Importance of considering uncertainty for ITS

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TrafficQuest CENTRE FOR EXPERTISE ON TRAFFIC MANAGEMENT

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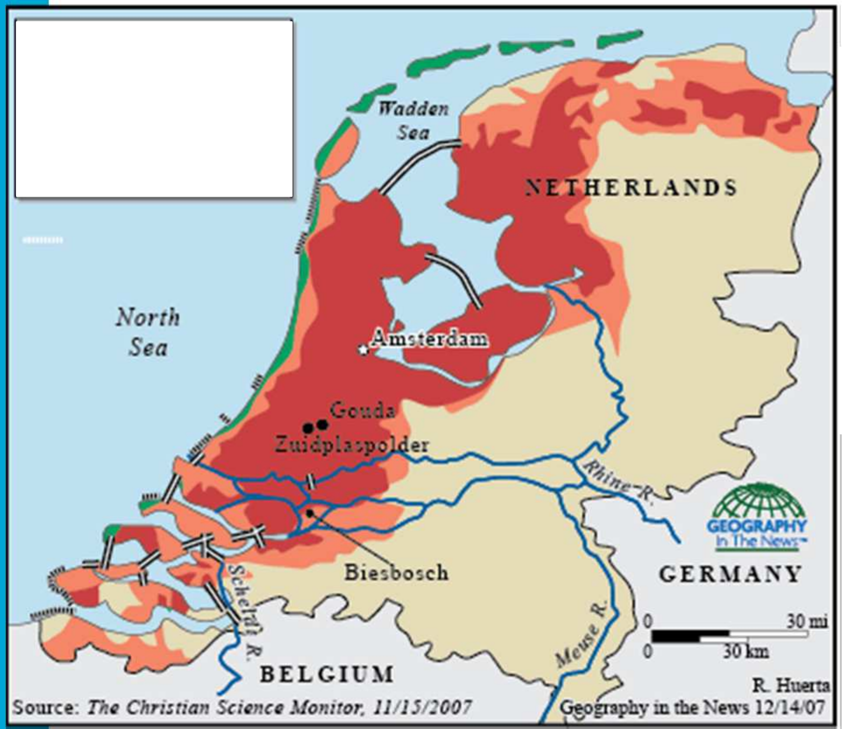
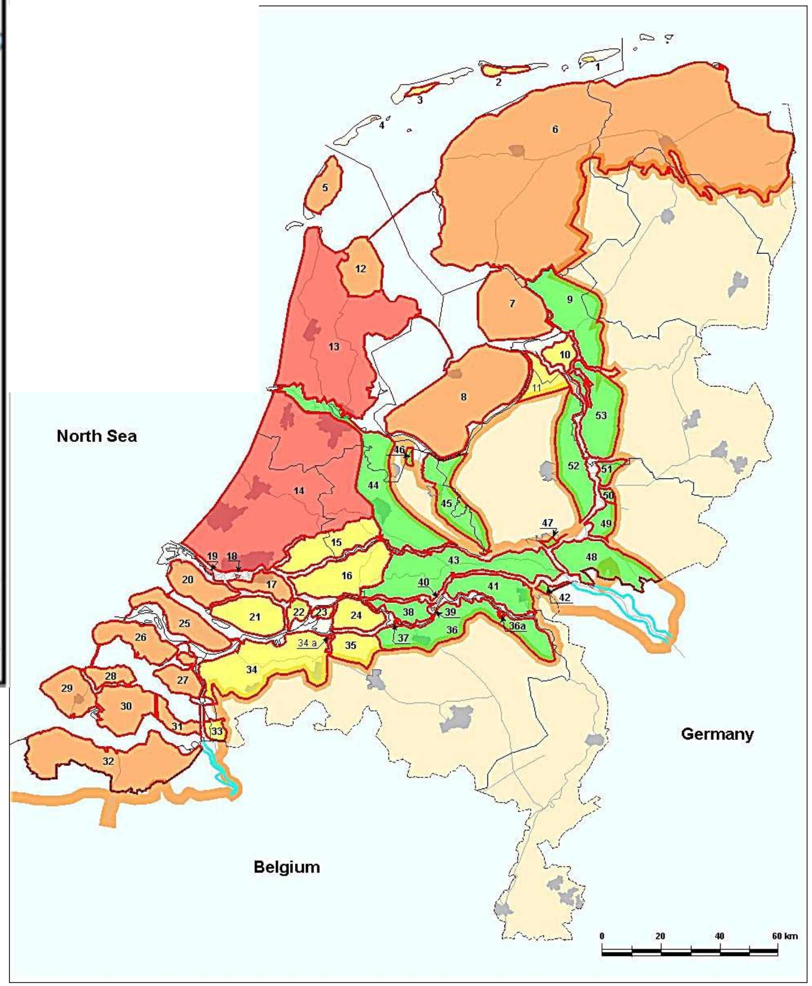
Introduction





- ITS & UNCERTAINTY
- GENERAL MODELLING APPROACHES
- ADVANCED TECHNIQUES
- DEMONSTRATION
- FINAL NOTES

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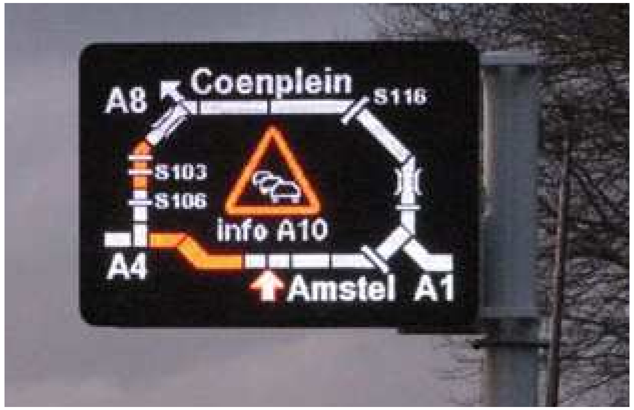
Why do we need ITS/DVM?



What’s the model for?

- To evaluate the performance of a traffic system
  - Existing situation
  - Hypothetical scenarios

What's the model for?

- Where it is not feasible to extract information through observation
  - Situation or scenario does not exist
  - Too expensive
  - Too invasive

- Models are tool for decision makers, not the decision makers!

A description of traffic flow…

- Traffic flow is directly related to how people drive
- People (= drivers) often drive on ‘auto-pilot’
- People are effective with driving -> they are all experts
- Pretty irrational experts,
  - Sometimes do weird stuff
  - Sometimes underperform
  - Certainty not uniform
  - … and more…

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A description of traffic flow…

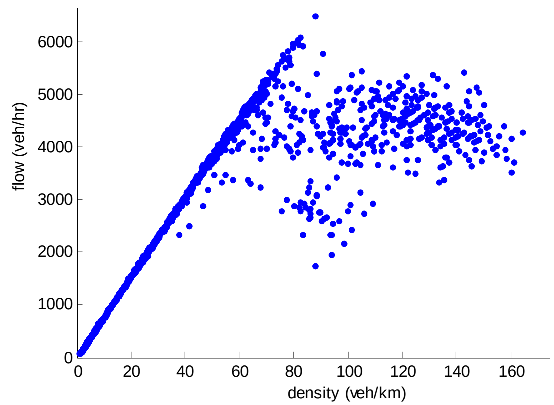
- Therefore traffic flow…
  - Can be described by universal equations
  - With a fair share of certainty (free-flow FD)
  - And a fair share of sprawl (cong FD)
  - …

$$q = kv$$

$$\frac{\partial k}{\partial t} + \frac{\partial q}{\partial x} = 0$$

$$q = Q_E(k)$$

- Conclusions:
  - General theory does apply, BUT…
  - With much uncertainty and stochastics



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What goes wrong when we ignore uncertainty in traffic analysis?

