KU LEUVEN

# Capacity drop in Belgium: empirical observations and implications


L-MOB
KU Leuven Mobility Research Center

Prof. dr. ir. Chris Tampère
Dr. ir. Willem Himpe



TRAIL masterclass Mysteries on motorway traffic operations
14 december 2016

# Overview

- Part 1: capacity drop on Belgian motorways
  - R0 ring of Brussels
  - empirical observations
  - implications for potential impact control applications

- Part 2: capacity drop on Belgian intersections
  - concept and definition
  - empirical set-up
  - empirical observations

# Capacity drop on Belgian motorways

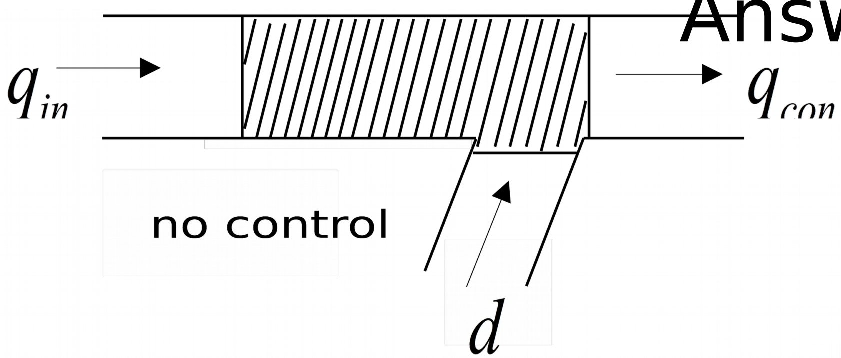
master thesis Thijs Van Tieghem
KU Leuven master Traffic & Logistics

# Motivation and objective

- potential for traffic control claimed
  - literature
    - capdrop = one of two main degradation mechanisms
    - e.g. work Papageorgiou predicts ~50% TTS reduction by eliminating capacity drop and spillback
    - if even 20% of that were true…
  - field deployment
    - coordinated metering in Melbourne confirmed spectacular gains
    - e.g. John Gaffney (VicRoads)
- this finally convinced Flemish road authority to support study into potential for ramp metering in Belgium

# 2. Why Ramp Metering?

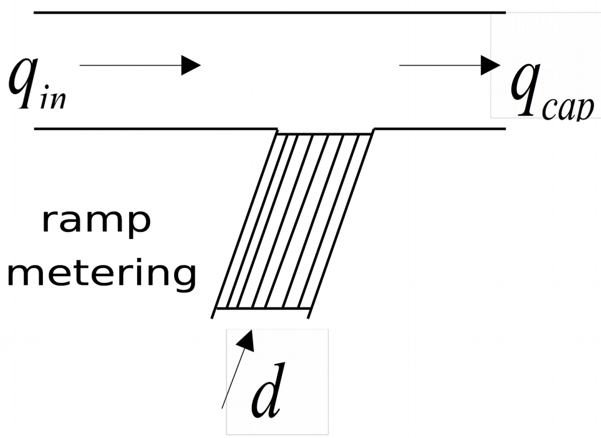
## 1st Answer

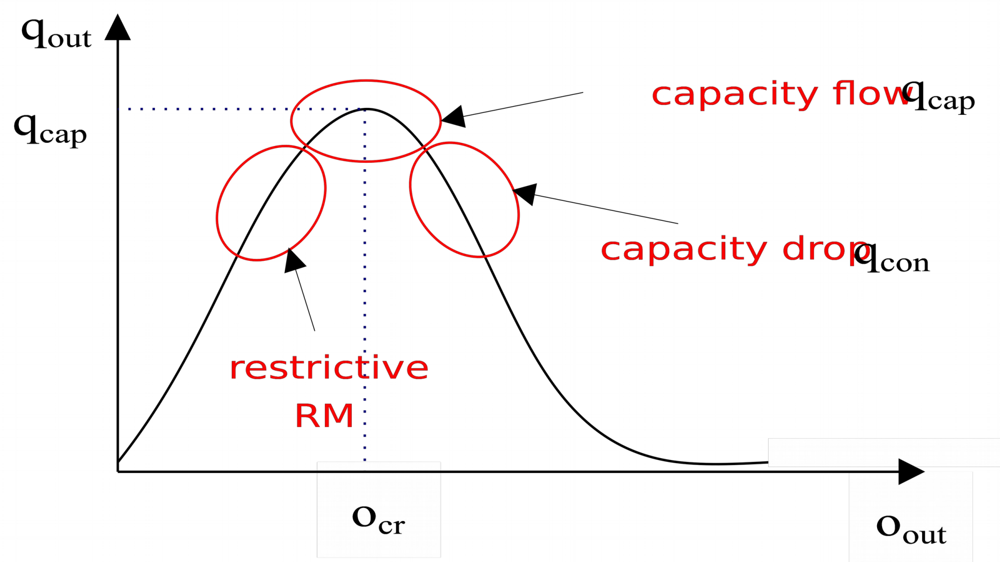



$$\Delta T_s = \frac{T_s^{nc} - T_s^{rm}}{T_s^{nc}} = \frac{q_{cap} - q_{con}}{q_{in} + d - q_{con}}$$

e.g. $q_{con} = 0.95 q_{cap}; \quad q_{in} + d = 1.2 q_{cap}$

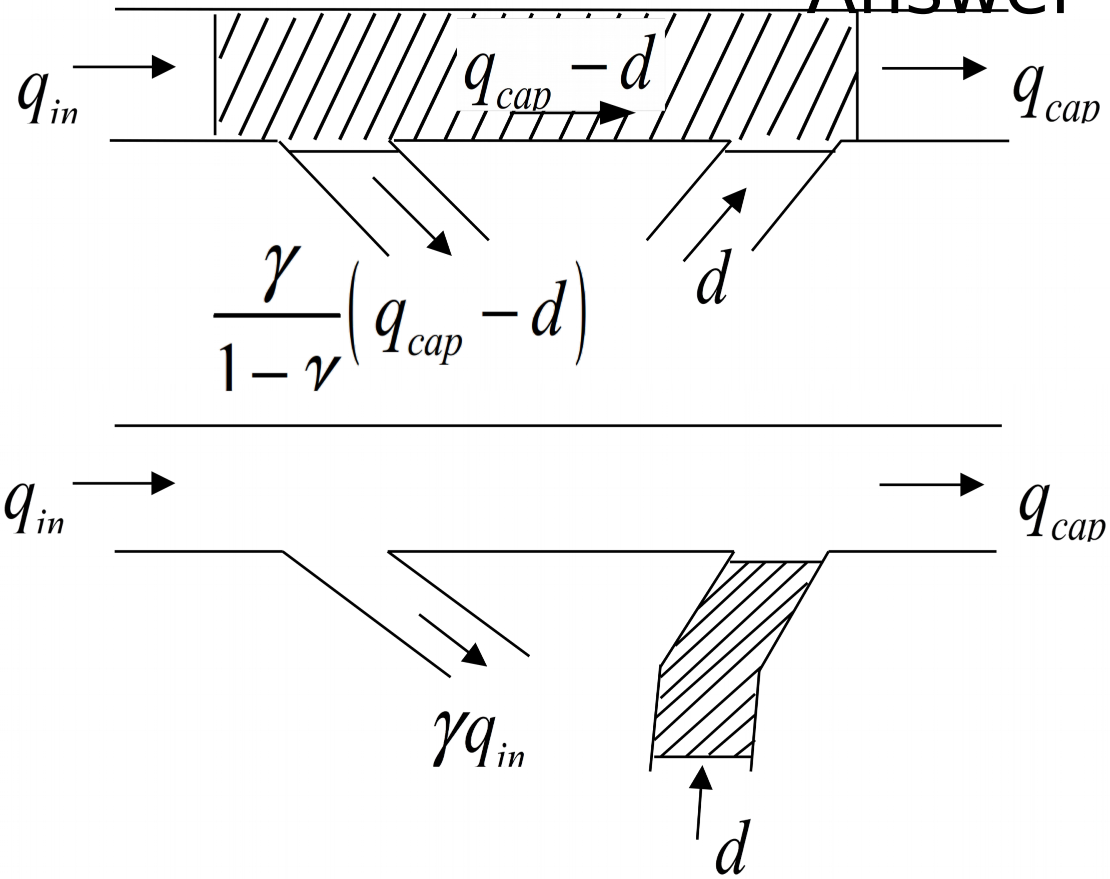
$\rightarrow \Delta T_s$ A $20\%$




prof. Markos Papageorgiou (TU Crete) is kindly acknowledged for sharing these slides!

# 2nd Answer



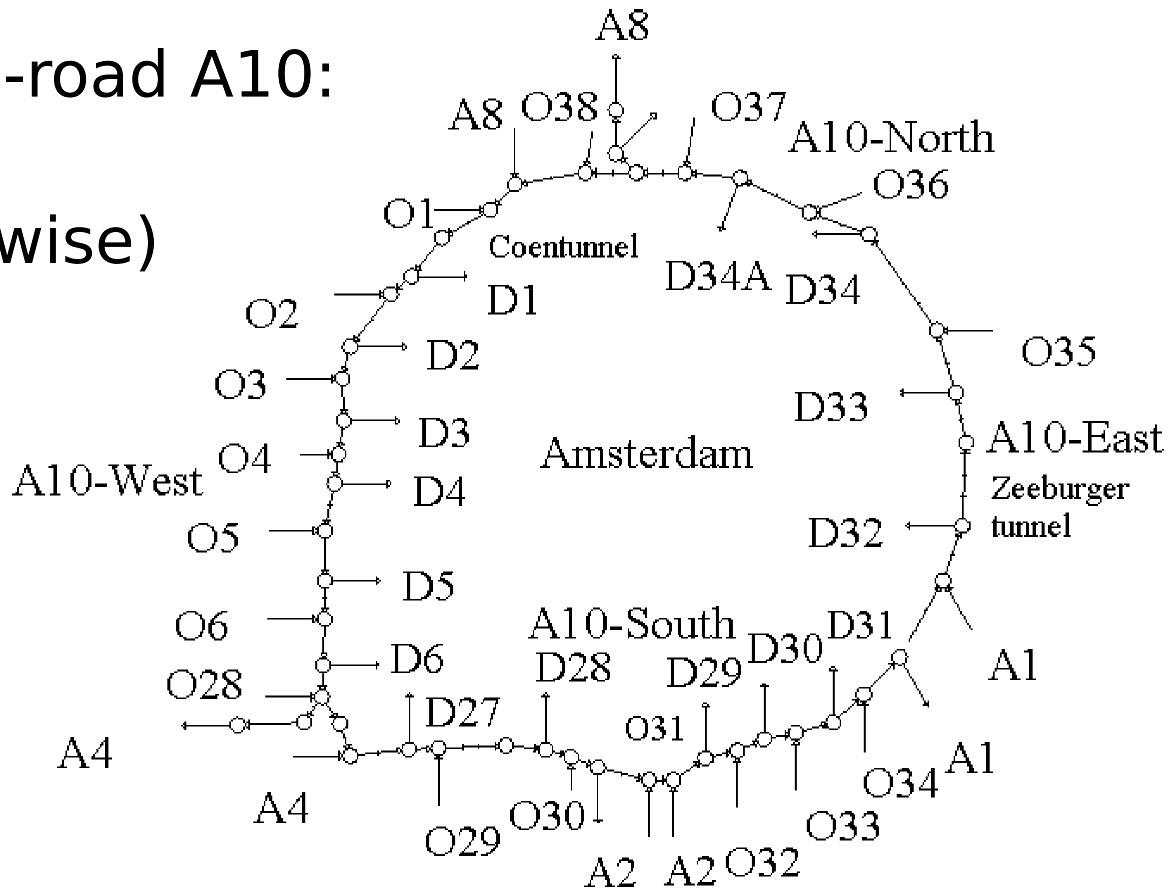

$$\Delta T_s = \frac{T_s^{nc} - T_s^{rm}}{T_s^{nc}} = \gamma$$

**Note:** On-ramp queue should not interfere with surface street traffic.

# 6. Simulation Results

Amsterdam ring-road A10:

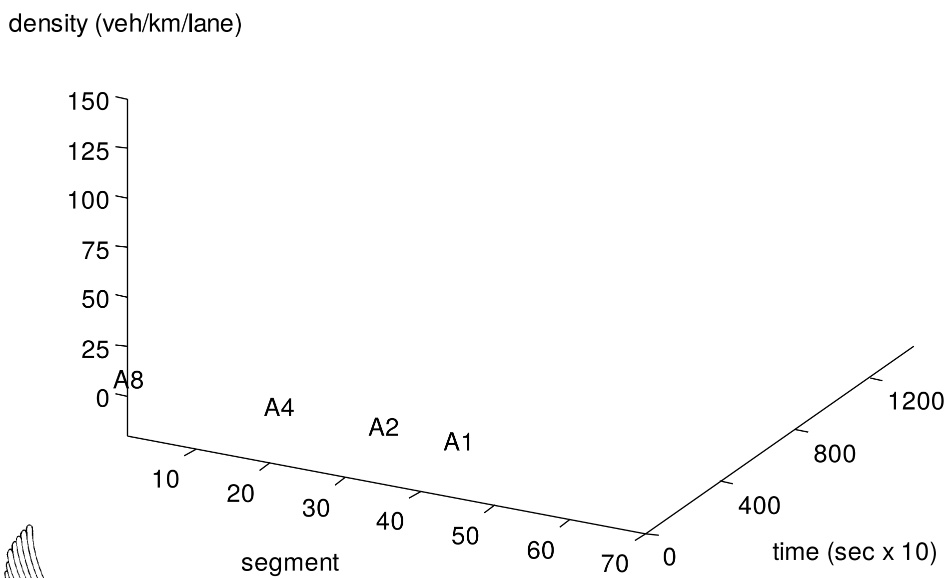
- 32 km (counterclockwise)
- 21 on-ramps
- 20 off-ramps



