Traffic Control in Action

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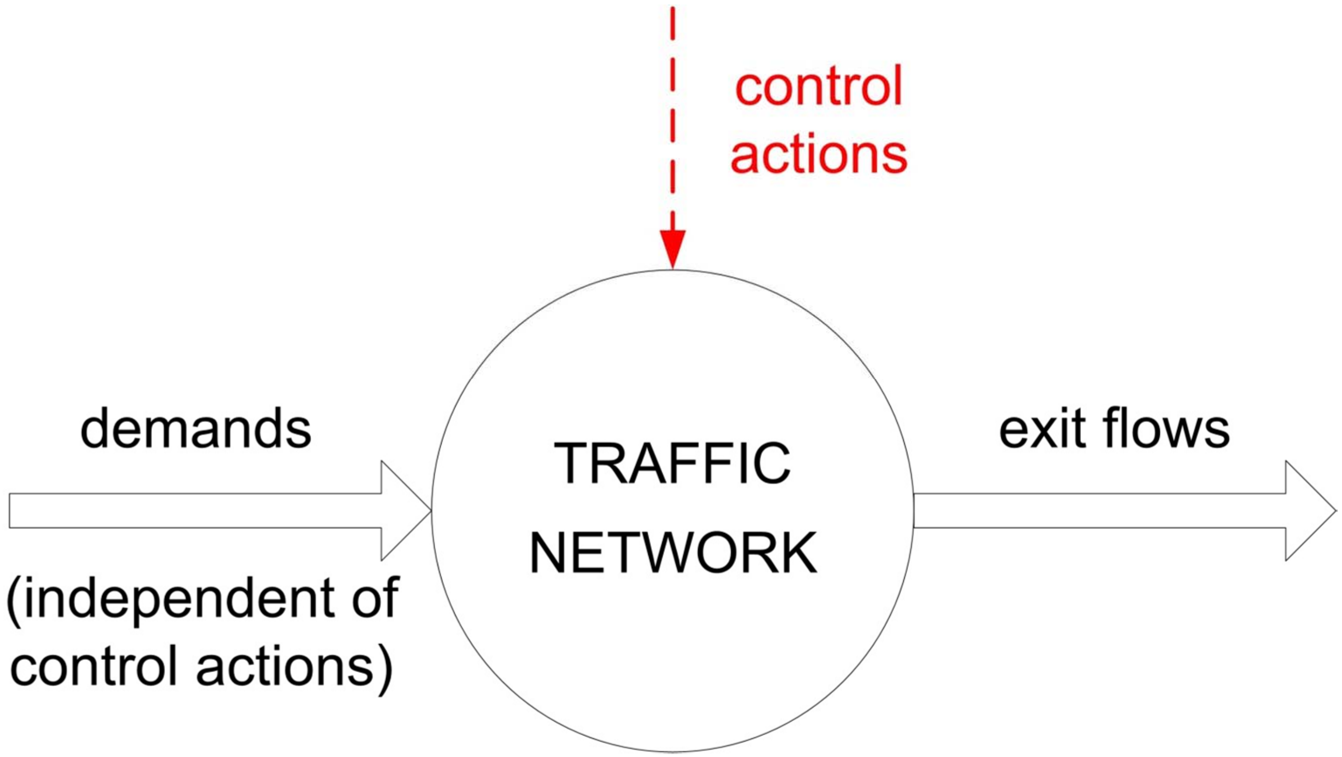
1. INTRODUCTION

Man has reached to the moon but …

… even ants were taught by evolution to address their transportation problems more efficiently, see

I.D. Couzin and N.R. Franks: "Self-organized lane formation and optimized traffic flow in army ants",
Proc. R. Soc. Lond. B (2003) 270, 139–146



Minimization of Total Time Spent

⇔

Maximization of (Early) Exit Flows

Simple Queuing Systems

- Demand > Capacity ⇨ Queuing
- Capacity ≠ f (Queuing)

⇨ Delay depends on D–C only!

Water Systems

More Inflow ⇨ Higher Pressure ⇨ Higher Outflow

Traffic Networks

- Congestion degrades the infrastructure (capacity)

Local link demand exceeds local capacity

⇨ Local congestion degrades local capacity

Accelerated increase of congestion

Further capacity degradation

... until generalized network congestion
although
Demand << Nominal network capacity

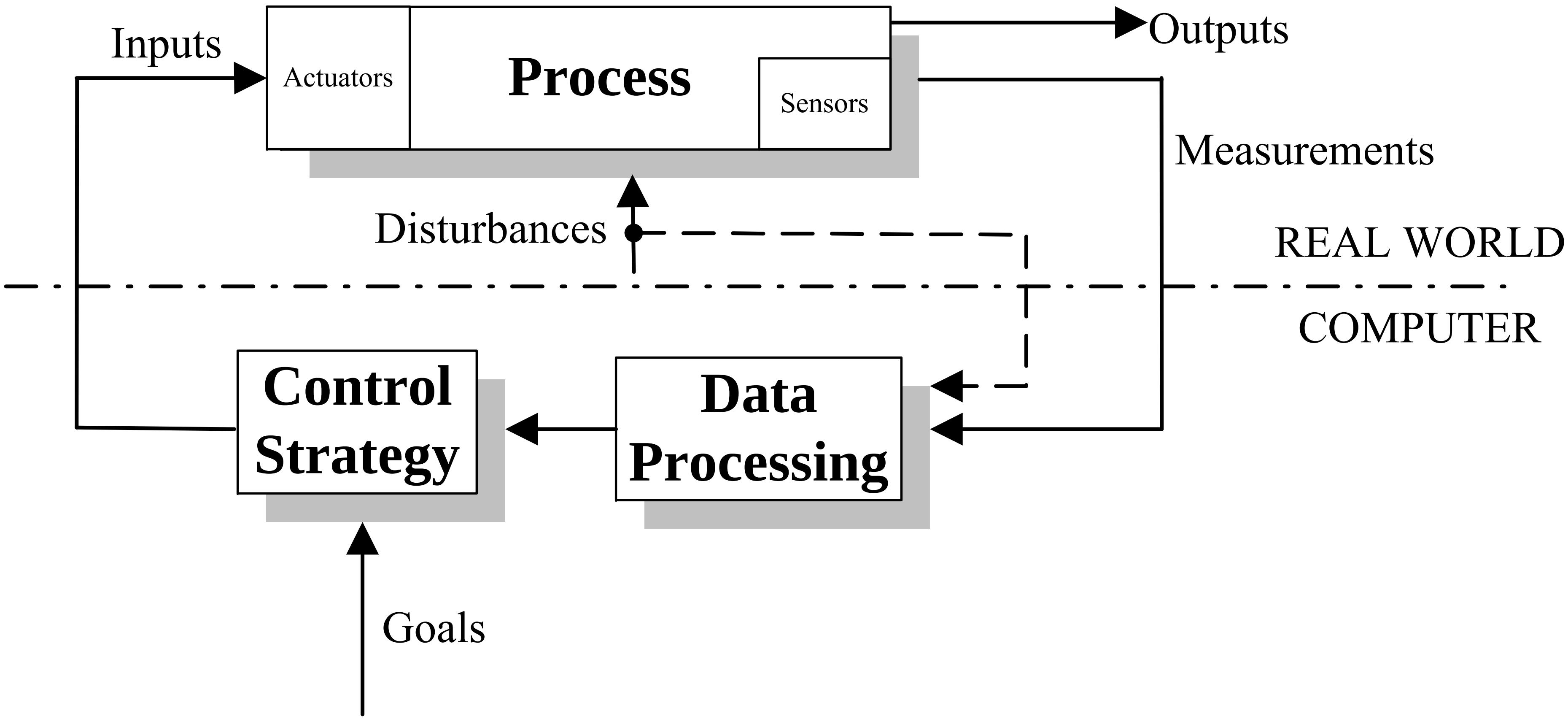
Ile-de-France Expressway Network

12 January 2011, 8:14 am

Conclusion: Generalized traffic congestion is not only due to high demand.

Congested Traffic Networks: Expensive infrastructure capacity not fully available at the **only** time it is actually needed, i.e. the peak periods!

Goal: Operate traffic networks optimally (as a **controllable** system)