Garbage in = Garbage out

What goes wrong when we ignore uncertainty in traffic analysis?

- But seriously: a little garbage (= inaccuracy) can lead to a lot of bias
- Traffic management considering stochasticity:
  - DRIP for accidents (A10): **9%** higher total delay time (Calvert & Taale, 2012)
  - Regular congestion: **33%** higher total delay time (Calvert, Taale, Snelder & Hoogendoorn, 2012)
  - Peak-hour lane (A13): **20%** higher total delay time (van Lint, Miete, Taale & Hoogendoorn, 2012)
  - Ramp-metering (A20): **2-12%** higher total delay time (Calvert, 2016)

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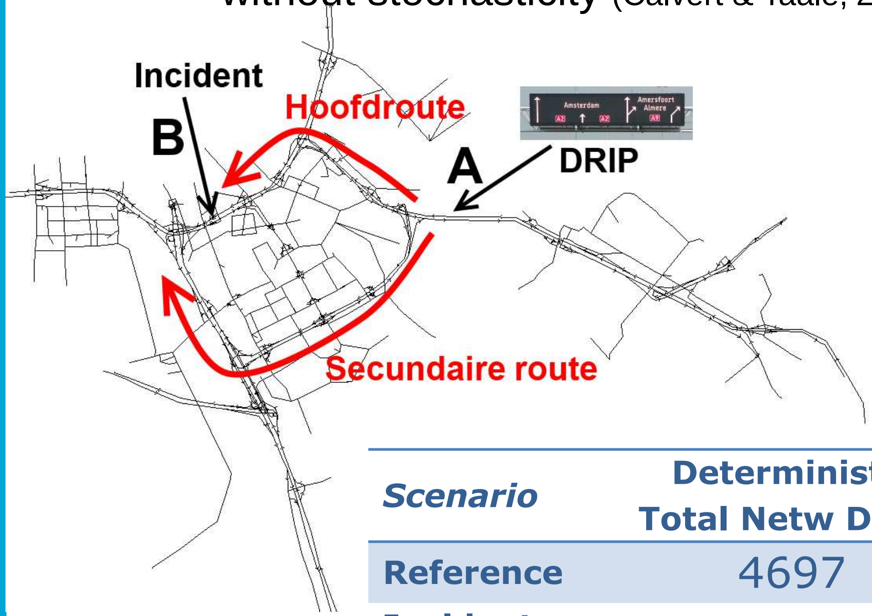
What goes wrong when we ignore uncertainty in traffic analysis?

- Traffic management considering stochasticity:
  - DRIP for accidents (A10): **9%** under-estimation of total delay time without stochasticity (Calvert & Taale, 2012)



Scenario	Deterministic Total Netw Delay	Stochastic Total Netw Delay	Difference
Reference	4697	5158	
Incident Scenario	7825	8578	
Difference Ref-incident	3128	3420	**292 (9%)**

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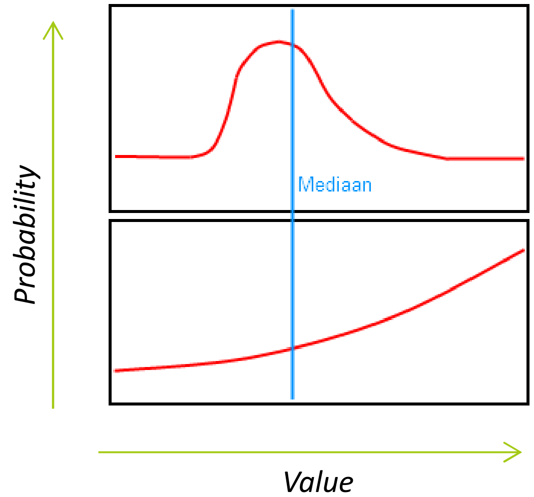
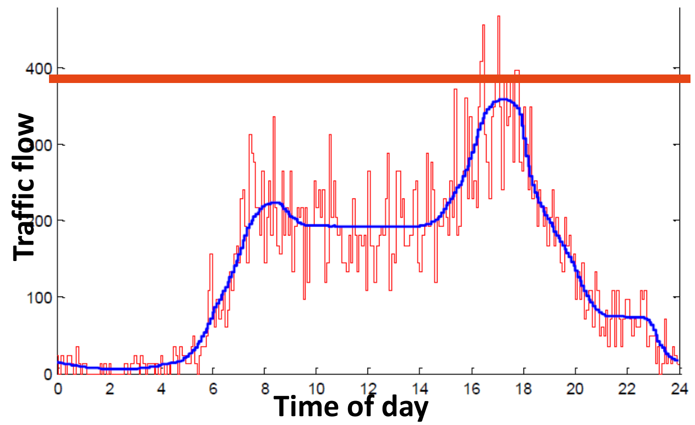
What causes these effects?

- Non-linearity of system performance vs parameter values



- Secondary (network) effects

- Trigger value vs mean/median



So what's the solution?

- Consider which **input variables** are stochastic
- And which ones have a **non-linear influence** on traffic
- Apply a **suitable approach** that considers this
- When to use probabilistic modelling:

Stochastic modelling	***Deterministic modelling***
Applicable for…	*Applicable for…*
Variation in input variables	Negligible variation in input variables
Distribution of input variable is **reliable** and can be **easily determined**	Distribution is unreliable and cannot be easily determined
Variation in input variables has an **amplified effect** on model outcome	Variation in input variables has a limited or linear effect on model outcome
Congested network with **high congestion volatility**	Uncongested network or congested with low congestion volatility
Comprehensive overview of network performance	General indication of network performance

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Modelling approaches

- Monte Carlo simulation
- Sensitivity analysis / modelling
- Scenario approach
- Analytical calculation
- Core-probabilistic traffic modelling

