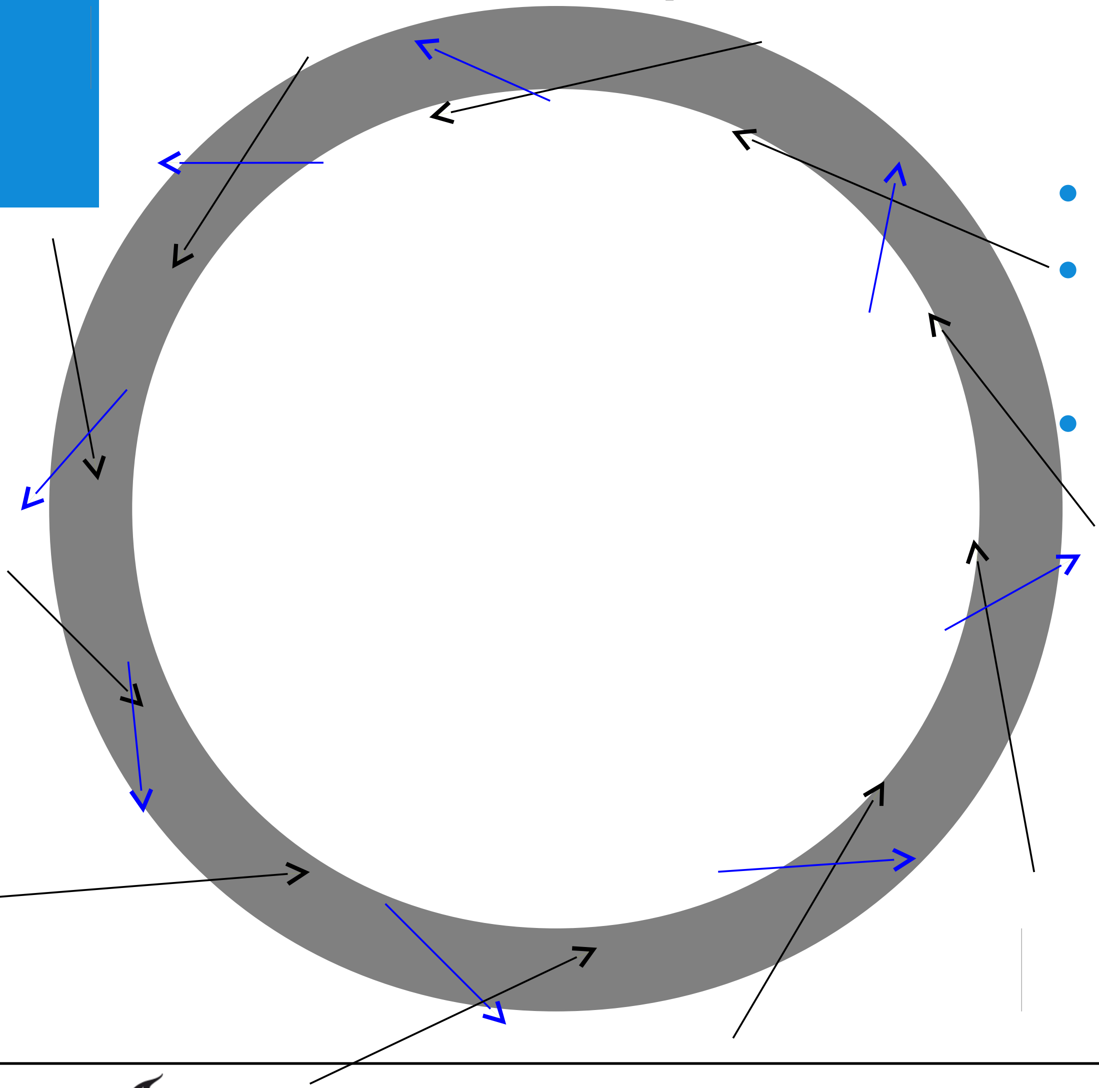
Fig: (Geroliminis and Daganzo)