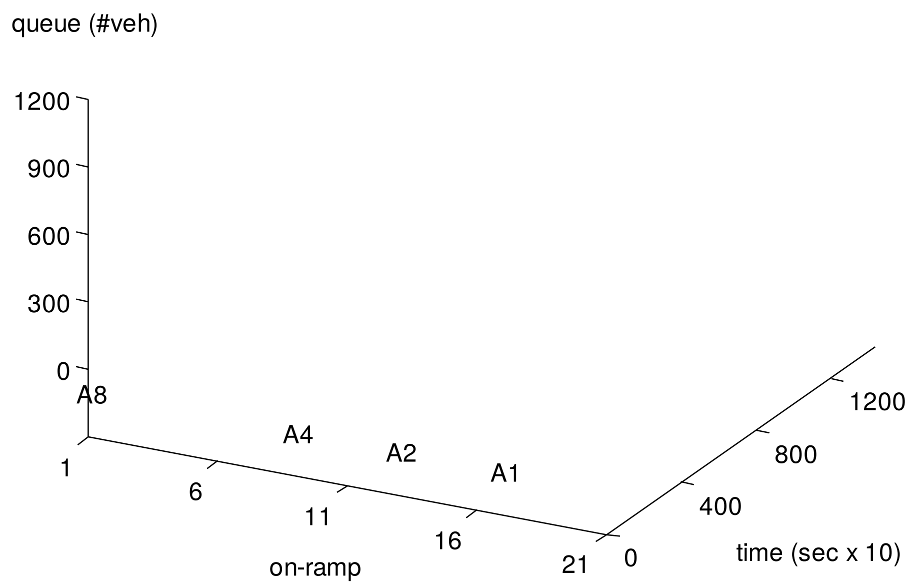
# No-Control Case

TTS = 14167 veh•h

Density profile



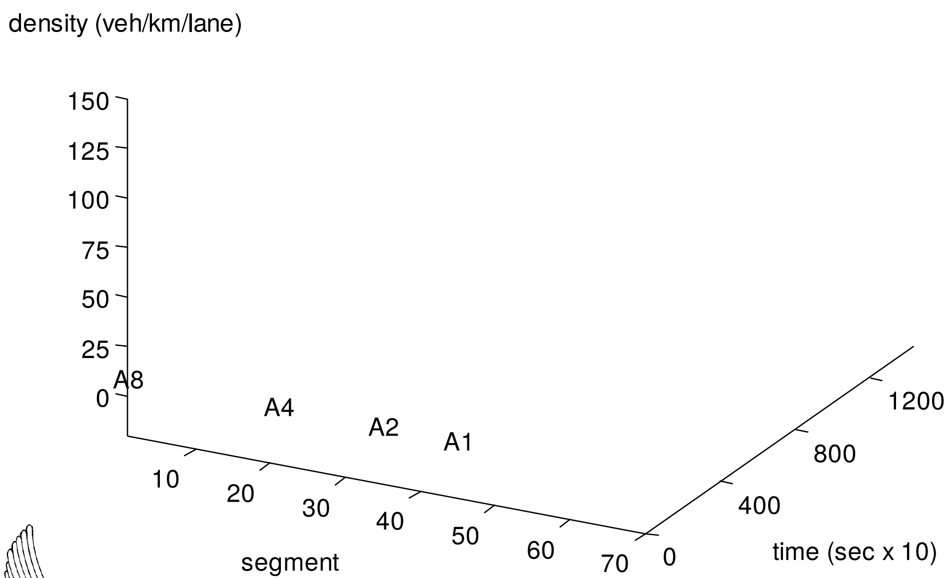

Ramp queue profile



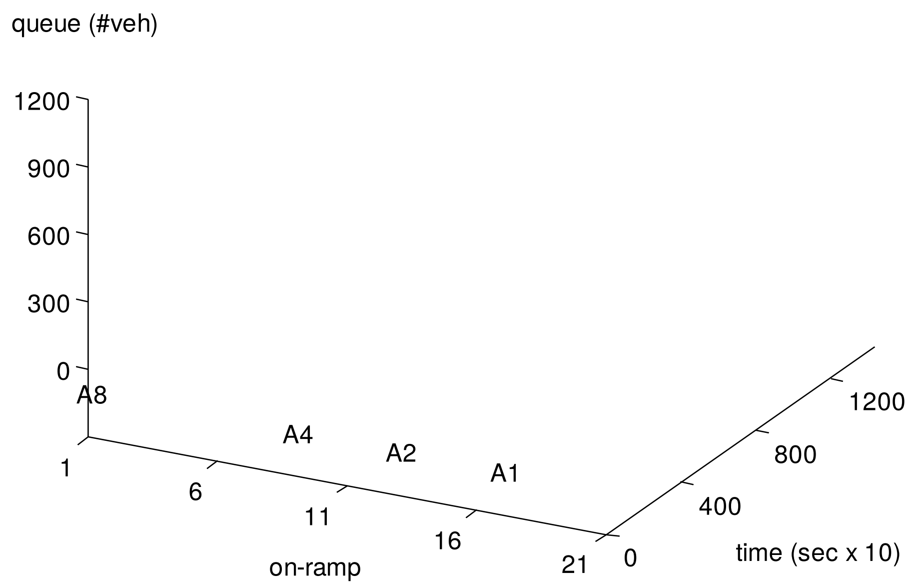
# ALINEA without Queue Control

## TTS = 7563 veh•h   -47%

### Density profile




### Ramp queue profile



# Motivation and objective

- potential for traffic control claimed
  - literature
    - capdrop = one of two main degradation mechanisms
    - e.g. work Papageorgiou predicts ~50% TTS reduction by eliminating capacity drop and spillback
    - if even 20% of that were true…
  - field deployment
    - coordinated metering in Melbourne confirmed spectacular gains
    - e.g. John Gaffney (VicRoads)
- this finally convinced Flemish road authority to support study into potential for ramp metering in Belgium

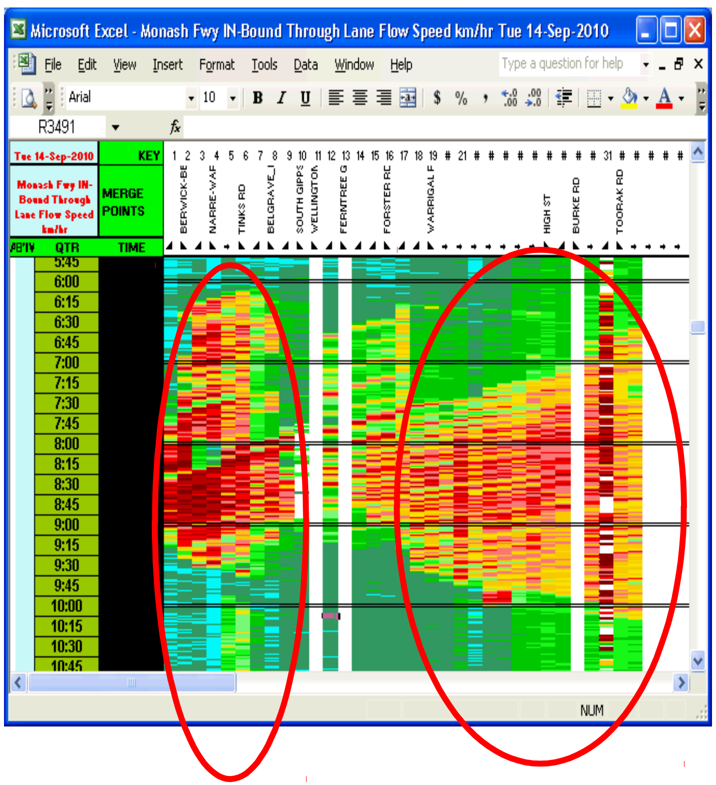
KU LEUVEN

# M1 Corridor – what are the traffic patterns?

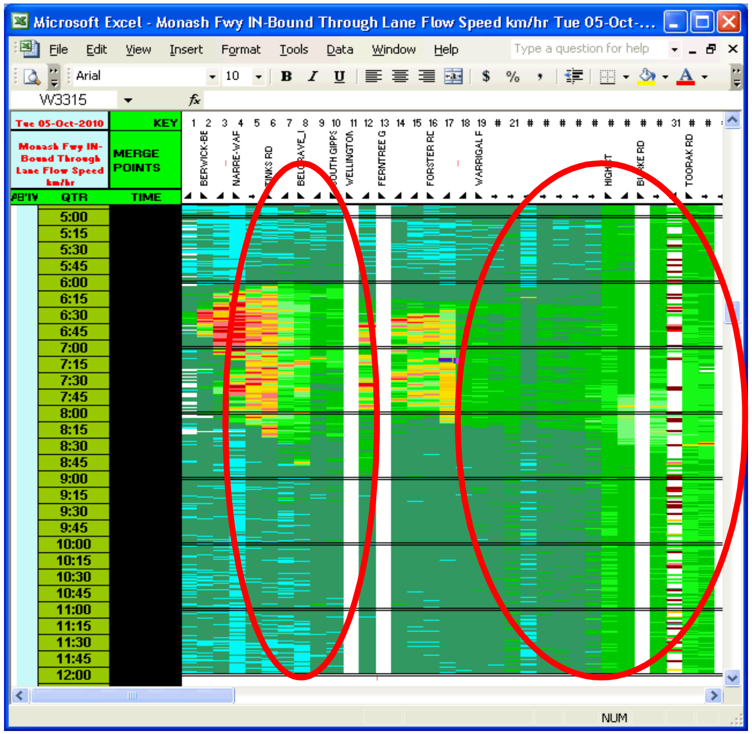

John Gaffney (VicRoads) is kindly acknowledged
for sharing these slides!