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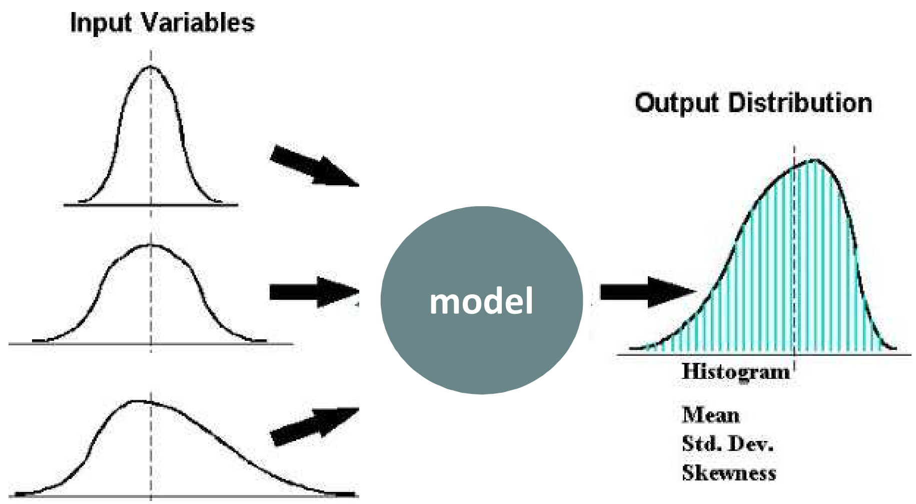

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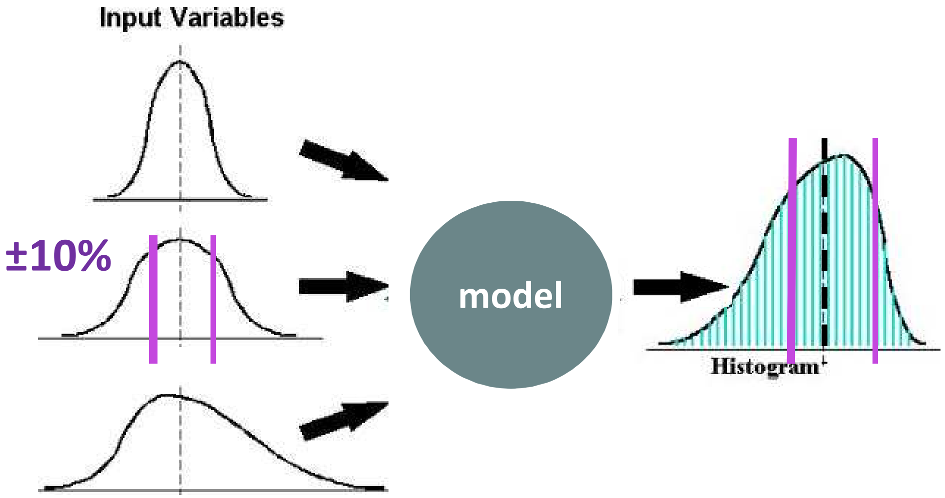

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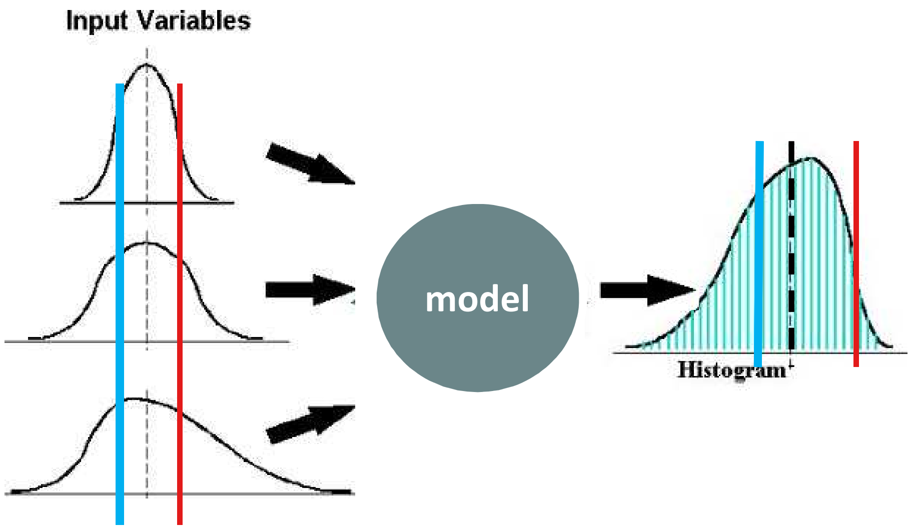

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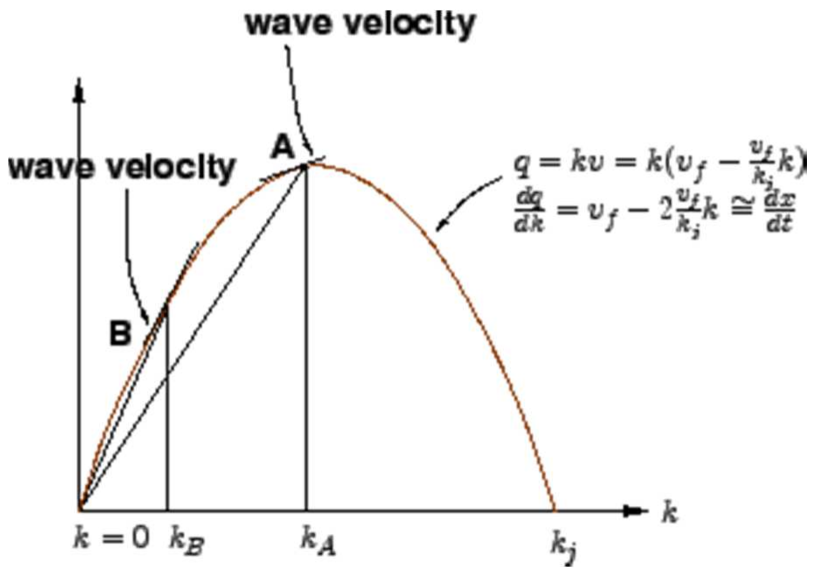

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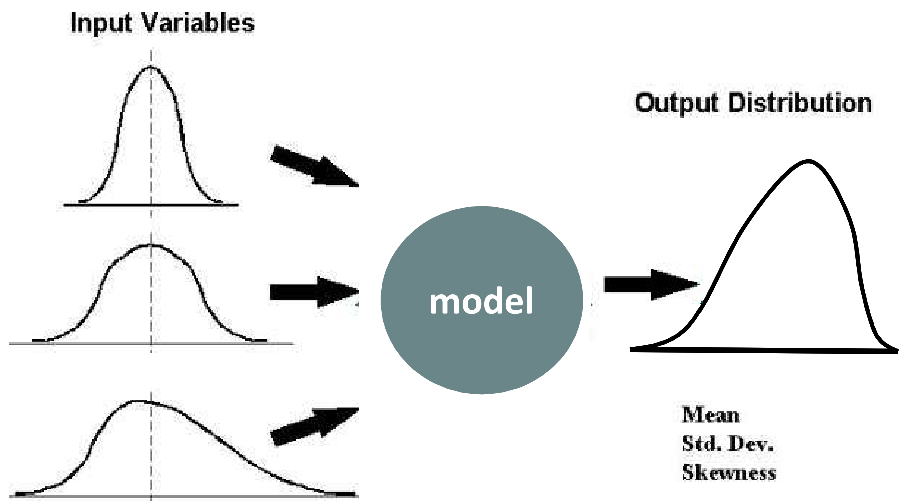