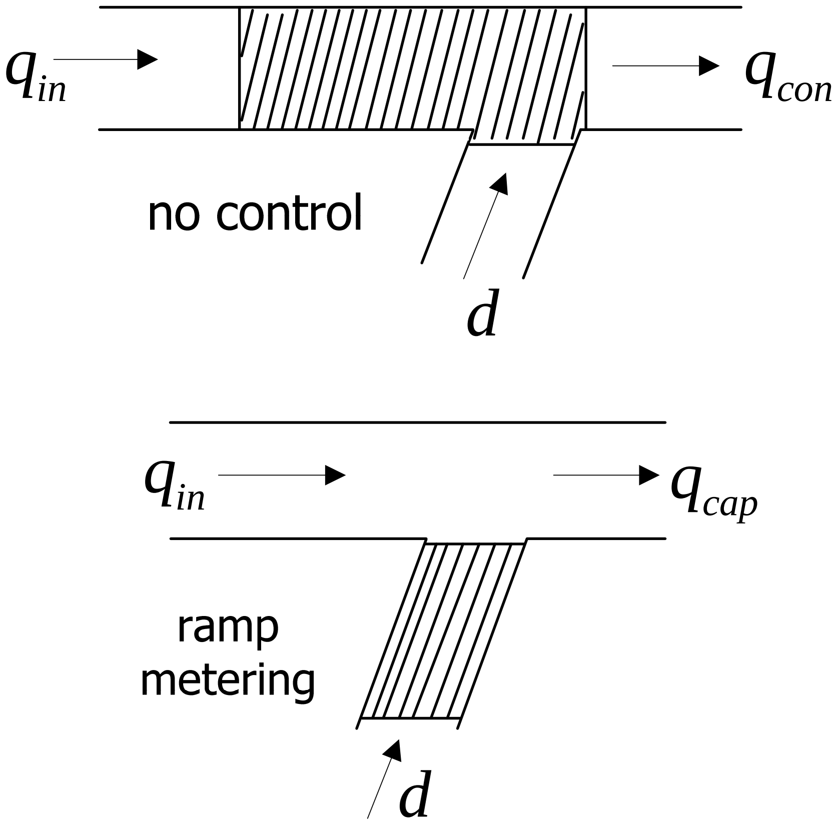


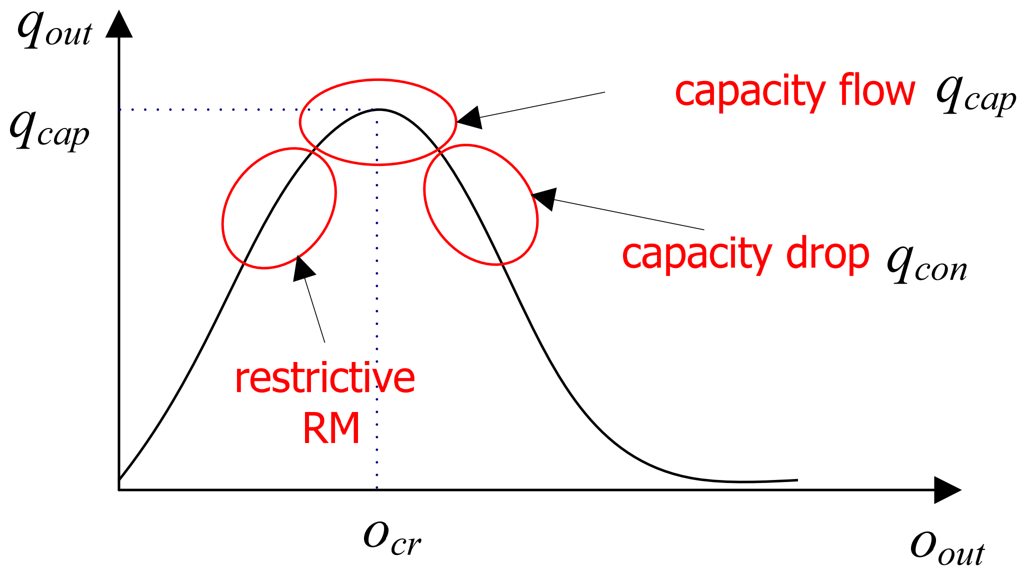
Basic elements of an automatic control system

2. RAMP METERING

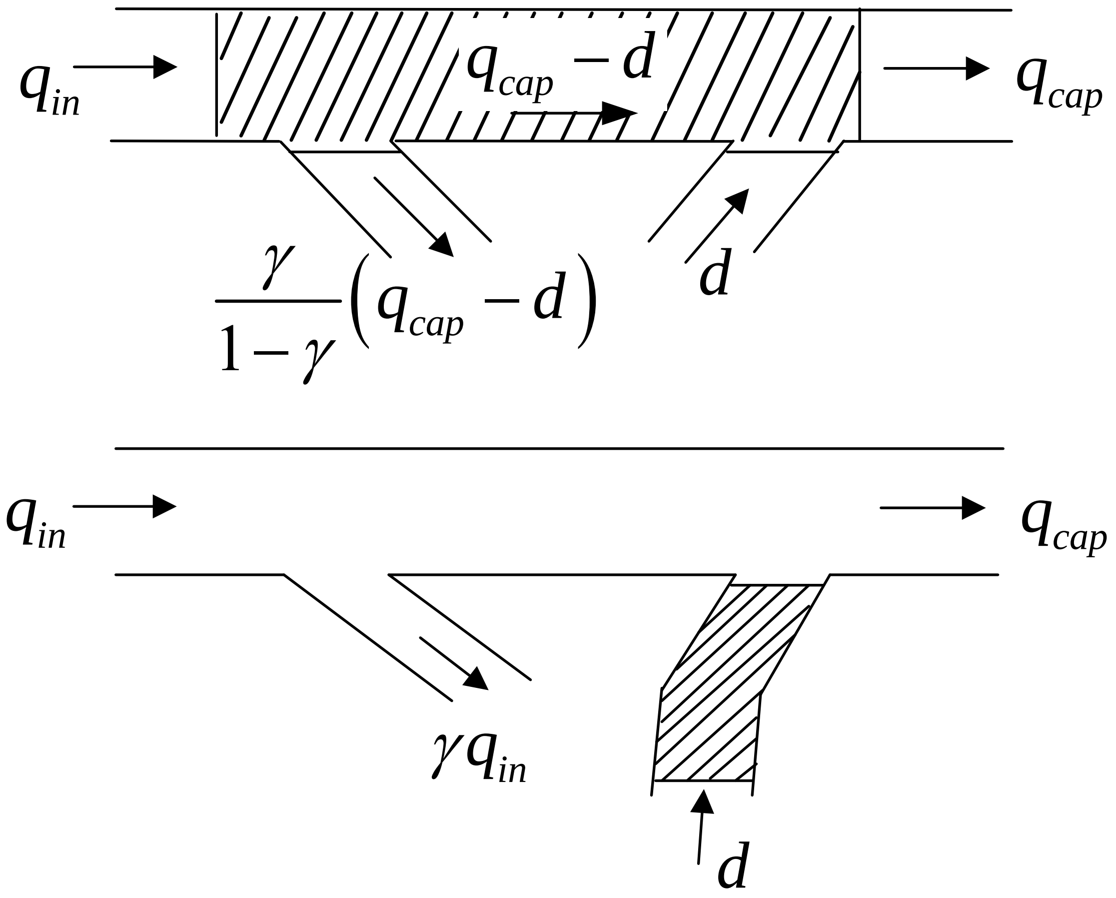
Why Ramp Metering?