# Getting Control of the Freeway

**Before**

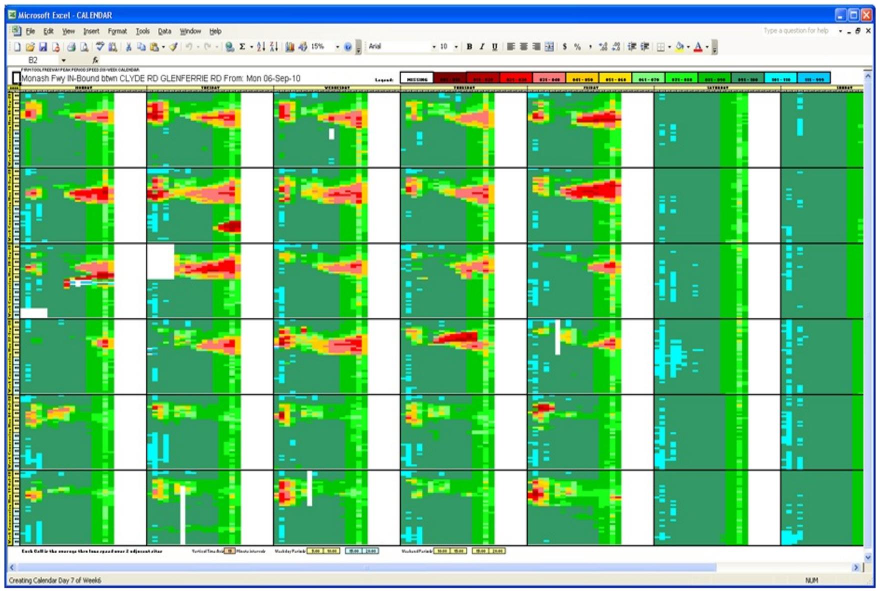



**After**

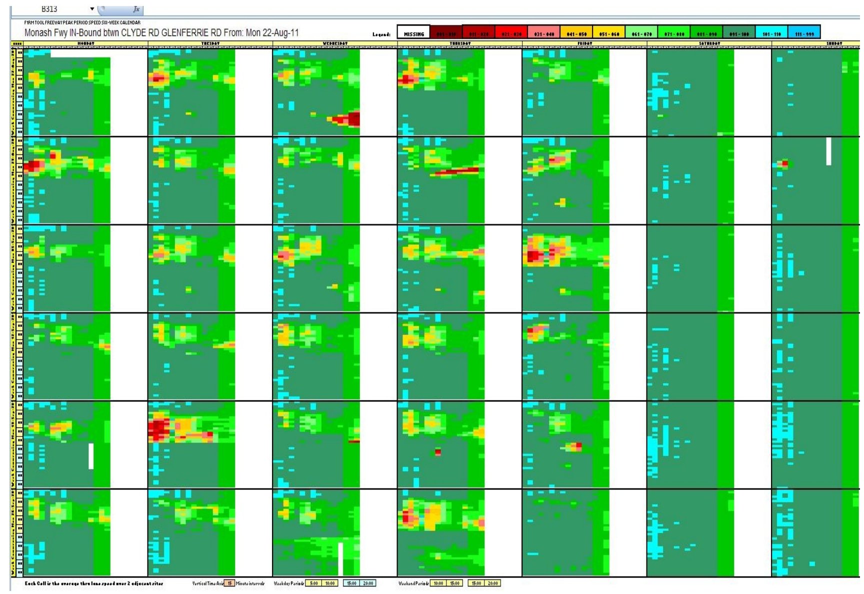


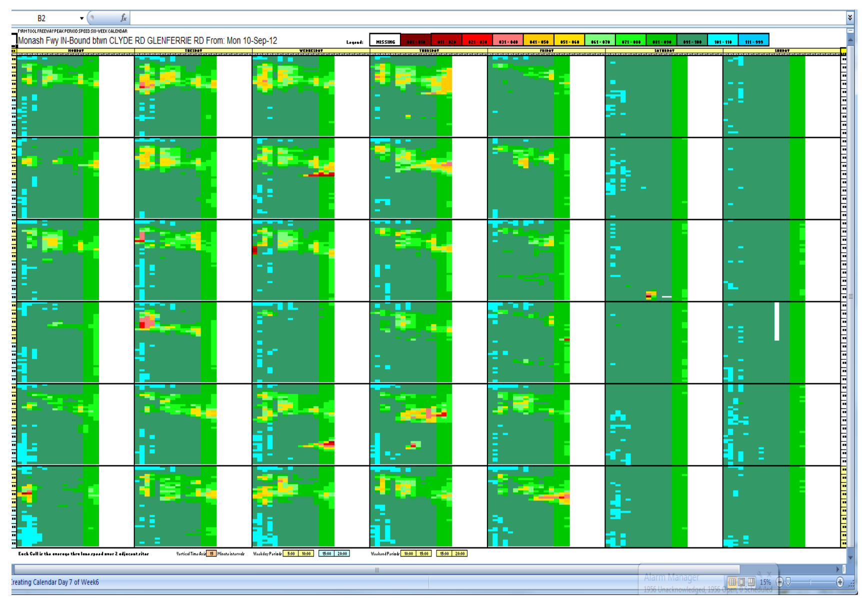

**2rd Bottleneck** **1st Bottleneck** **2rd Bottleneck Reduced** **1st Bottleneck Removed**

# Before




# After

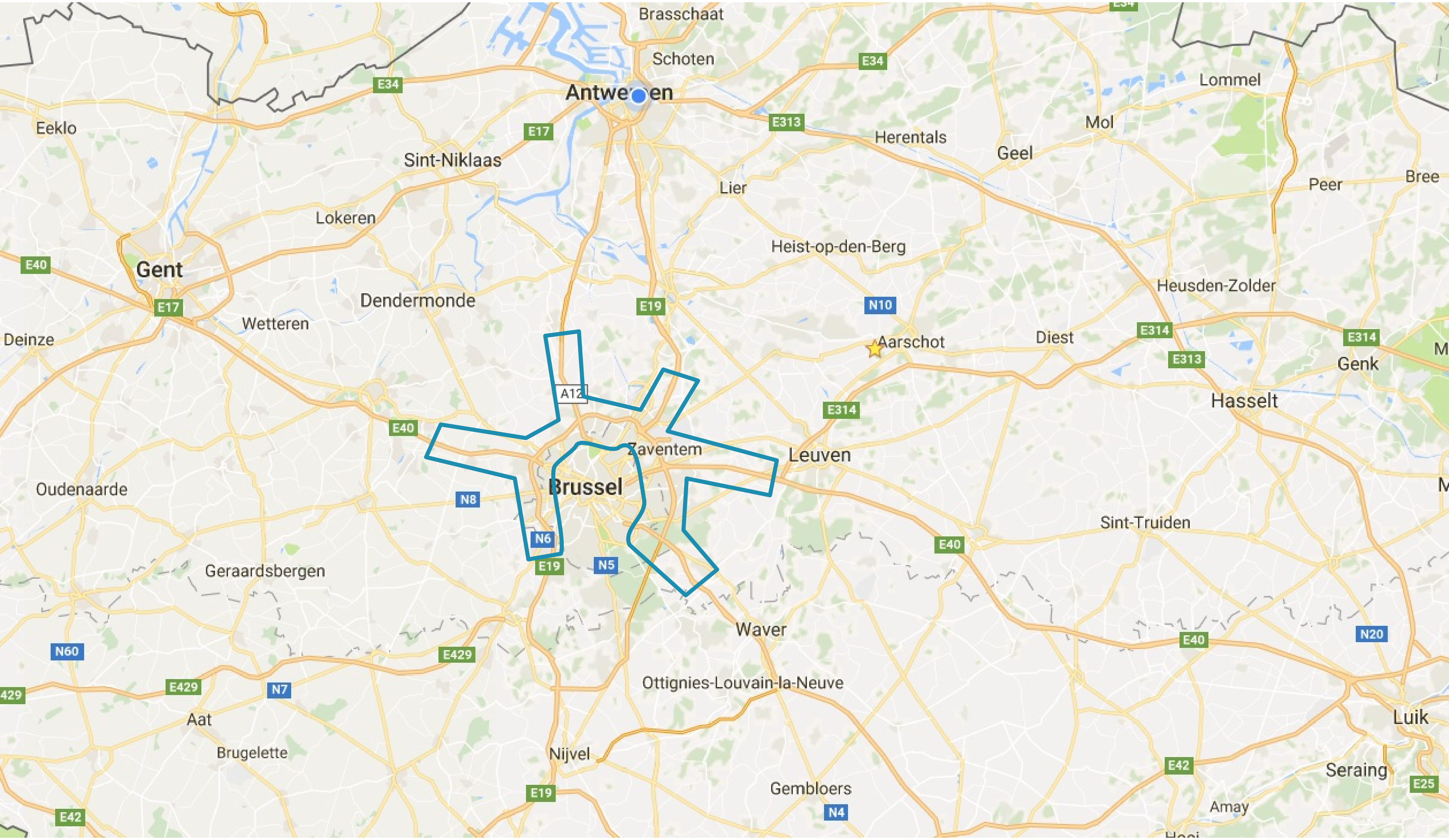


# Empirical set-up

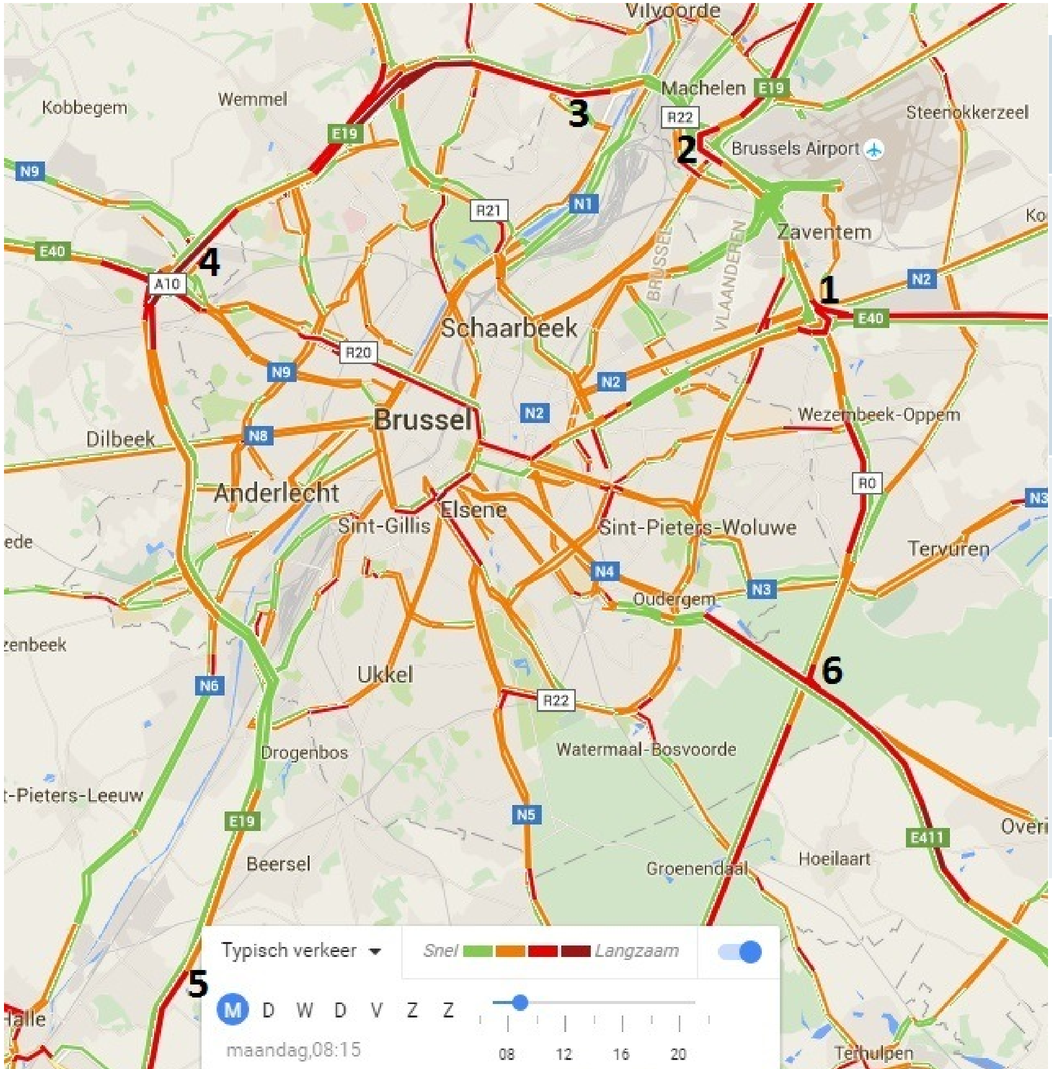
- R0 ring of Brussels
  - massive daily queuing on ring and connecting radial motorways, AM and PM
  - succession of on-off ramps with much exchange of traffic
    - many bottlenecks ▭ capacity drop?
    - many blocked outflows
  - little support for capacity extension

- Research question:
  “*can we quantify the drop in capacity during bottleneck activation, as an indicator for potential of managed motorway?*”


Brasschaat
Schoten
Antwerpen
E34
E17
E313
Herentals
Geel
Mol
Lommel
Peer
Bree
Eeklo
Sint-Niklaas
Lier
Lokeren
Heist-op-den-Berg
Gent
E40
E17
Dendermonde
Wetteren
Deinze
E19
N10
Aarschot
Diest
Heusden-Zolder
E314
E313
Genk
Hasselt
A12
E40
Zaventem
Leuven
E314
Oudenaarde
N8
Brussel
N6
E19
N5
Sint-Truiden
E40
Geraardsbergen
Waver
N60
E429
N7
Aat
Brugelette
Ottignies-Louvain-la-Neuve
E40
N20
Luik
Nijvel
E19
Gembloers
N4
E42
Seraing
E25
Amay

40 km

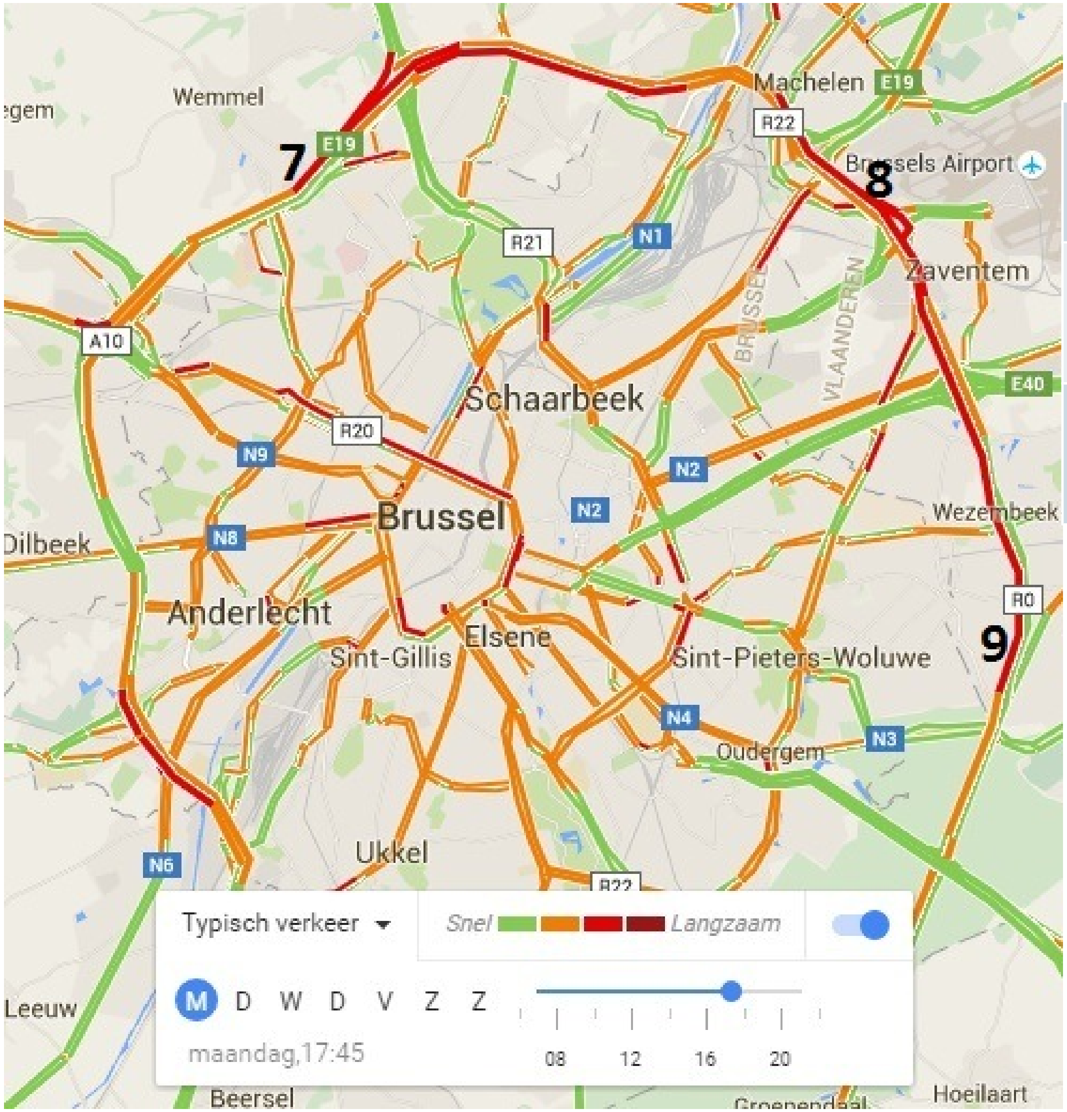
# Queues AM




1. E40 ▭ Buitenring, Sint-Stevens-Woluwe
2. E19 ▭ Binnenring, Machelen
3. Binnenring, Vilvoorde
4. Binnenring, Zellik
5. Binnenring, Huizingen/Halle
6. E411 ▭ Buitenring, Leonardkruispunt