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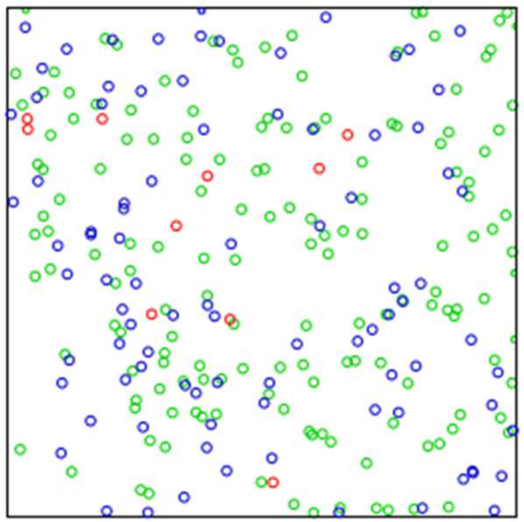
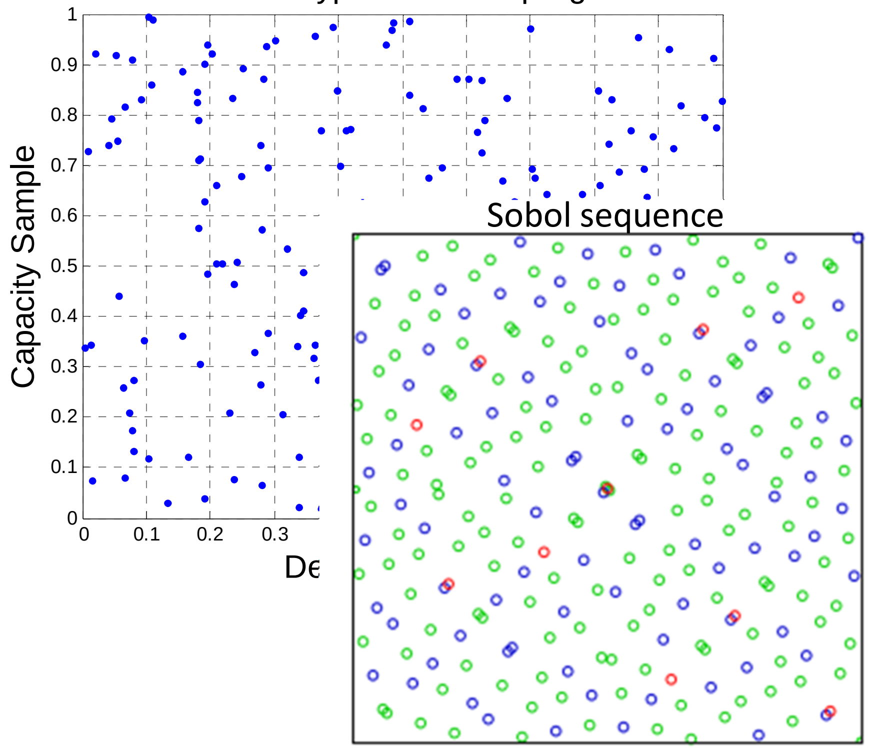
Modelling approaches:
Up-grade the traditional approach

- Monte Carlo simulation is simple & effective, but slow!
- Advanced Monte Carlo simulation:
  - uses variance reduction techniques to limit the number of simulations

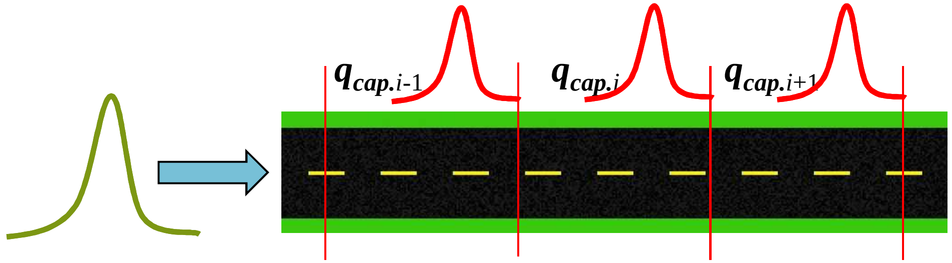
Random samples

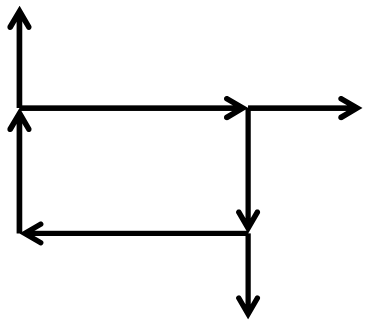




Modelling approaches: Core-probabilistic traffic

- Ideal approach: as basic model is kept simple & fast, while uncertainty is included
- However number of unsolved drawbacks
  - Mainly related to dependencies





Cap\Dem (veh/min)	P(30) = 0.5	P(35) = 0.5
P(29) = 0.5		
P(33) = 0.5		

	P	P	P	P
P	...			
P				
P				
P				

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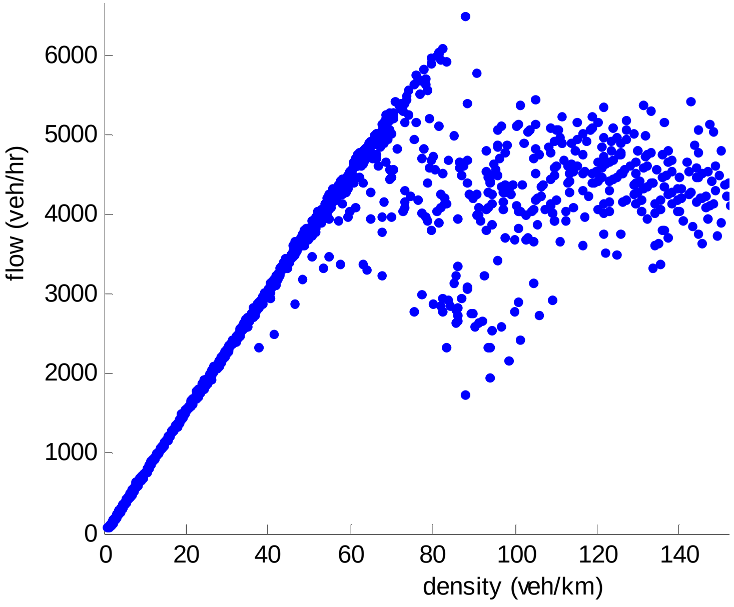
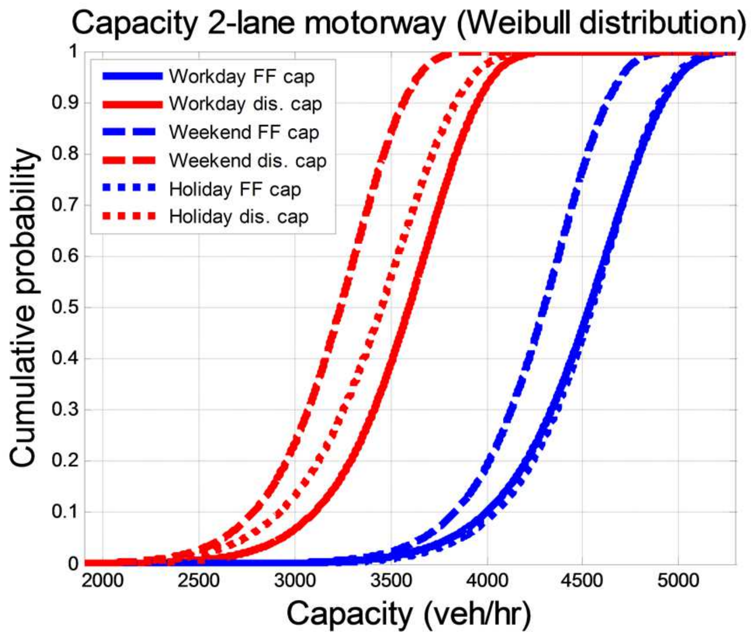
Modelling approaches: Tactical & Operational

