Traffic: an Interplay between Models, Simulations, and Control Actions

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Overview

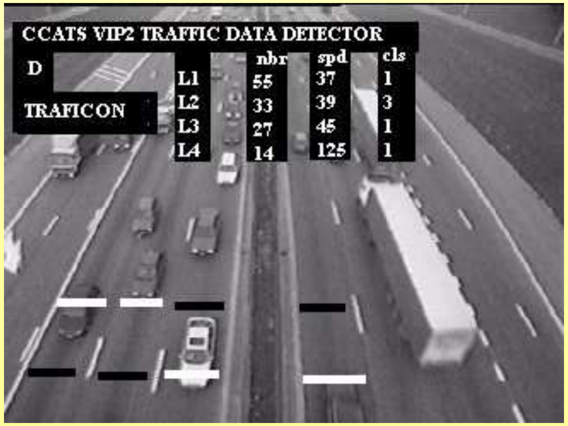
- **Gathering traffic data**
  - Available infrastructure
  - The nature of the measurements
- **Modelling traffic flows**
  - Macroscopic models
  - Microscopic models
- **Simulating traffic flows**
  - Microscopic simulators
- **Controlling traffic flows**
  - Available control actions

Gathering traffic data (1/3)

- Single/double loop detectors (embedded in the concrete)

- Gatso-meters

- Cameras



- *(counting by 'hand')*
- …

TRAFICON Video Detection Field proven. Easy to install.

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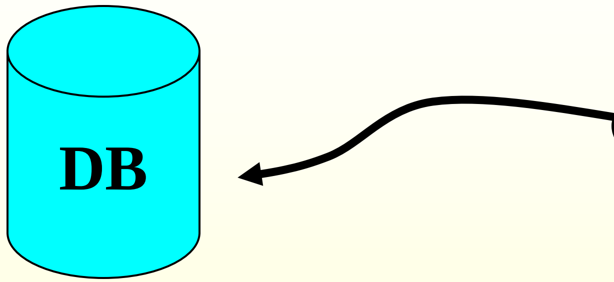
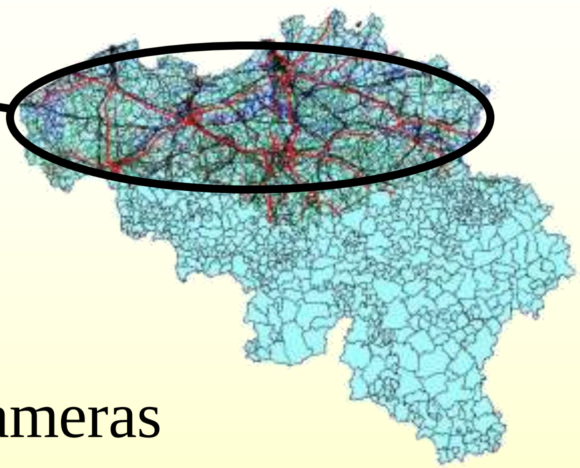
Gathering traffic data (2/3)

- <u>Automation</u> is becoming a core business:

Gathering traffic data (3/3)





200 cameras

1500 single loop detectors

± **1655** sensors (1 for each lane)

≈ 869,868,000 measurements (**3.24 GB**)

(this is for ***one*** *year)*

What is being measured ?

- **Density** (number of vehicles /kilometre)

  ⟹ k

- **Flow** (number of vehicles /hour)

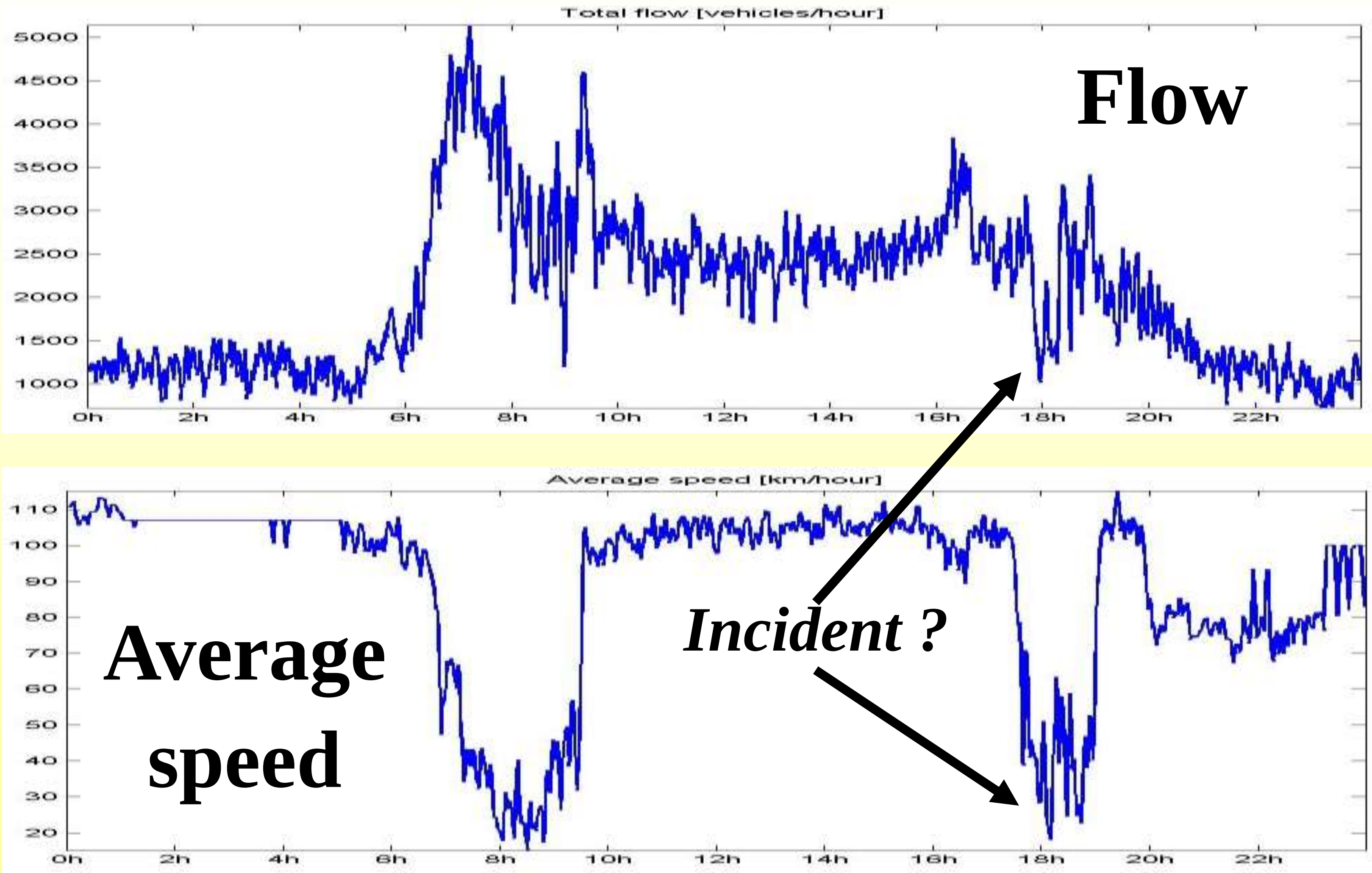
  ⟹ q

- **Average speed** (kilometres/hour)