KU LEUVEN

# Queues PM




7. Buitenring, Wemmel
8. Buitrenring, Zaventem
9. Binnenring, Wezembeek-Oppem

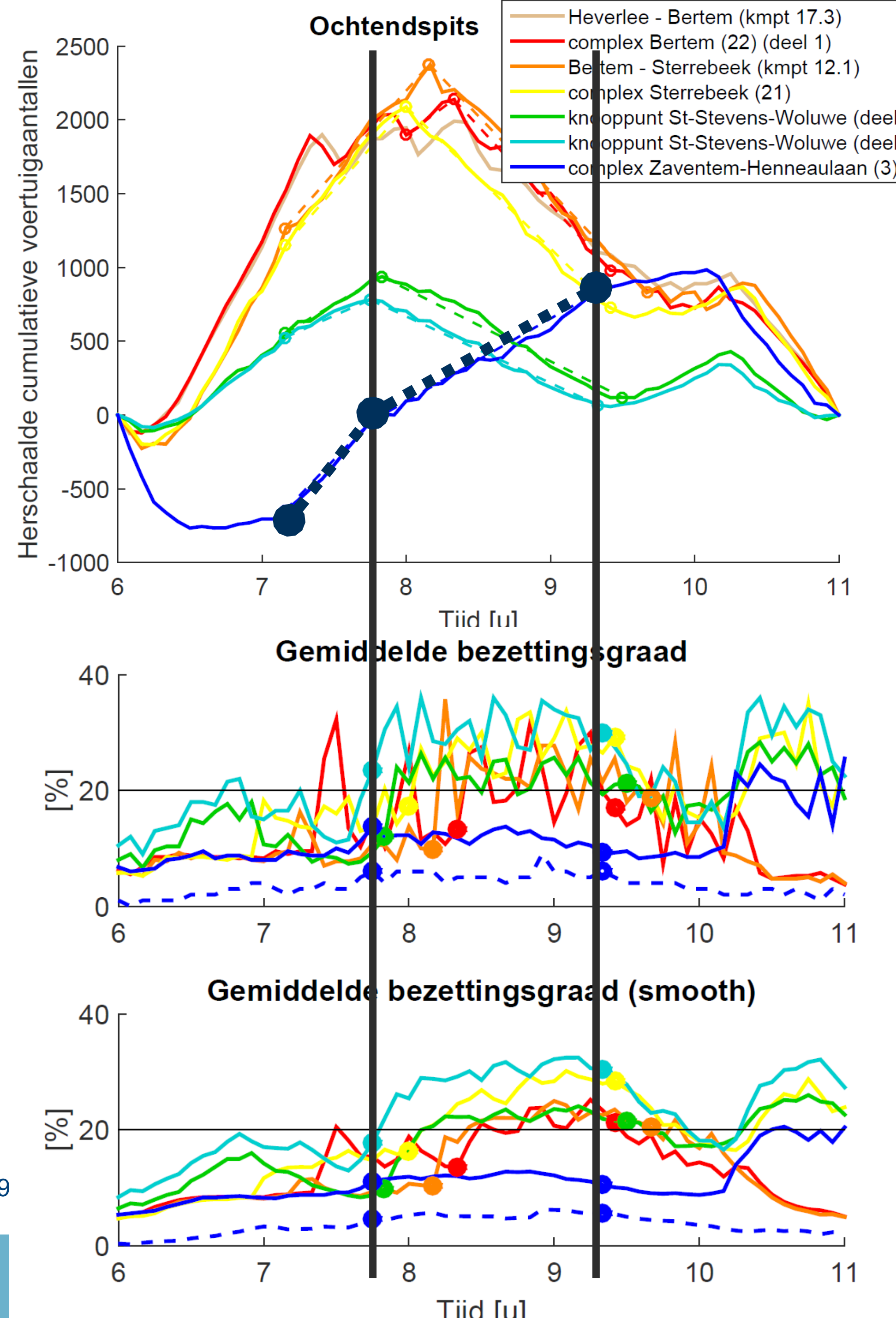
KU LEUVEN

# Data availability and methodology

- double loop detector data
  - 44 working days March & October 2015
  - speed, occupancy + flow per lane
  - 5-min aggregate
- methodology
  - aggregation over lanes
  - cumulative flow analysis
    - discharge just downstream, if needed aggregated main+off-ramp
    - bottleneck activation / de-activation by occupancy just upstream

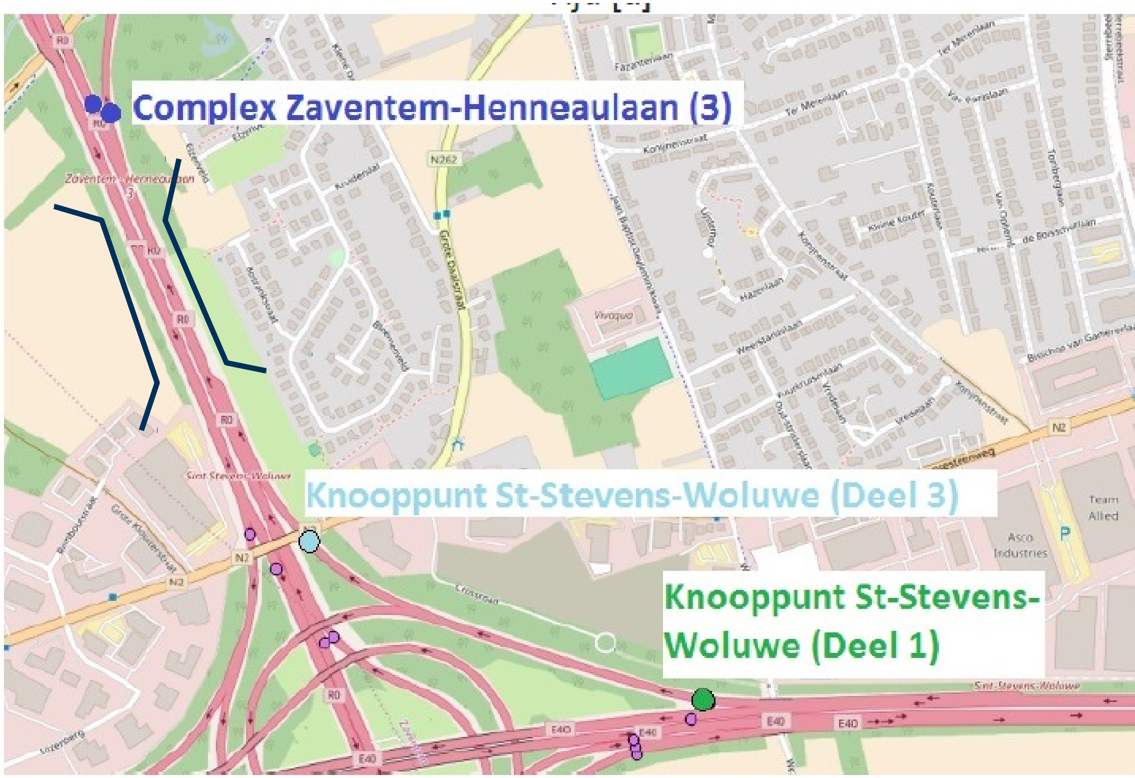
# Capacity drop

- occupancy 1st upstream detector
  - threshold site specific
  - determines discharge period
- average flow during discharge period = discharge rate
- longest “constant” flow period prior ▭ pre-queue capacity



# Result example: E40 (East) ▭ R0 (outer - North) Sint-Stevens-Woluwe AM peak

- weaving zone bottleneck
  - 3+2 lanes
  - activated 38 times
- pre-queue cap
  - 7970 veh/h
- discharge rate
  - 7528 veh/h
- drop
  - 5.52%

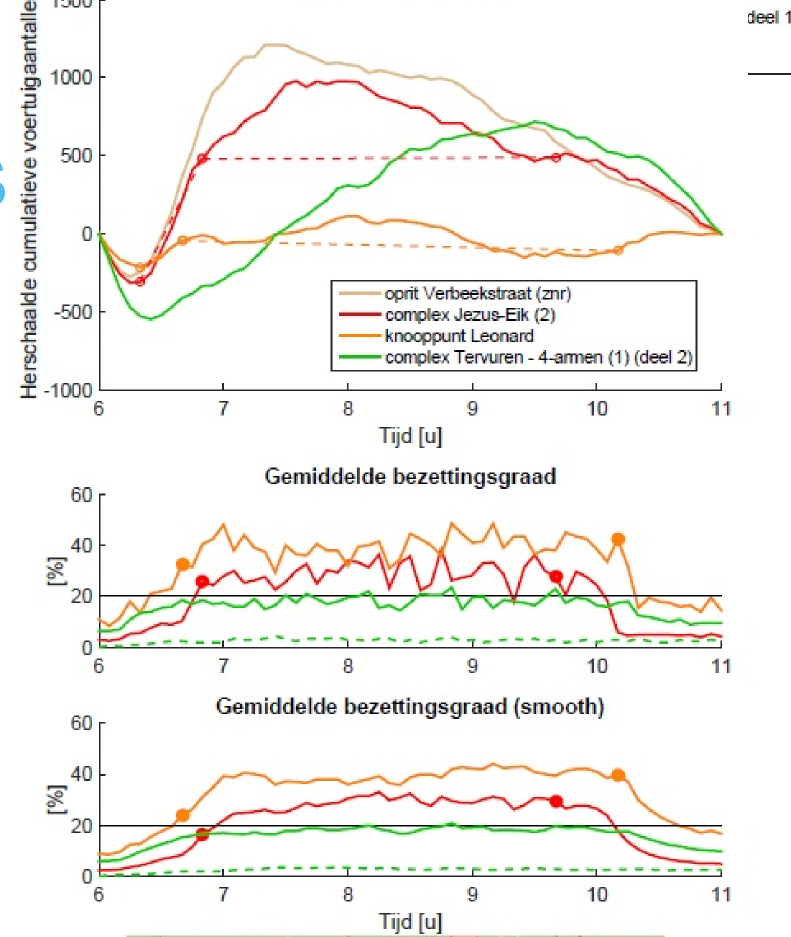


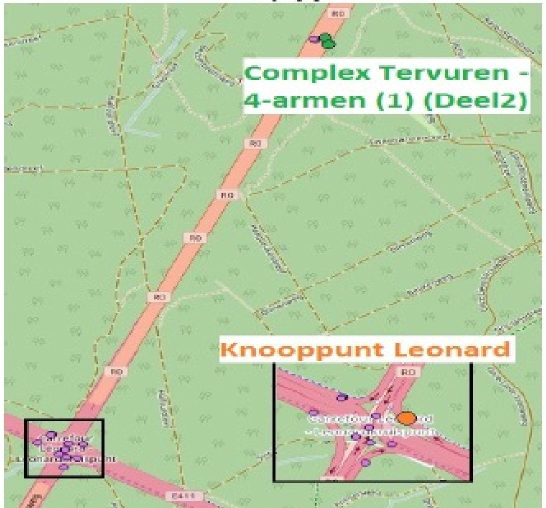



KU LEUVEN

# Examples special cases

- bottleneck in on-ramp *before* the merge (only on merge)
  - no downstream observation
  - detector on merge (i.e. just in queue) used
- E19 (North) → R0 (inner – South) Machelen AM peak
  - pre-queue: 3585 veh/h
  - discharge: 3303 veh/h
  - drop: 7.8%
- E411 (SE) → R0 (outer – N) Leonard interchange AM
  - pre-queue: 2604 veh/h
  - discharge 1995 veh/h
  - drop: 23.3%
    → to be distrusted, instable discharge (no cause found)