Simple road



- Road with bottleneck
- What happens to the outflow

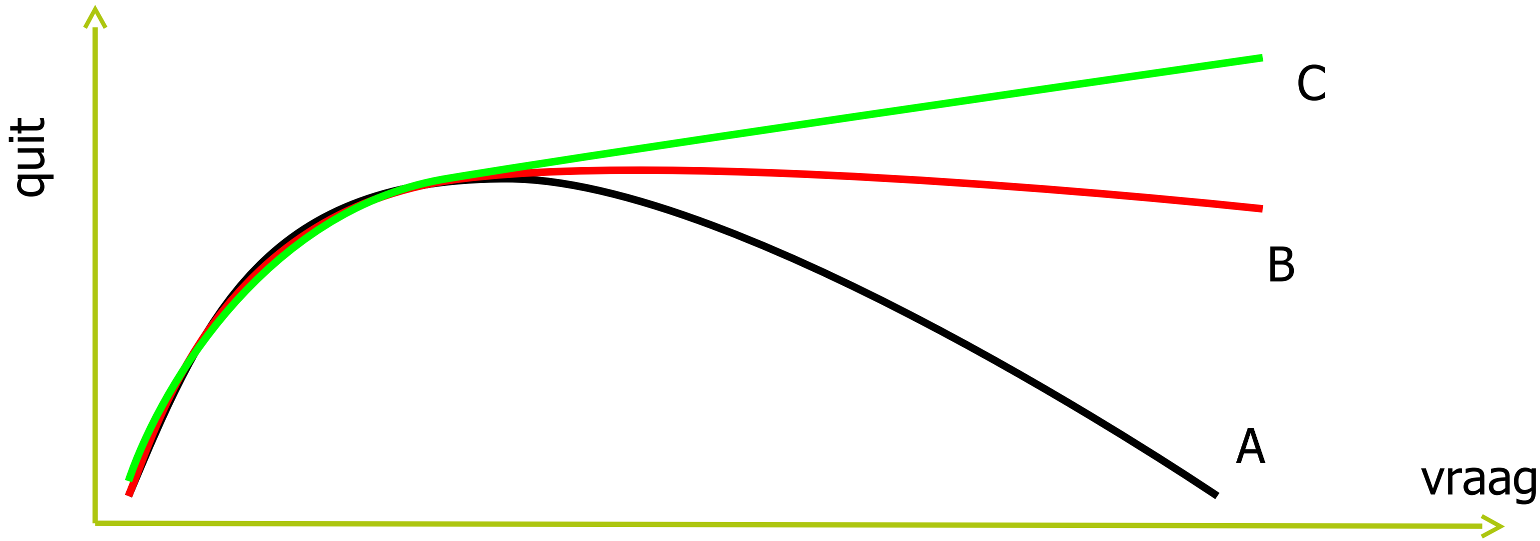
Not so simple road



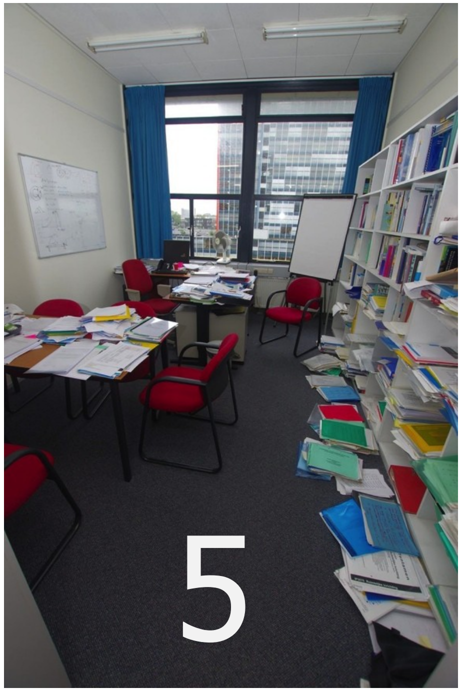
- www.traffic-simulation.de
- Origins and destinations everywhere
- Increased demand => **jams**

Network Fundamental Diagram

- What happens to the flow if the density increases?
-



Many other applications – desks



Now: simulation models for NFD

Network Transmission Model
A dynamic traffic model at network level

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www.victorknoop.eu/research

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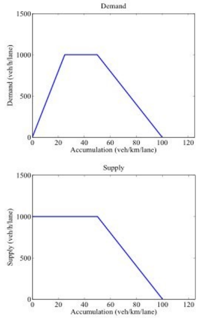
Abstract