1st Answer



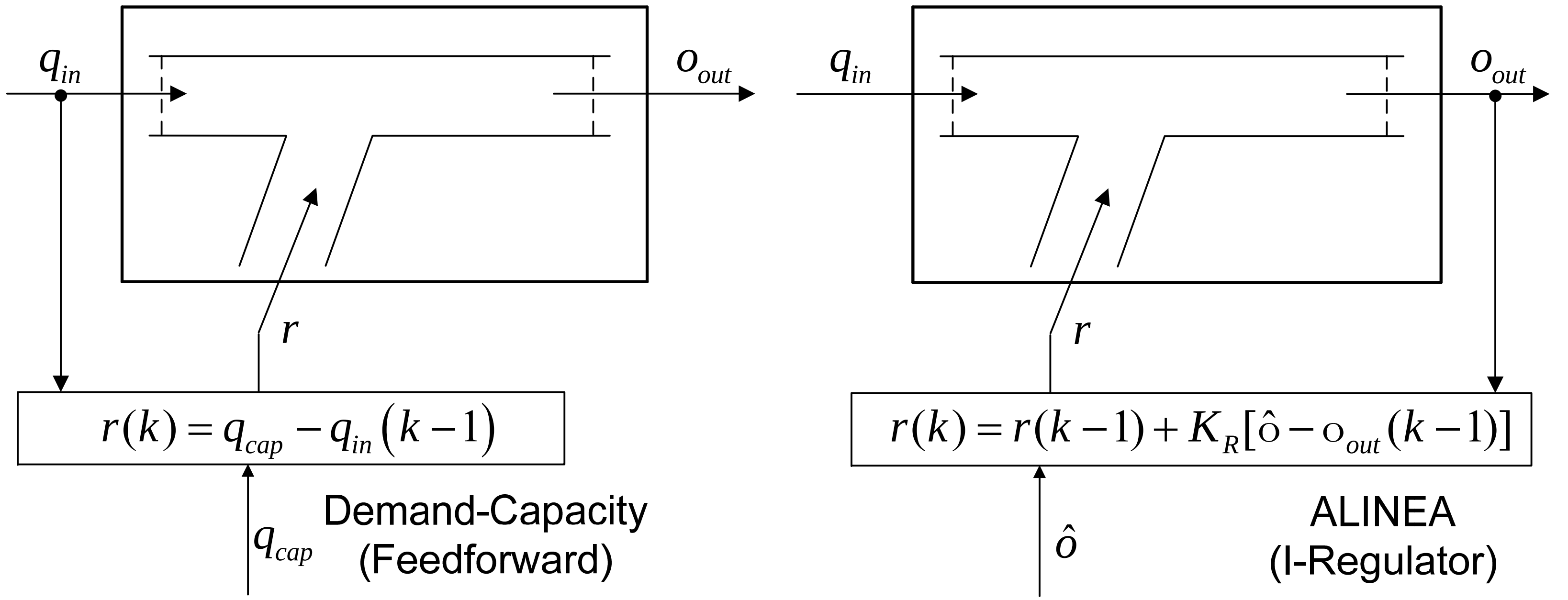


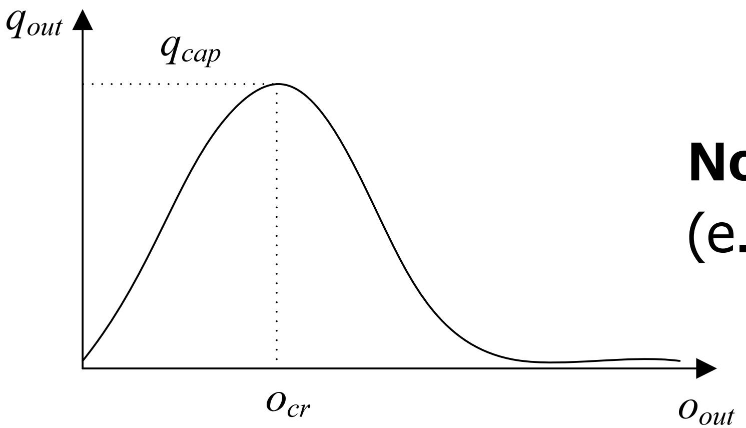
2nd Answer



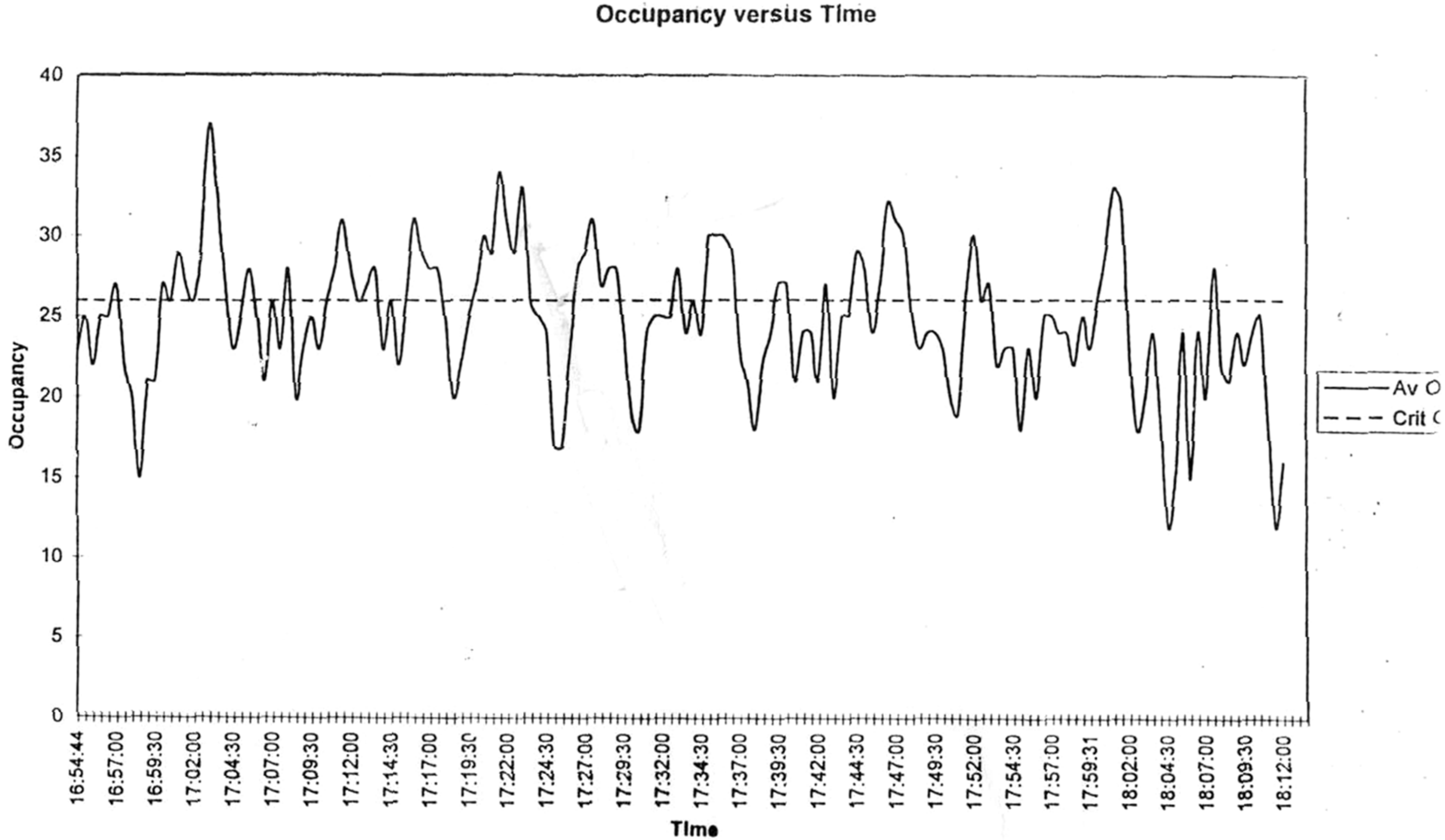
Note: On-ramp queue should not interfere with surface street traffic.

Local Control Issues



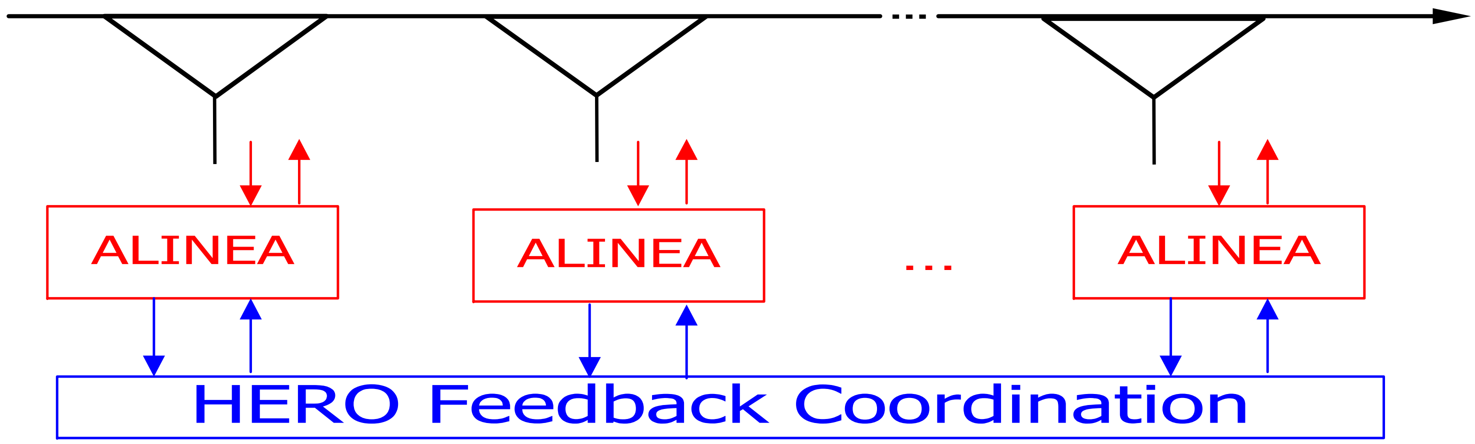


Note: o_{cr} is less sensitive than q_{cap} (e.g. under adverse weather conditions).



Sample from Glasgow Implementation of ALINEA

HERO Feedback Coordination

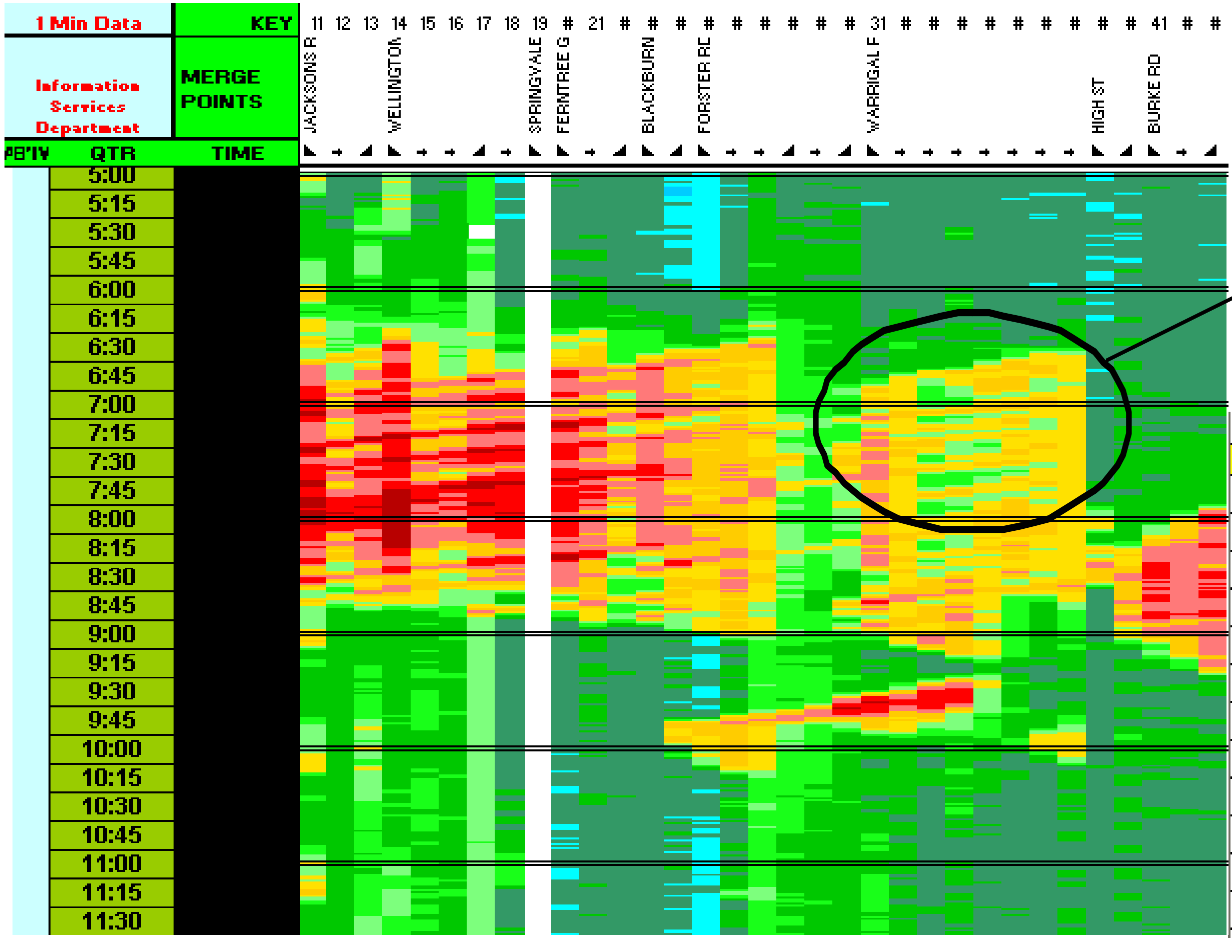


- ALINEA Activation? → Master Ramp
- HERO hires gradually (upstream) Slave Ramps
- Cluster: Master + Slaves
- HERO MIMO Feedback: Balance relative ramp queues in Cluster (create 1 super-ramp)
- Cluster de-activation logic

HERO Implementation at the Monash Freeway, Melbourne, Australia

- Test pilot: 6 consecutive ramps
- Significant improvements in all PI: Productivity, Speed Variation, Reliability
- 11 days payback period!

AM PEAK Typical day (Fixed Time)

