Generalised Network Fundamental Diagram Modlleing and control

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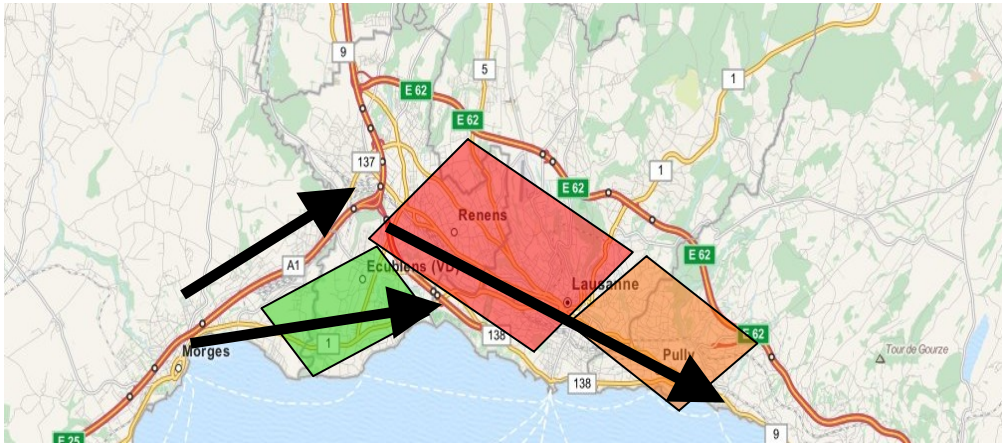
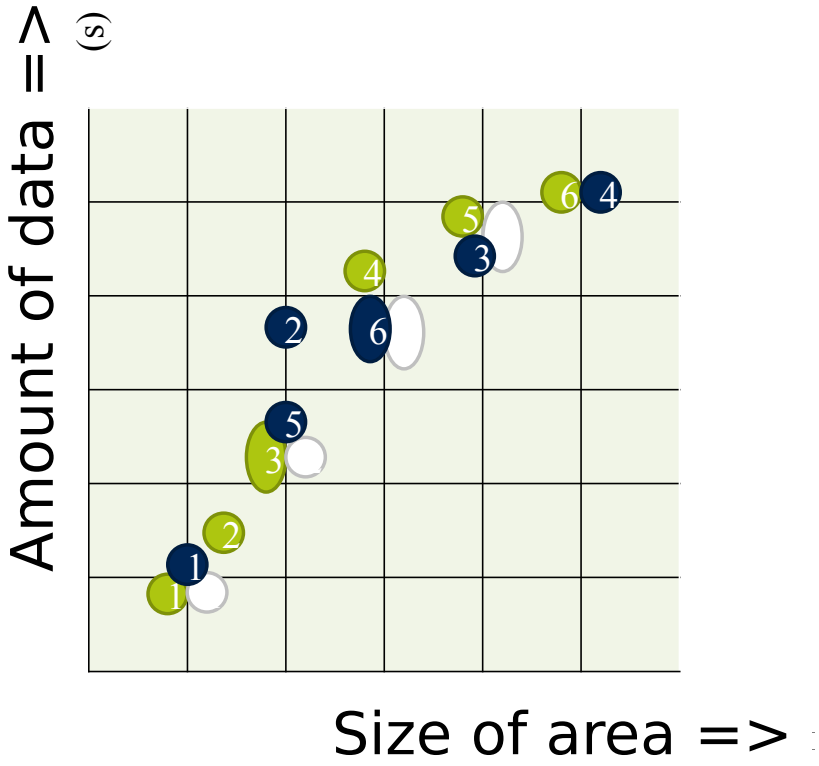
8-04-13

Contribution

- Network fundamental diagram studied and empirically checked
- Make influence of inhomogeneity explicit
- Empirical checks
- Modelling & control



Data increase with scale



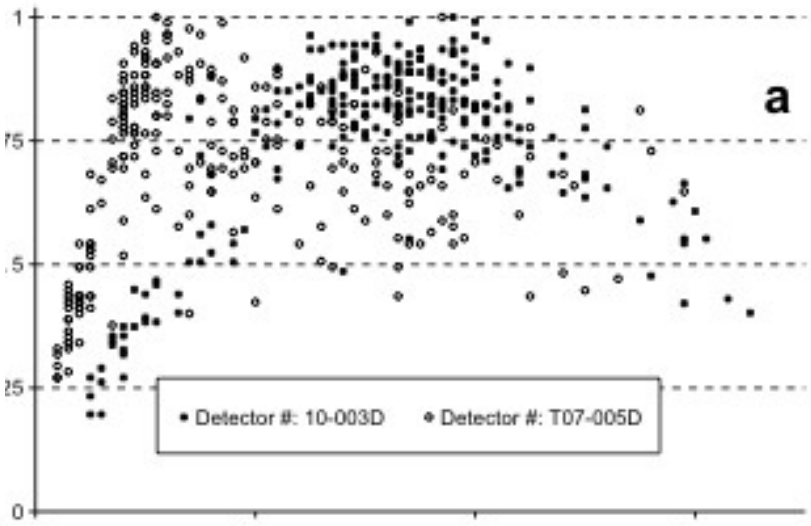
- Data requirement increases with scale
- Time horizon increases with scale
- Solution space increases with scale

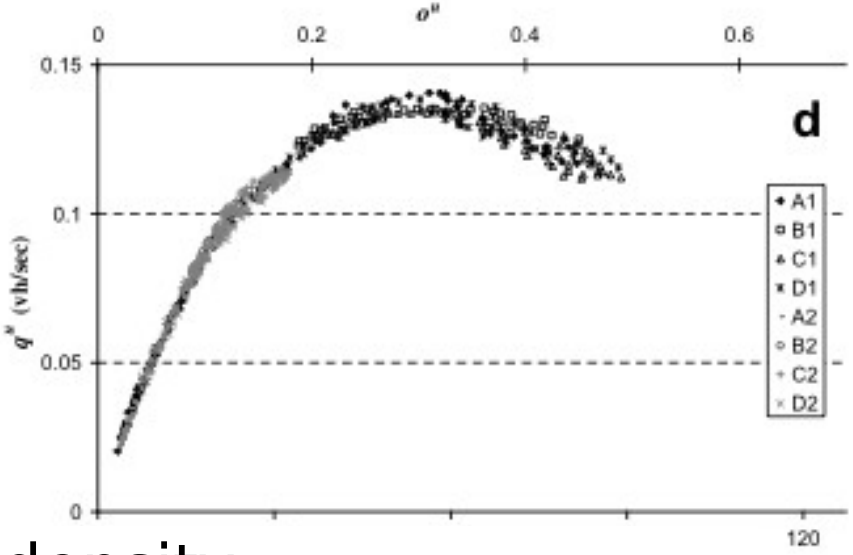
Simple relationships are needed

Stochasticity in local data

- Macroscopic fundamental diagram
- “Average” fundamental diagram for an area

- (Avg.) Flow =>



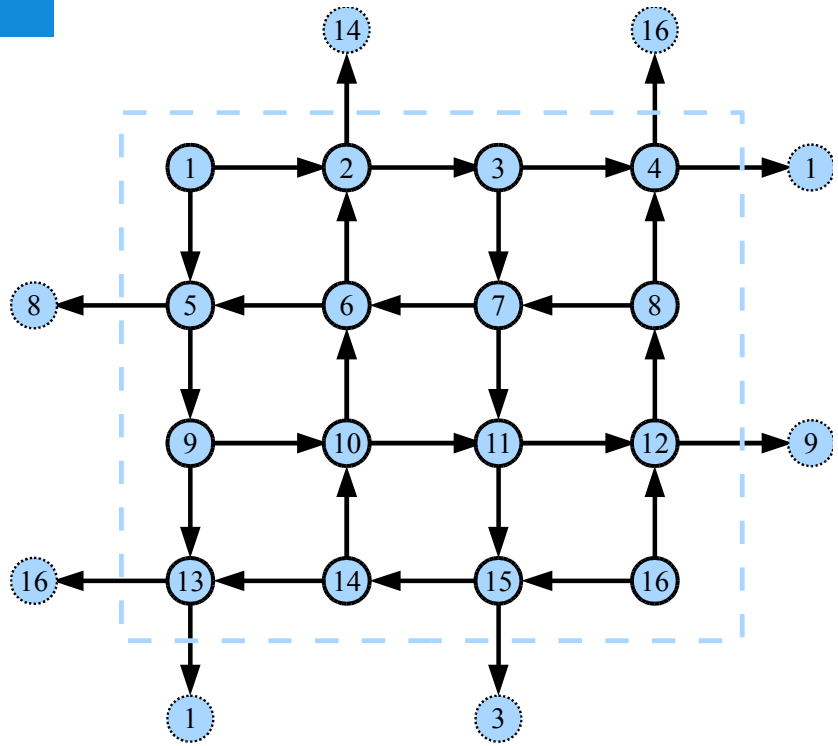


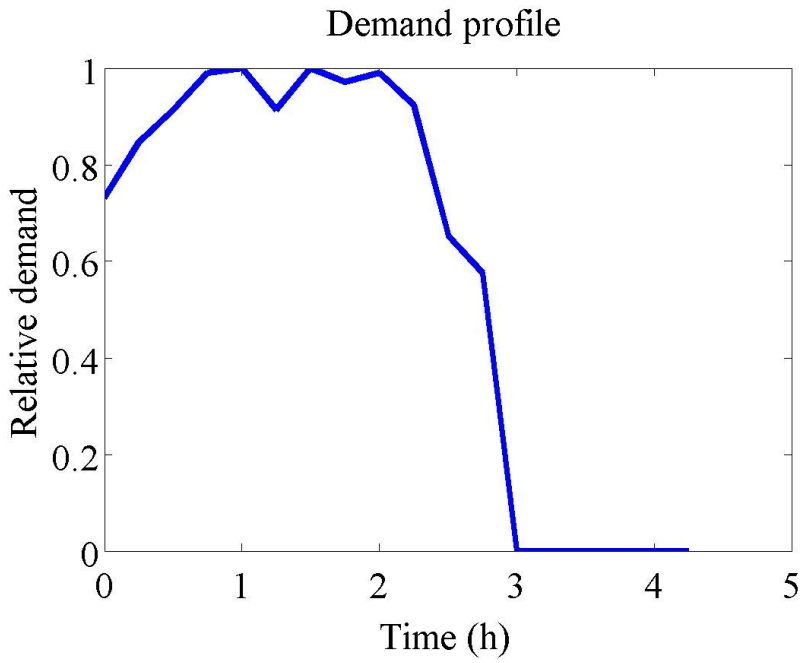
Density Average density

Fig: (Geroliminis and Daganzo)

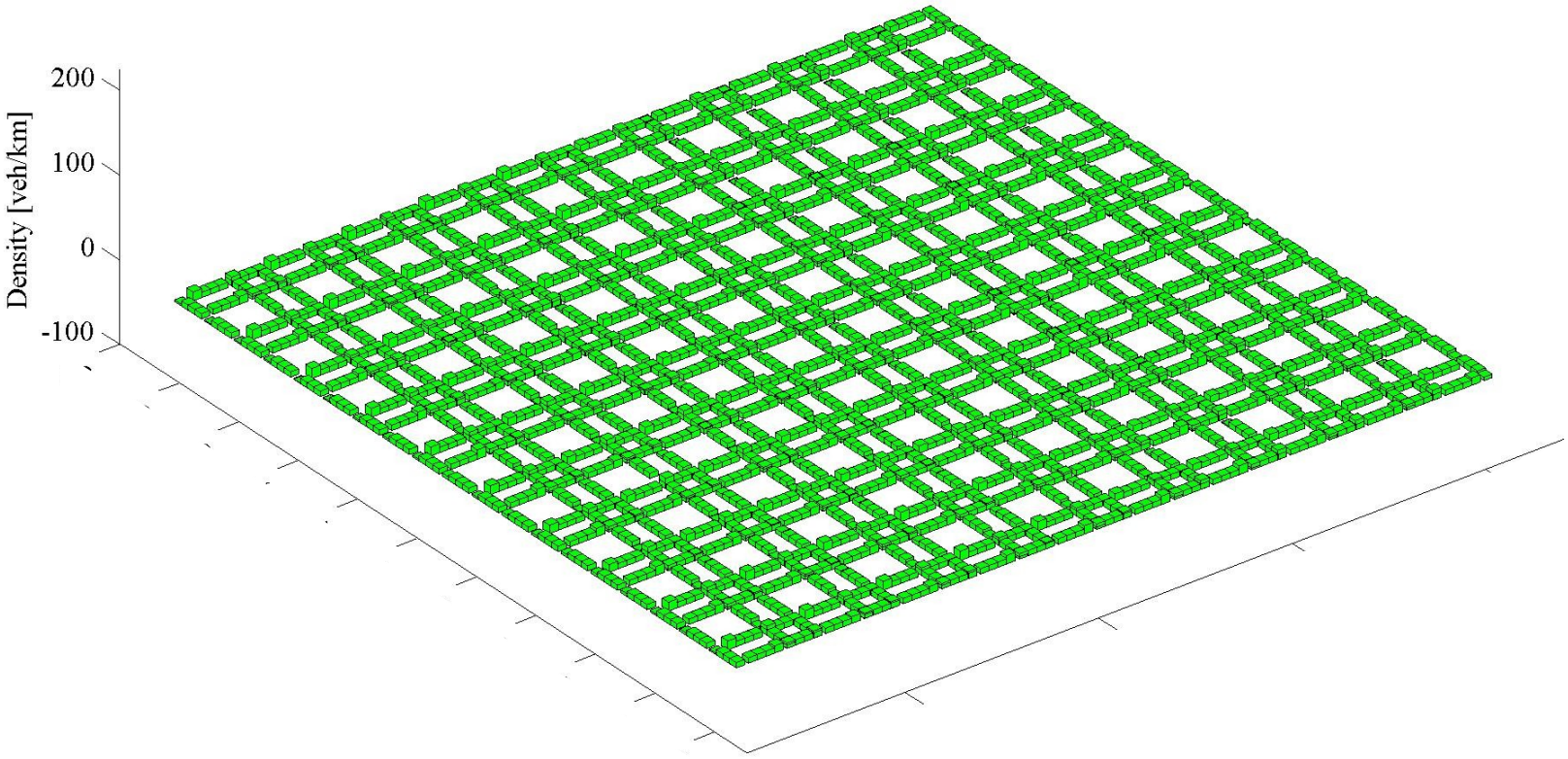
Concept – *Generalised Network Fundamental Diagram*