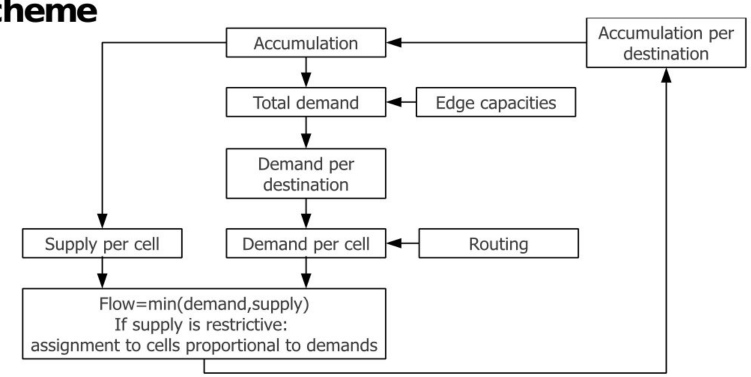
New IT techniques allow communication and coordination between traffic measures. To best use this, one needs to coordinate over longer distances. Optimization of the measures is not possible using traditional microscopic or macroscopic simulation models.
The Network Fundamental Diagram (NFD) describes the relation between flow and density on a network level. This paper introduces a traffic model which uses this relationship, representing traffic and traffic dynamics at a high spatial scale.
The model shown to work on an example network. The model can be used to predict the effect of routing information or perimeter control.

Simulation scheme

Supply & demand

- Supply and demand are based on the NFD.
- **Demand is the same as the NFD for all densities.** This is contrary to the cell transmission model where demand stays high for overcritical situations. However, in networks gridlocks can occur.
- Supply is, similar to the cell transmission model, at capacity at under critical accumulation and follows the NFD for higher accumulations. Supply reduction is essential for blocking back



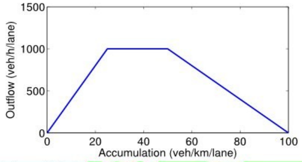


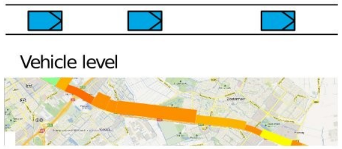
Background

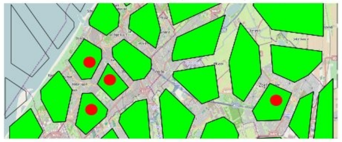
Introduction

- Modern IT techniques allow for coordination of traffic management measures.
- Larger areas need a longer time horizon for the traffic optimization
- Microscopic and macroscopic simulation programs are too slow for large area and long simulation times

The **Network fundamental diagram** describes the relationship between accumulation (average density) and the (unrestricted) outflow out of the network

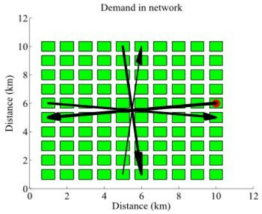






(Sub-)network level

Case study



- 20x20 square areas of 1x1 km
- Cross demands

Control measures

- Dynamic route guidance
  - based on speeds in areas
  - variable update times
- Gating
  - Limit inflow such that accumulation stays under critical accumulation
  - Vary the traffic areas where gating is applied

Results

- Gridlocks prevented
- Considerable decrease of delay

Next steps

- Calibrate for a real world network
- Implement in a model predictive control framework

Conclusions

We propose a model that describes the traffic dynamics on a network level scale. The base elements are the subnetworks, and the flows from one subnetwork to another are calculated using the proposed scheme. The model accounts for blocking back from downstream as well as internal gridlocks within a cell.
A case study showed how the model can be for traffic control (gating and routing). We used feedback controllers to optimize the traffic stream, but given the limited computation steps the model can also be used in a model predictive control framework.