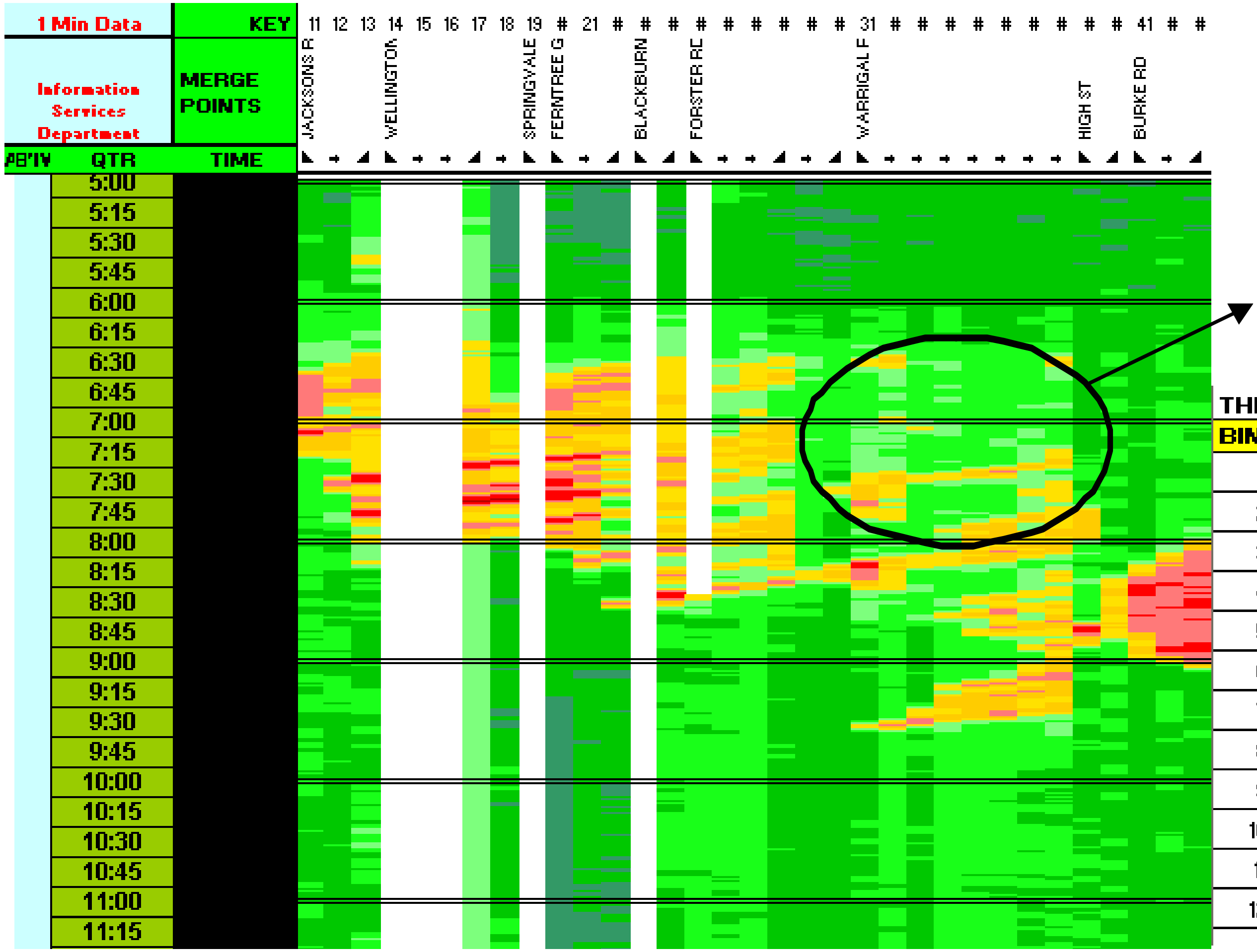


Bottleneck created due to large number of lane changing

THRU LANE SPEED RANGES in KM/HR

BIN	Low	High	LEGEND	INDEX
1	1	10	001 - 010	17
2	11	20	011 - 020	18
3	21	30	021 - 030	19
4	31	40	031 - 040	20
5	41	50	041 - 050	21
6	51	60	051 - 060	22
7	61	70	061 - 070	23
8	71	80	071 - 080	24
9	81	90	081 - 090	25
10	91	100	091 - 100	26
11	101	110	101 - 110	27
12	111	999	111 - 999	28

AM PEAK Typical day (ALINEA/HERO)



Bottleneck cleared

THRU LANE SPEED RANGES in KM/HR

BIN	Low	High	LEGEND	INDEX
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9	81	90	081 - 090	25
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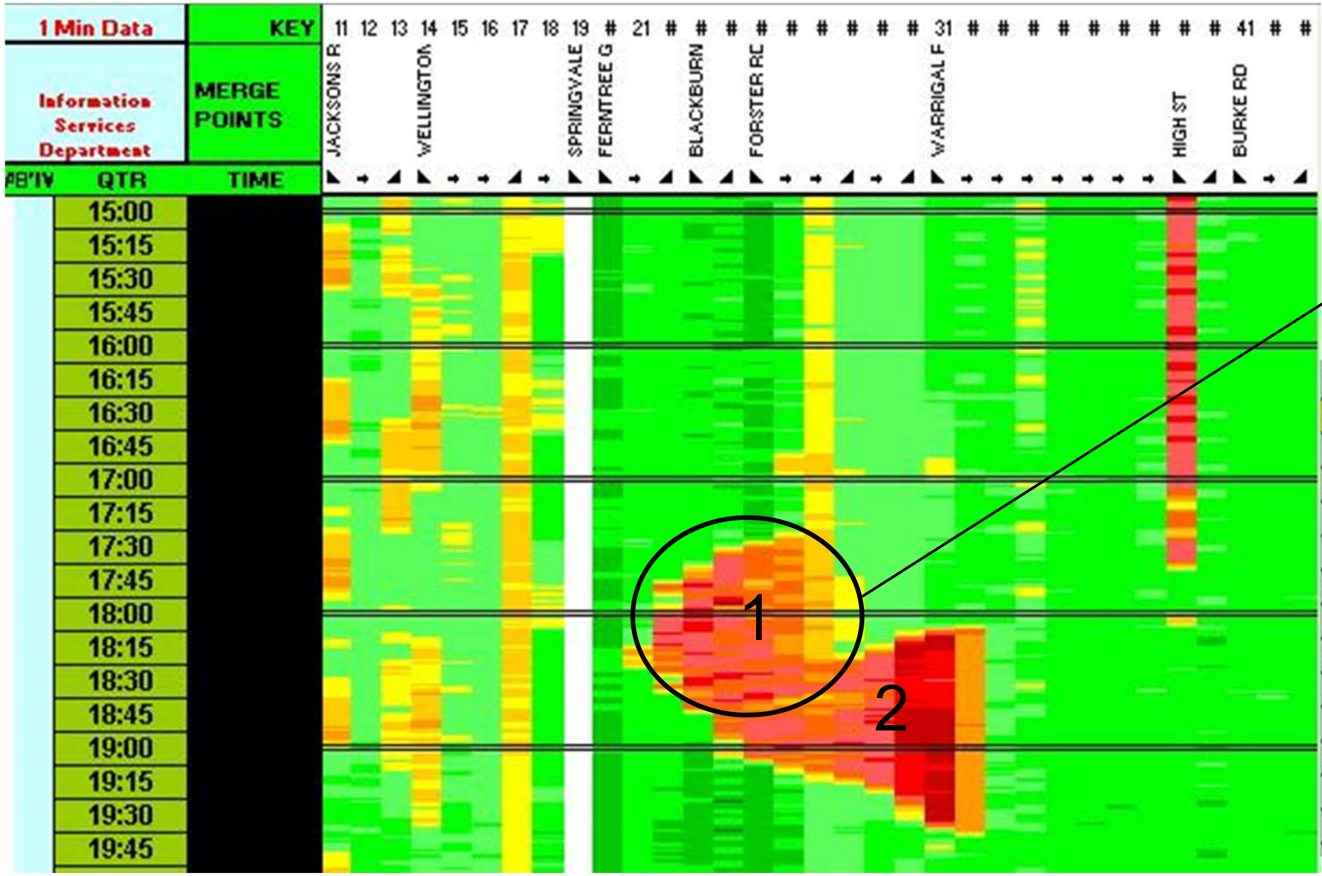
PM PEAK Typical day (No RM)



Bottleneck created due to merge at Forster ramp

THRU LANE SPEED RANGES in KM/HR

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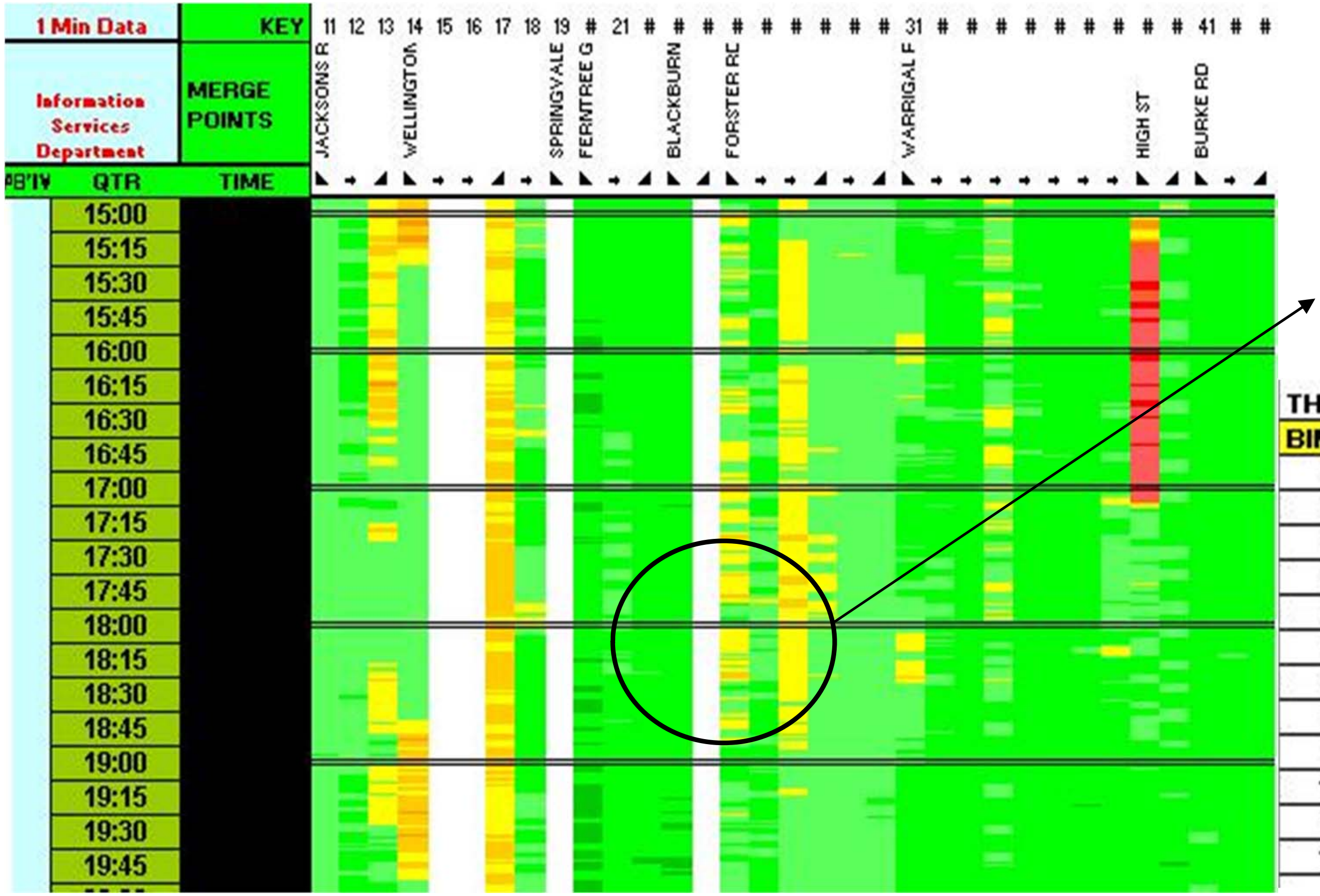
PM PEAK Typical day (ALINEA/HERO)