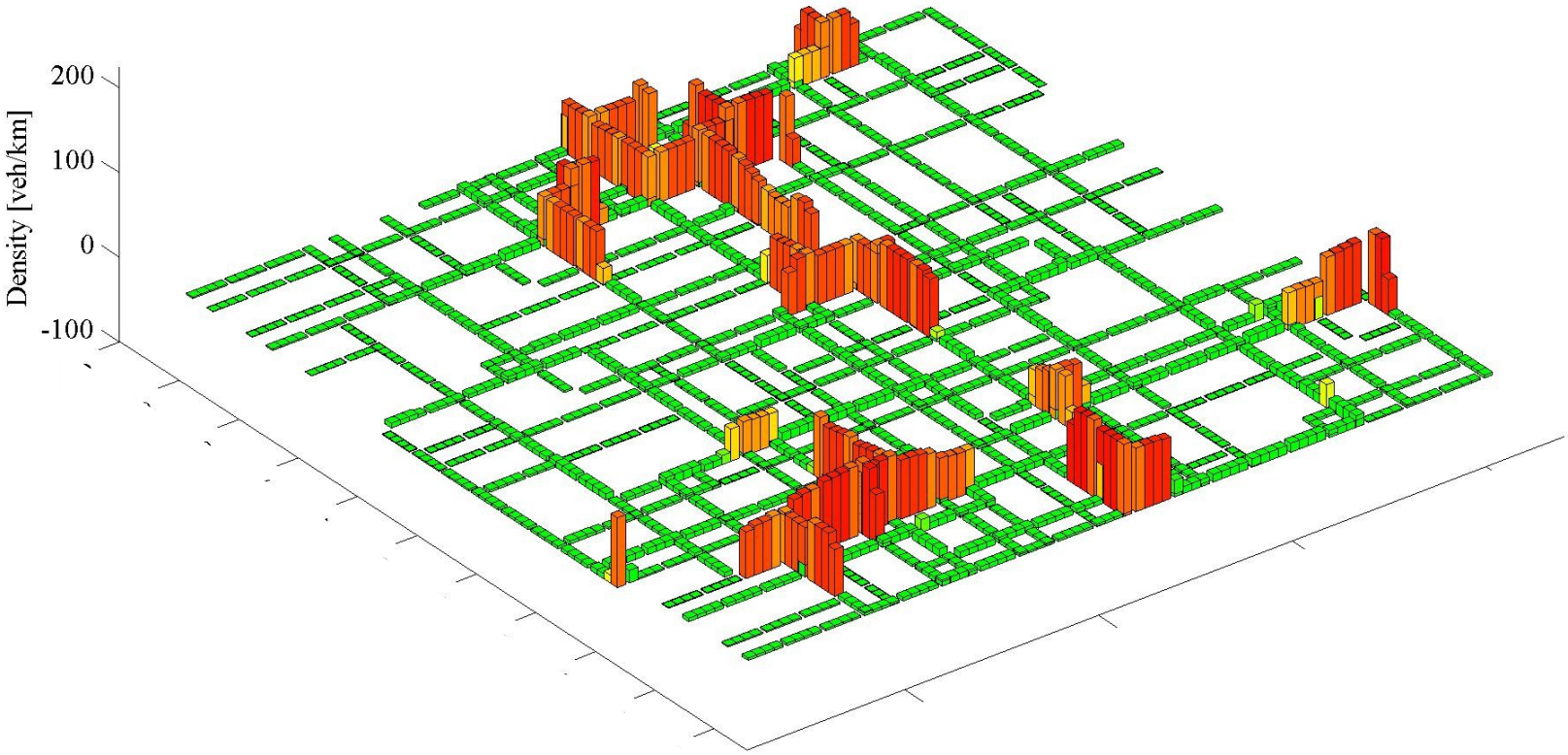
Network with periodic boundary

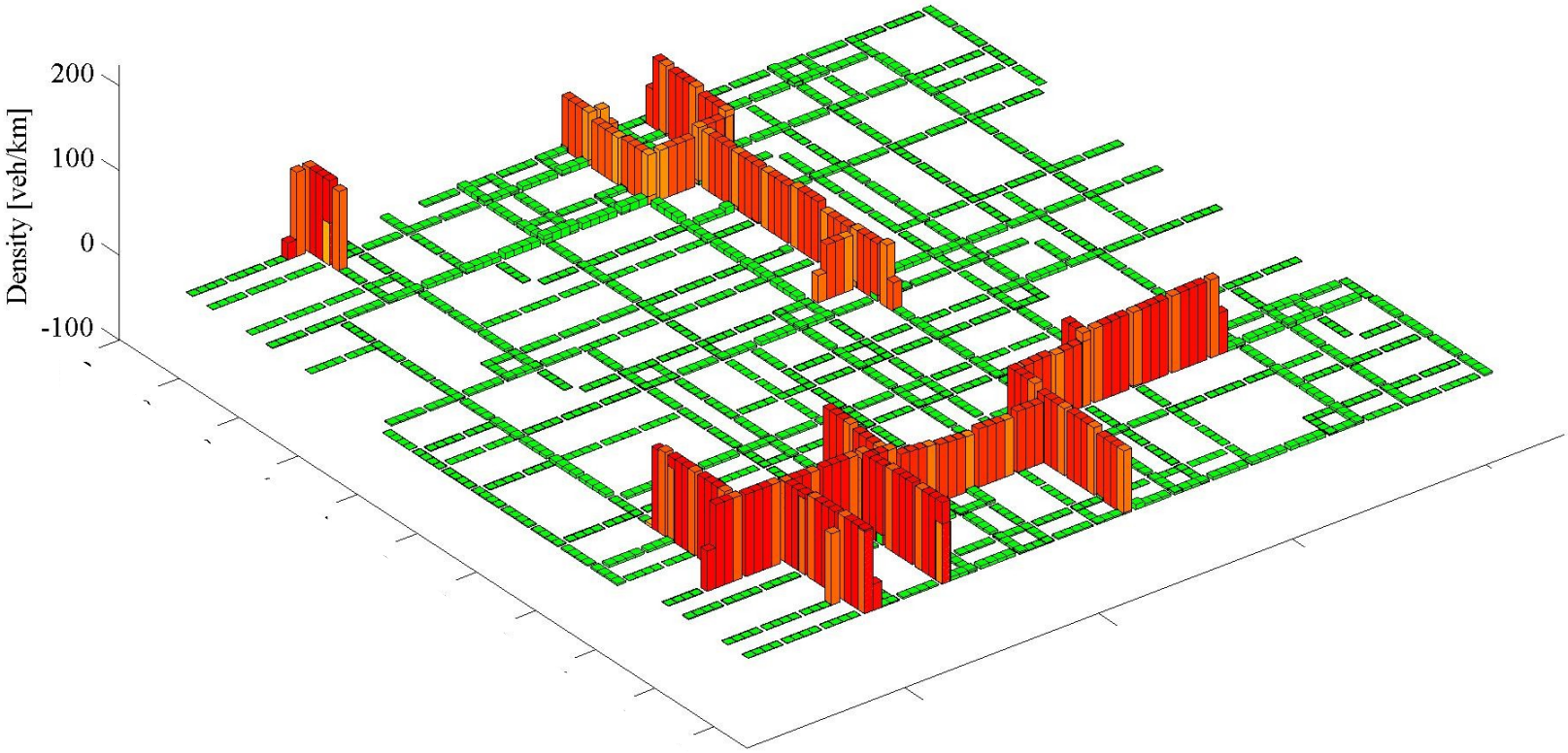




Build up of congestion

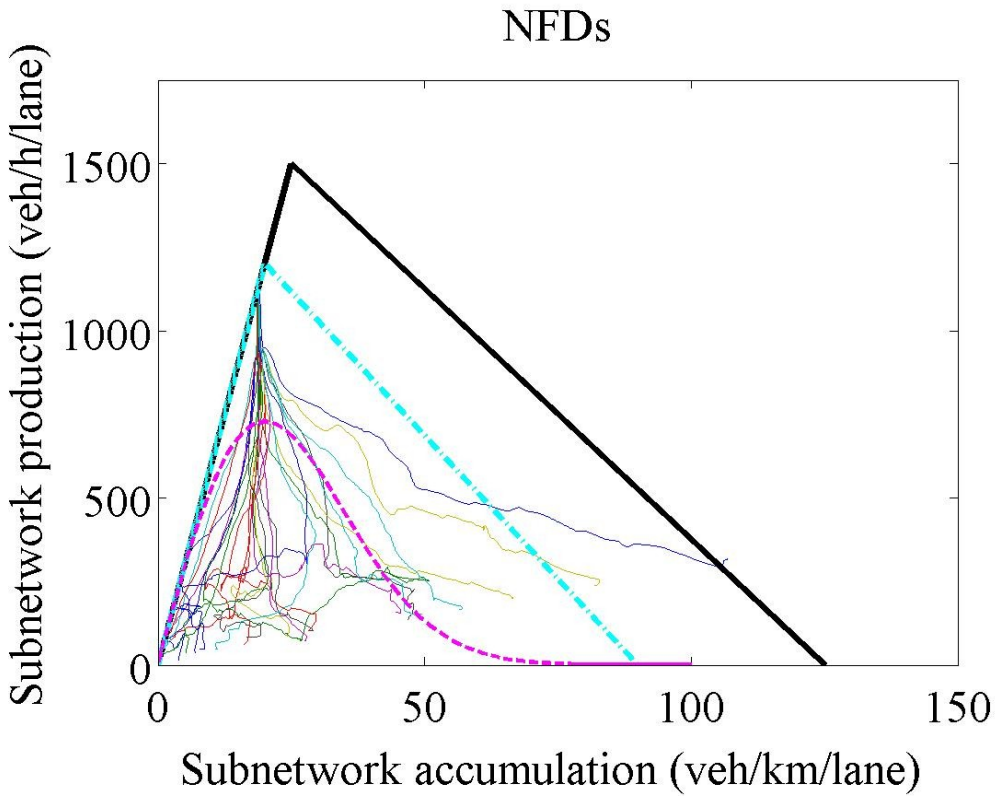



Density [veh/km]
200
100
0
-100


Density [veh/km]
200
100
0
-100

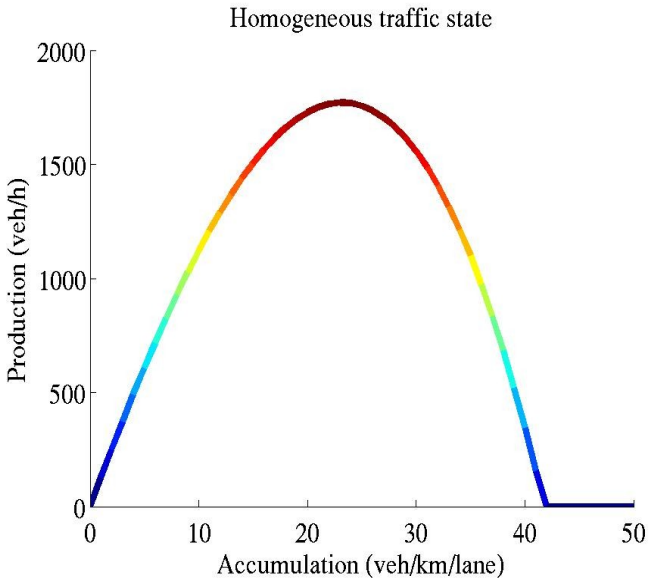
Resulting NFDs?