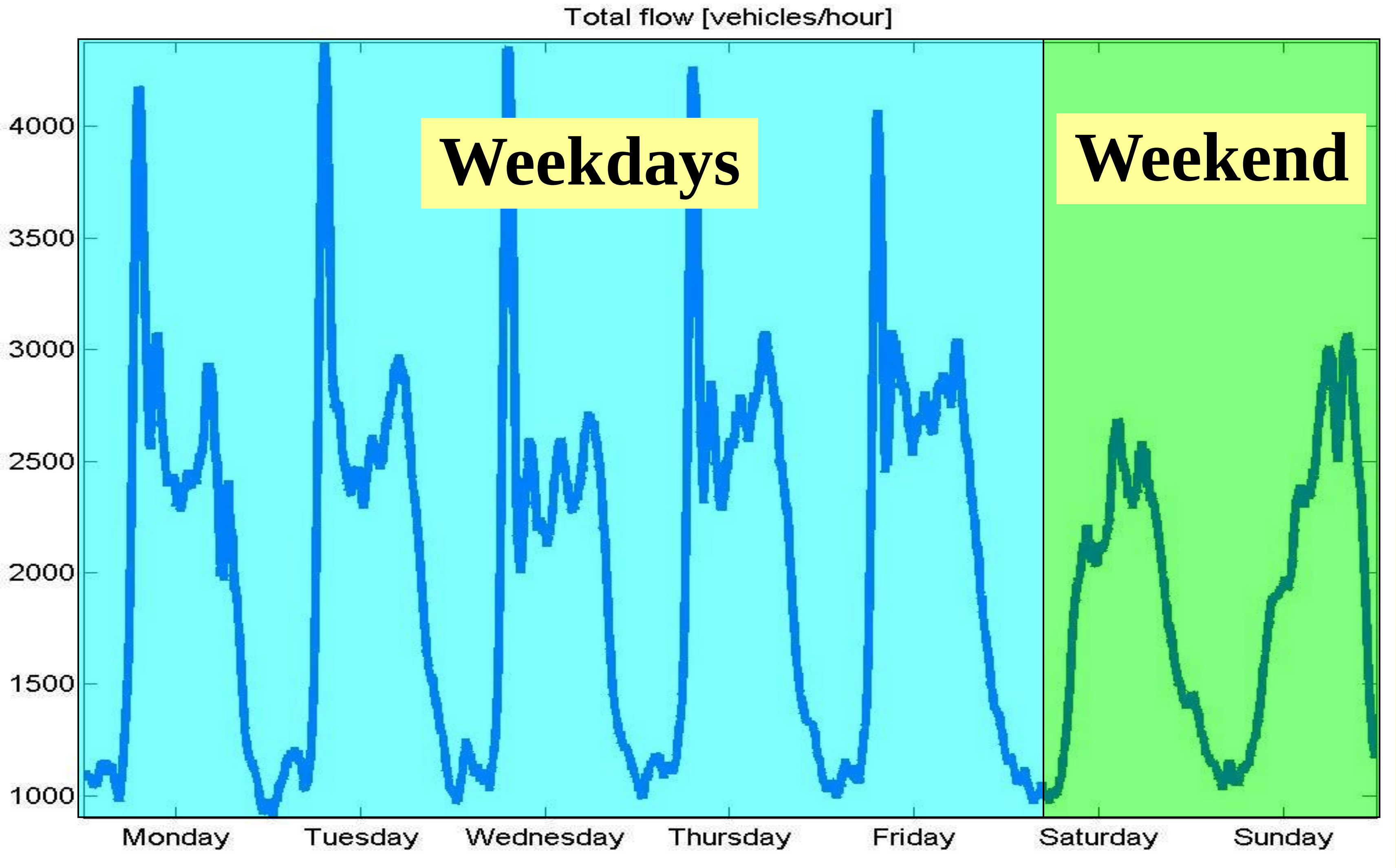
  ⟹ $\bar{v}$

Fundamental relation: $q = k \cdot \bar{v}$

What do the measurements look like ?

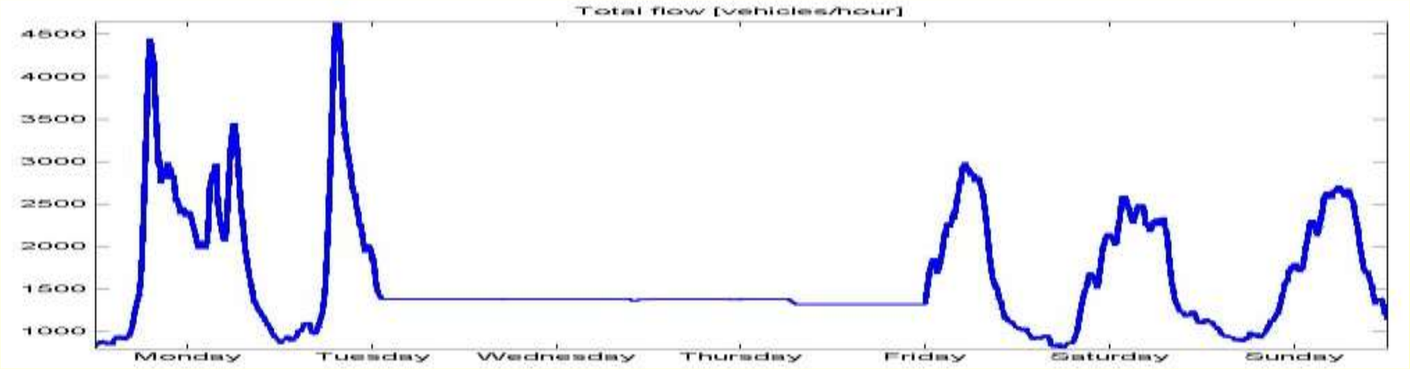


A full week of measurements

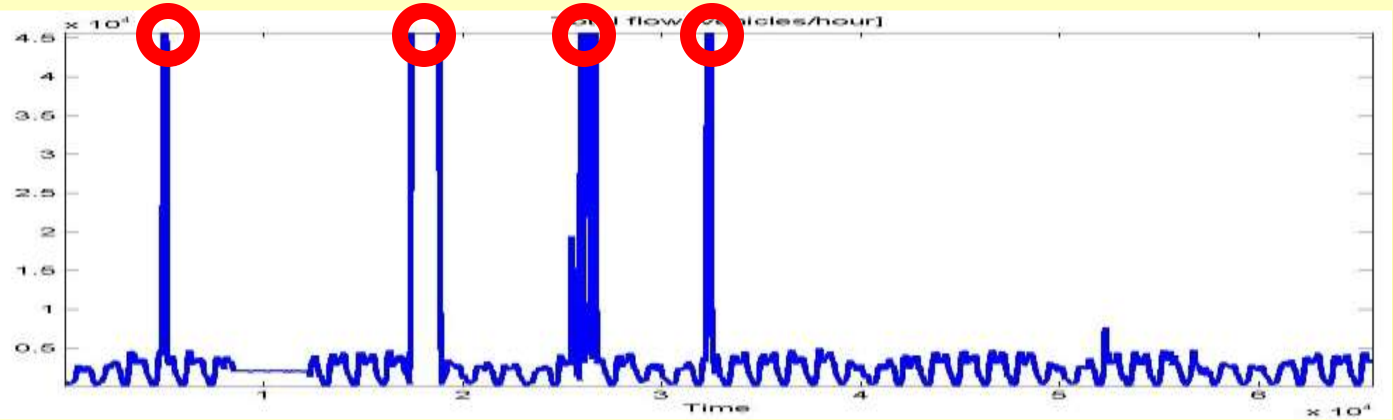


Quality problems !

- Sometimes, a sensor gets ‘stuck’ for several days:



- Or the wrong values are being registered:



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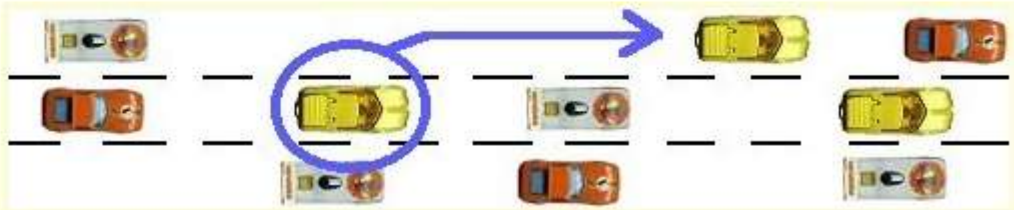
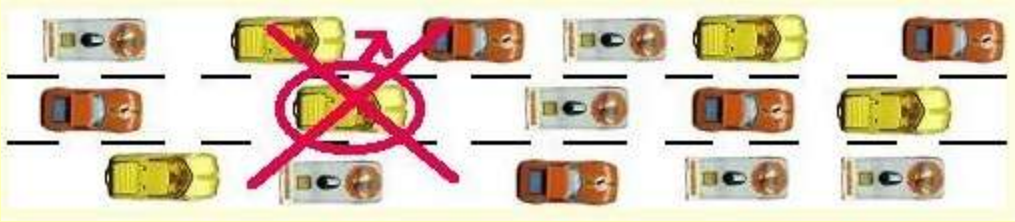
Traffic regimes

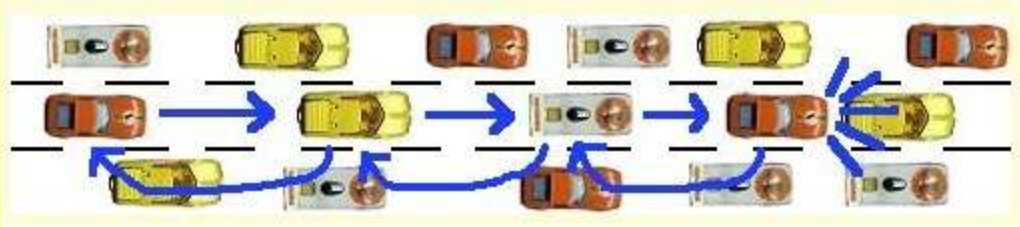
- Low density allows for safe overtaking:



- Higher densities complicate overtaking manoeuvres:



- Congested traffic results in **shock waves**:



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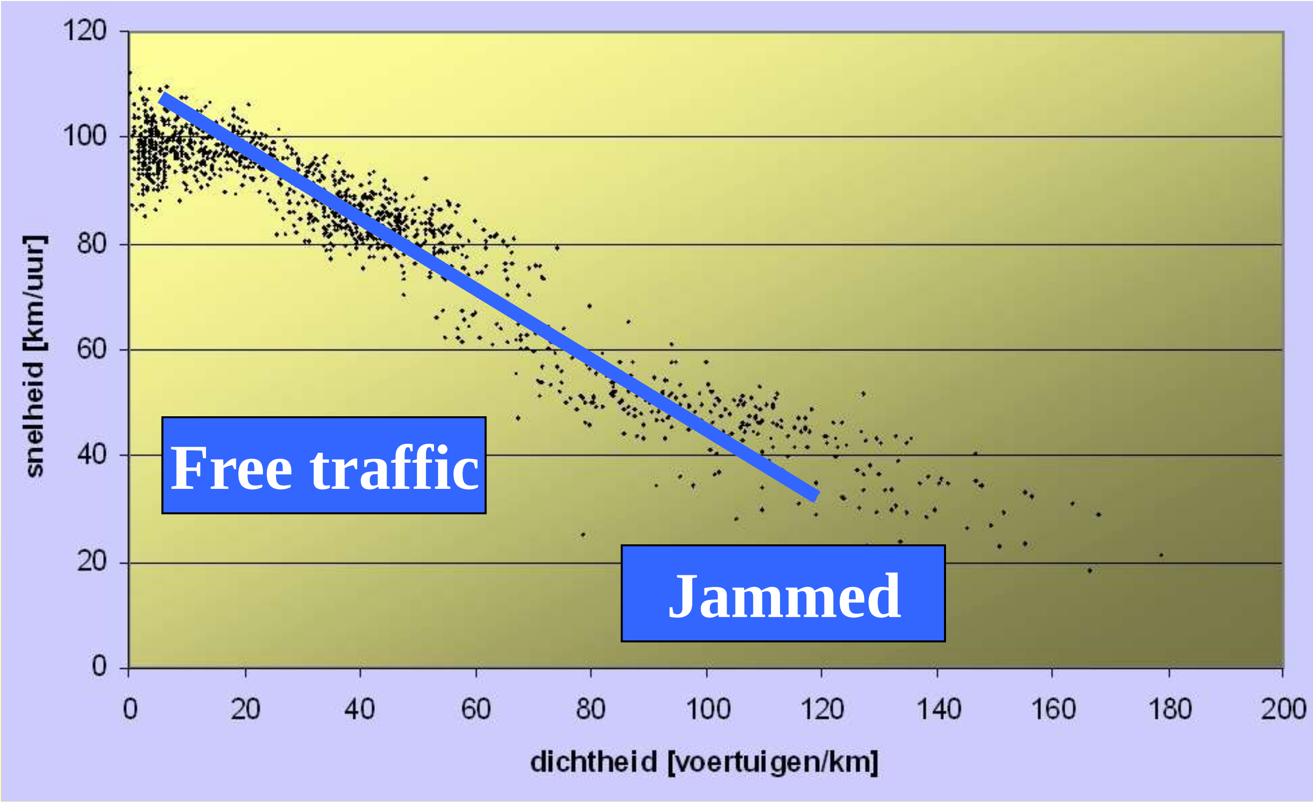
Measurement correlations

- Example: traffic on the E17



“Fundamental diagram”

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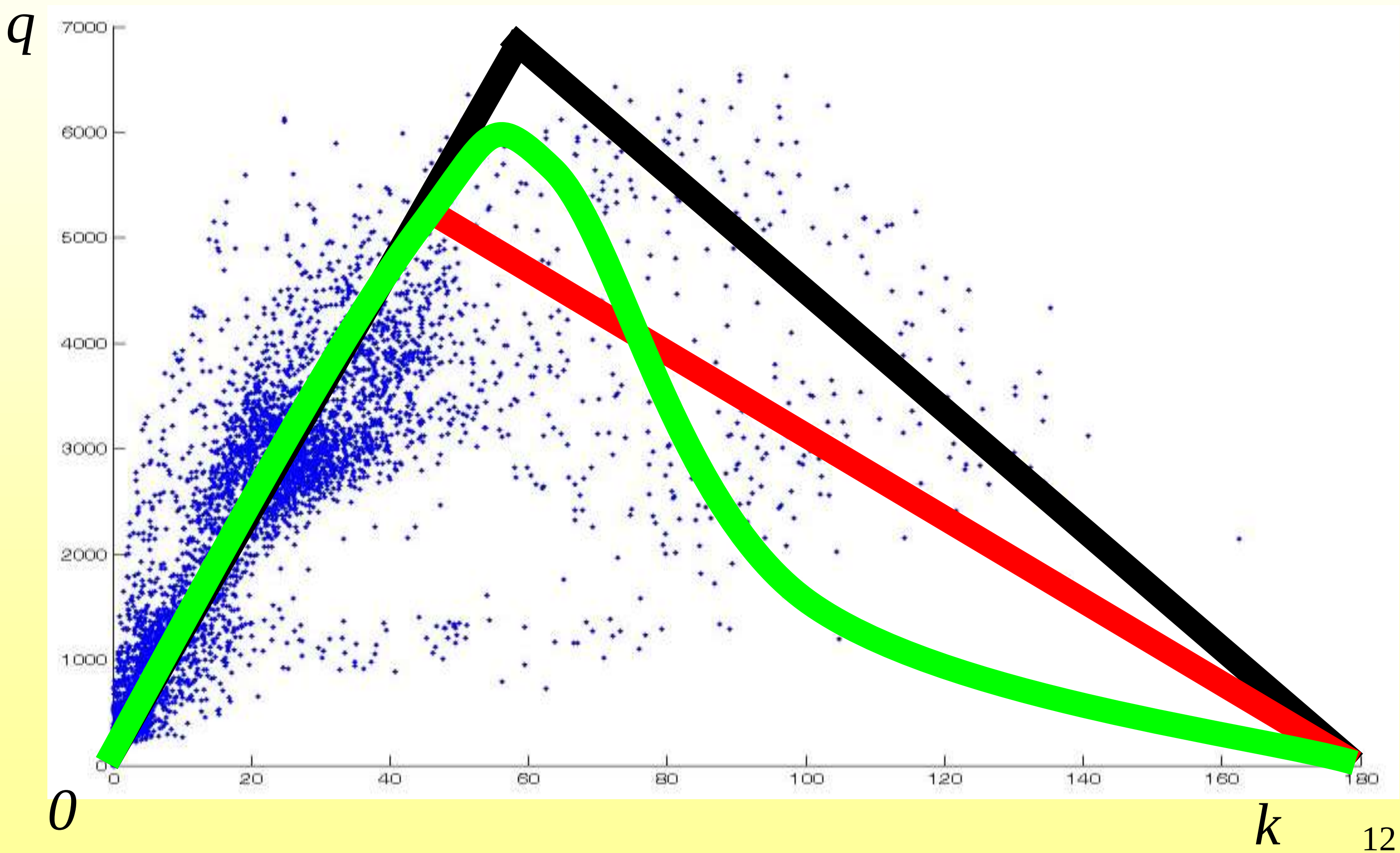
Regimes and fundamental diagrams

- In the (k,q) fundamental diagram:



Models of traffic flows

- The mathematical models are based on the consideration of a traffic flow:
  - as a *whole*

    → **macro-/mesoscopic flow models**

  - as being composed of *individual vehicles*

    → **microscopic flow models**

Macroscopic: fluid or gas ?

- Based on partial differential equations.

- *Fluid-dynamic* models consider a traffic flow as a **compressible fluid** (i.e., *continuum* models).

- *Gas-kinetic* models consider a traffic flow as a **many particle system** (= *'mesoscopic'*).

Americans vs. Germans: the former apply *'rocket science'*, the latter *'particle physics'*.

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Microscopic flow models

- Computationally very intensive !

- Many (unnecessary) parameters !
  ⟹ Sensitivity analysis.

- Much harder to calibrate and validate than macro-/mesoscopic models !

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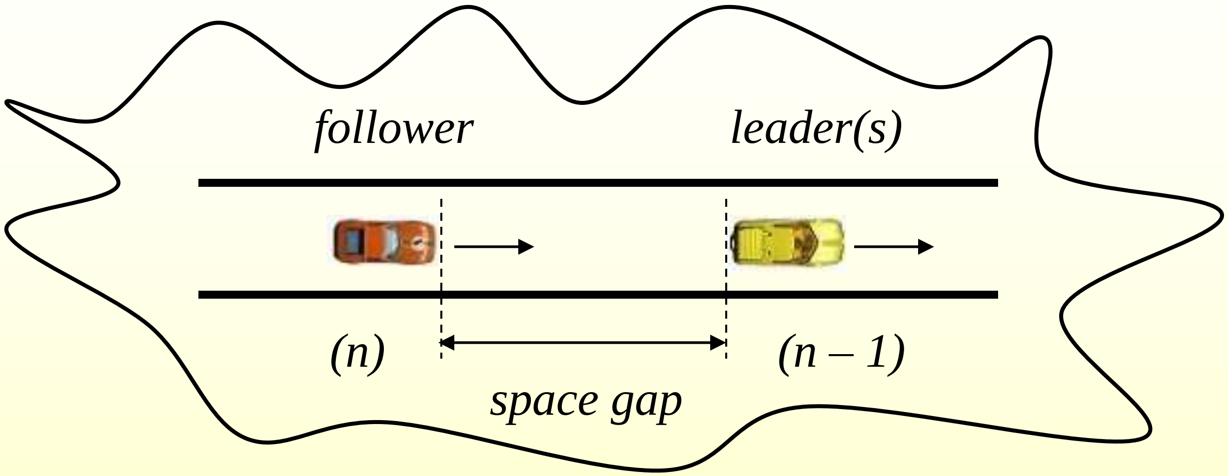
Car following submodel



response depends on ***stimuli***

$a_n(t + \tau) \sim f(t, \Theta)$

reaction time

with $\Theta \ni$ { agression, space headway, time headway, (relative) speeds, … }