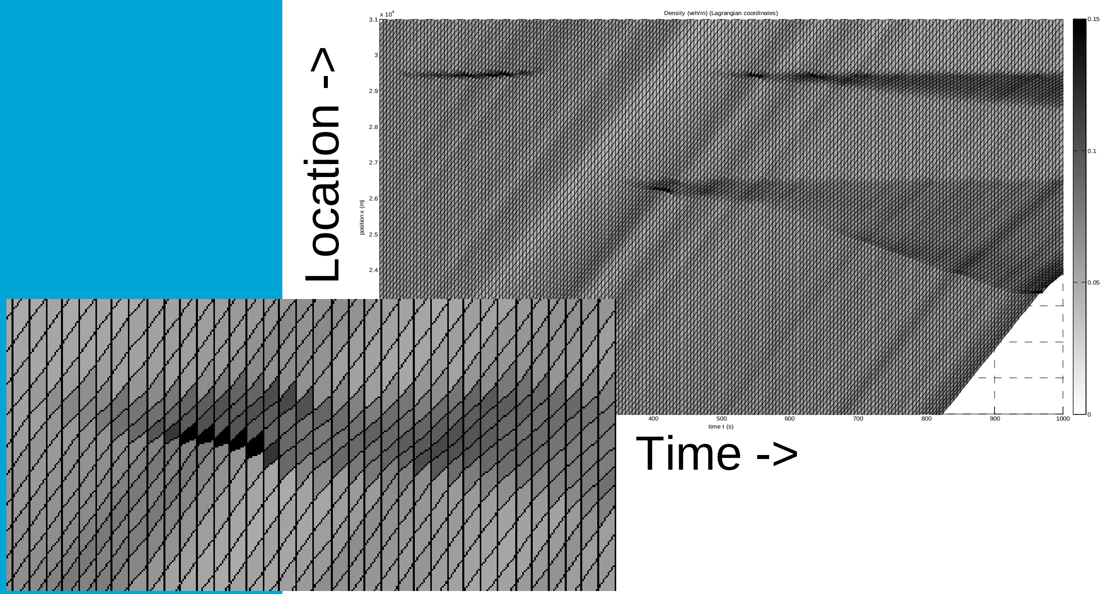
- Microscopic fluctuations influence congestion onset & severity

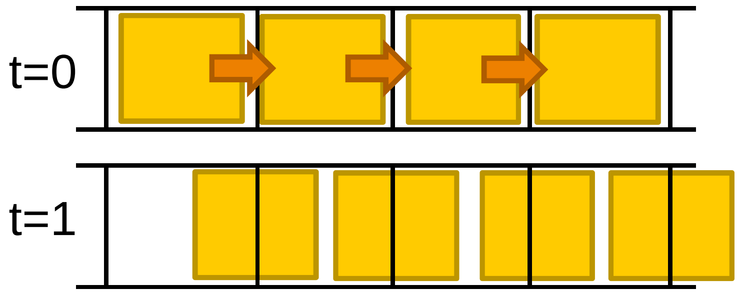




Modelling approaches: Tactical & Operational

- First Order Macroscopic model with Stochastic Advection (FOMSA)
  - Allows macroscopic consideration of microscopic dynamics
  - Works much faster than microscopic simulation
  - Based on **Lagrangian flow** / **vehicle specific stochastics**





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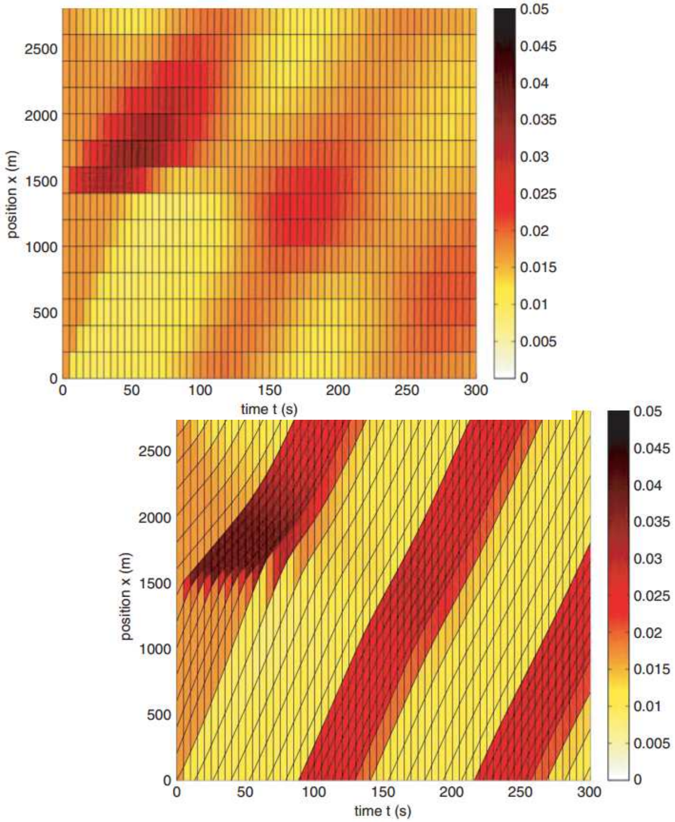
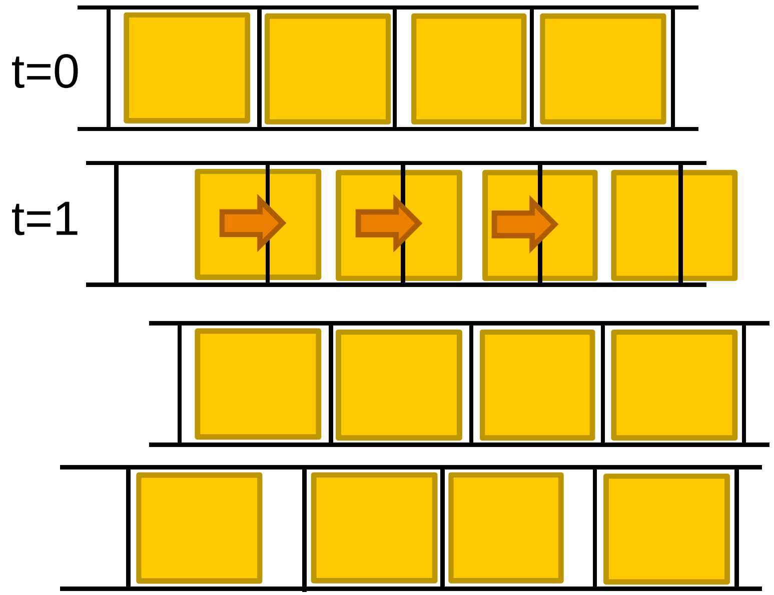
Modelling approaches:
Tactical & Operational