# Overview results

| | Stroom voor | Stroom na | CD [%] | Stdev(CD) | n | Starttijd |
|---|---|---|---|---|---|---|
| Bottleneck 1: complex Zaventem-Henneaulaan | | | | | | |
| | 7970 | 7528 | -5.52 | 2.61 | 38 | 7u51 |
| Bottleneck 2*: complex Machelen (E19 → binnenring) | | | | | | |
| | 3585 | 3303 | -7.81 | 3.65 | 28 | 6u48 |
| Bottleneck 3: knooppunt Machelen (binnenring) | | | | | | |
| | 6105 | 5919 | -3.03 | 0.99 | 21 | 7u30 |
| Botlleneck 4: complex UZ-Jette (binnenring) | | | | | | |
| | 6454 | 6119 | -5.16 | 2.43 | 31 | 6u33 |
| Bottleneck 6a: complex Hoeilaart (Leonardkruispunt) | | | | | | |
| | 3924 | 3710 | -5.38 | 2.43 | 33 | 7u33 |
| Bottleneck 6b*: Leonardkruispunt (E411 → buitenring) | | | | | | |
| | 2604 | 1995 | -23.34 | 4.72 | 39 | 6u37 |
| Bottleneck 7: complex UZ-Jette (buitenring) | | | | | | |
| | 6728 | 6449 | -4.17 | 2.18 | 15 | 13u47 |
| Bottleneck 8: knooppunt Machelen (buitenring) | | | | | | |
| | 7185 | 7009 | -2.56 | 1.99 | 6 | 14u20 |

KU LEUVEN

# Conclusion and implication

- Some bottlenecks allow for CD estimation, which reproduces reliably
  - 2.5 – 5.5% (range over sites)
  - 0 – 16% (range over days and sites)
- Others give unreliable estimates
- Others exhibit no noticeable drop

- Implication:
  "*Does not seem like a sound basis to recommend CD-avoiding traffic control operations like ramp metering or MTFC?*"

- Would you agree or am I missing something?


# Capacity drop on Belgian intersections

Master thesis Martin Camerman
KU Leuven master Traffic & Logistics

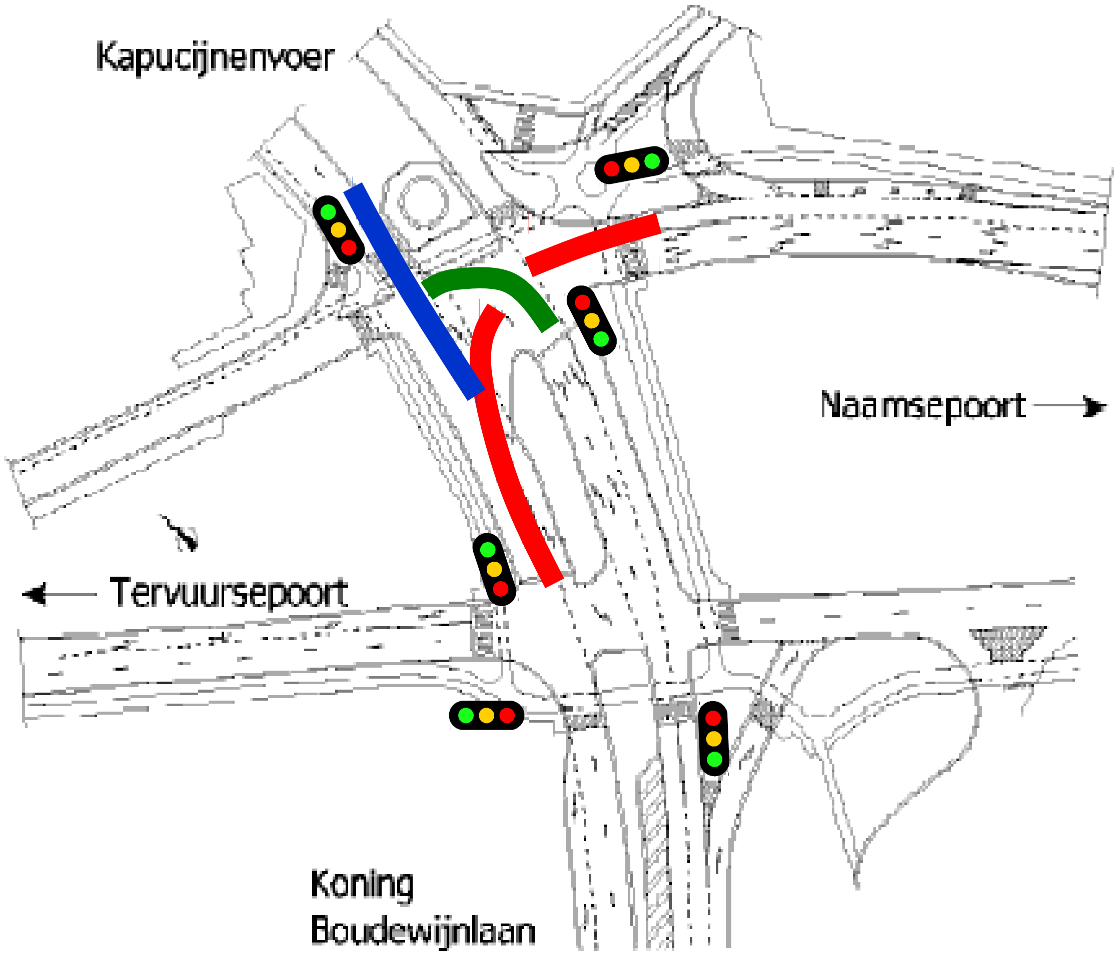
# Capdrop of intersections - definition

*“Capacity drop is the reduction in throughput for a movement over the intersection, caused by conflicts that were underestimated during design of the traffic control, or that were supposed to be excluded by traffic control but still activate due to problems in evacuating the intersection.”*

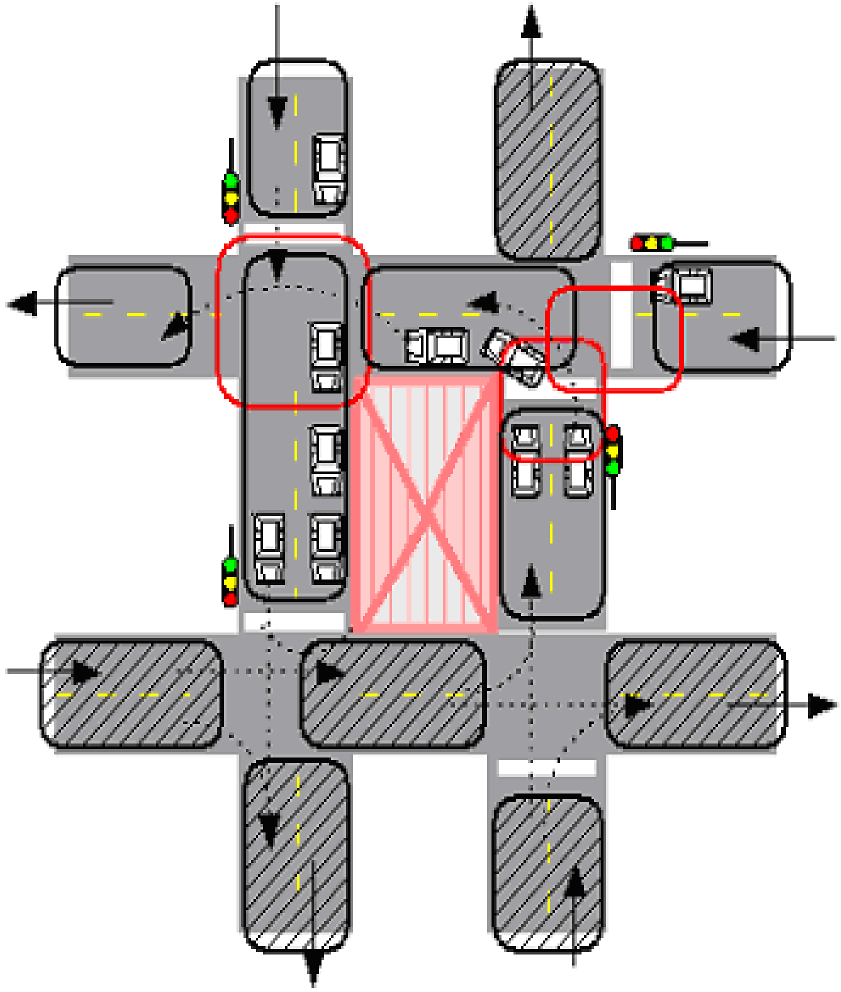
# Let’s go back 10 years…

- my presentation at masterclass November 2006 – PhD Francesco Viti

# Application

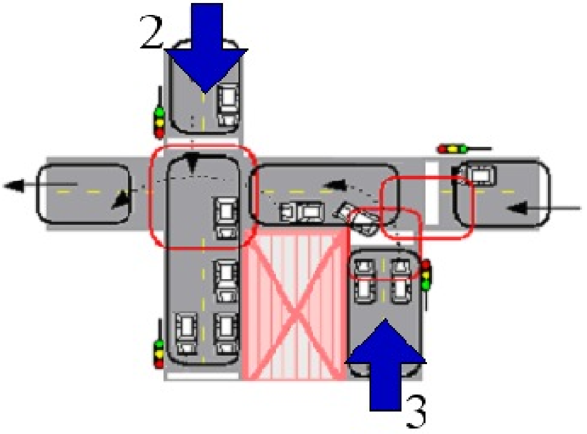


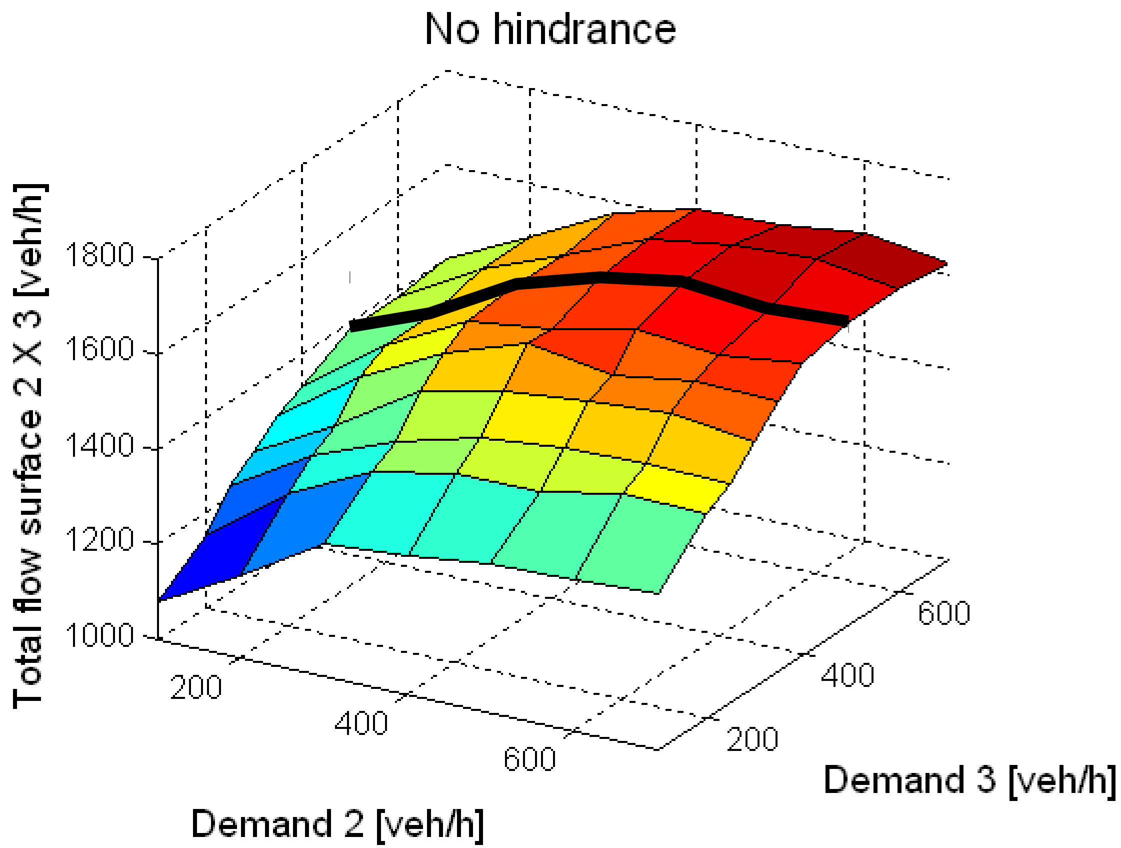
# Modelling the network



# Simulation results: reference without hindrance

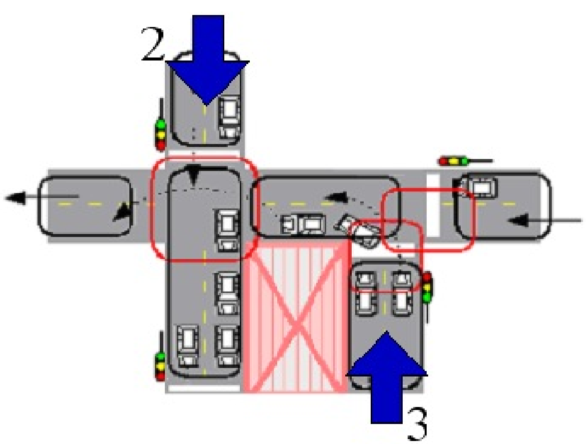
- averaged over 50 15’ runs for each gridpoint
- other demands 500 veh/h