Sponsored by: NWO Netherlands Organisation for Scientific Research

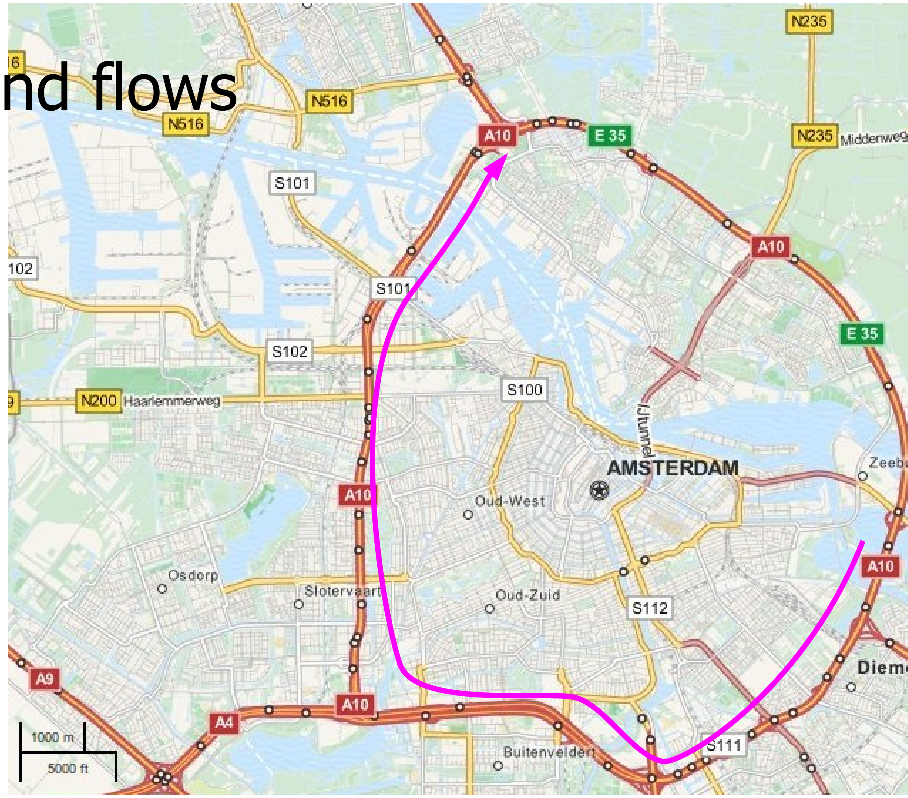
Project: there is plenty of room in the other lane

Delft University of Technology
Transport & Planning

Practical implementation Amsterdam

Coordination of ramp metering

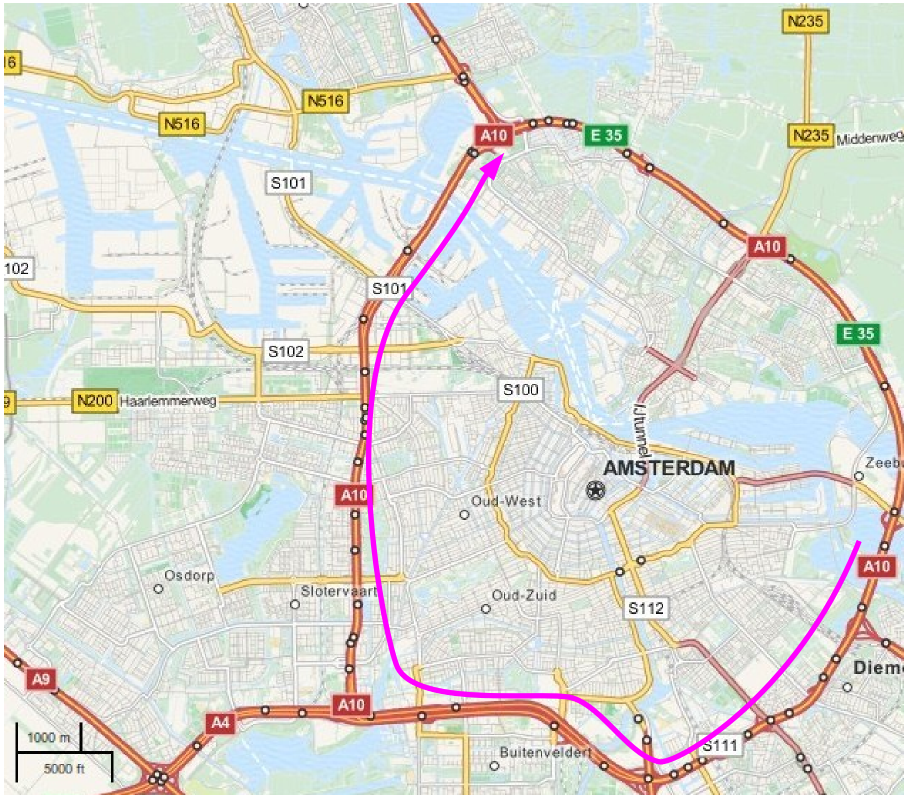
- Delay between access and measurements => To many cars in network
- Banace between spillback and flows => limit inflow upstream