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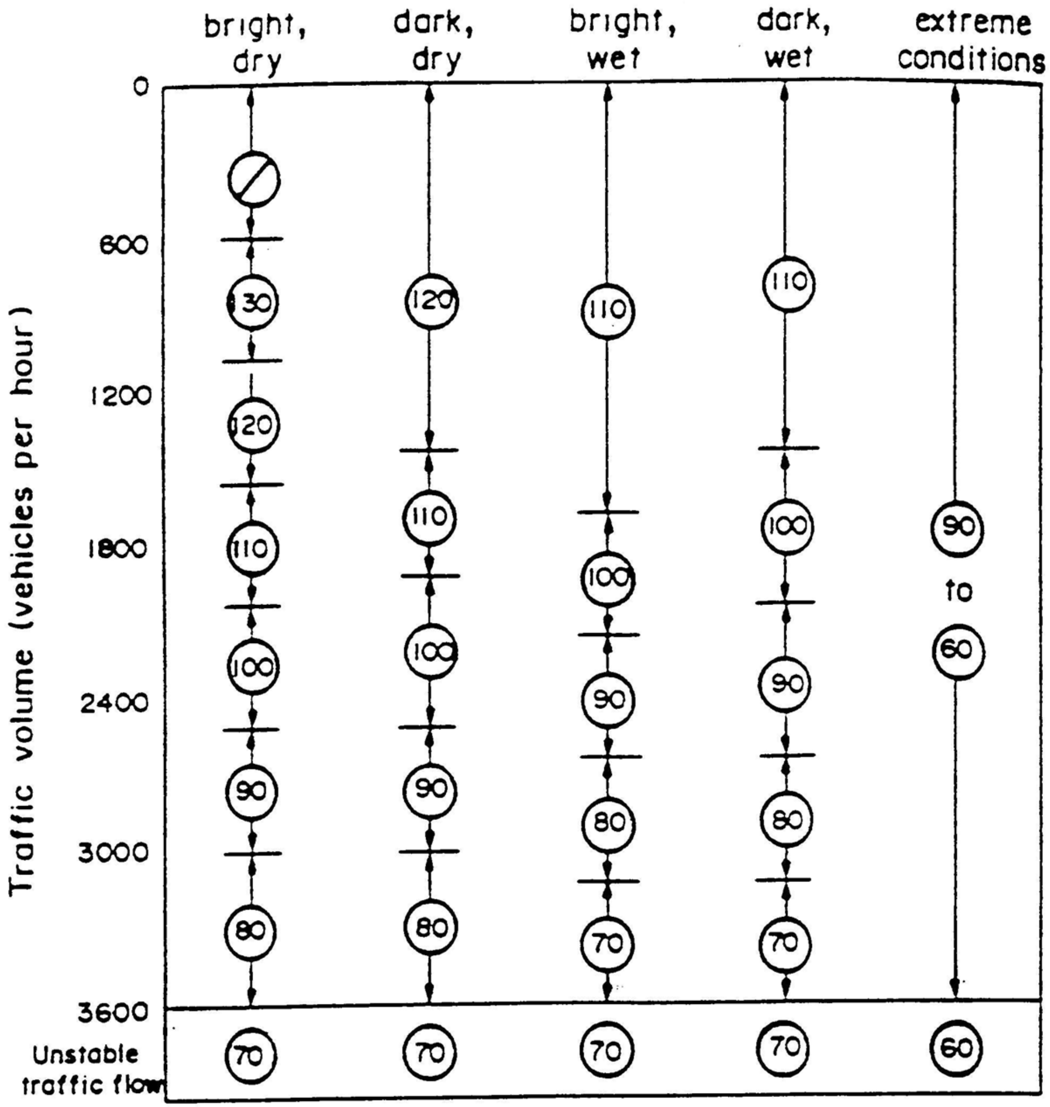
Currently: HERO extension to 65 ramps, i.e. whole freeway, 75 km, both directions

3. VARIABLE SPEED LIMITS

- Many application stretches in many counties
- Impact: "homogenisation" of traffic flow
  - Traffic safety: –20-30% accidents
  - Travel times: questionable impact of existing systems
- Simplistic control strategies



Switching plan

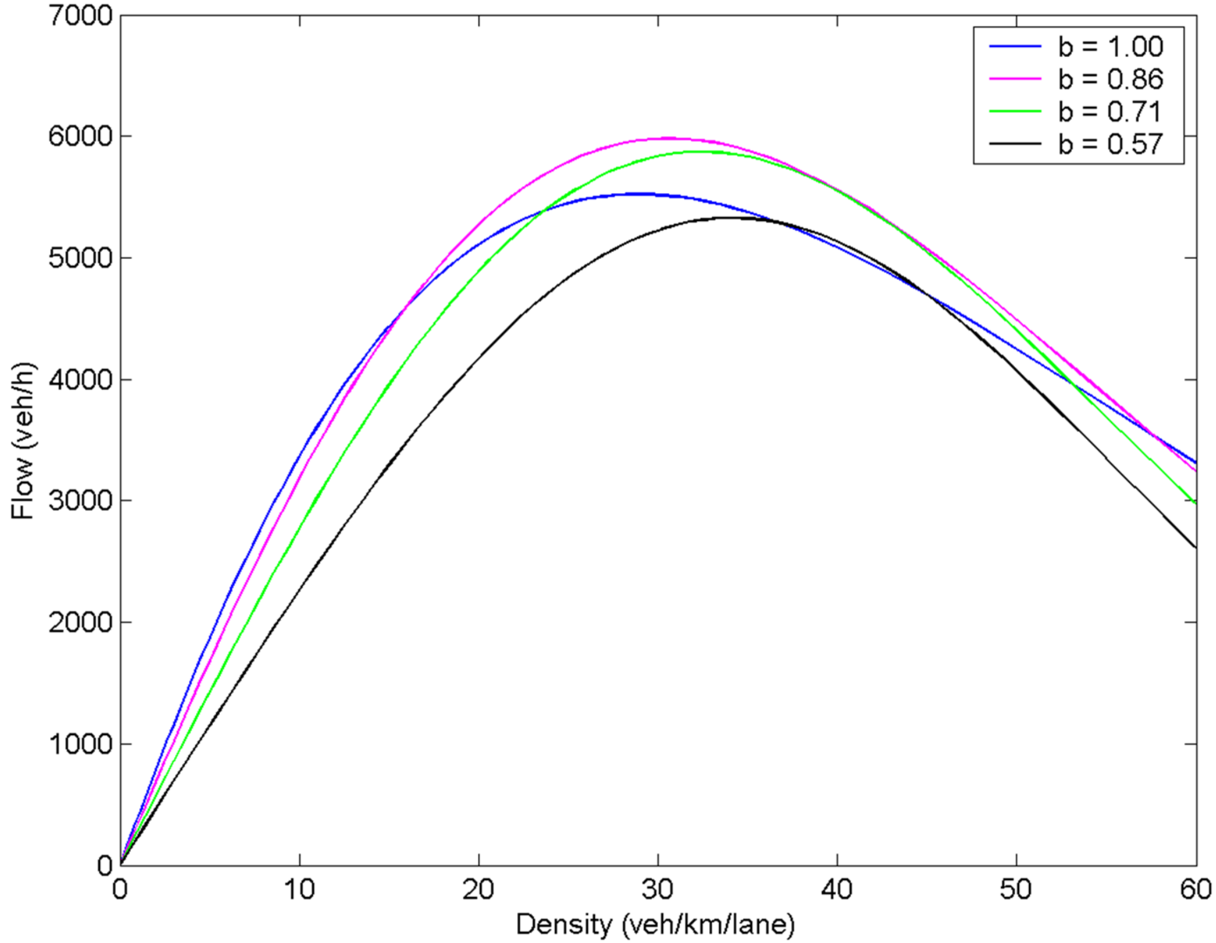
Speed indications at subsequent VSL-stations