- Still scattered
  - hysteresis?
  - 2nd expanatory variable: *stdev of density*
  - **Generalised Network Fundamental Diagram**

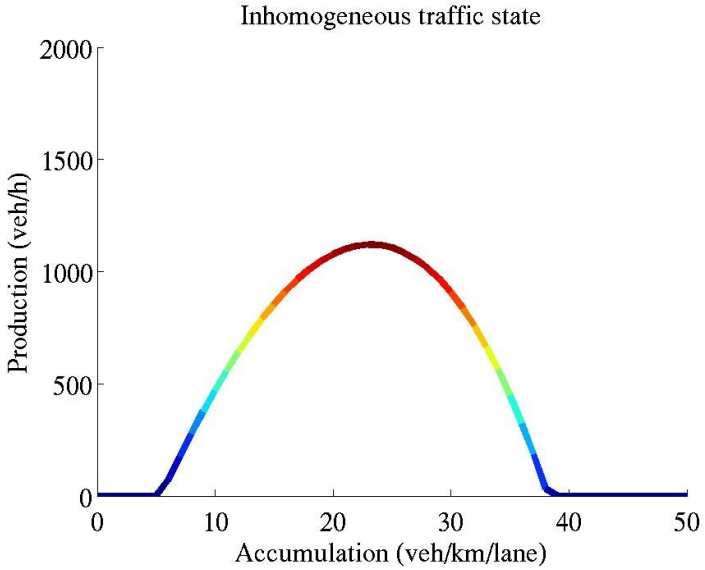


Fitting a functional form

P(A)=A*(c1+c2A+c3A2)-c4σ



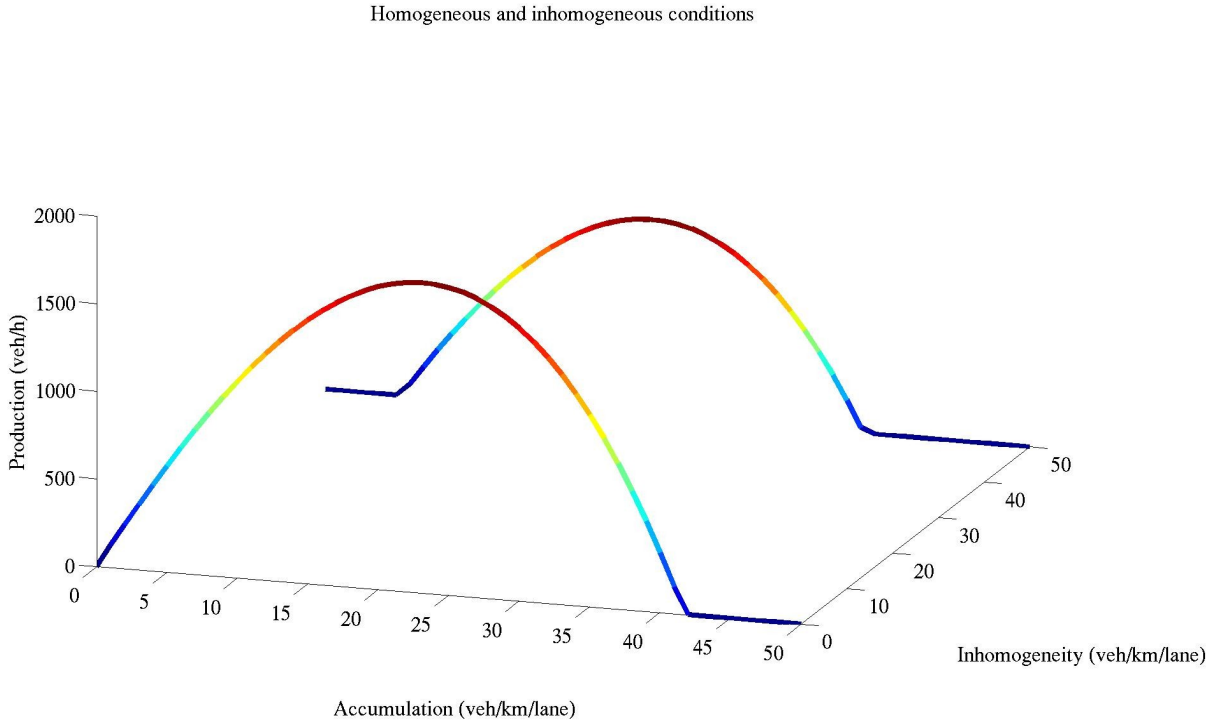
Homogeneous traffic situation



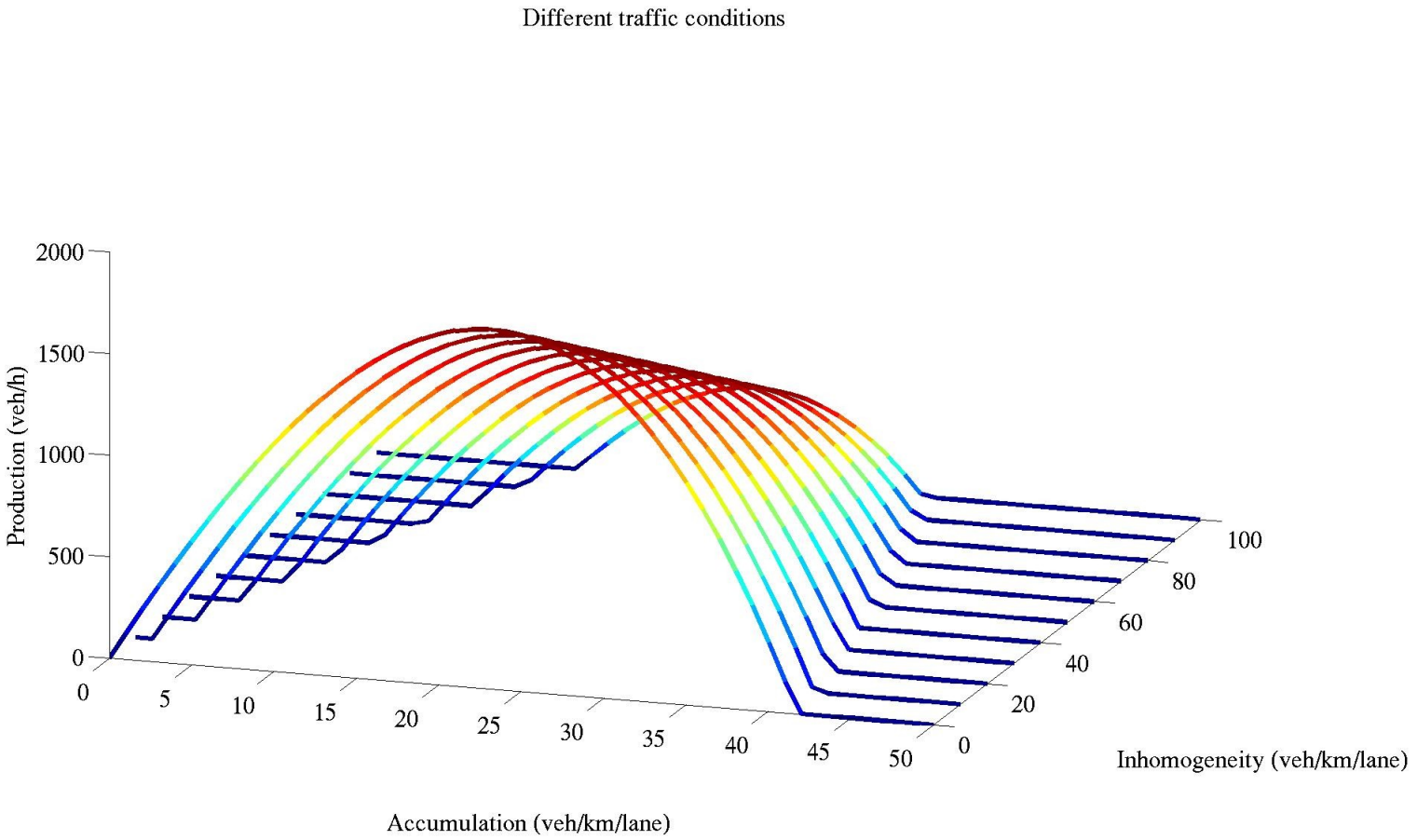
Inhomogeneous traffic situation

Fitting a functional form

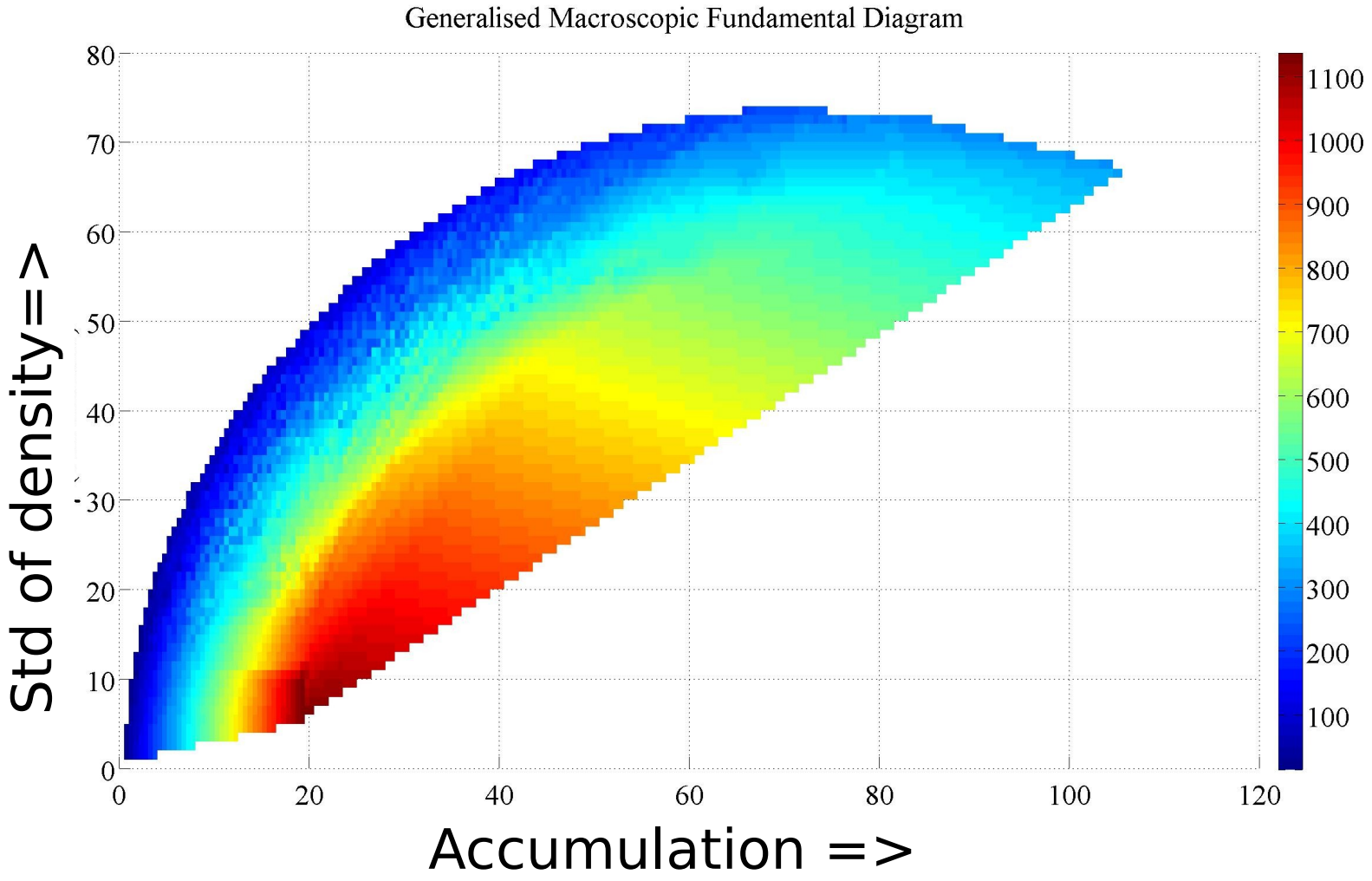
P(A)=A*(c1+c2A+c3A2)-c4σ



Fitting a functional form

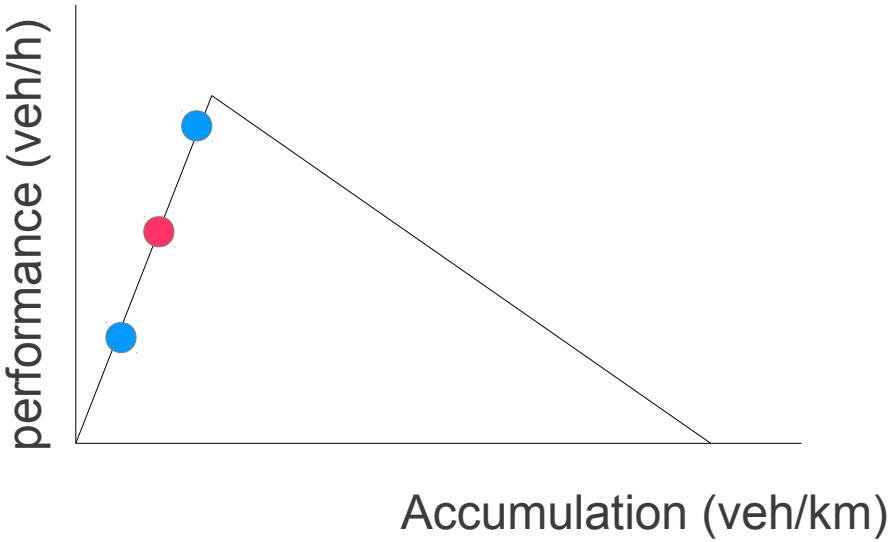