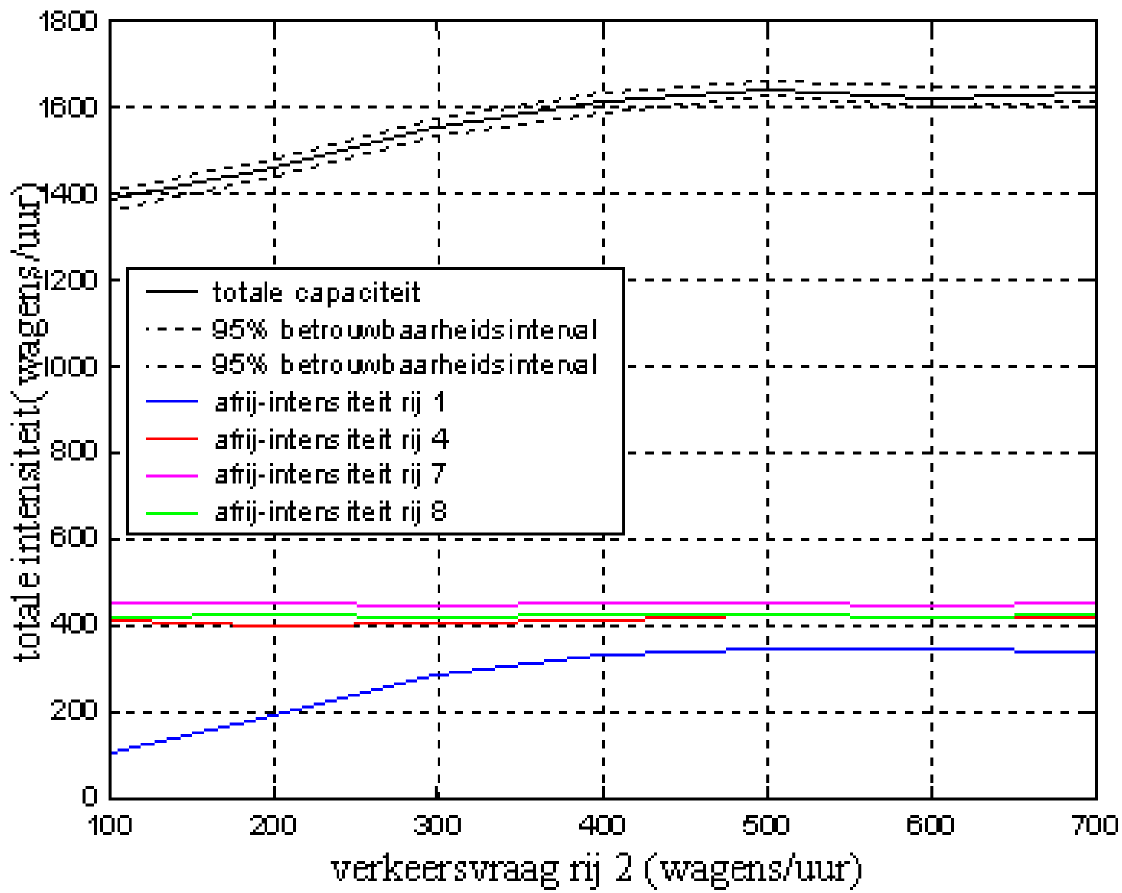


# 95% confidence interval and composition

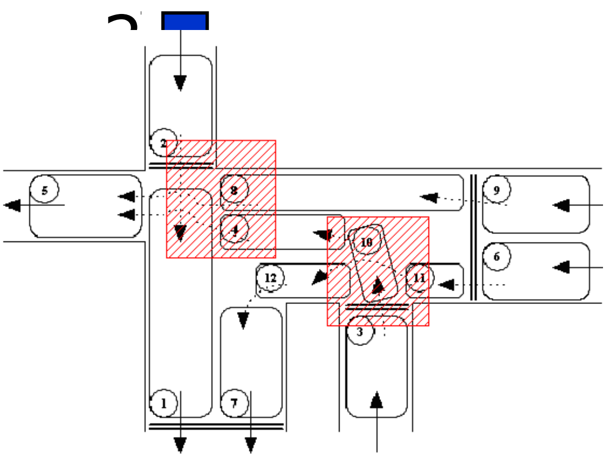
**+/- 20 veh/h**

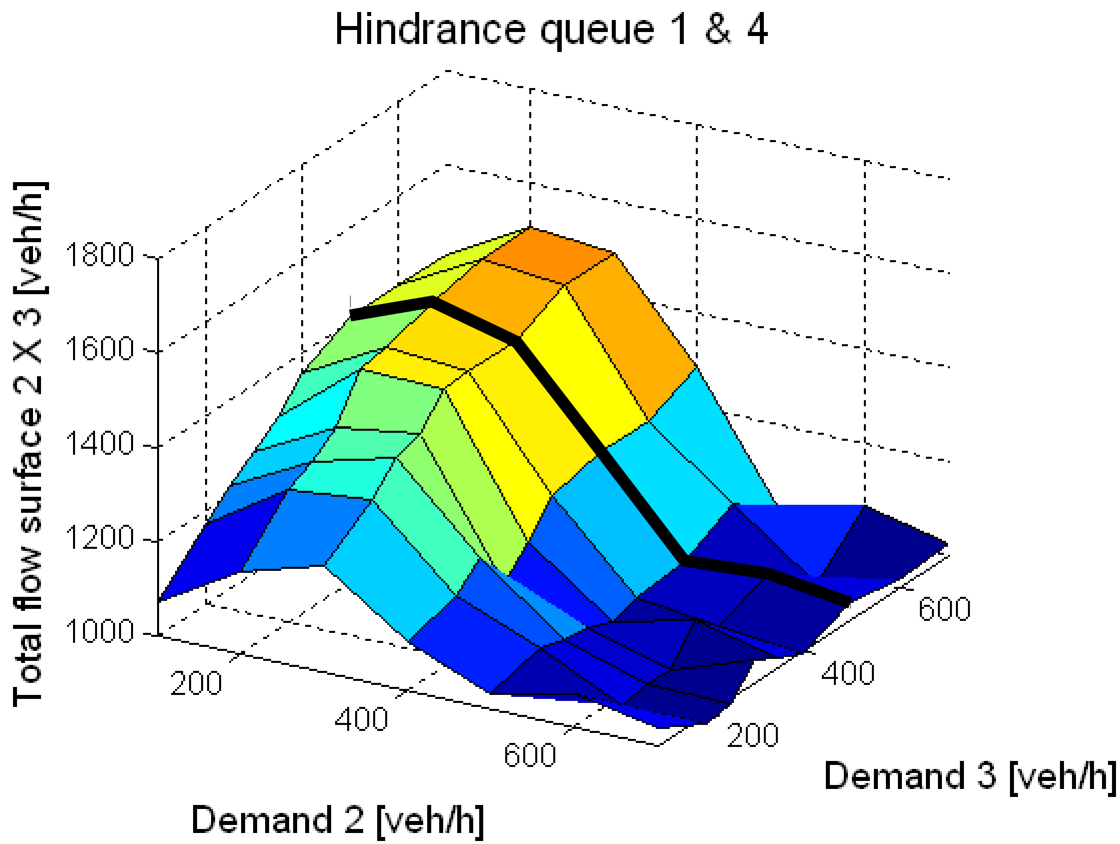


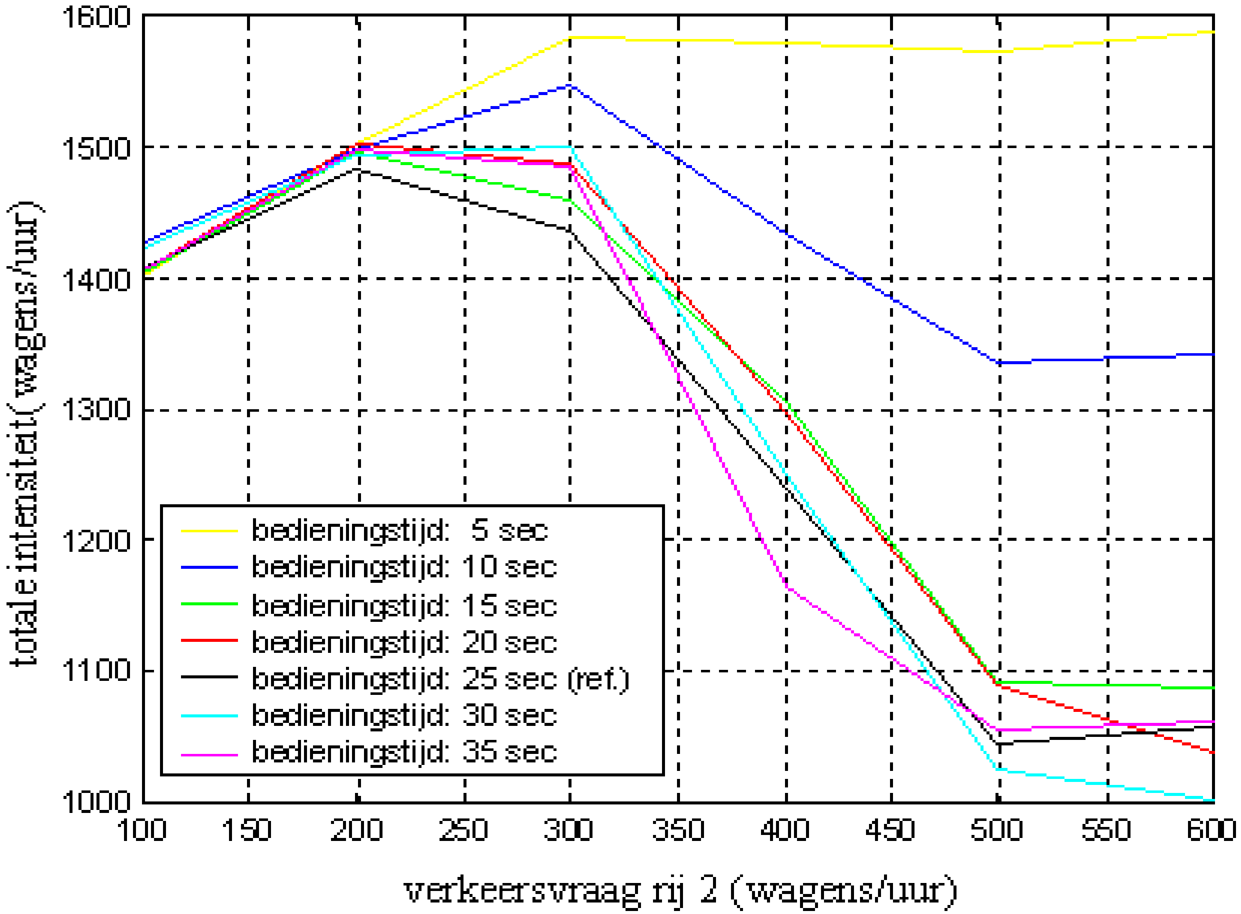
# Simulation results: capacity drop!