Parameter estimation at one particular location

A = 0.42

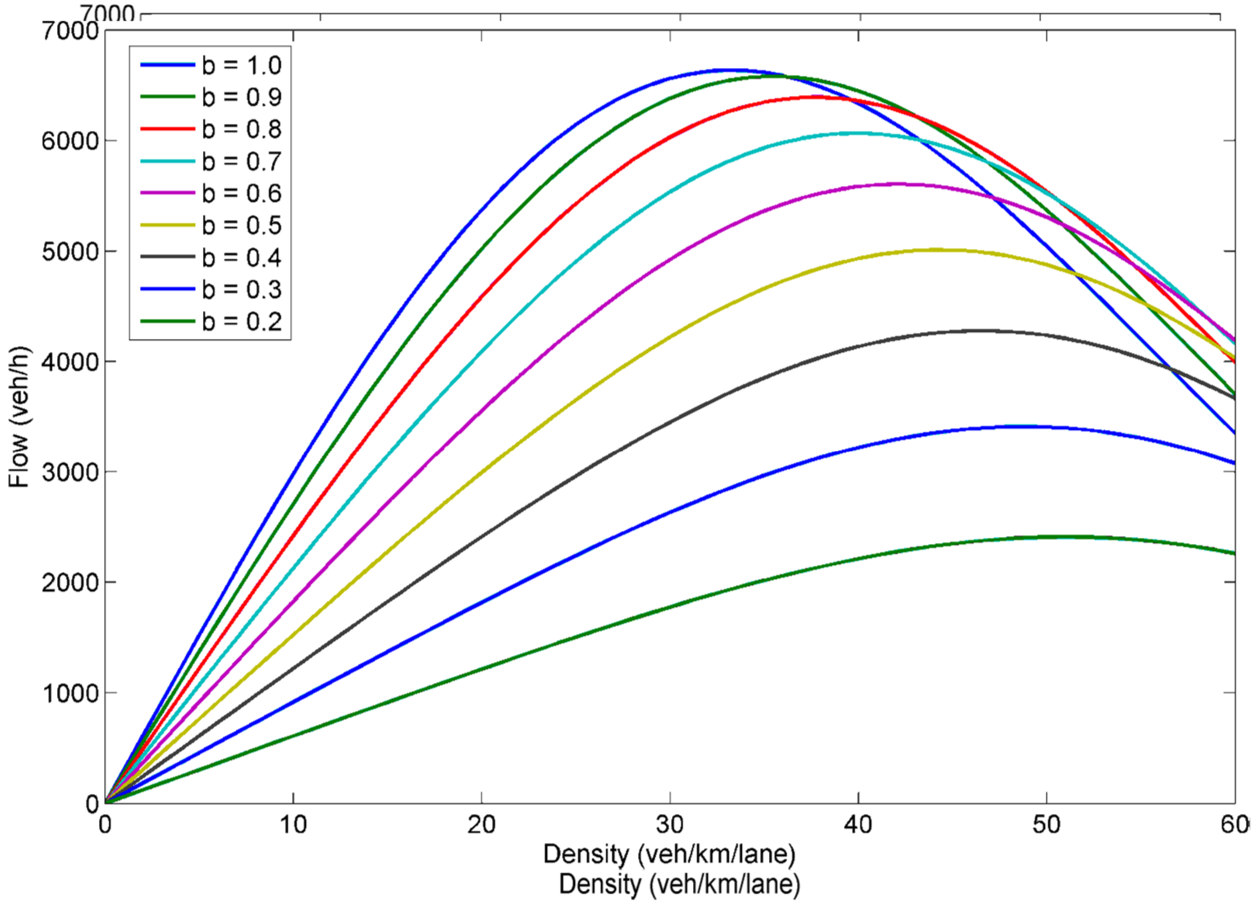
E = 3.16

leading to capacity increase by 8%

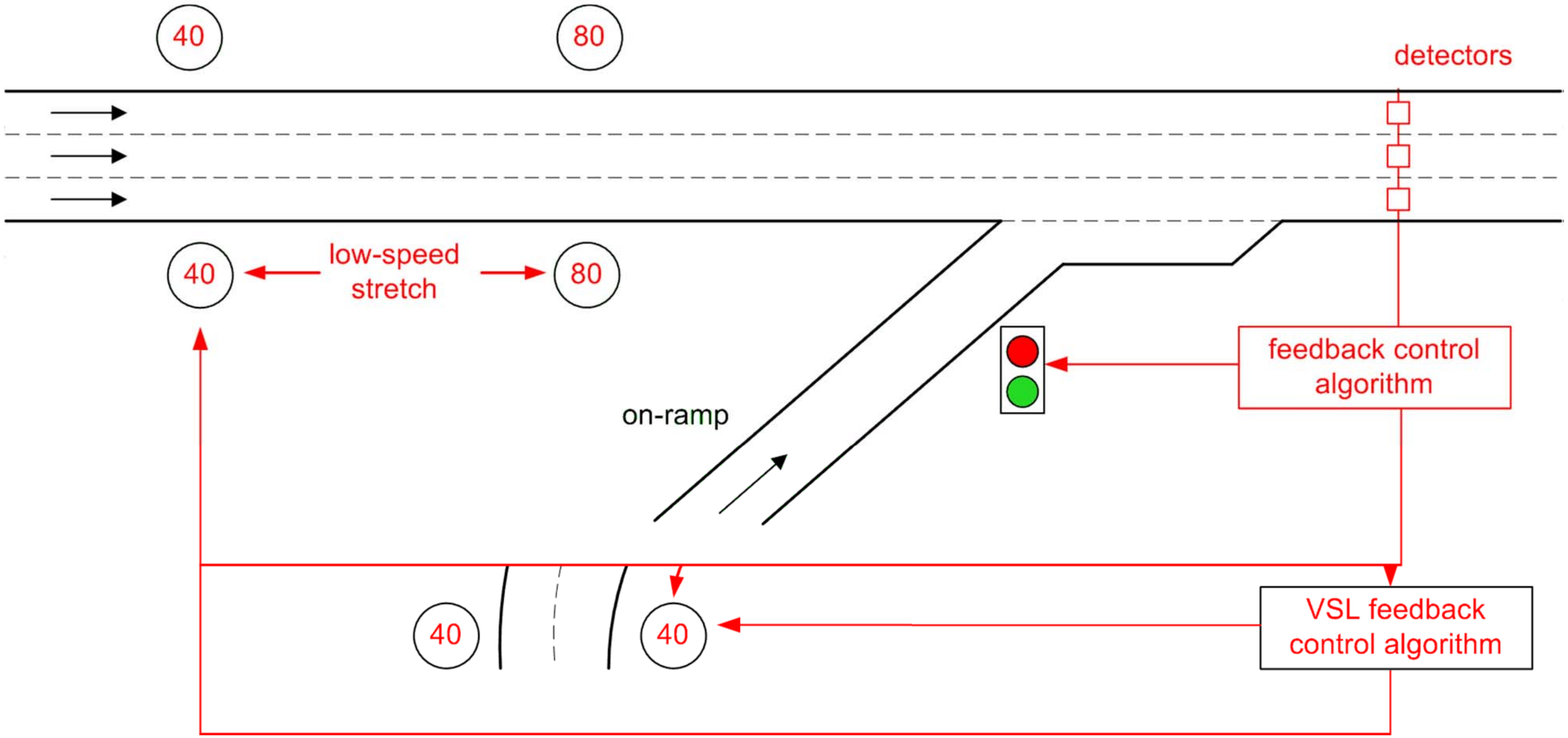


Other location

A = 0.7
E = 1.9
no capacity increase!

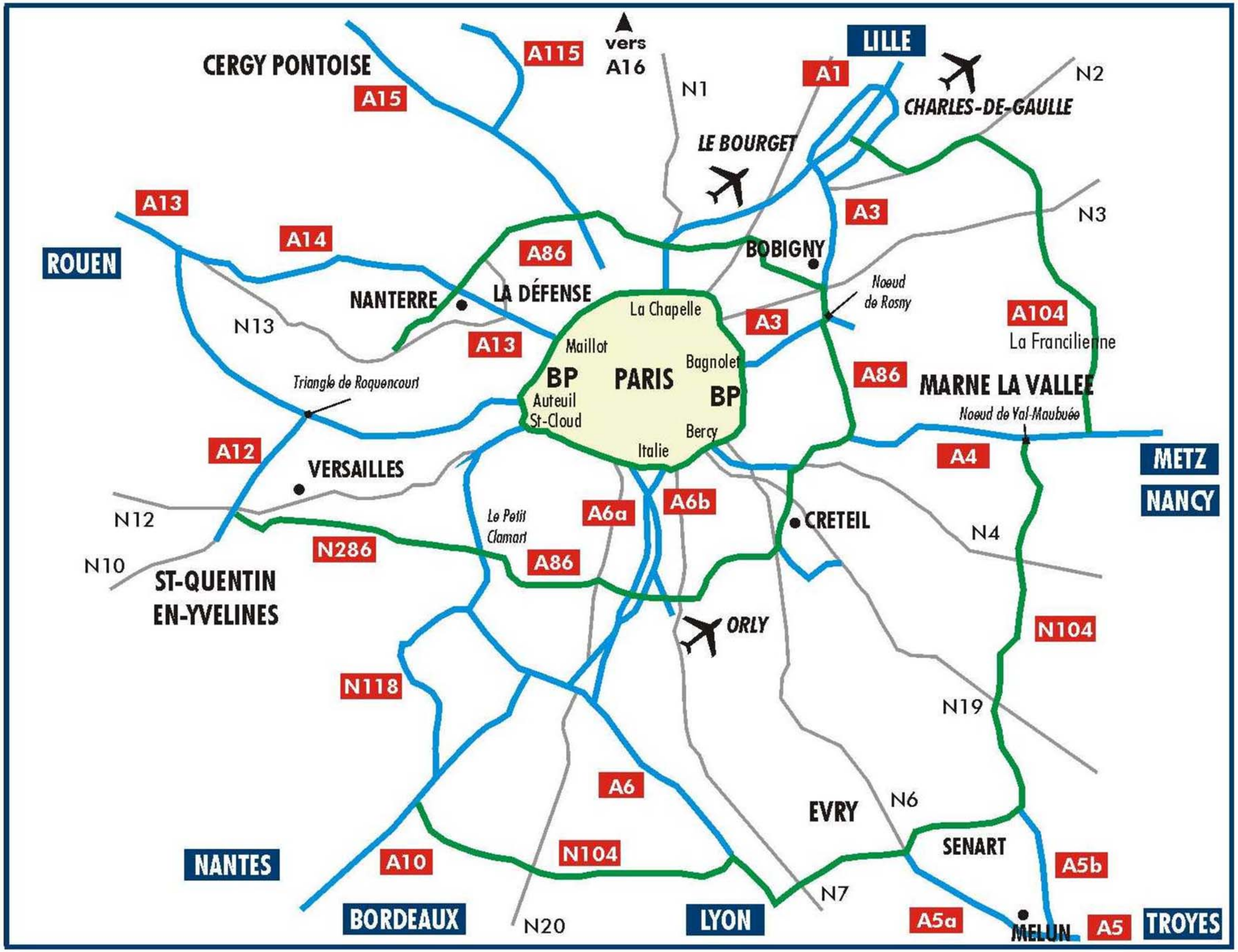


Feedback MTFC



4. ROUTE INFORMATION AND GUIDANCE

- Multi-origin, multi-destination, multi-route per O-D pair
- Fixed direction signs: shortest path in absence of congestion
- Rush hours
- Changing demands, weather conditions, exceptional events, incidents
  - underutilisation of infrastructure
  - congestion, delays, reduced safety, increased fuel consumption, environmental pollution



CERGY PONTOISE
A15
A115
vers A16
N1
LILLE
A1
N2
CHARLES-DE-GAULLE
LE BOURGET
A13
A14
ROUEN
A86
A3
N3
BOBIGNY
NANTERRE
LA DÉFENSE
La Chapelle
Noeud de Rosny
A104
La Francilienne
N13
A13
A3
Maillot
Bagnolet
A86
MARNE LA VALLEE
Triangle de Roquencourt
BP
PARIS
BP
Auteuil
St-Cloud
Noeud de Val-Maubuée
Bercy
Italie
A12
VERSAILLES
A4
METZ
NANCY
N12
Le Petit Clamart
A6a
A6b
CRETEIL
N4
N286
A86
N10
ST-QUENTIN EN-YVELINES
ORLY
N104
N118
N19
A6
N6
EVRY
SENART
NANTES
A10
N104
A5b
N7
BORDEAUX
N20
LYON
A5a
MELUN
A5
TROYES

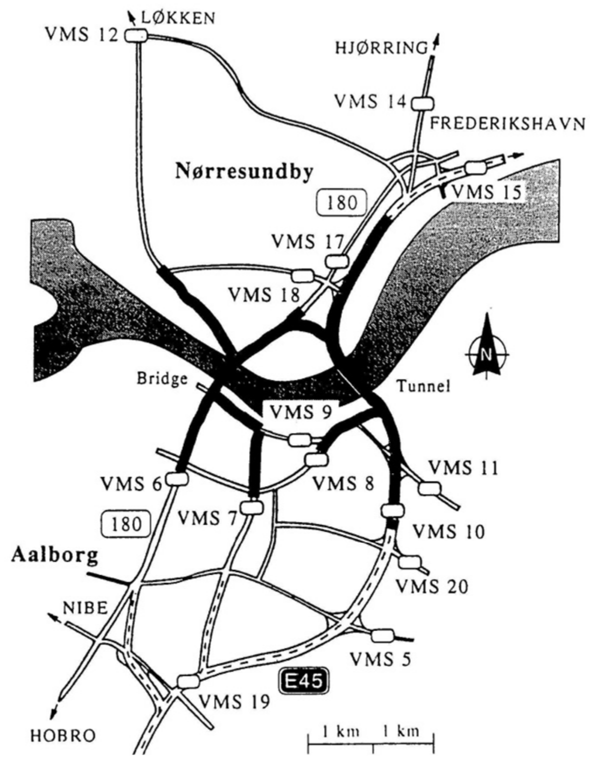
VMS (Variable Message Signs) or two-way communication with equipped vehicles