Improvement: Generalised NFD



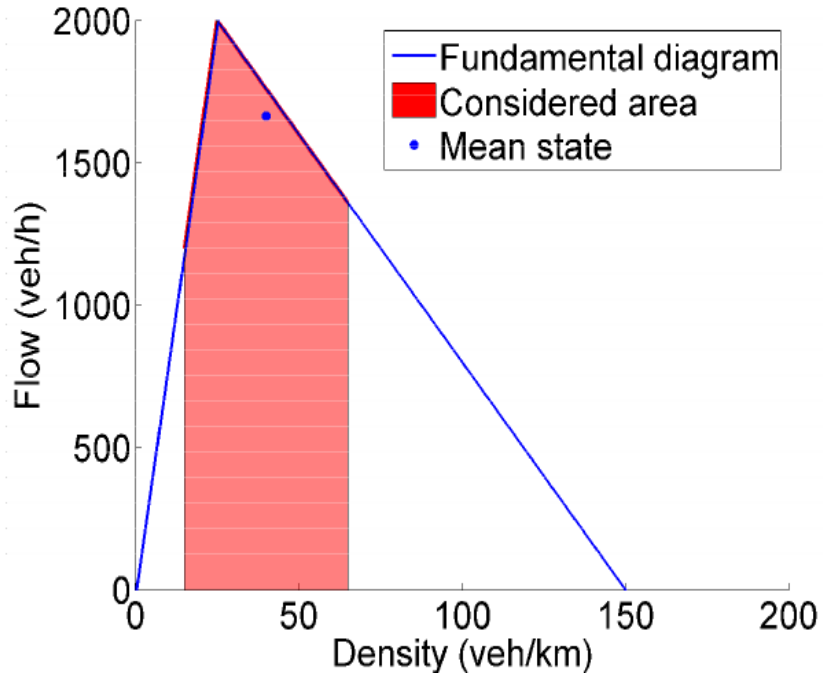
Causes of decrease with inhomogeneity

1) Averaging of states
2) **Network dynamics**

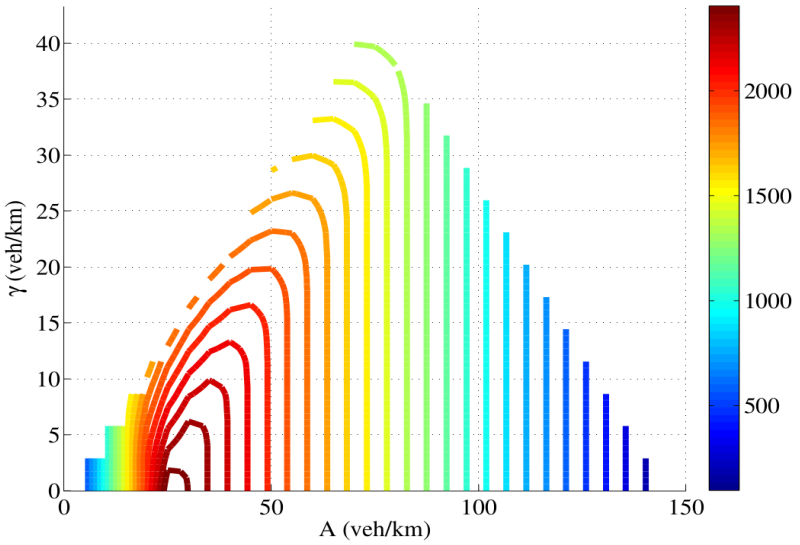


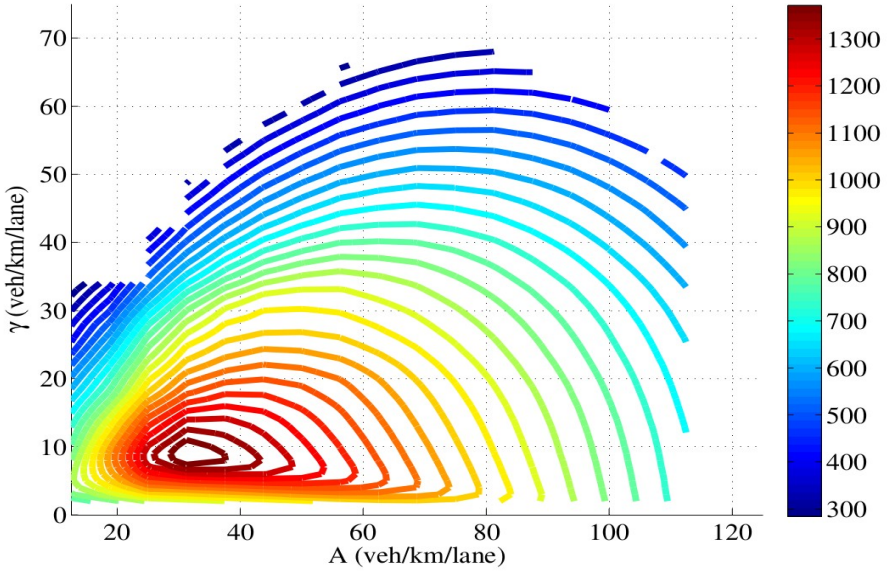
Causes of decrease with inhomogeneity

Create GNFD without dynamics



Impact of network dynamics

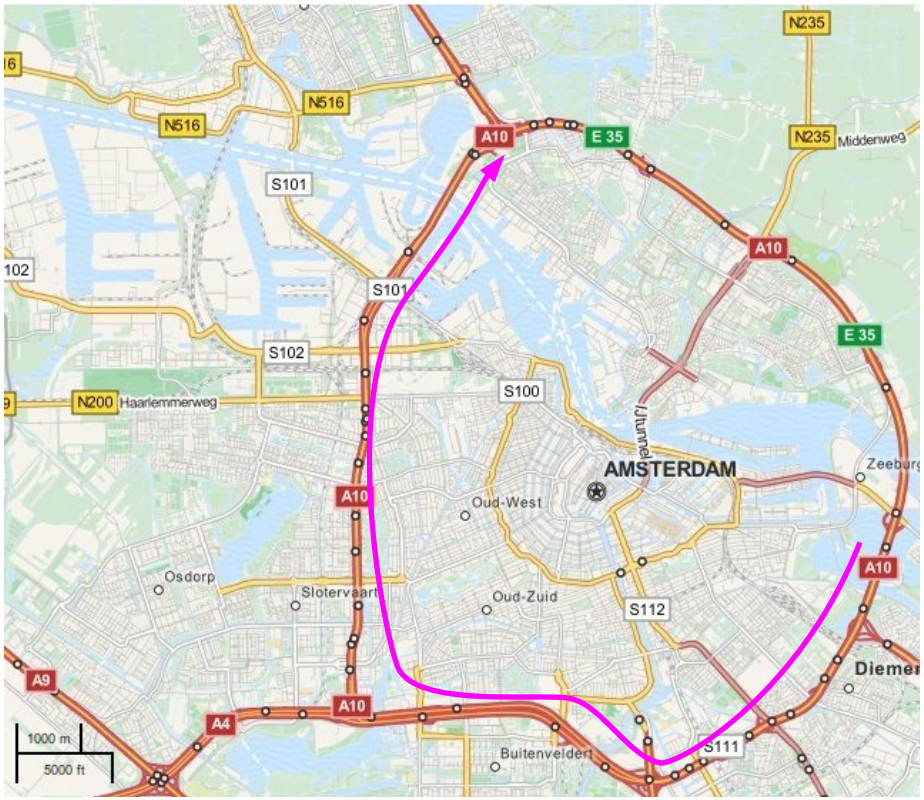




Empirics

Empirical study – site

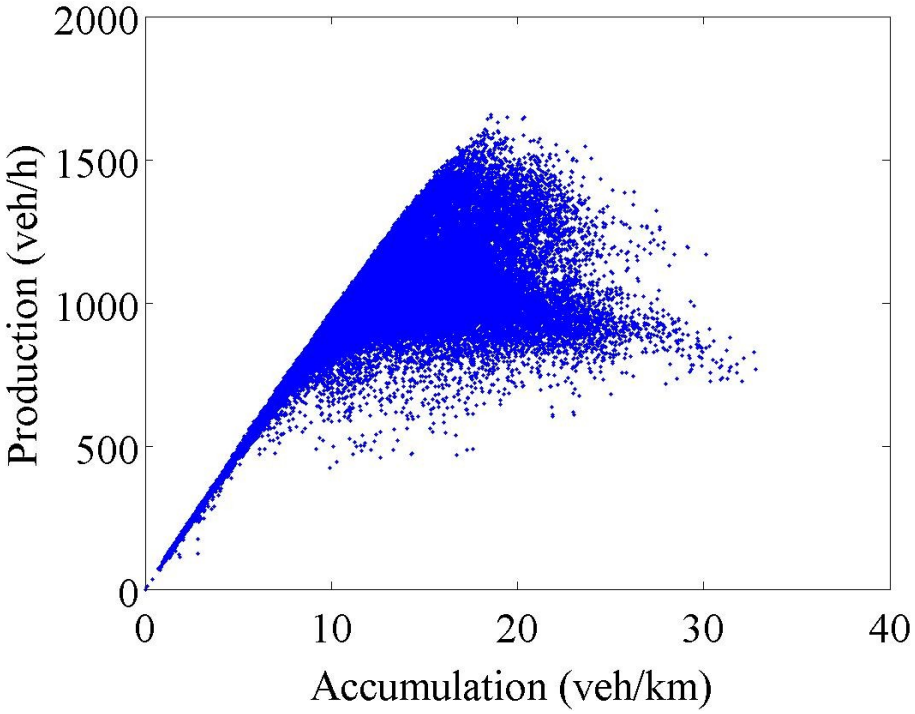
- A10 motorway
- 21 km
- Mostly 3 lanes
- 80-100 km/h speed limit