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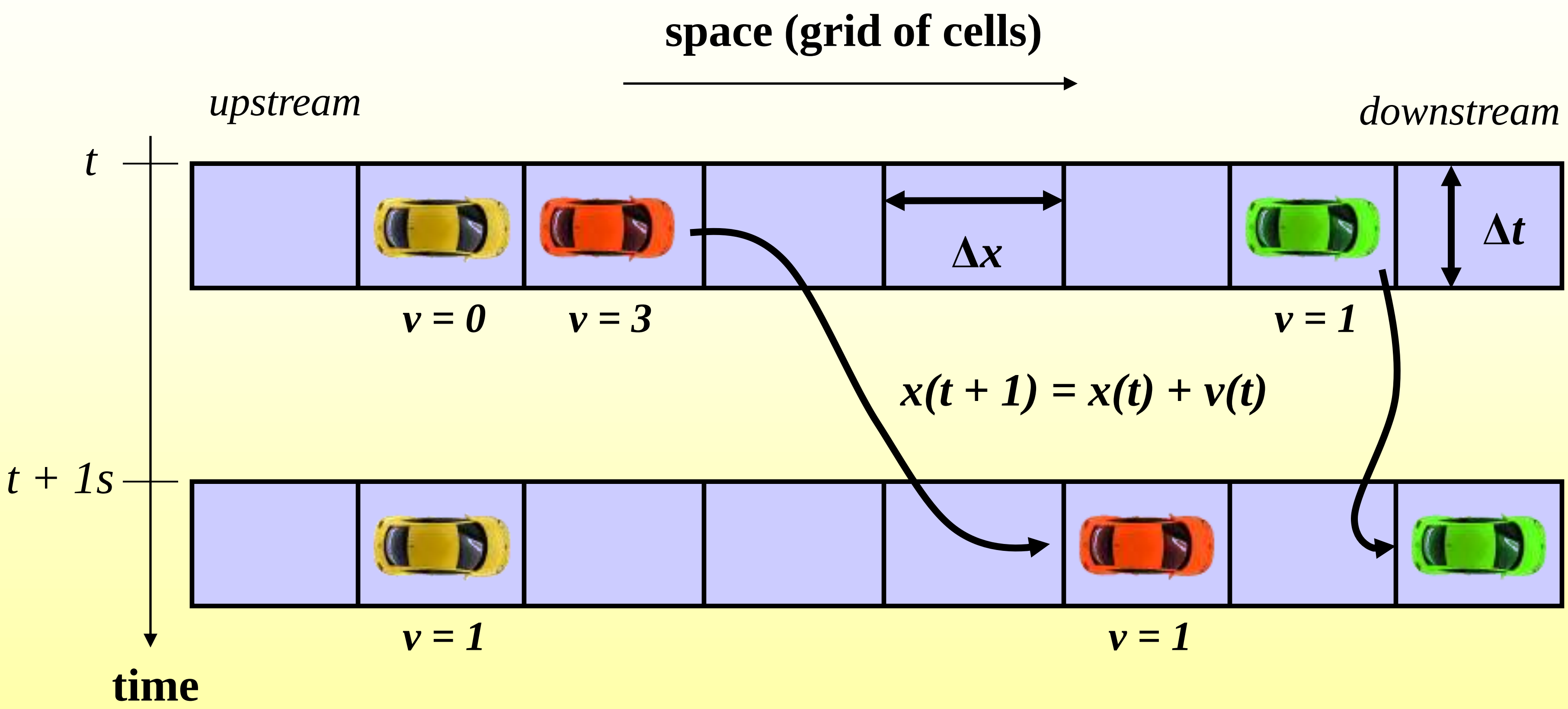
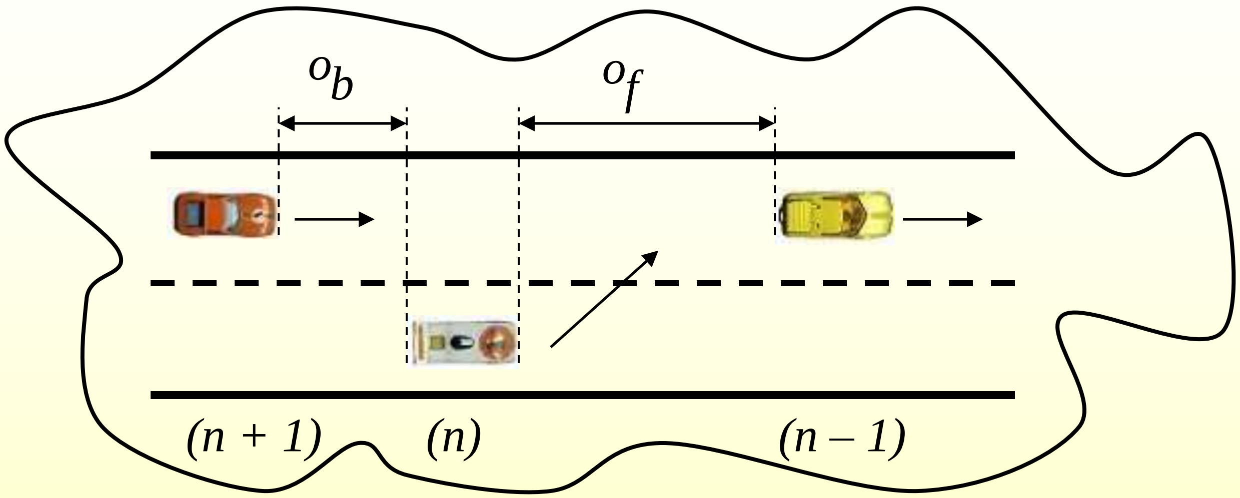
Example: traffic cellular automata



Car following submodel = set of local rules

Lane changing submodel



$p(lane\ change) \sim f(\Theta)$

with $\Theta \ni$
- (critical) gap size(s),
- distance to on/off ramp,
- (desired) speed,
- lane changing rules,
- …

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Routing

- *'Each vehicle needs to know where to go.'*

- A lane changing submodel needs to do the practical implementation of routing:
  - **mandatory lane changes**
  - **discretionary lane changes**

- The actual routing happens on a higher level:
  - **OD-matrices**
  - *splitting rates* (also known as *turning fractions*)

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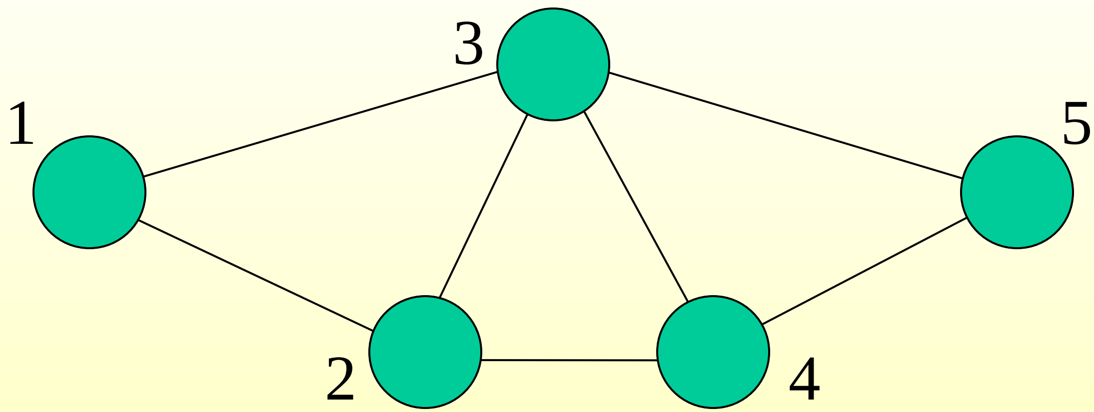
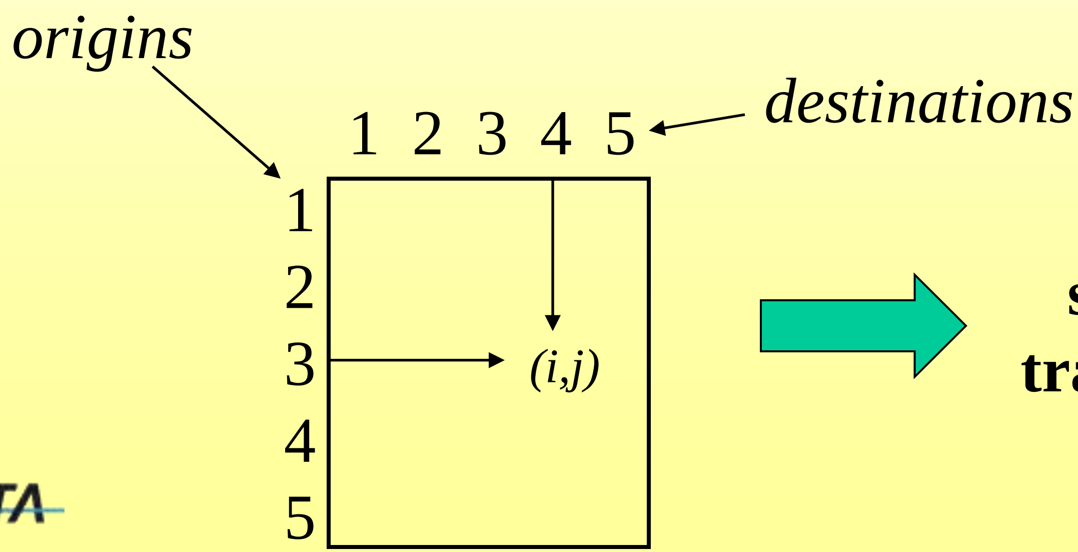
OD-matrix