- FOMSA
  - Based on **Lagrangian flow / vehicle specific stochastics**



Source: Van Wageningen-Kessels et al 2010



- Perspective: Why ITS and modelling (keep short!)
- Intro
- What goes wrong when we ignore uncertainty / fluctuations? -> and the consequences
  - Traffic anal / SCBA / …
- What are the phenomena/dynamics that cause this?
- .
- How can we avoid these difficulties? (in general / abstractly)
- Modelling uncertainty and stochastics -> general approaches / important issue to keep in mind
- Explain some specific approaches (from PhD)
- Some cases to demonstrate
- Therefore: what should we do?
- What about the future:
  - What do we still need?
  - What should we consider (of not)? (i.e. so much uncertainty ni 30 years time – AV's etc – also we are modelling details while the global variables are so variable)

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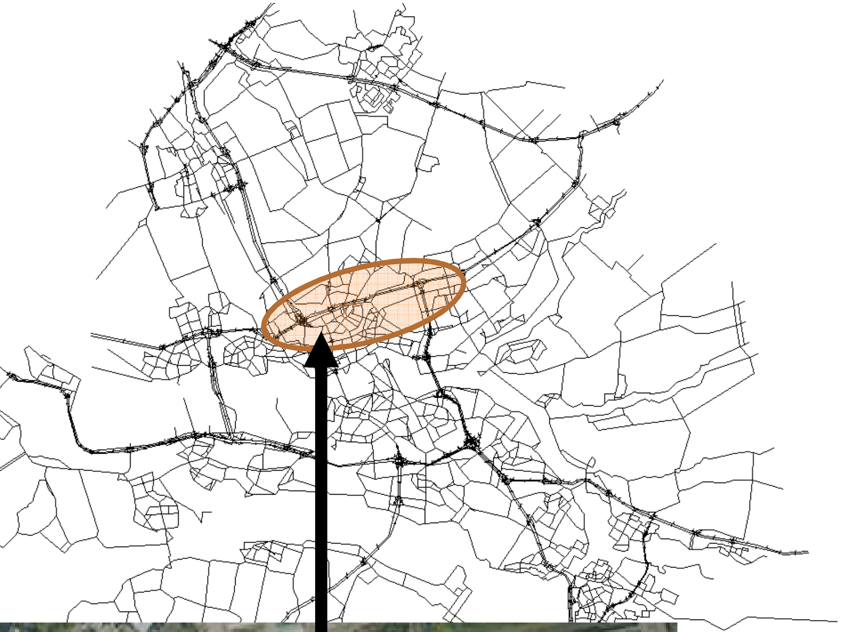
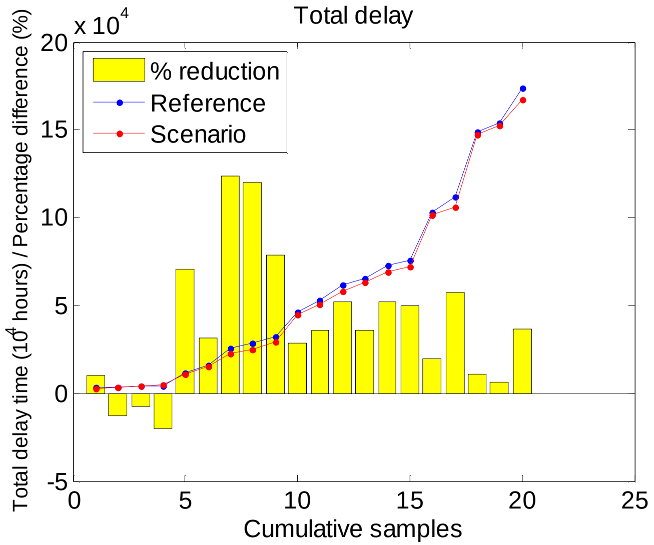
Demonstration case 1

- A20 motorway NL
- Ref: no ramp-metering
- Scen: ramp-metering
- 20 scenarios (samples)
- Advanced Monte Carlo

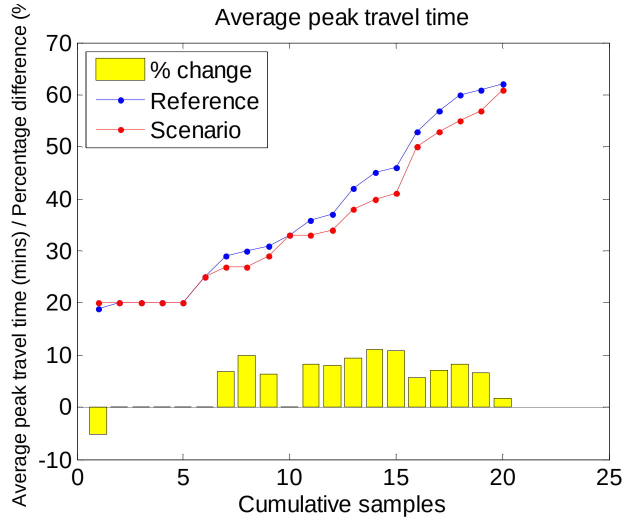


Demonstration case 1

- Reduction in delay
- 0-12% decrease



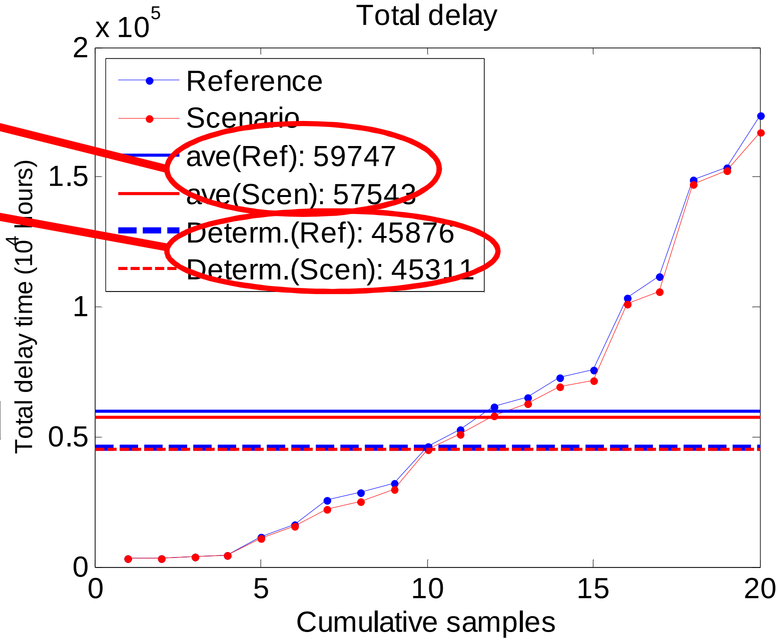
- Reduction in travel time
- 0-11% decrease