Field test

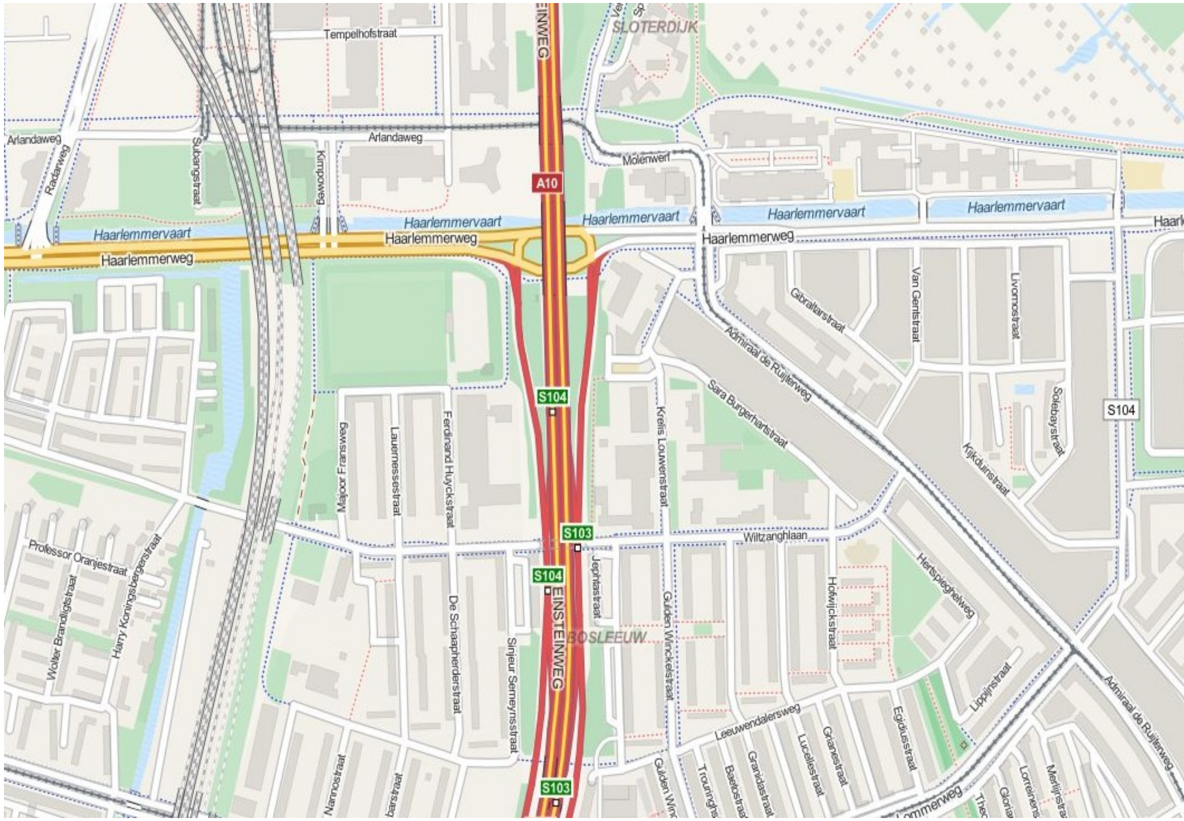
- Coordinate ramp metering
- Limit upstream

- How much to allow from which ramp?



Network measurements

- Use of ramp metering limited
- More buffer space by coordination with underlying road network
- Maximum queue length per traffic light



Questions

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