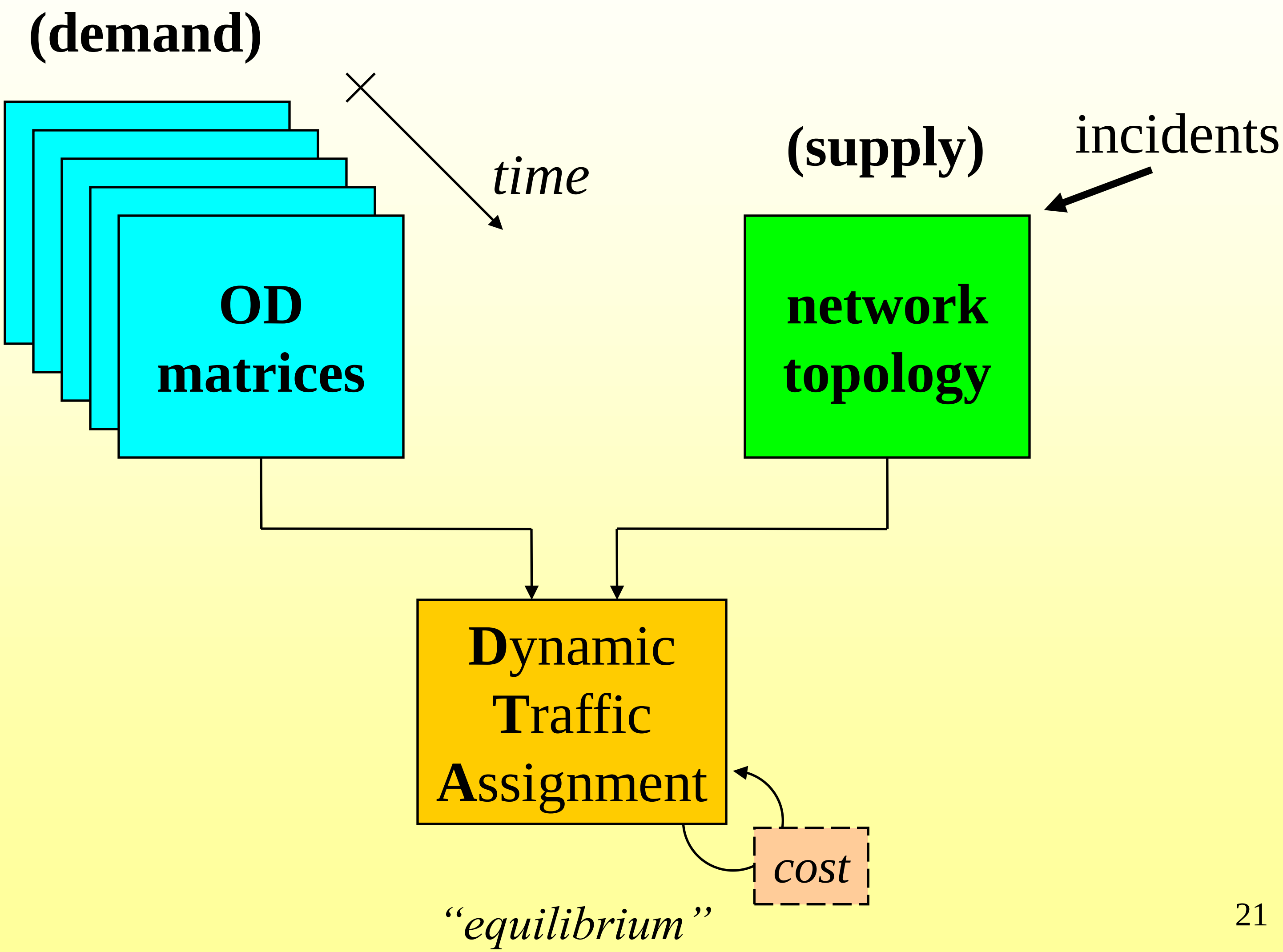
- O = **origin**, D = **destination**



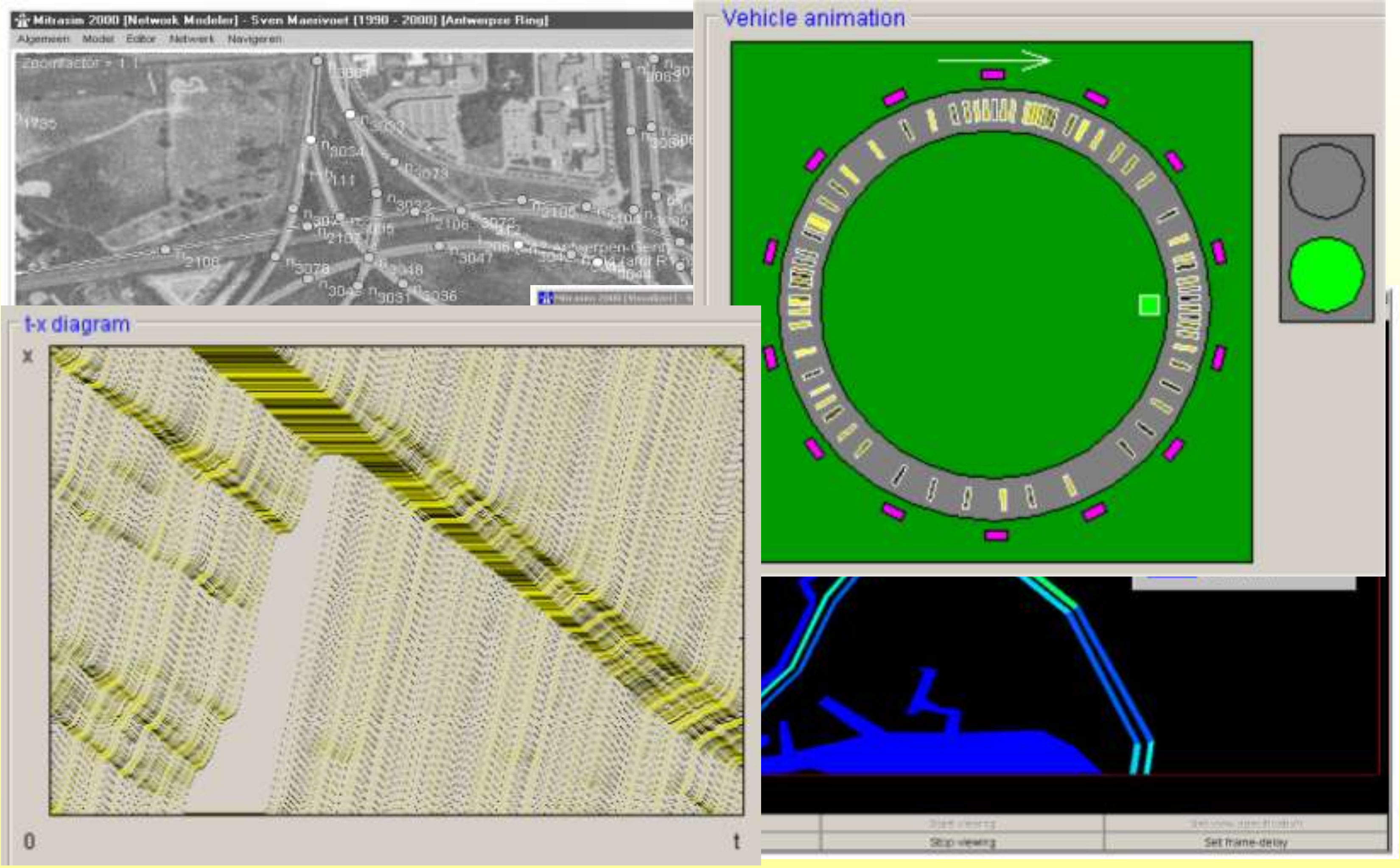


static/dynamic traffic assignment

DTA as a core business

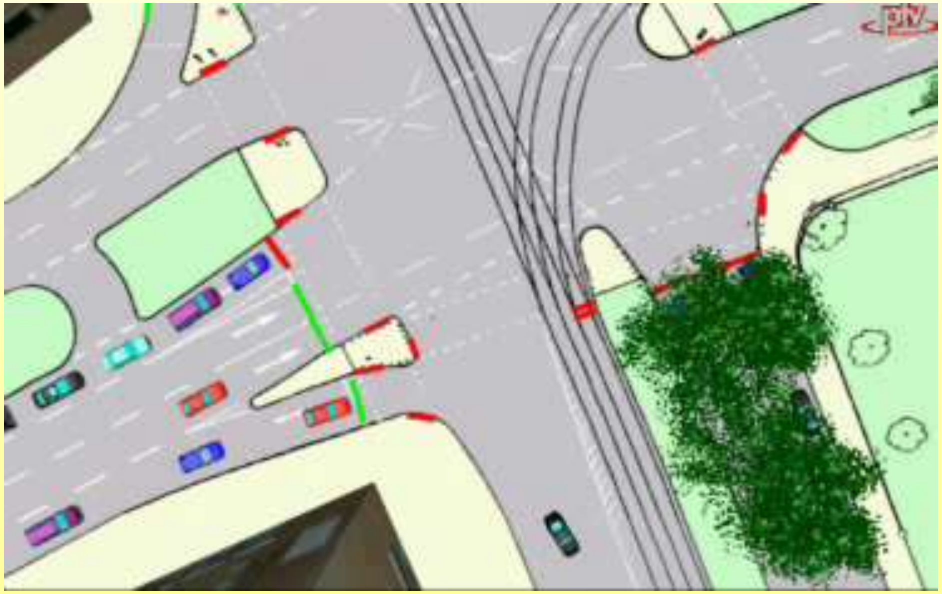


Microscopic simulators (1/2)