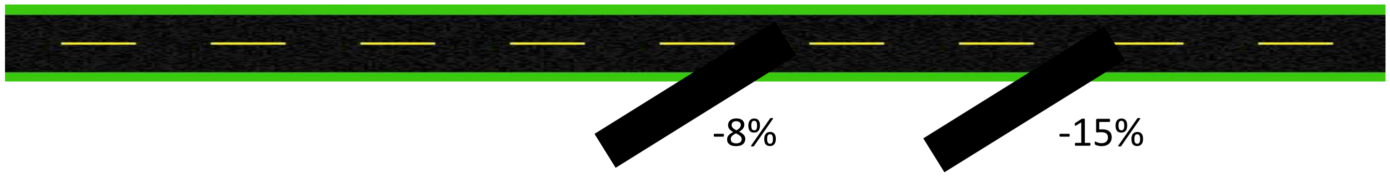
- Measure is effective
- BUT…

Demonstration case 1

- With Uncertainty: 4% gain!
- Without uncert.: 1,2% gain!
- Effectiveness is greater than expected



Demonstration case 2



- Motorway corridor:
  - 11 kilometre
  - Uniform traffic flow: 2000 veh/hr
  - Dual bottleneck: capacity reductions: 8% & 15%
  - Capacity reduction of 11% is sufficient to lead to congestion
  - Stochastic boundary parameter (alpha) = [0.2]
  - Therefore 20% deviation from average vehicle performance (measured as car-following distance)

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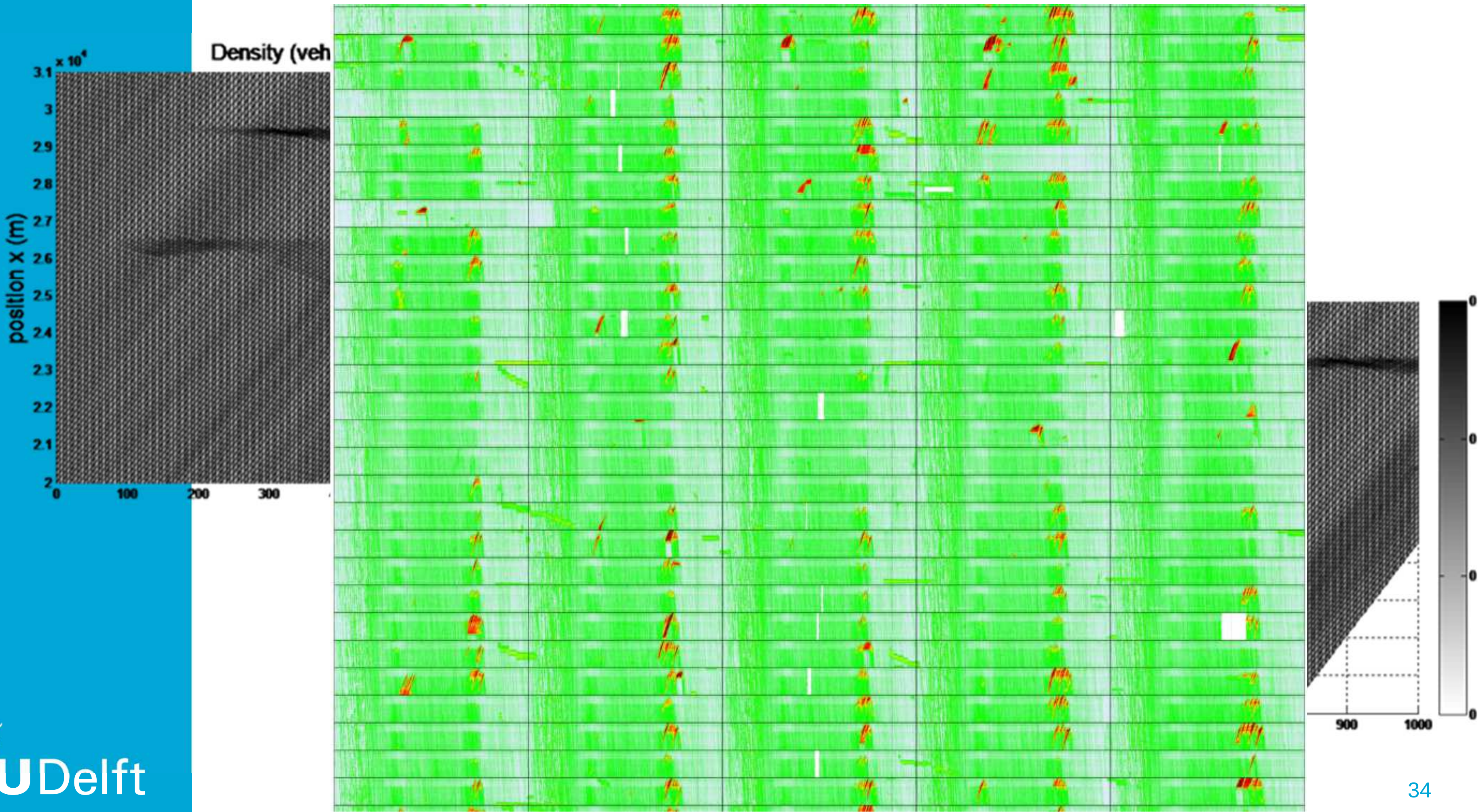
Demonstration case 2