Road impression

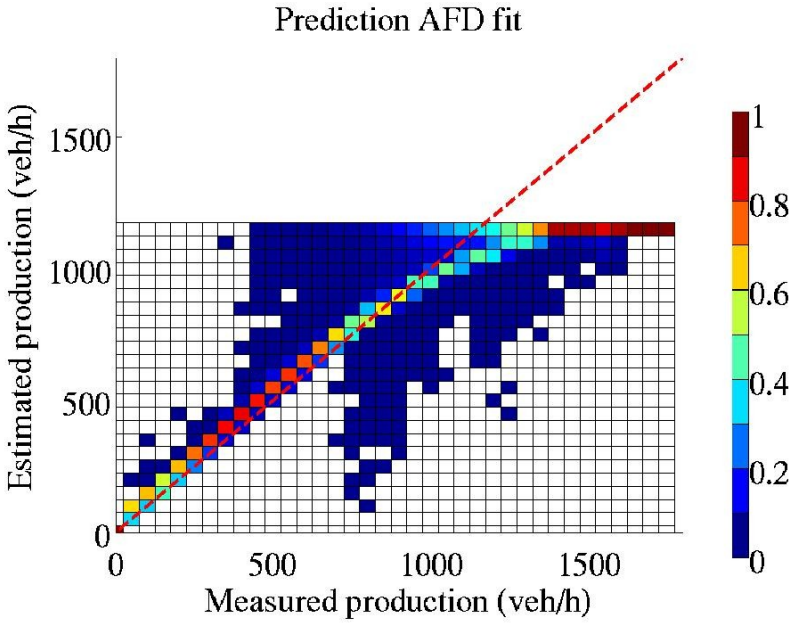
Predicting production: methodology

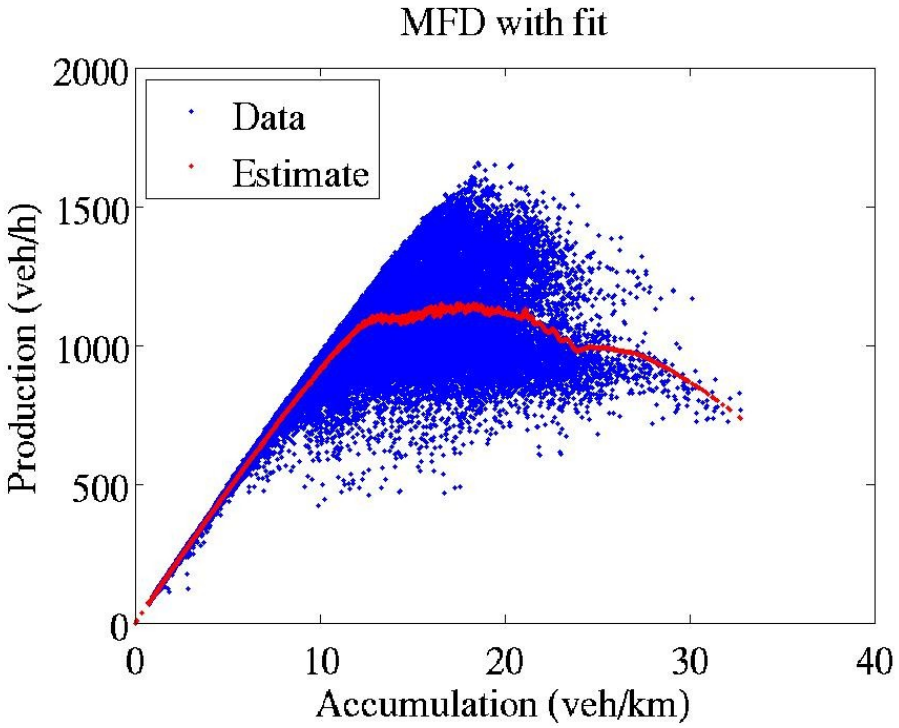
1. Split data set (calibration/validation)
2. Create NFD
3. For validation set: predict production based on accumulation using NFD



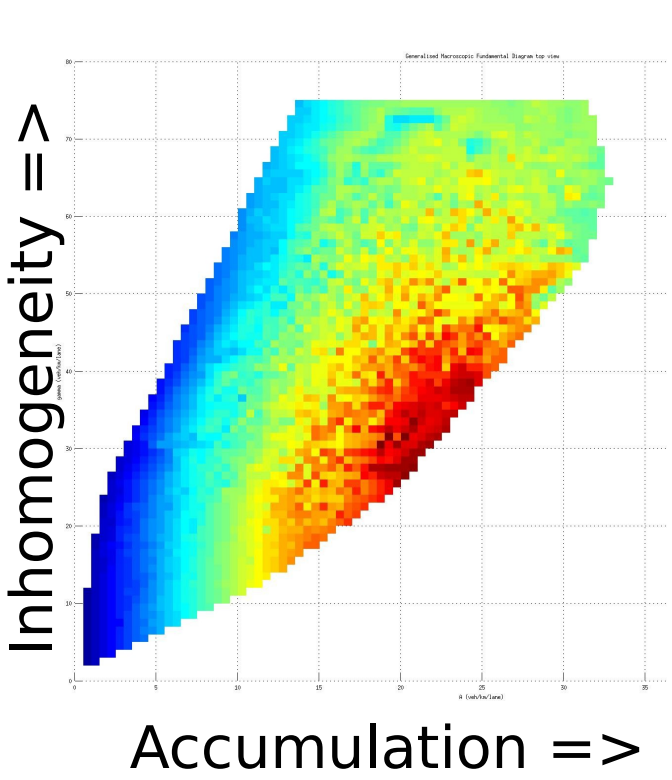
Fit and predictive power

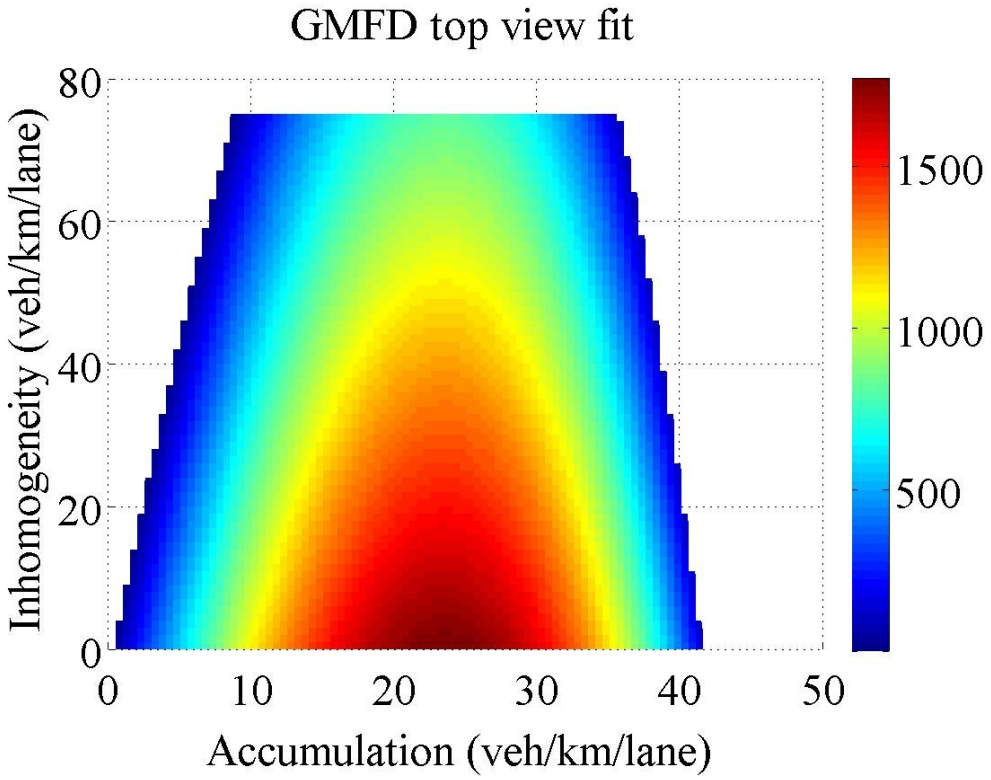
- Severe underestimation of production near capacit





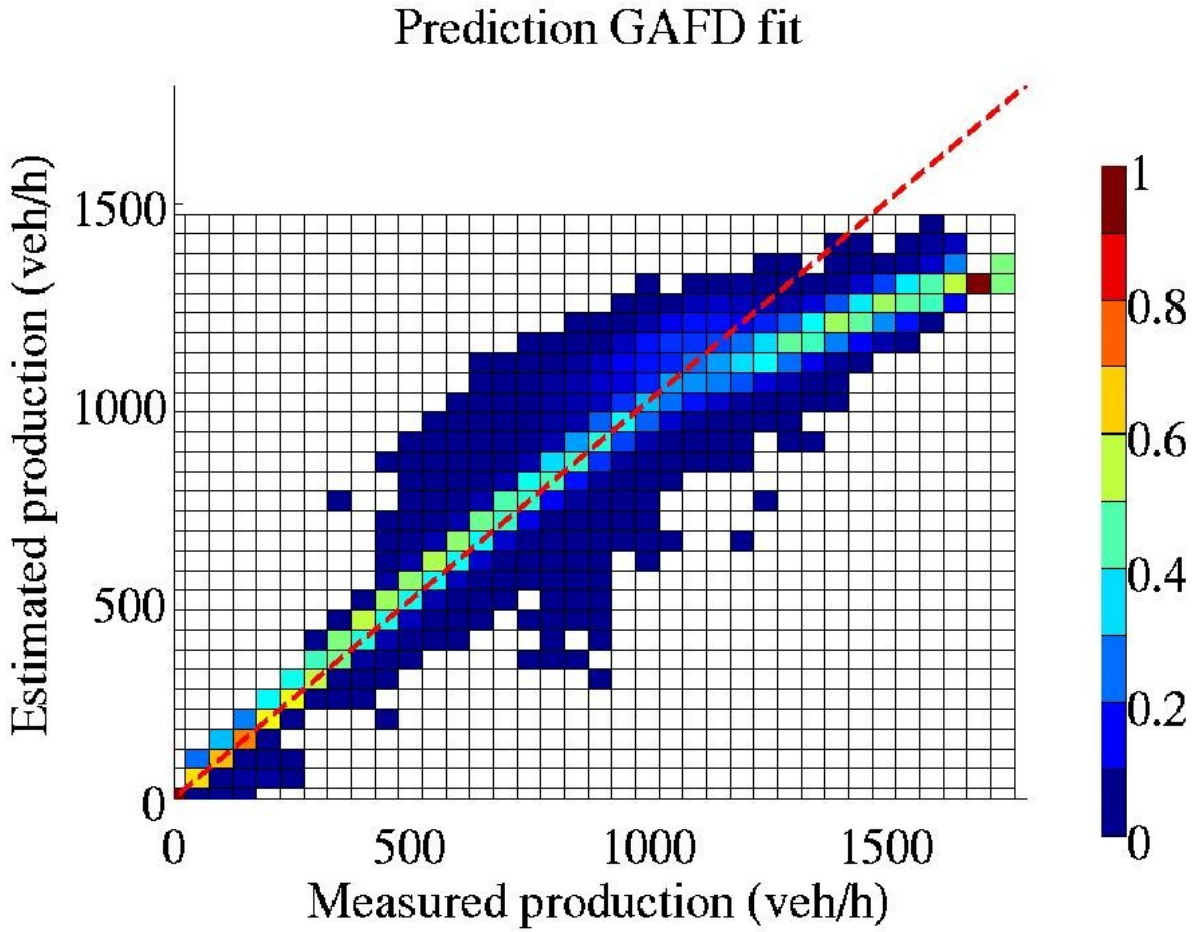
Empirical evidence





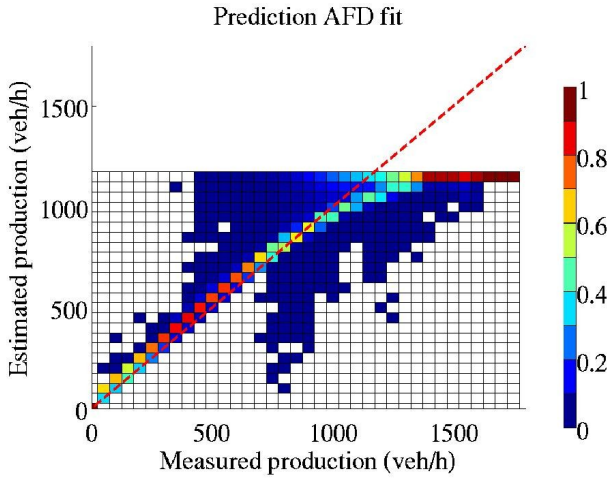
Fit and predictive power (2)