Microscopic simulators (2/2)

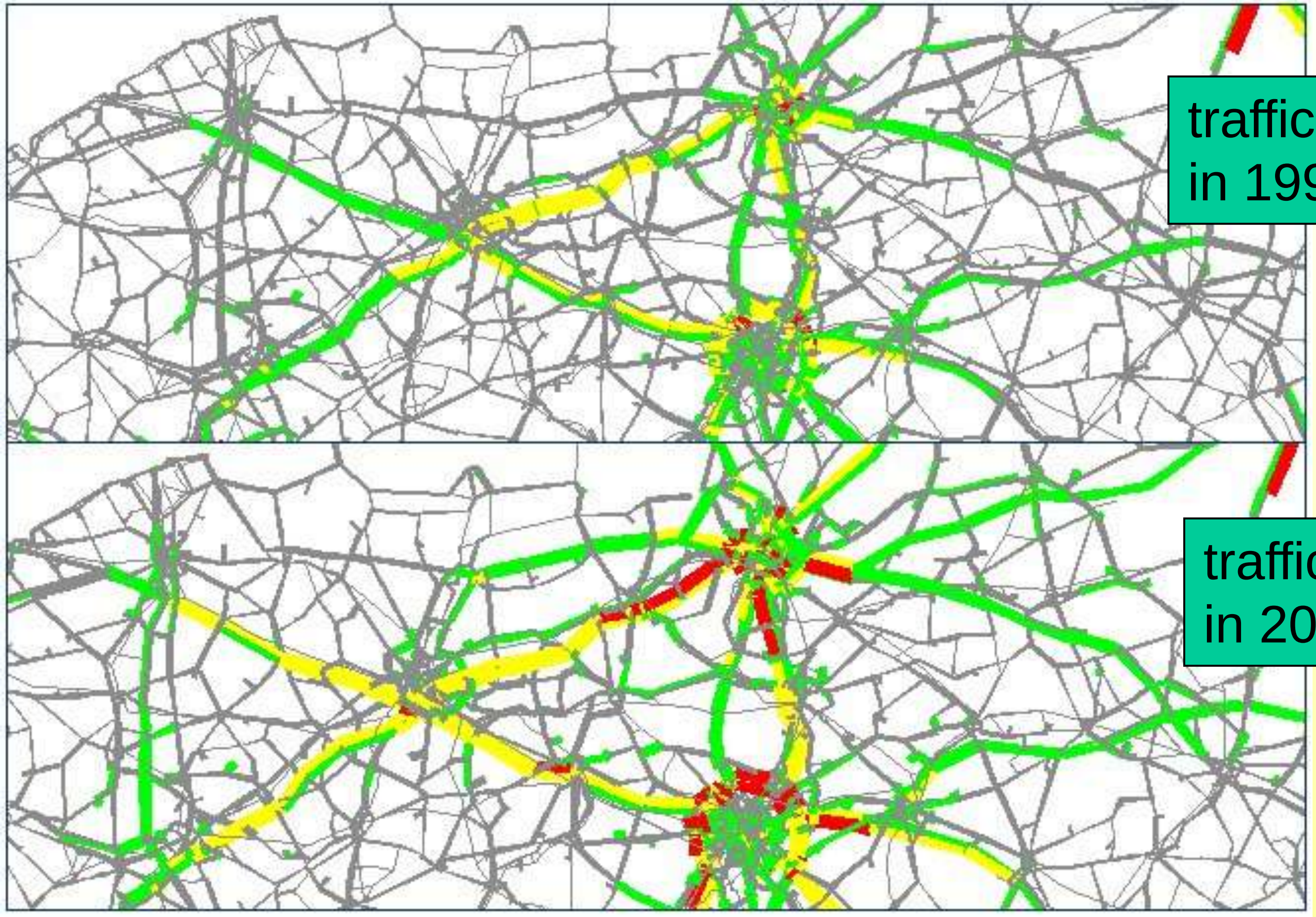
- <u>Commercially:</u> *PARAMICS, AIMSUN, VISSIM, …*



Controlling traffic flows ?

- Why **control** the traffic ?
  - postpone/eliminate traffic jams (if possible),
  - early detection and timely reaction to incidents,
  - pursue an environmental friendly policy,
  - …
- At this moment, Flanders works **locally**.
- In the future, we strive to control on a **network level**.

Prognosis of future traffic flows



traffic volumes
in 1994

traffic volumes
in 2010

Source: “multimodaal model Vlaanderen”

Flanders' Traffic Centre

Controlling traffic lights

– At the level of crossings

– At a *network* level (e.g., de “ Leien “ in Antwerp)

➔ “traffic must leave the city centre as fast as possible”

– At a *corridor* level (e.g., the A12 Antwerp-Brussels)

➔ “The good feeling: always green lights…”

or “The bad feeling: I keep encountering red lights !”

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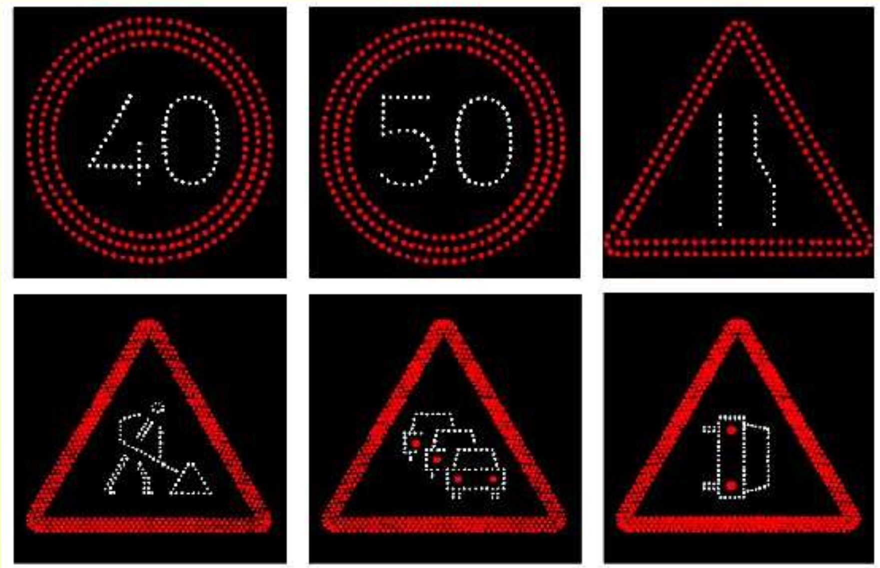
Dynamical route guiding

- Dynamic routing information panels (DRIPs)
  - Travel times
  - Traffic jams (physical length **and time duration !**)
  - Alternative routes

Variable Message Signs (VMS)

- Dynamic speed limits (cfr. Dutch motorways)



Incident detection

- Closing of lanes; diverting traffic
- **Rubbernecking** effects on the opposite lane

Automatic incident detection

Other possible control actions

- Change the drivers’ travel times (leave earlier, depart later, don’t make the journey, ...).
- Road pricing and congestion charging.
- Public transport uses special lanes.
- Parking management.
- Lanes have a variable width.
- Detection of fog, snow, heavy rain, ...
- …