- Initial outcome



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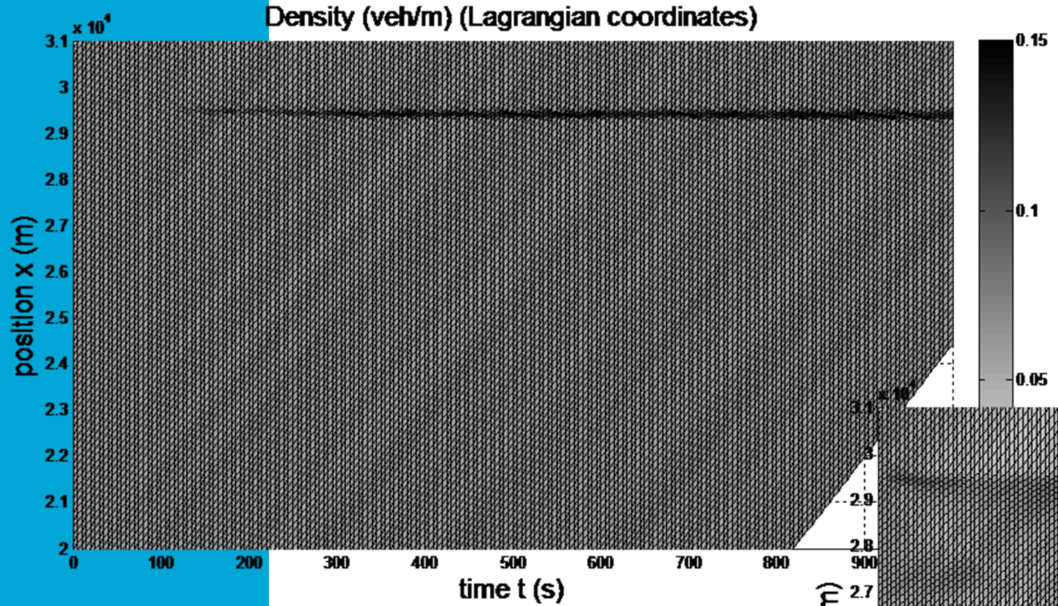
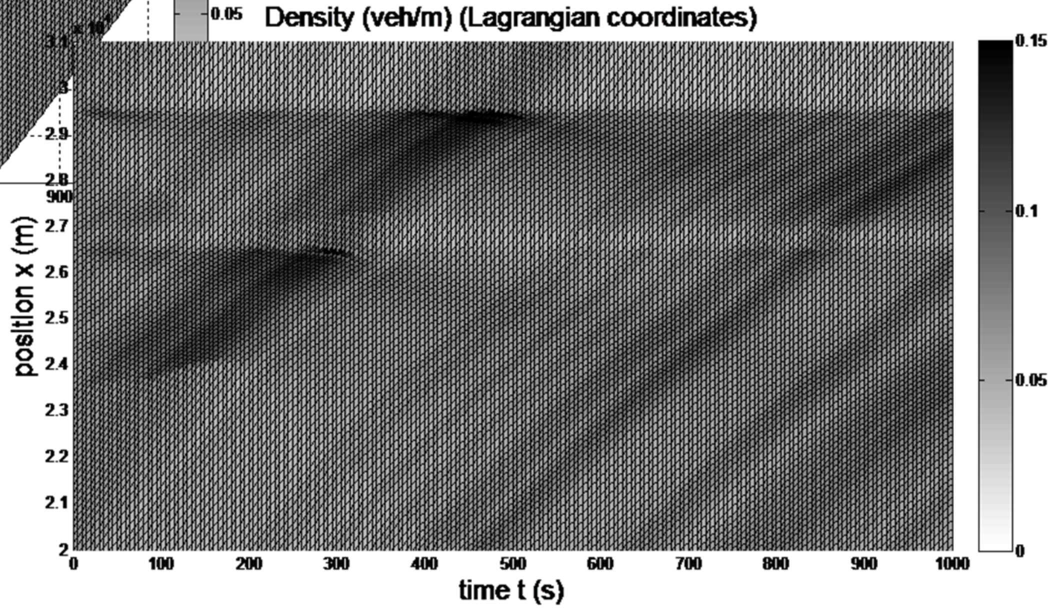
Demonstration case 2

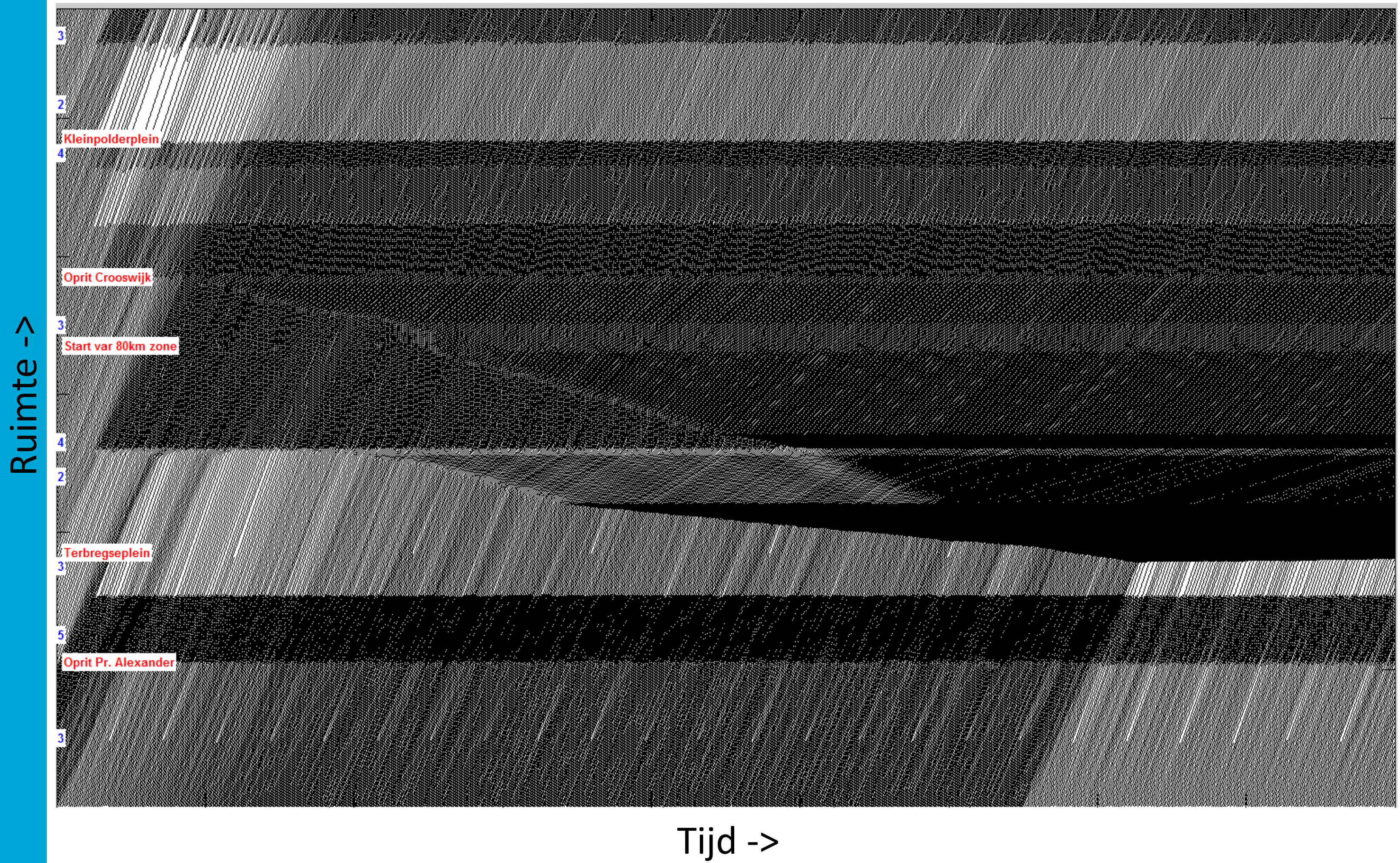


a=0.05

a=0.40



Demonstration case



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Final remarks; what should we do?

- Evaluation in ITS/DVM is important
  - also after implementation
- ITS/DVM is often more effective than we think
  - and cheaper
- Uncertainty & stochastics in traffic should be considered
- Current model practices do not sufficiently consider this
  - Both government & industry need to realise this
- Challenge to devise new models, but also new practices
- Be realistic: sometimes quick & dirty is OK
  - Sometimes it is most certainly not
- Maintain perspective: what is the scale of predictions vs uncertainty?
  - No point modelling small details when macro uncertainties exist
  - The future is not always extrapolation

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Thank you for your attention!

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