- Real-time information:
  - Drivers' knowledge
  - Message length
  - Decision efficiency
  - System controllability
  - Travel time or queue length: drivers' stress (e.g. BP in Paris) but also basis for route choice
  - Instantaneous (estimation) or predicted information
- Route guidance
  - Control strategy

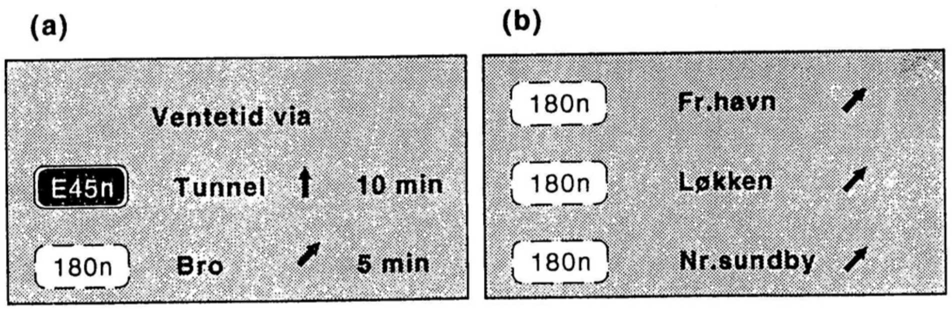
Issues

- Modelling: micro, meso, macro
- Integrated Optimal Control: AMOC
- User vs. System Optimum
- Instantaneous vs. Experienced travel times
- Algorithms: feedback vs. predictive feedback vs. iterative

Automatic Control of VMS in Aalborg, Denmark

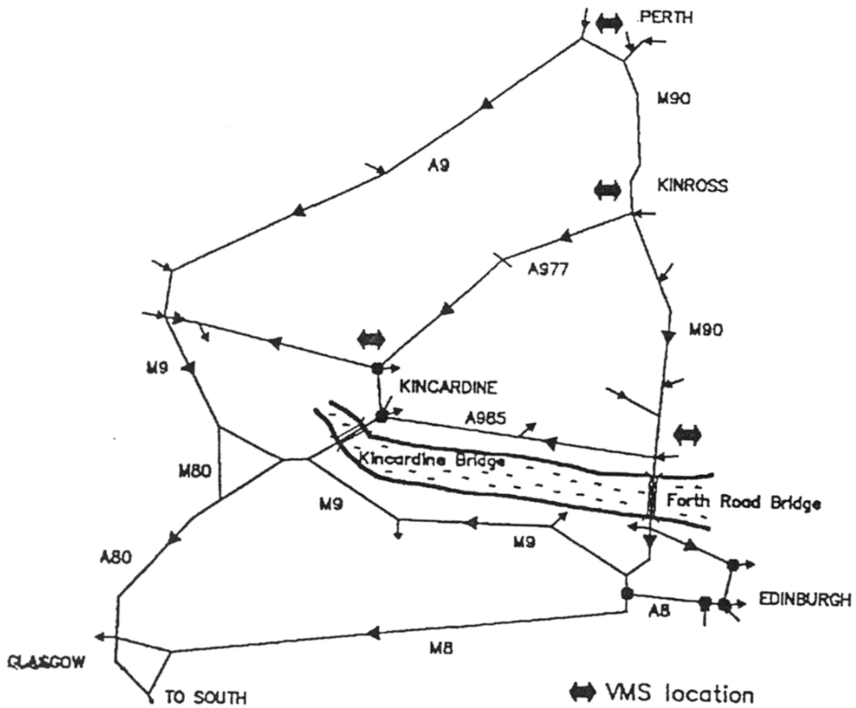


Aalborg network with VMS positions indicated.
Bold black lines represent detector equipped segments.



VMS control modes:
Delay information (a) and route guidance (b).

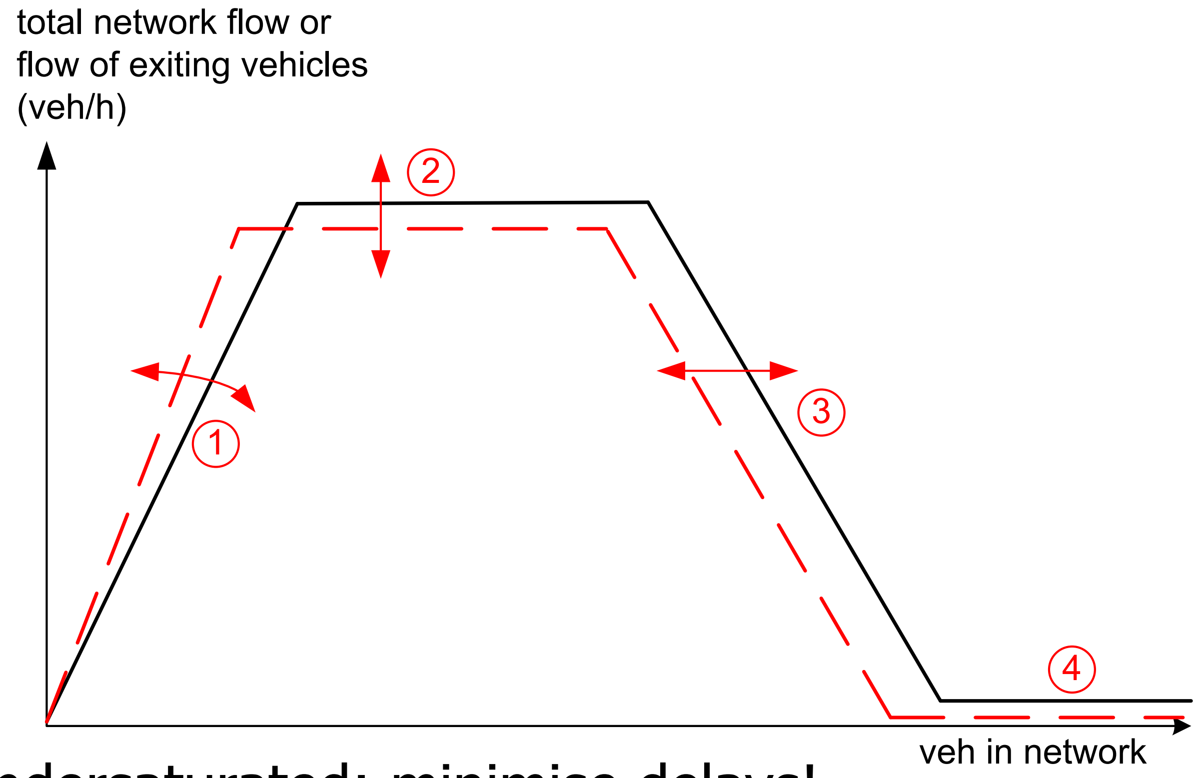
Automatic Control of VMS in the Interurban Scottish Highway Network



5. TRAFFIC SIGNAL CONTROL

- Original reason for traffic lights: safe crossing of antagonistic streams of vehicles and pedestrians
- Once they exist, they can be set in different ways. Which is best? $\rightarrow$ Optimisation problem
- Difficulties:
  - Binary variables
  - Large dimensions
  - Many disturbances
  - Difficult measurements
  - Real-time constraints
- Many control strategies, both heuristic and systematic

“2-D Fundamental Diagram” for urban networks
(PhD-Thesis by Geroliminis, 2007; Fahri, 2008)



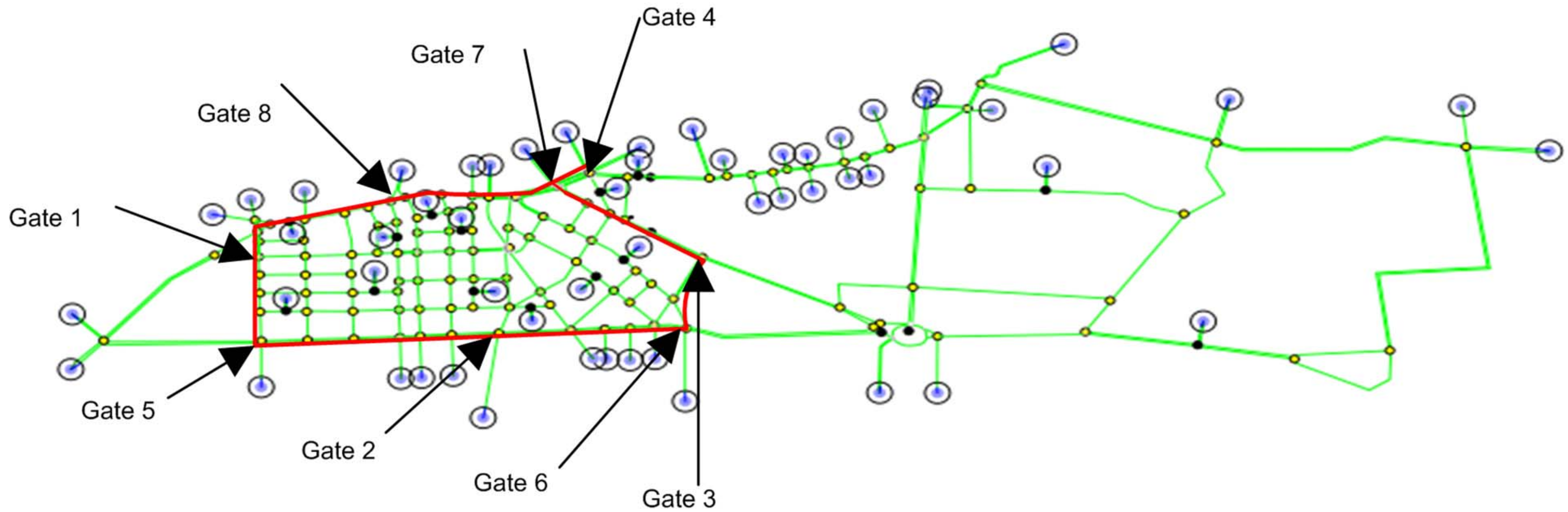
① undersaturated; minimise delays!
② saturated: maximize capacity!
③ oversaturated: queue management, gating!
④ blocked: call the police or walk home!