→ **A**dvanced **T**raffic **M**anagement **S**ystems

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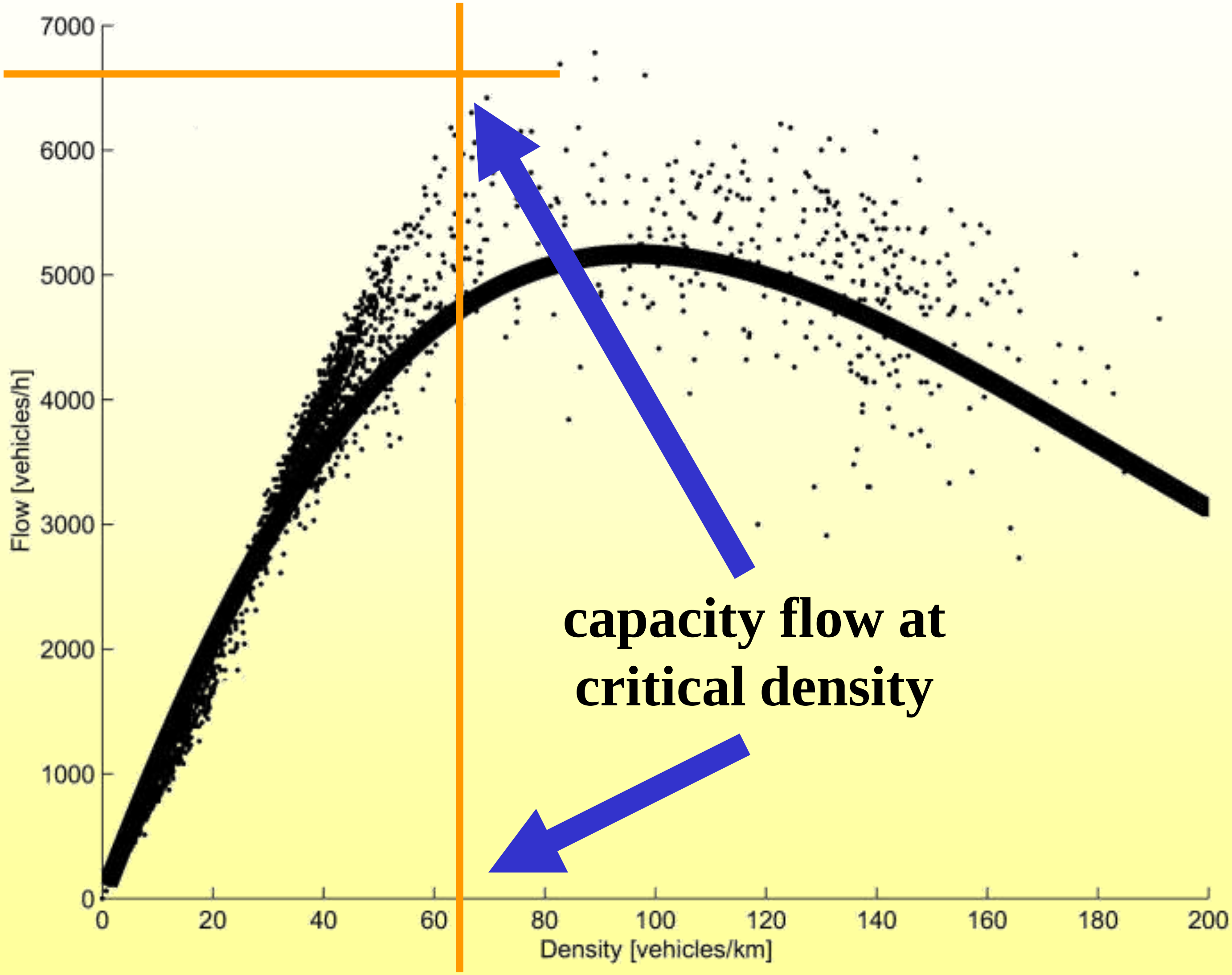
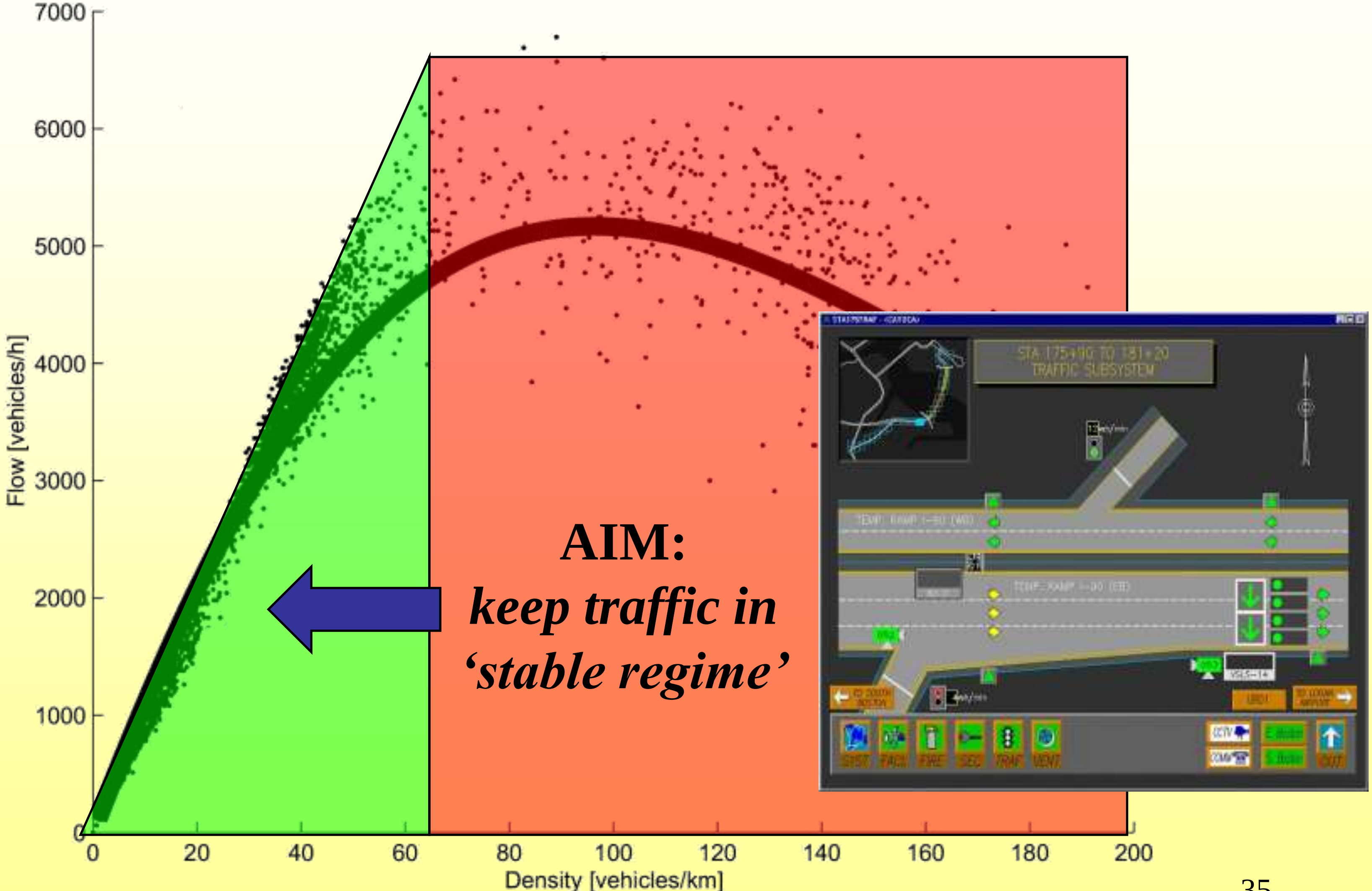
Ramp metering