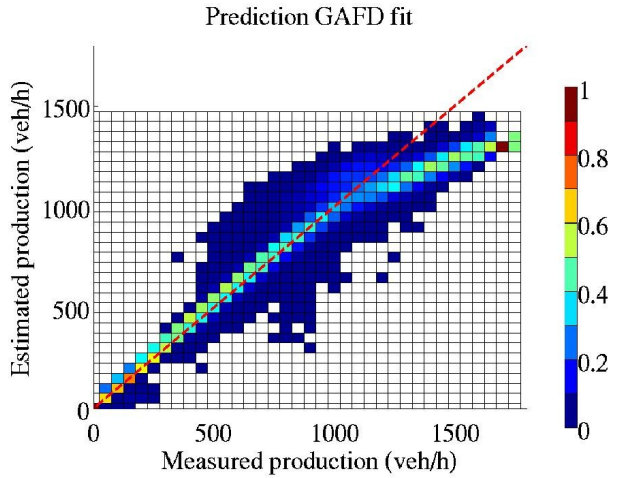
- Fit much better
- Bias much smaller



Quality of fit

R2	MFD	GMFD
All data	0.85	0.86



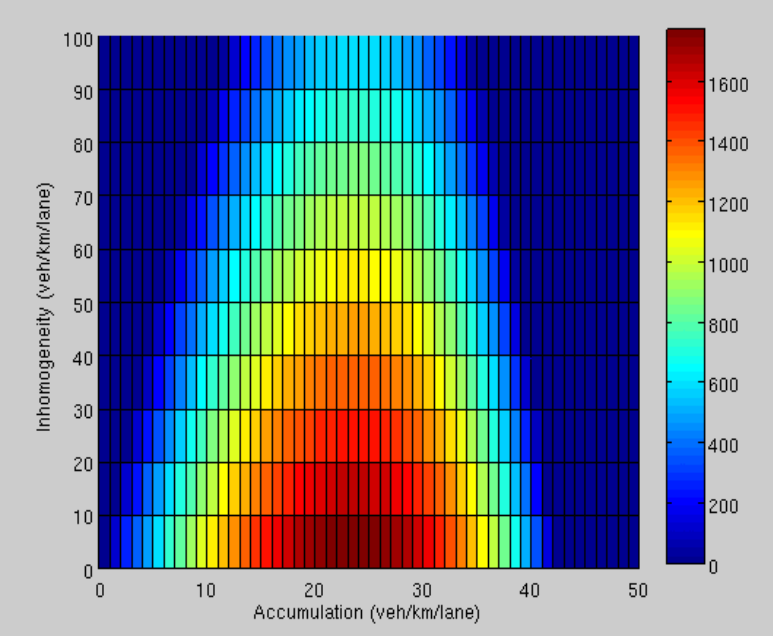


Two representations

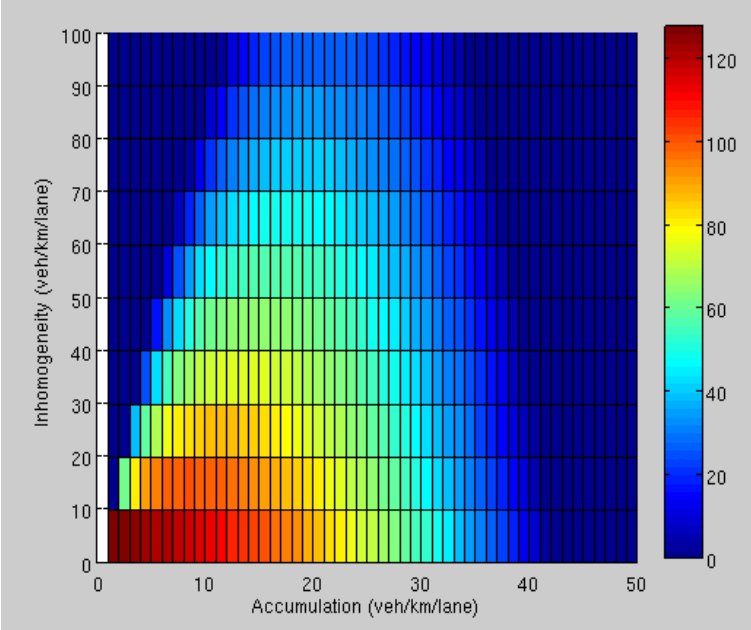
Production

Speed

Inhomogeneity =>

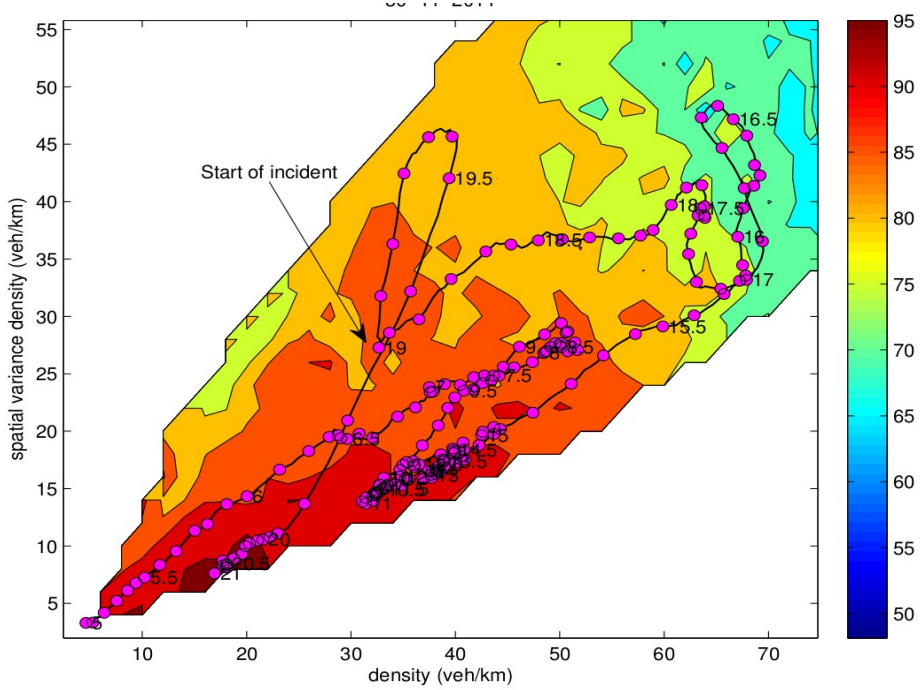


Accumulation =>



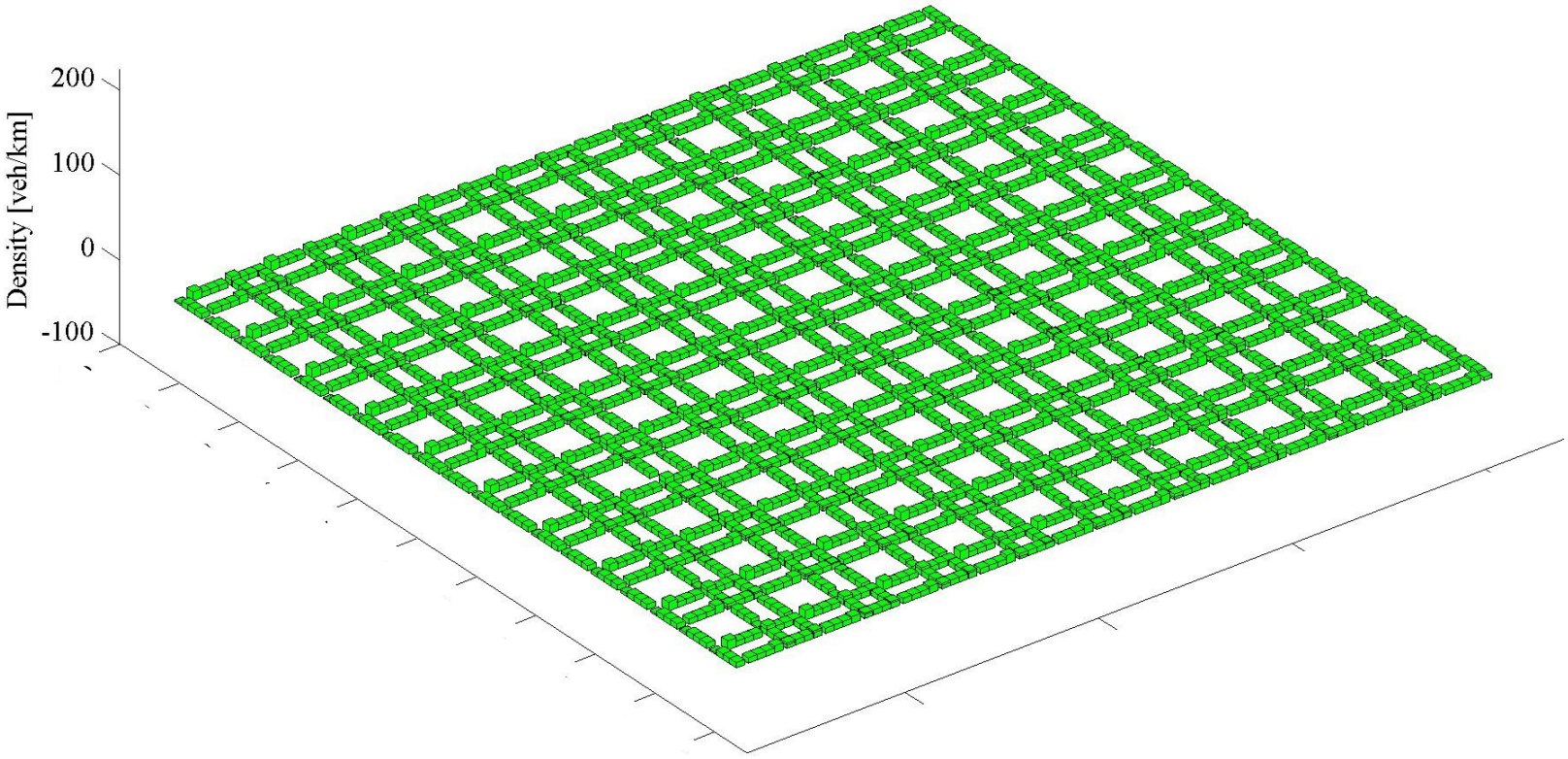
Accumulation =>

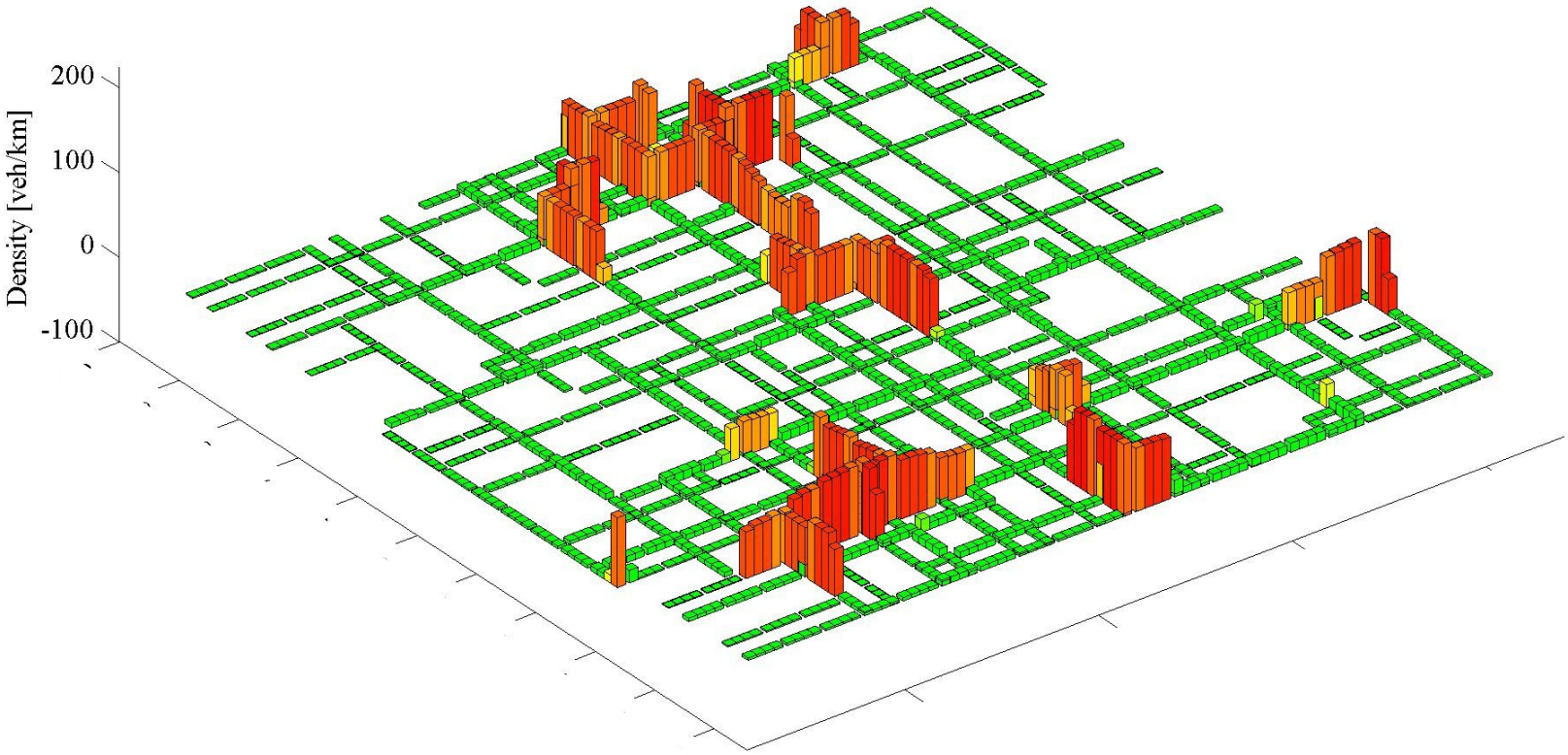
Tracing dynamics

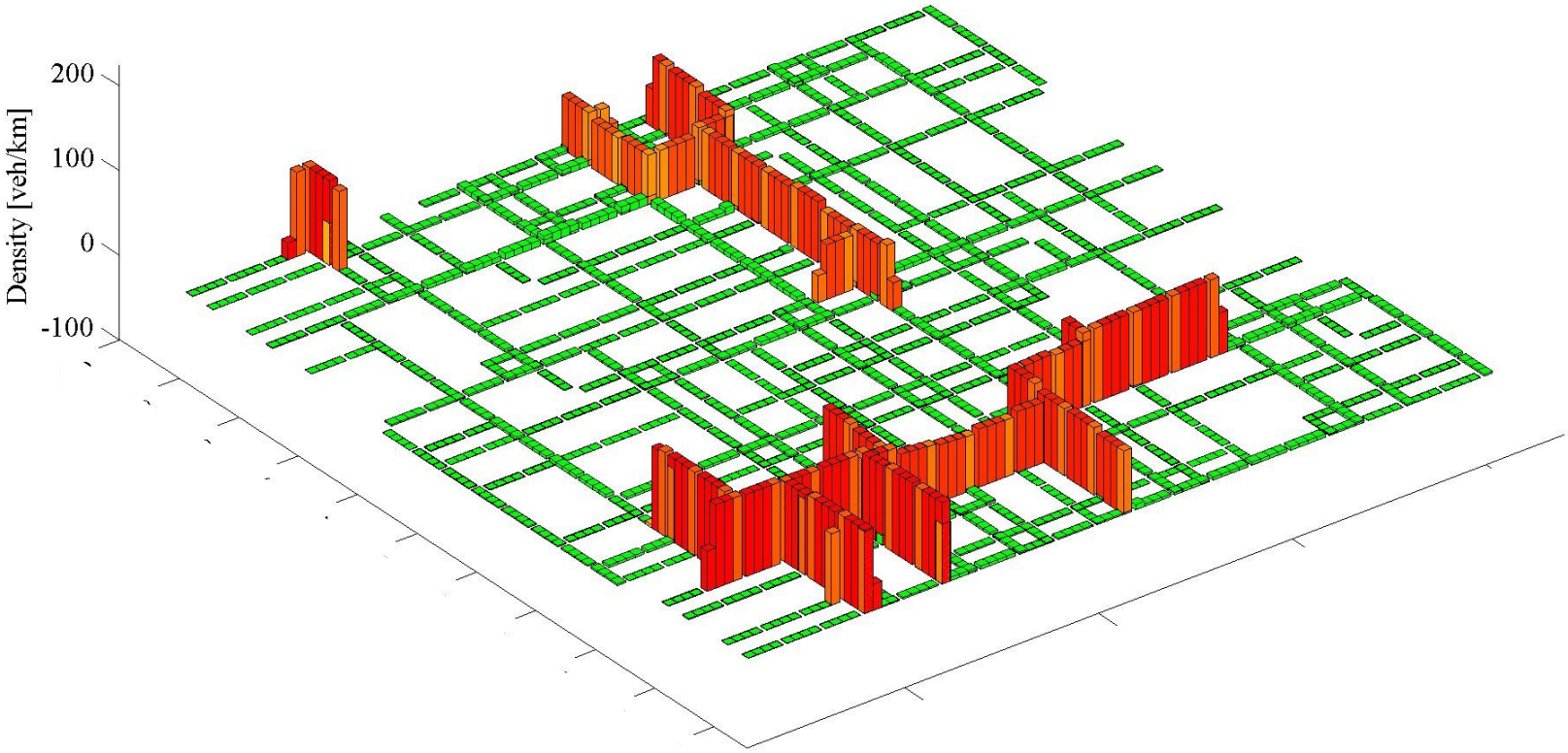


Control

Build up of congestion



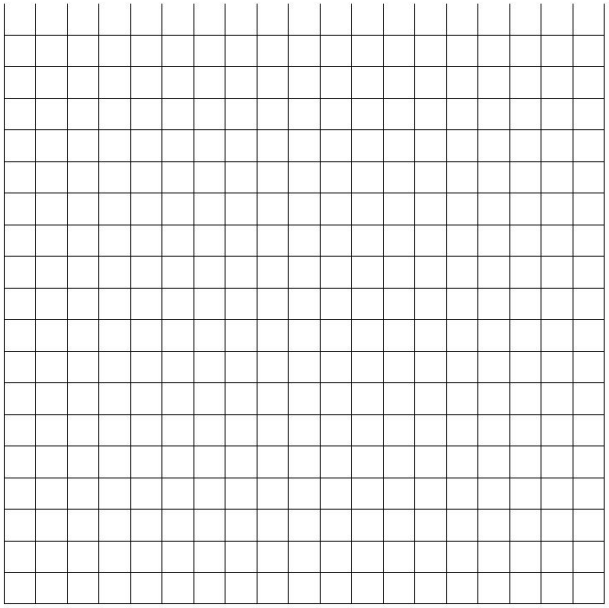

Density [veh/km]
200
100
0
-100

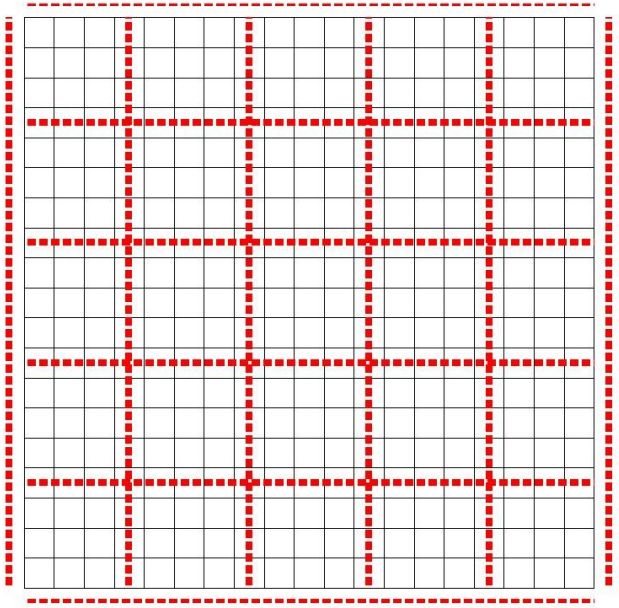

Density [veh/km]
200
100
0
-100