- averaged over 50 15’ runs for each gridpoint
- other demands 500 veh/h

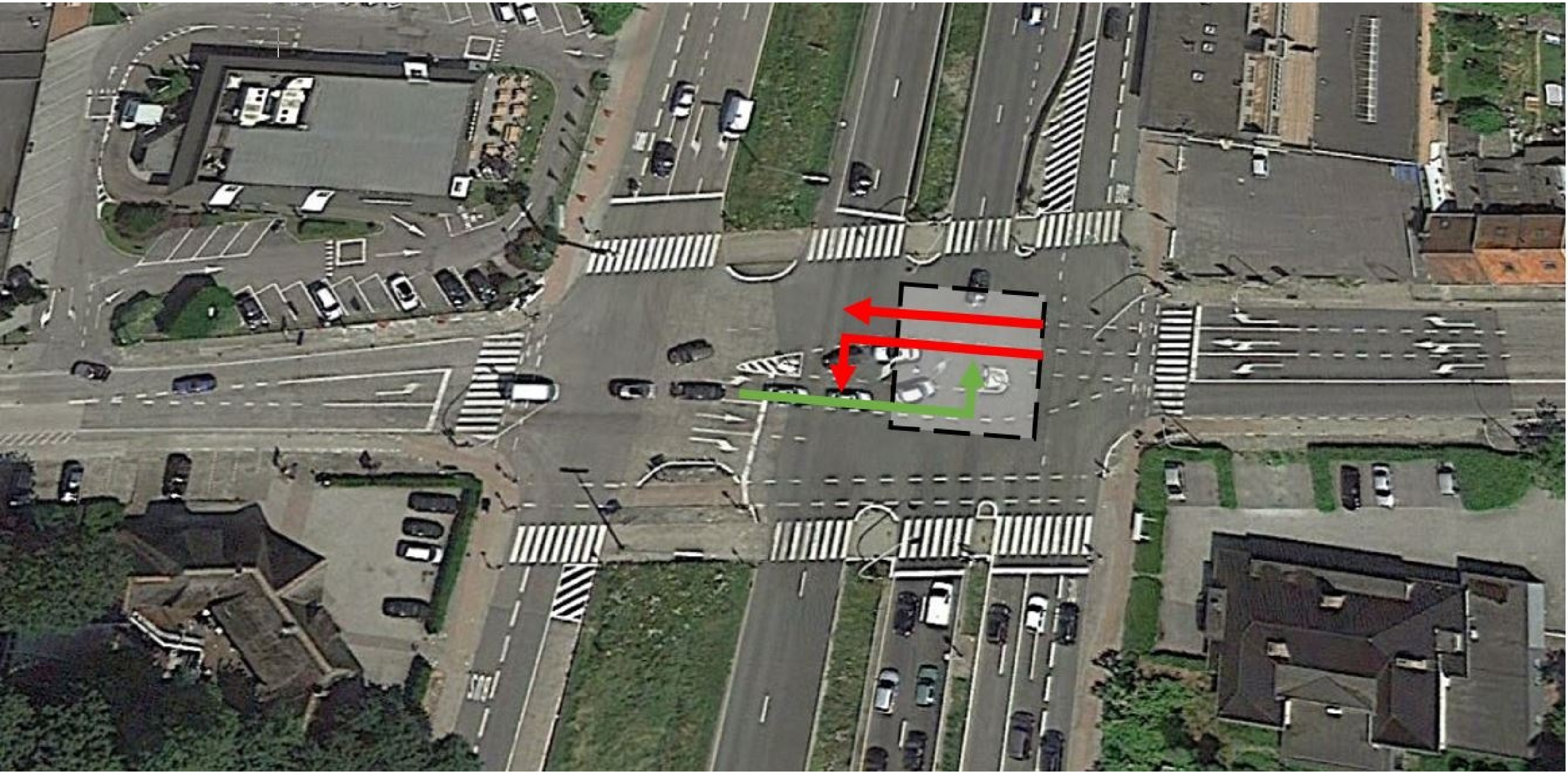




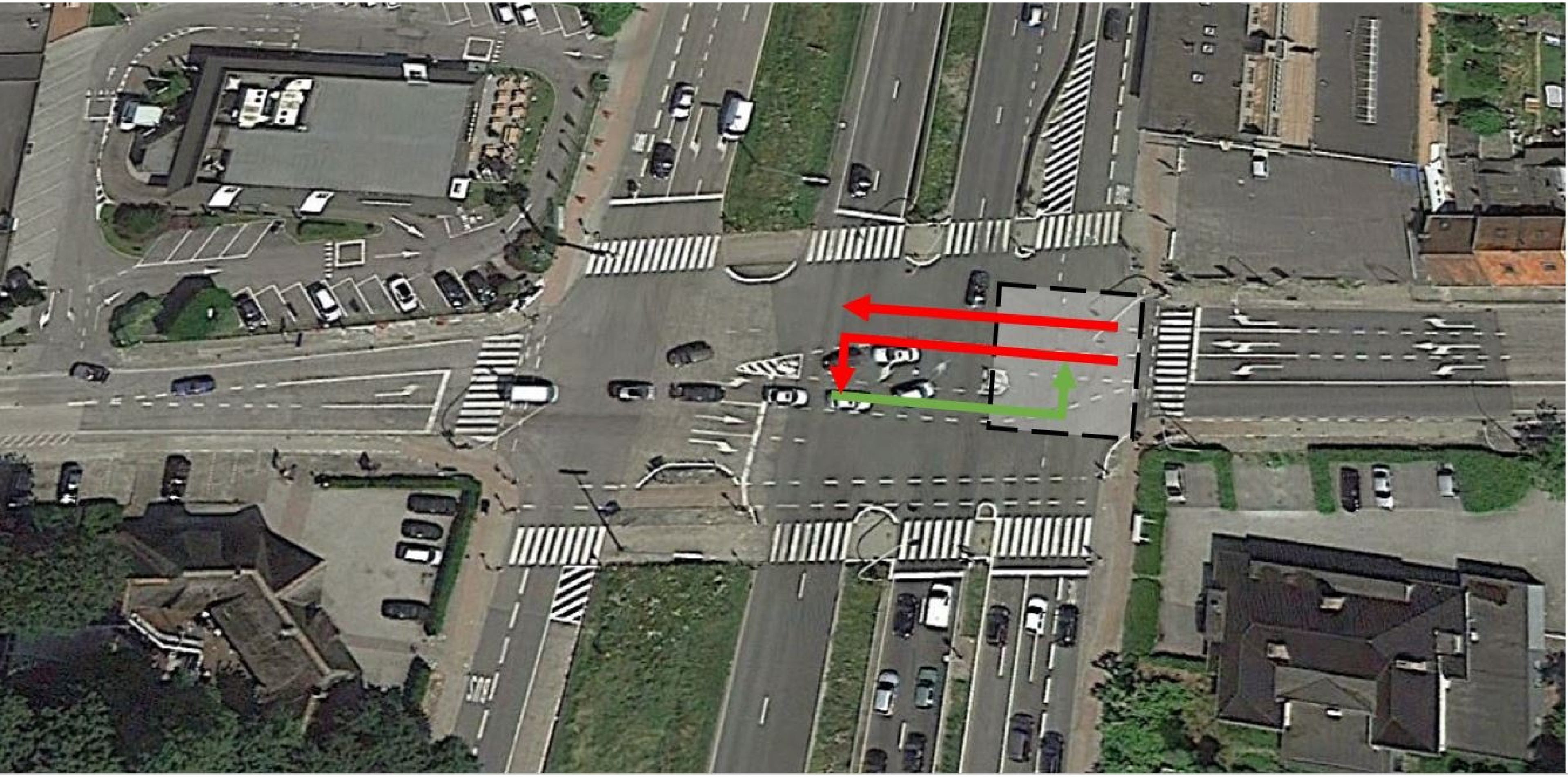
# Sensitivity analysis: influence service time increase when obstructed