- *“Try to control the inflow by drops.”*

The idea behind ramp metering

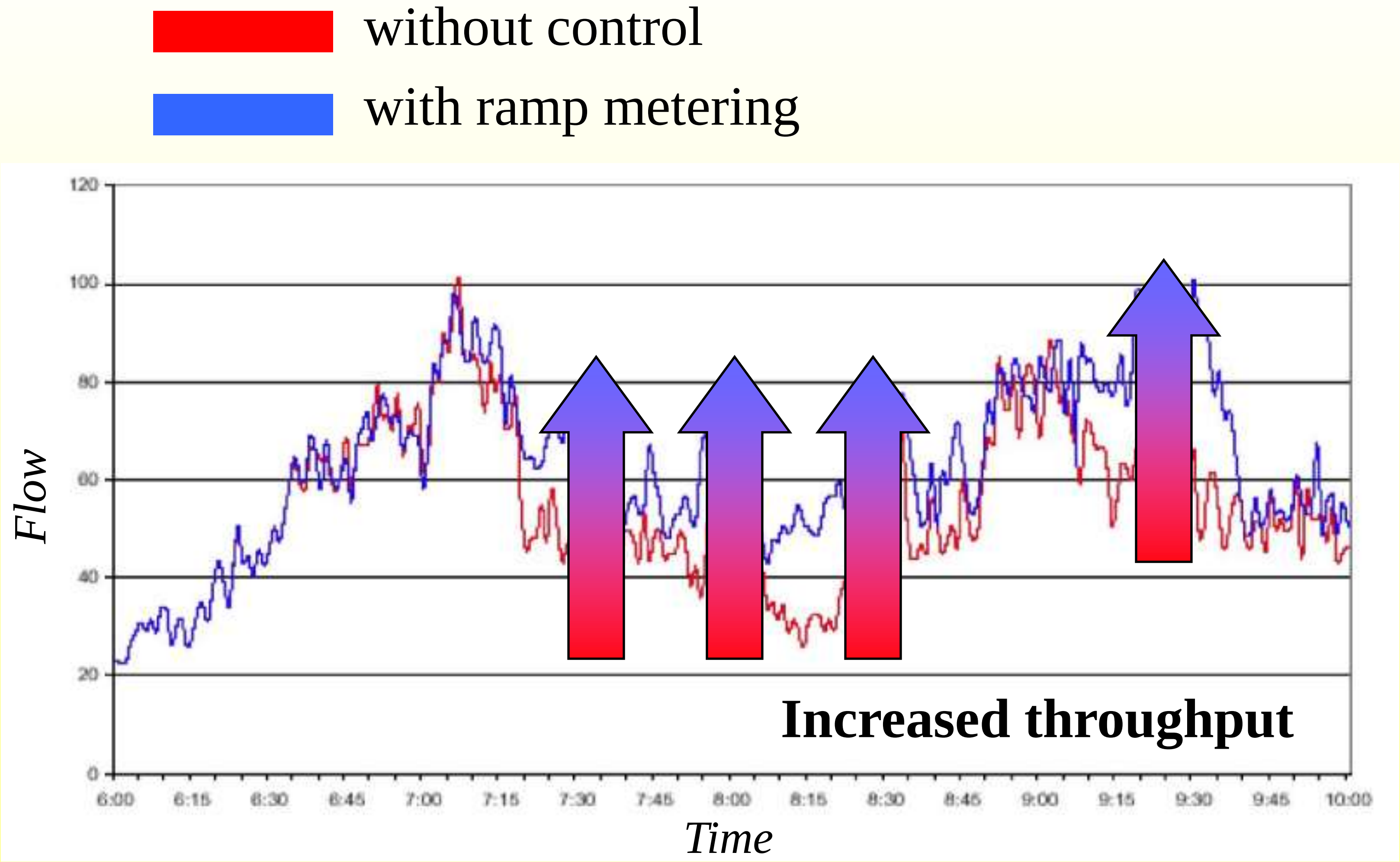


The idea behind ramp metering

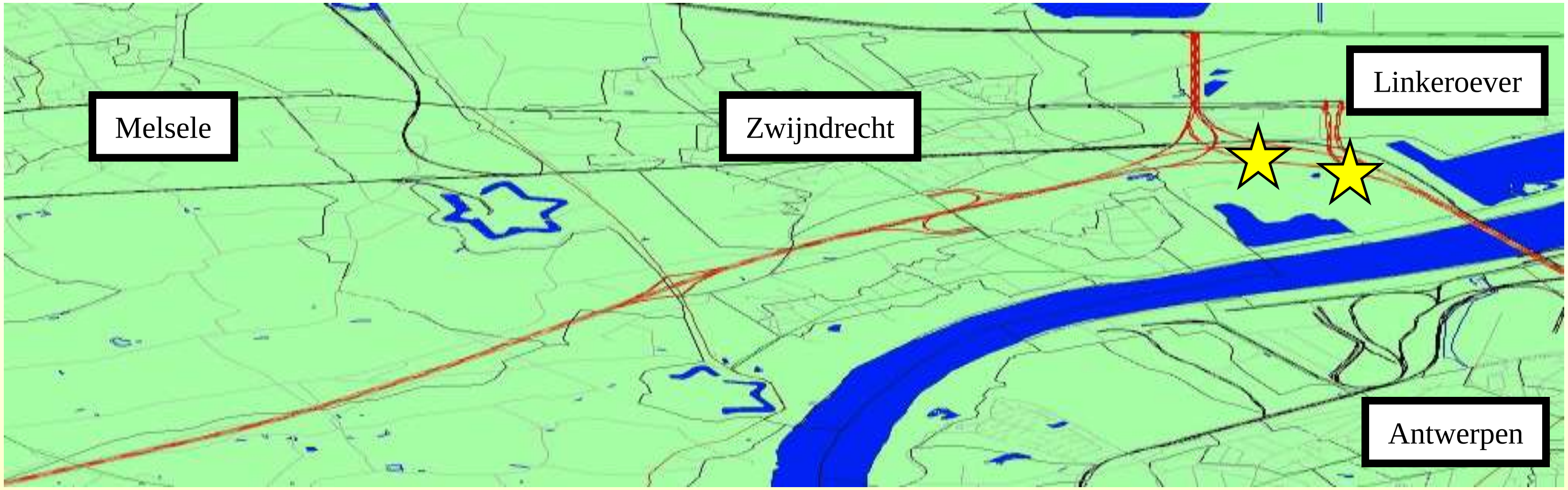


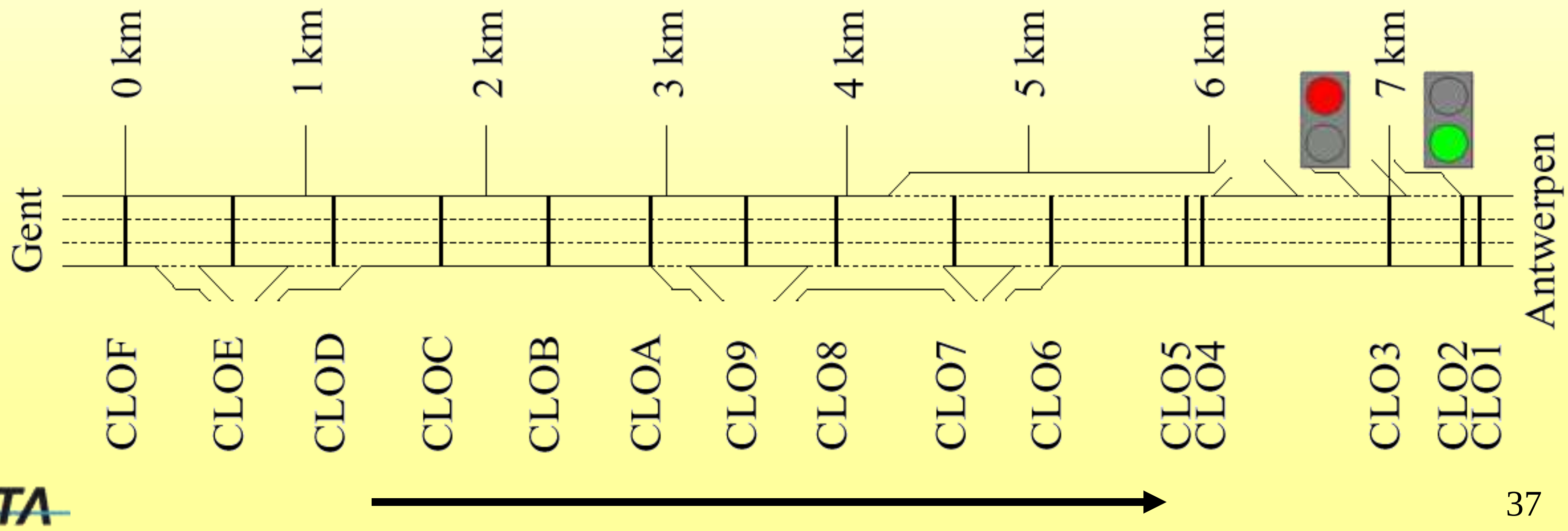
AIM:
keep traffic in 'stable regime'

Benefits of ramp metering



Ramp metering applied to the E17

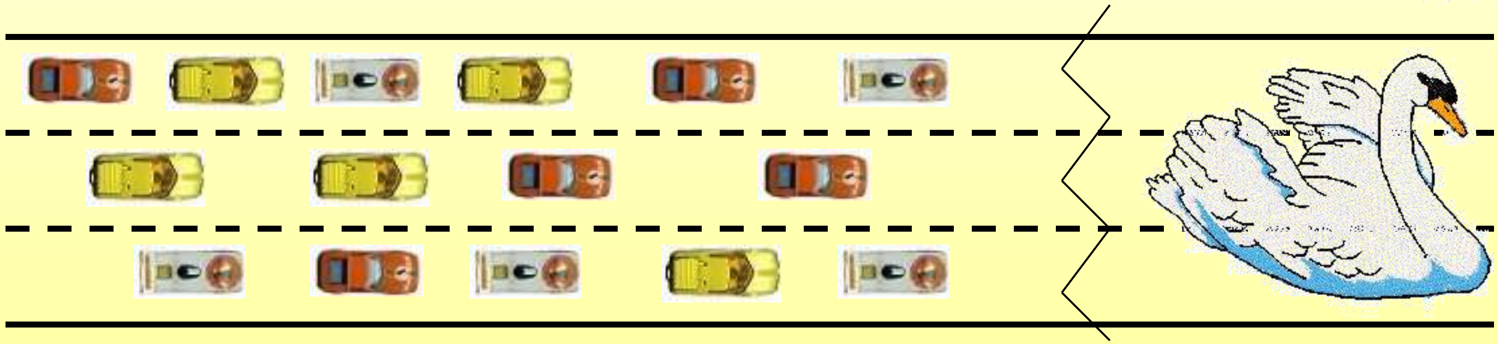




Platoon driving: myth or reality ?

- Vehicles are supposed to drive *close to each other* (in platoons), with a *lower average speed.*
  - It might be safer...
  - BUT is it better (in terms of flow) ?

→ **More research is needed !**



For several years now, the police (i.e., ‘zwaantjes’)
apply platoon driving at the E40
during the busy holidays (visits to the Northsea).

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Sustainability effects of ATMS

- *“Traffic is dynamic in nature”*

Demand ⟷ **Supply**

(travellers/traffic flows) **(road infrastructure)**

⇒ **Optimise** the traffic using the existing road infrastructure !

★ Tools for optimisation ? ⟶ **adaptive control strategies**
(e.g., model predictive control)

★ Optimisation criterion ? ⟶ **sustainable cost function**

Towards a sustainable cost function

- Characterise the concept of *‘sustainability’*, e.g.,

SCF = *emissions (air, noise)* → **environment**

+ *incident risks* → **supply**

+ *travel times* → **personal**

↓ €

- **Important:** the SCF involves a *trade-off* !

environment friendly ⟷ capacity throughput

Illustrative software demonstration