Methodology

- Test different routing strategies
- In a macroscopic simulation program
- Routing in a grid network
  1. Shortest path (distance)
  2. Shortest path (time)
  3. Area-based Reference
     a) Average speed
     b) Network Fundamental Diagram
     c) Generalised Network Fundamental Diagram

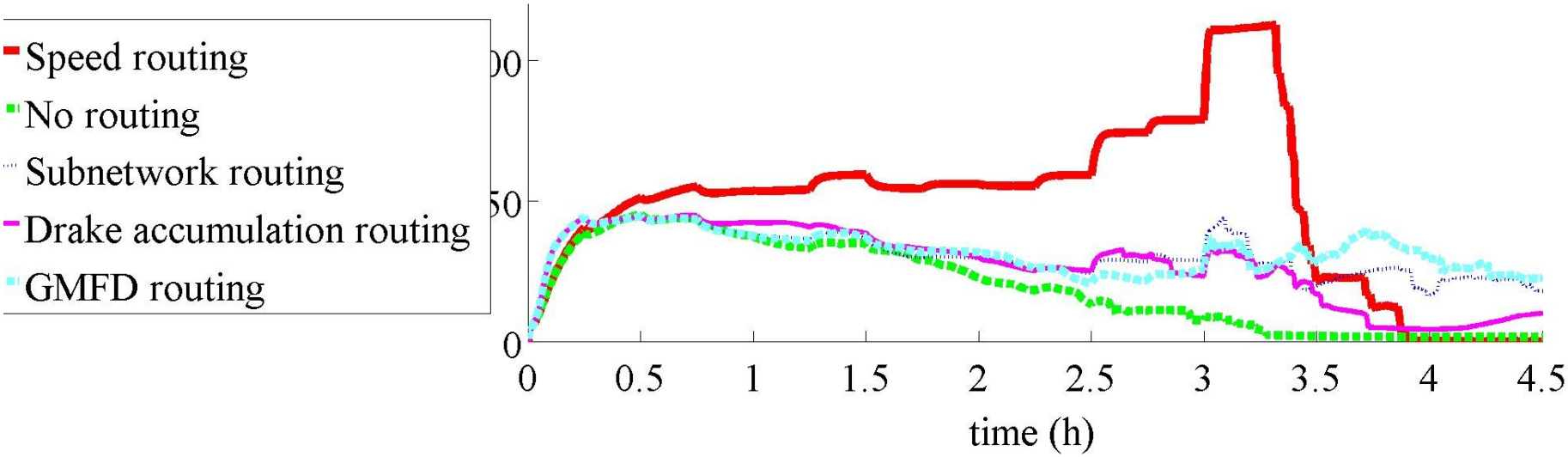
Create subnetworks





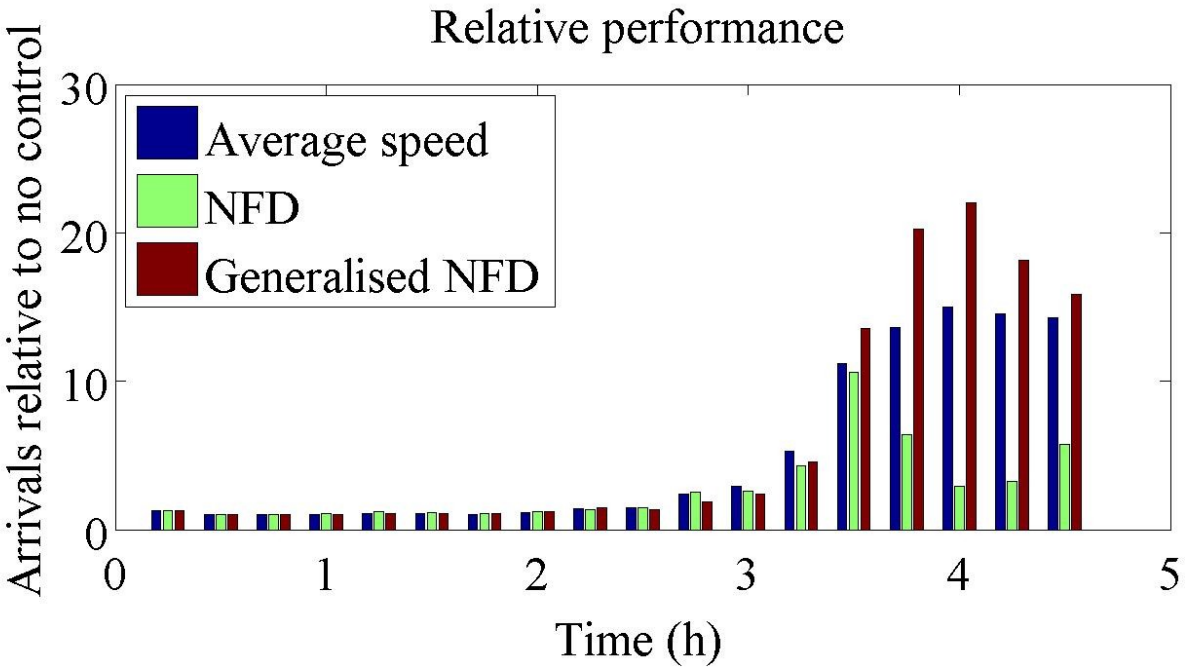
Good network performance

- Less than with “full routing”
- Factor 100 less data / computations needed



Good network performance (2)

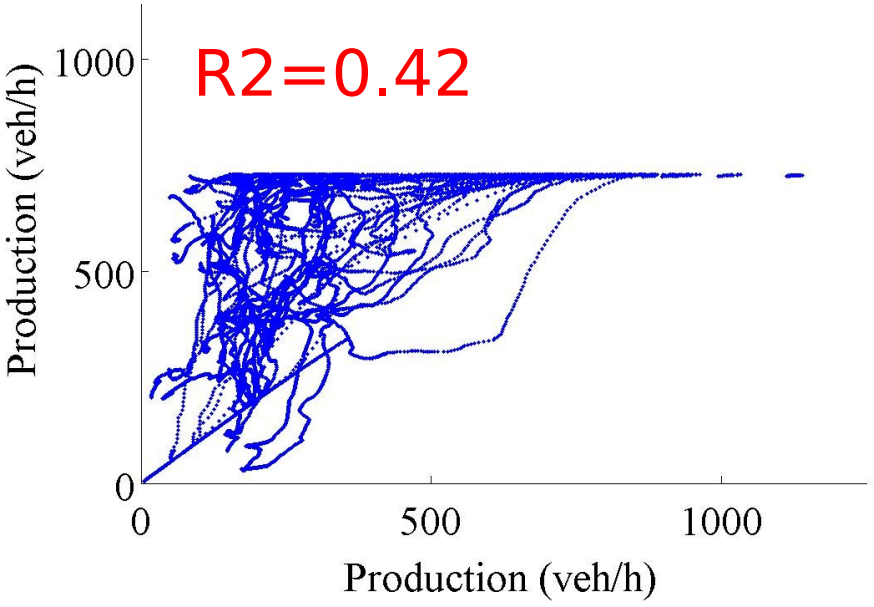
- Relative to no routing
- NFD relatively poor
- GNFD on par with full info (and sometimes better!)