# Boomsesteenweg – L1



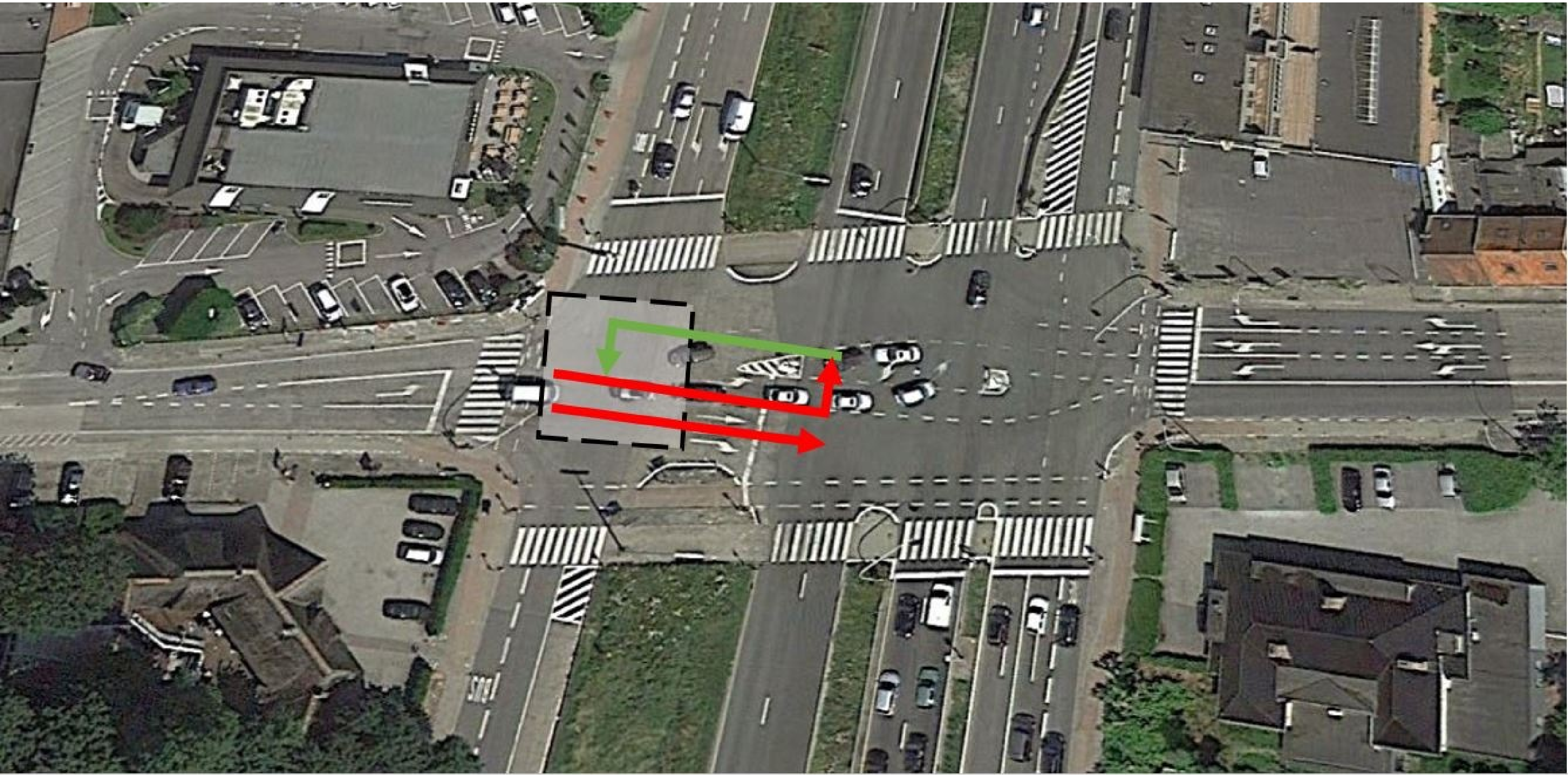
# Boomsesteenweg – L2





KU LEUVEN

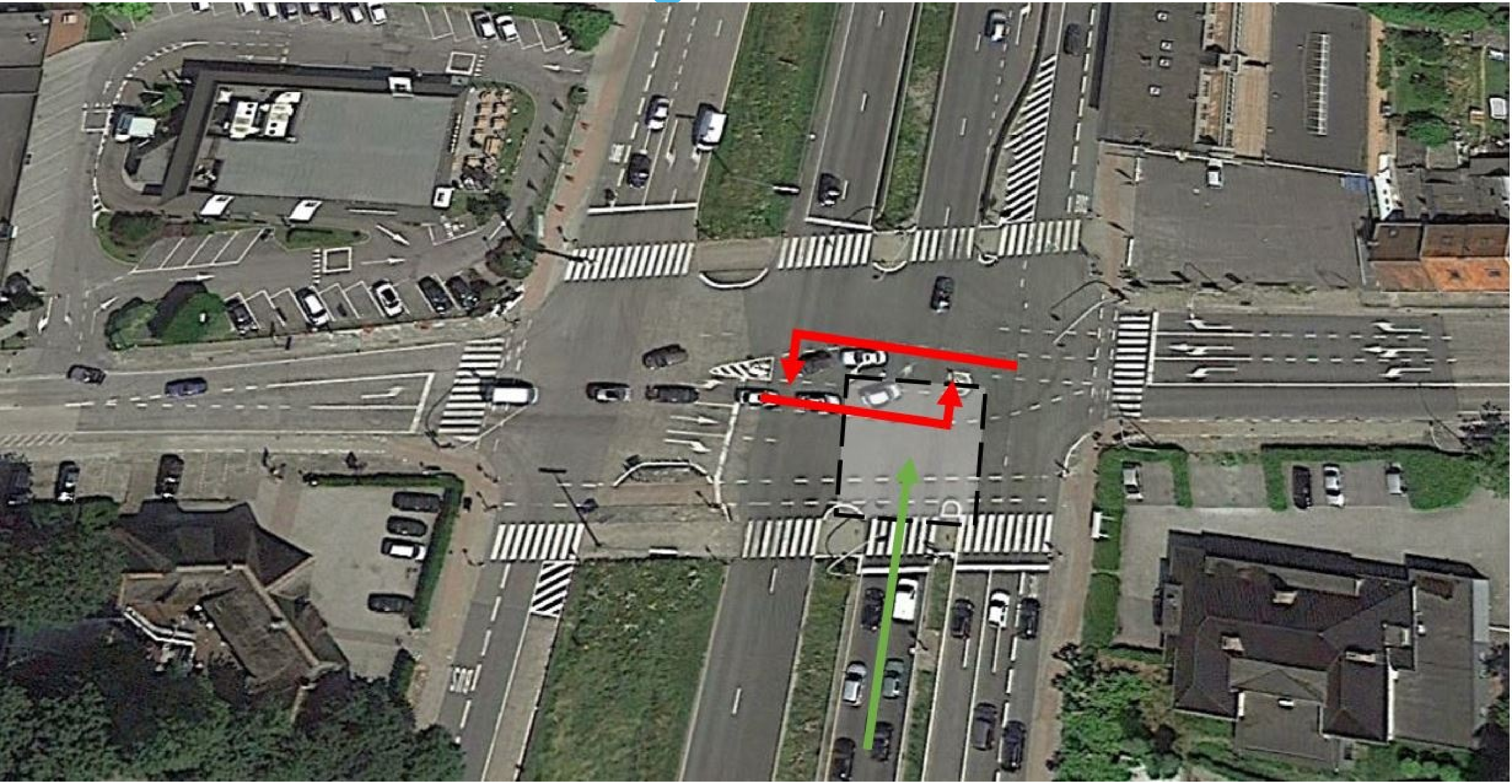
# Boomsesteenweg – L3





KU LEUVEN

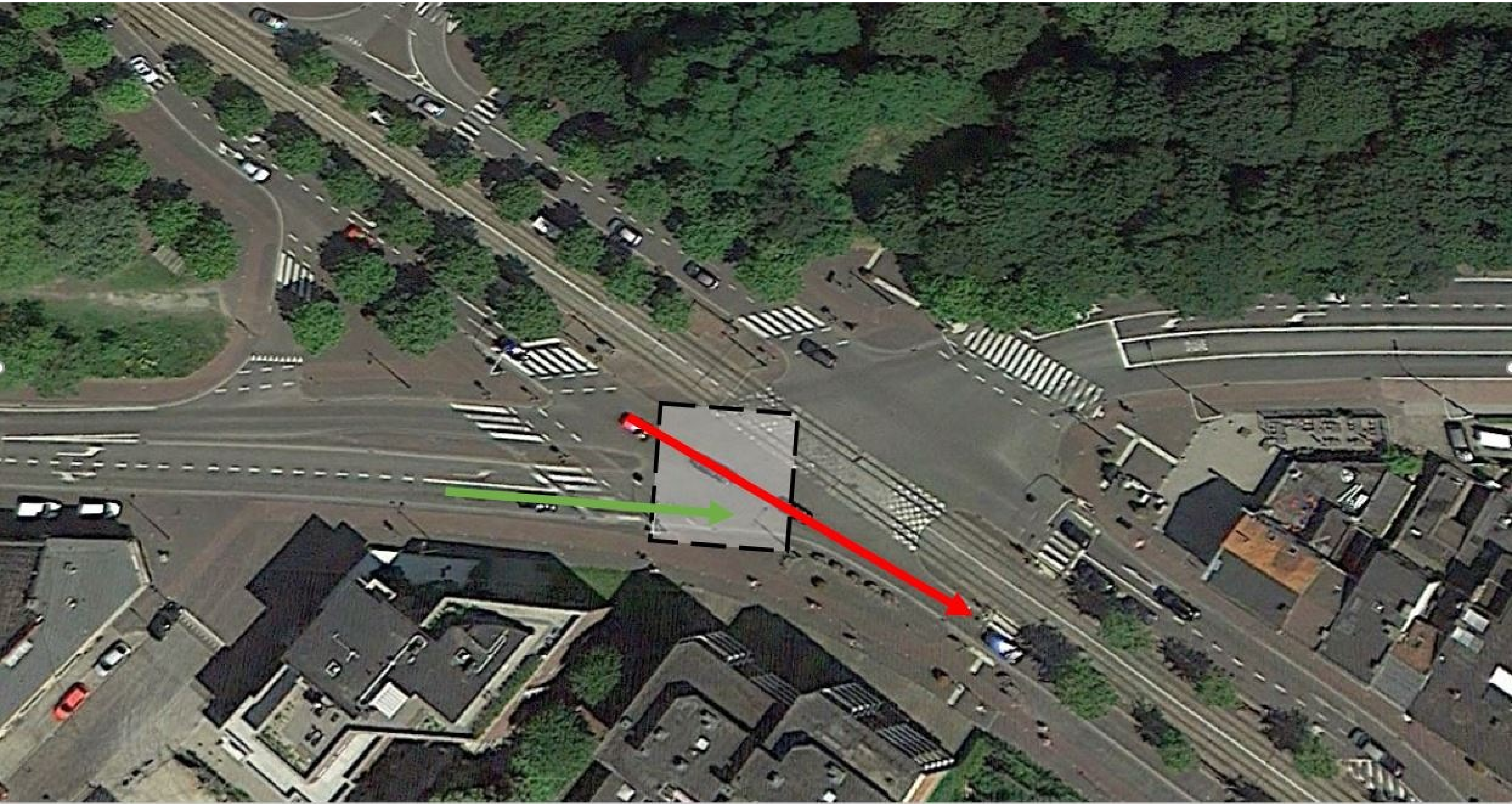
# Boomsesteenweg – R1





KU LEUVEN

# Mortsel – R2





KU LEUVEN

# Dynamische effecten - block




KU LEUVEN

# Dynamische effecten - push

# Dynamische effecten - squeeze

# Conflict 'linksaf' - referentiecapaciteit

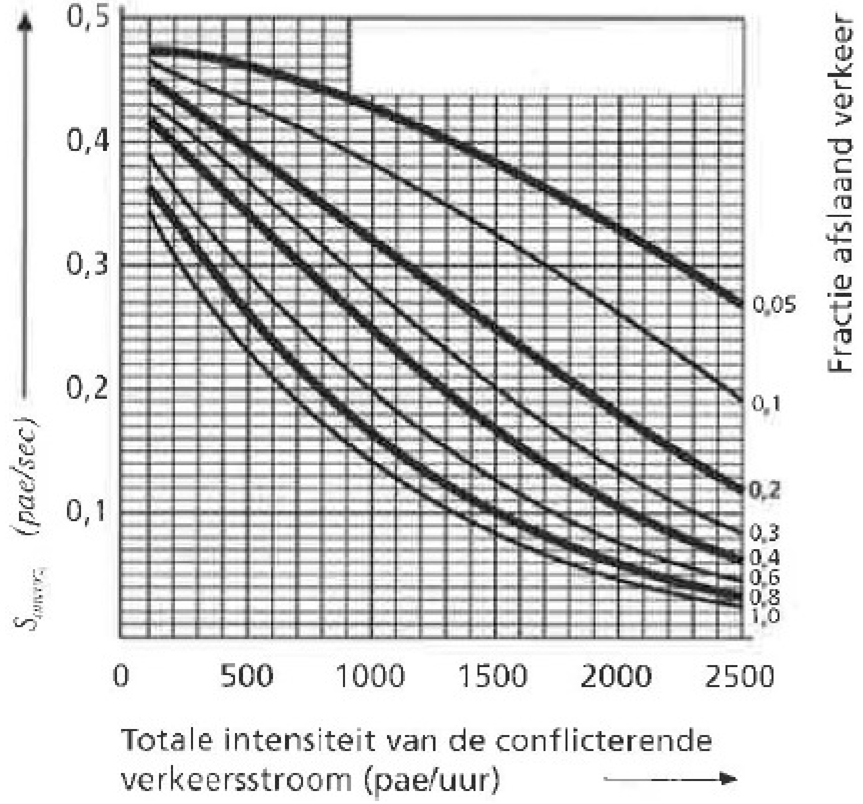
~ CAPCAL methode

$$PAE_{i,unsat} = \frac{G_{eff}}{T_{cyclus}} \cdot PAE_{i,tot}$$

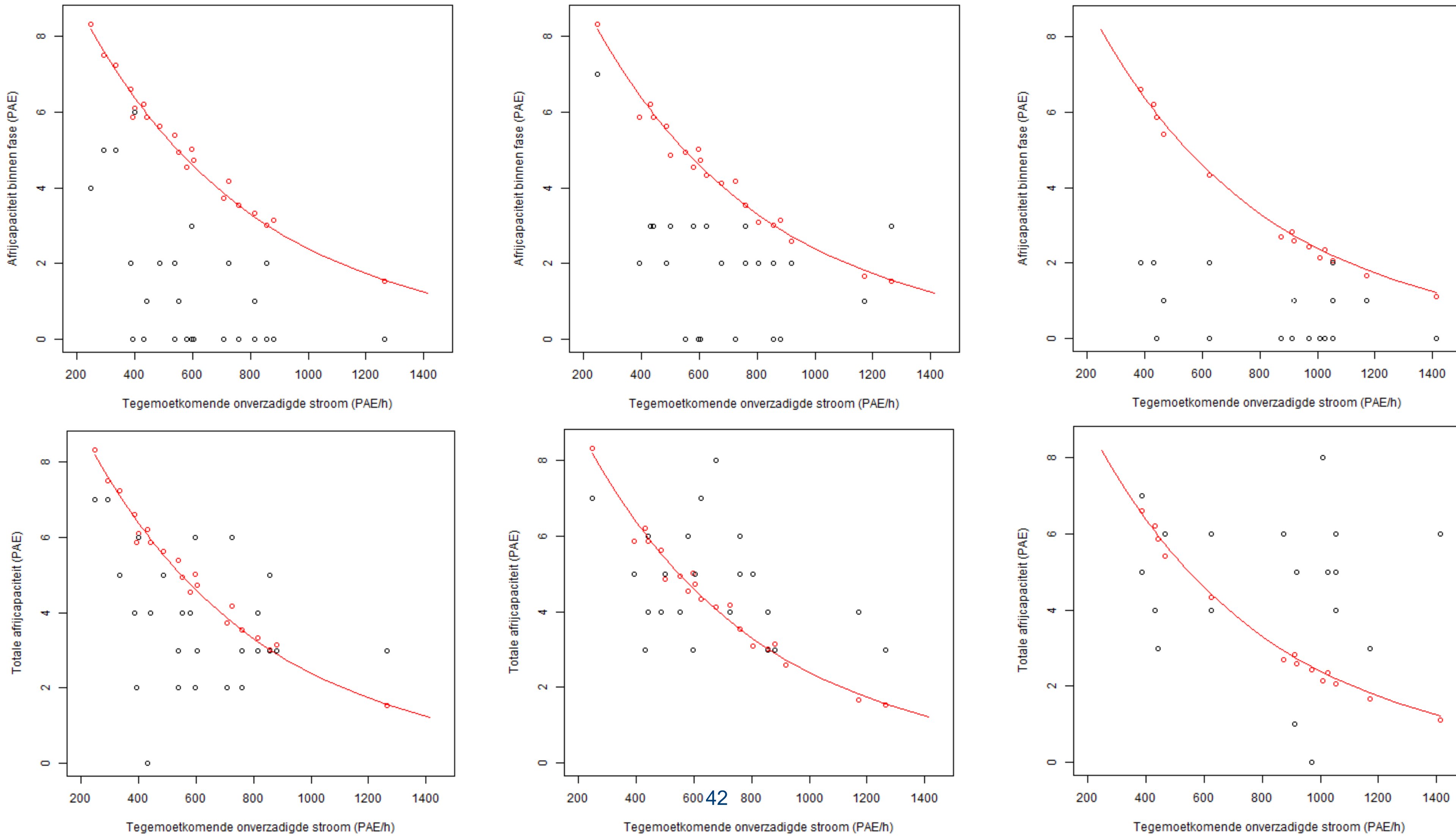
$$G_{i,sat} = \frac{3600(s/h)}{1800(PAE/h)} \cdot PAE_{i,sat}$$

$$Flow_{i,unsat} = \frac{PAE_{i,unsat}}{G_{i,unsat}}$$

$$Cap_{ref} = Cap_s \cdot min(G_{i,unsat})$$



# Conflict ‘linksaf’ – gemeten vs. referentie



# Conflict ‘linksaf’ – regressie totaal

| | Constante | $c_{block}$ | $c_{Squeeze}$ | $c_{Push}$ | $c_{Spill}$ | $c_{PAE_{left}}$ | $c_{Flow_{unsat}}$ | $c_{Opstel}$ | $R^2$ | $R^2_A$ |
|---|---|---|---|---|---|---|---|---|---|---|
| L1 | 8.876 | -0.066 | | | nvt. | -2.589 | 180.532 | nvt. | 78.32 | 75.72 |
| L2 | 7.420 | -0.053 | | 3.691 | nvt. | | -8.271 | nvt. | 65.52 | 60.35 |
| L3 | 5.611 | -0.055 | 1.389 | | -2.929 | | | nvt. | 77.51 | 73.02 |
| Totaal | 3.820 | -0.069 | 0.343 | 0.755 | -2.867 | | | 0.091 | 69.89 | 67.60 |

- $T_{block} = A + c_{PAE} \cdot PAE + c_{PAE_{left}} \cdot PAE_{left,tot}$

| | Constante | $PAE$ | $PAE_{left,tot}$ | $R^2$ | $R^2_A$ |
|---|---|---|---|---|---|
| L1 | 47.623 | -8.812 | 2.593 | 77.82% | 76.11% |
| L2 | 0.627 | -3.613 | 6.010 | 70.51% | 67.70% |
| L3 | -26.076 | -1.383 | 8.512 | 63.42% | 58.84% |
| Totaal | 19.086 | -5.876 | 4.924 | 68.09% | 67.17% |

- Dynamic effects (Squeeze, push) influence significantly but not predicted themselves

# Conclusions of this first exploration

- Literature: unrealistic performance of saturated intersections ⇨ need for theory and observations of capacity drop of intersections
- Proposed definition of capacity drop intersections
- Exploration of role of 3 dynamic effects
  - Block
  - Push
  - Squeeze
- Some empirical results prove their influence on intersection discharge, along with
  - (time blocked)
  - volumes of conflicting flows

# Can I consult you?

- Do you think my conclusion about capacity drop on R0 Brussels is justified?

  "*Empirical results do not appear to be a sound basis to recommend CD-avoiding traffic control operations like ramp metering or MTFC?*"

- Do you think capacity drop at intersections is a topic worth further consideration?
  - if so, which aspects? how?

Questions?