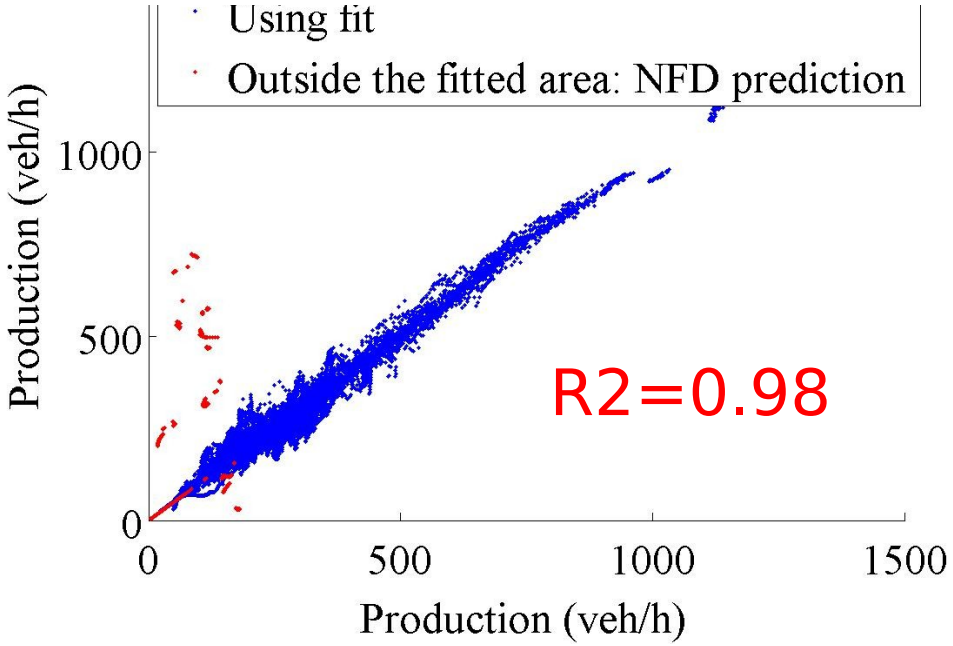
Performance similar to mean speed – but why?

- Similar arrivals due to perfect speed prediction

Best Network Fundamental Diagram



Generalised Network Fundamental Diagram

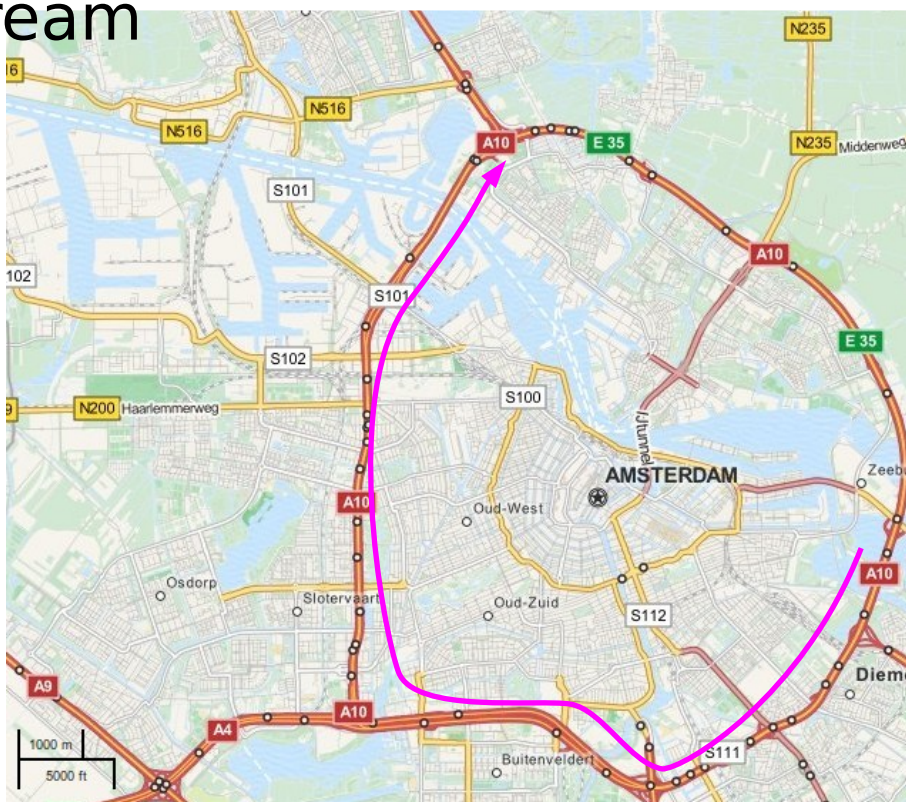


Modelling and practice

Use in traffic optimization

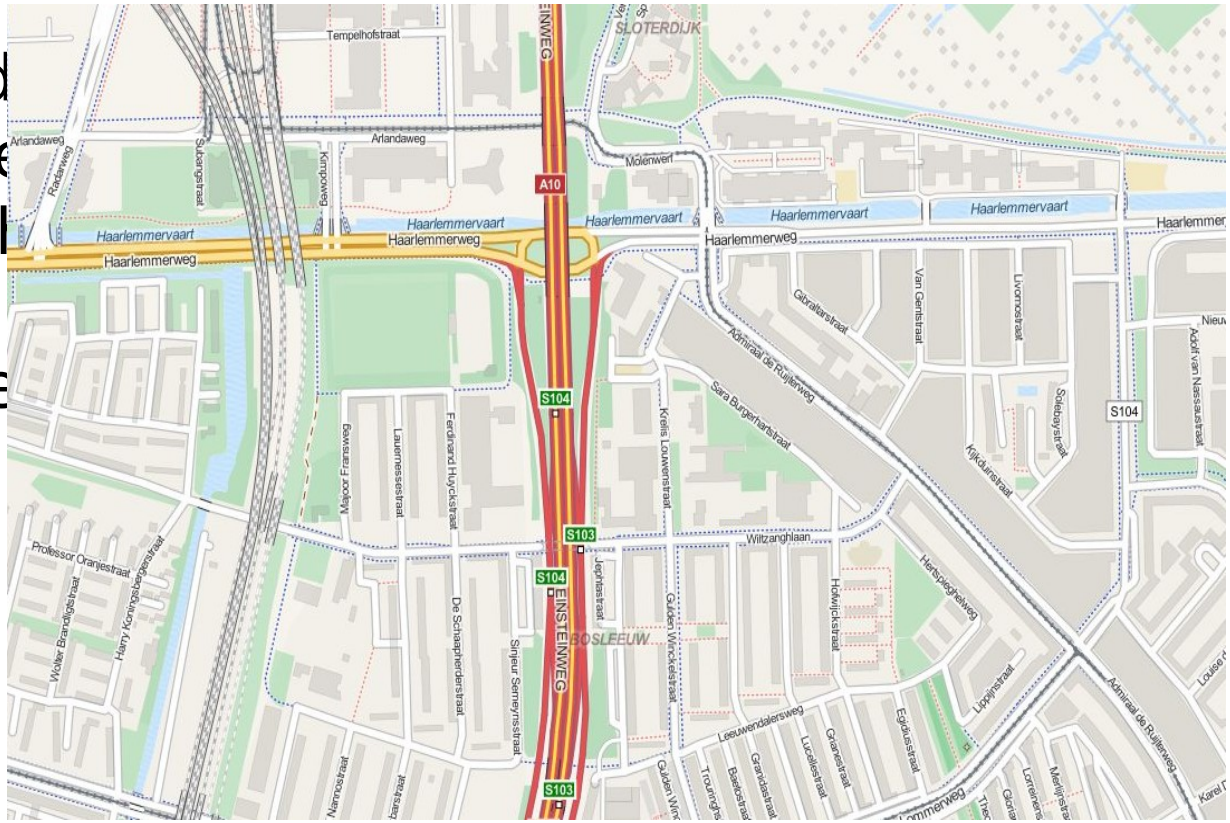
- Coordinate ramp meters
- Hold traffic further upstream

- What levels of metering to be used in which network parts



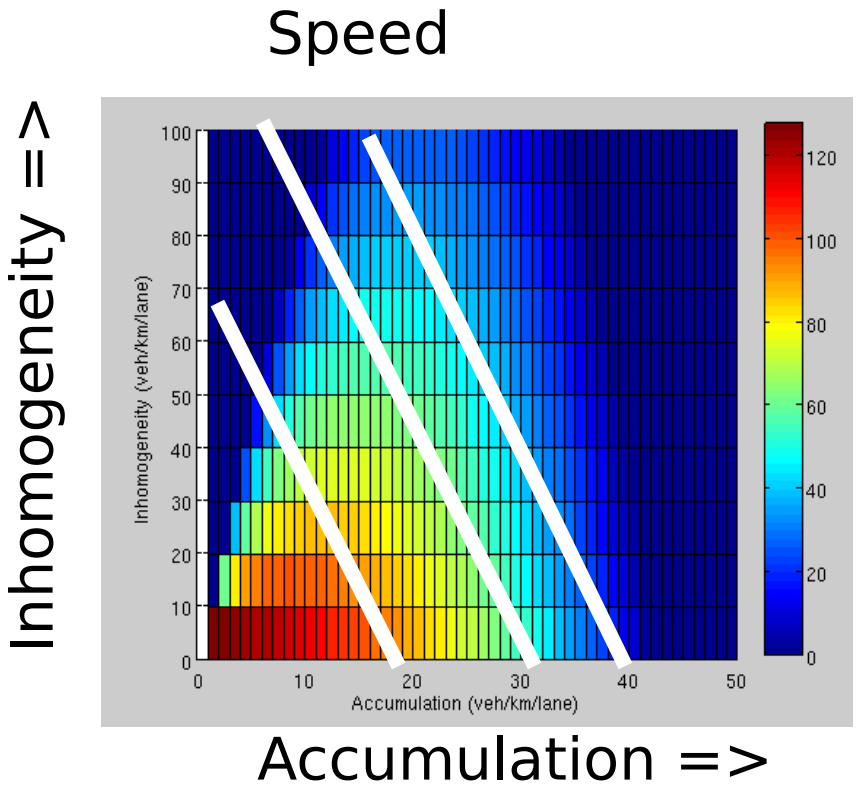
Network control

- Individual ramp metering limited
- Coordination doe not allow enough storage space
- Maximum queue lengths for each intersection determined



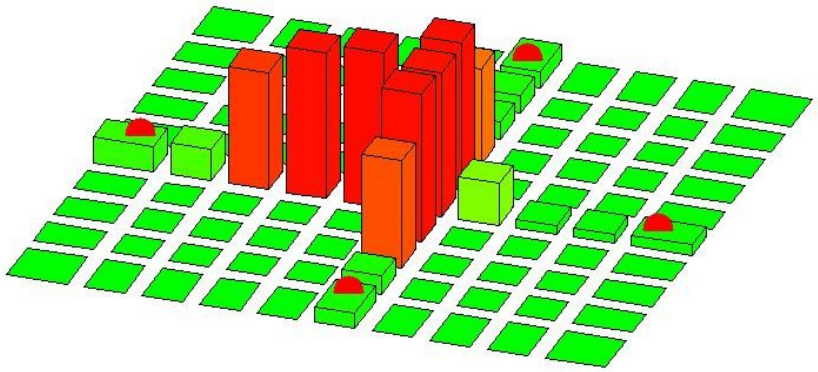
Network control

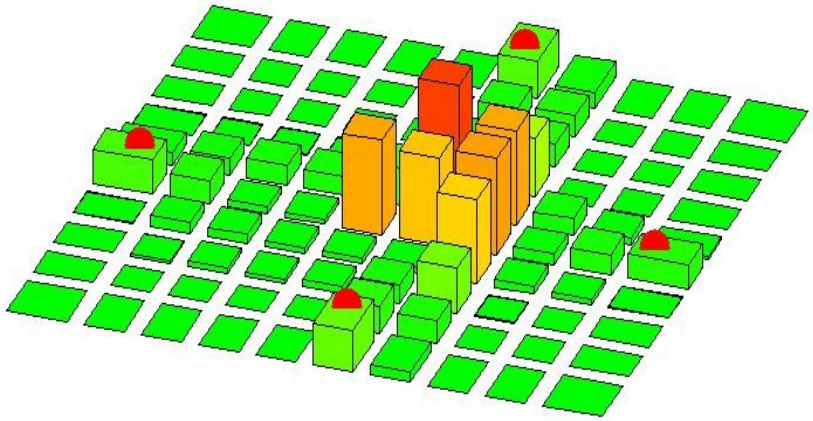
- Maximum queue lengths for each intersection determined
- Network-wide criterion which lengths allowed



Conclusions

- Traffic control using the Generalised NFD is possible
- Speed prediction is excellent
- Future work:
  - Predict future speeds
  - Interaction network properties and network dynamics
  - Use in model predictive control
  - Routing, perimeter control





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