Caution: Different underlying phenomena than on link – FD

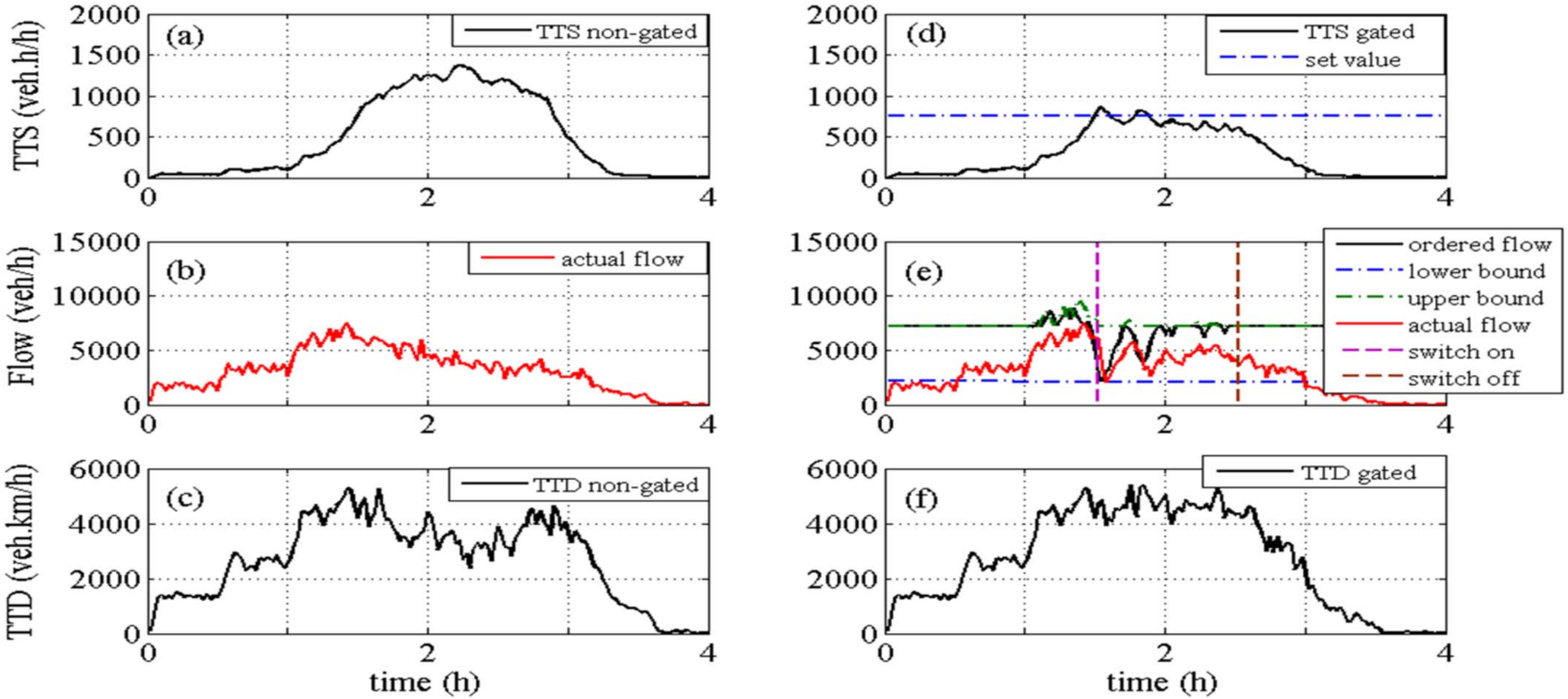
Real-time Signal Control Strategies/Systems

- Isolated
  - Traffic actuation, MOVA
- Network-wide
  - Plan selection
  - SCOOT, SCATS, UTOPIA, MOTION, OPAC, …
    (partially strong communication requirements)
- Saturated traffic conditions

- Store-and-forward based strategies
  - TUC and variations
  - Cycle-to-cycle changes
  - Low communication requirements
- Perimeter gating control



Replication R2



6. PUBLIC TRANSPORT PRIORITY

- Refers to all types of public transport vehicles (buses, trams, trains, etc. and even emergency vehicles)
- Technological implications
  - special detection technologies
  - programmable controllers
  - sec-by-sec communication with the controllers
- Implications for the road traffic
  - Frequent disturbances of signal control may lead to significant negative implications to road traffic
  - Recovery methods may not be sufficient to avoid negative implications

- Multiple approaches: Included in signal control strategies
- Easier: **one** PT vehicle **at a time**
- More challenging: multiple PT vehicles!
- Good improvements reported

7. MERGING TRAFFIC CONTROL

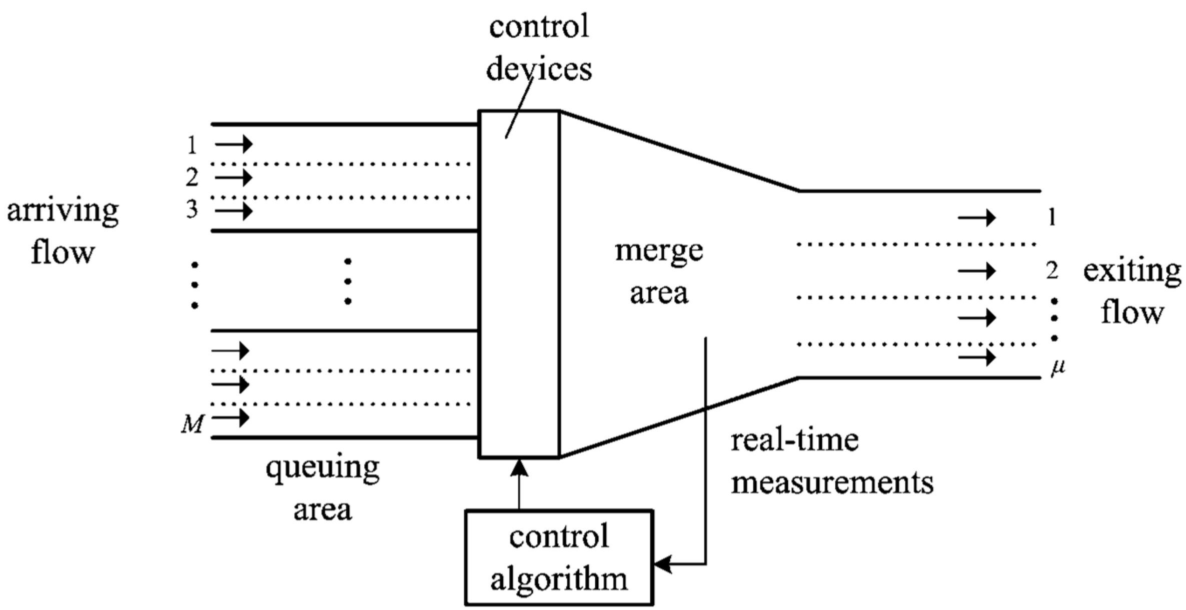
Merging traffic **infrastructures (M → μ lanes)**

- Merging of two Highways
- Motorway on-ramps
- Toll plazas
- Motorway work zones
- Tunnels.

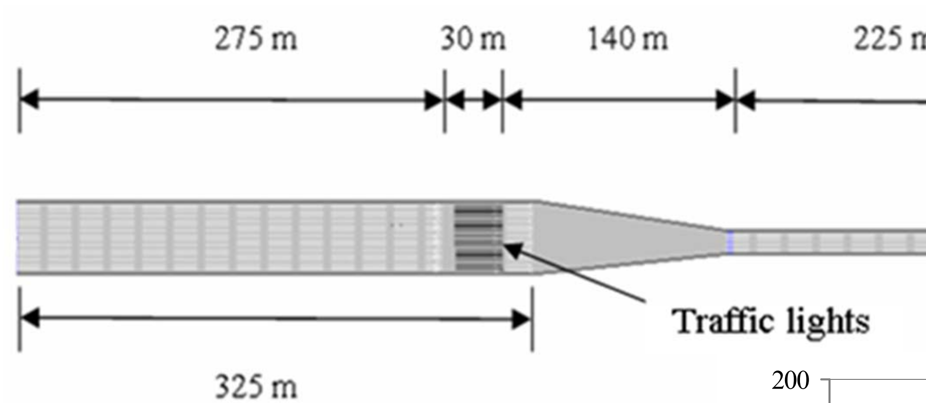
If arriving flow on M lanes > Capacity of μ lanes ⇒ Congestion ⇒ Capacity drop

Merging traffic control to restore capacity flow

Structure and Elements

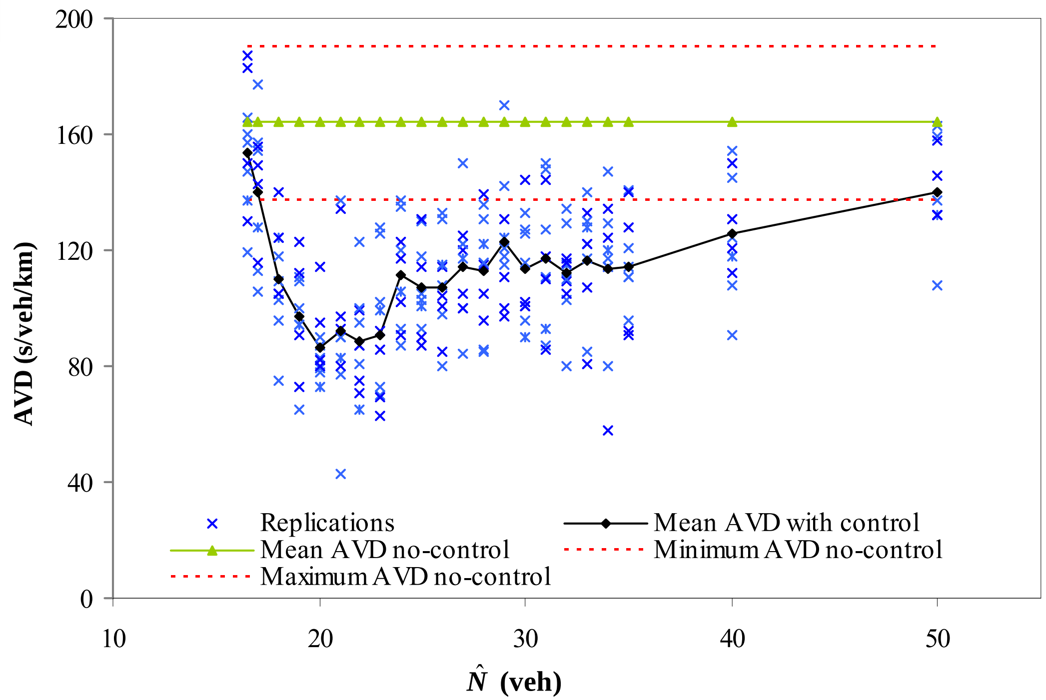


Simulation Example: Toll plaza
San Francisco-Oakland Bay Bridge

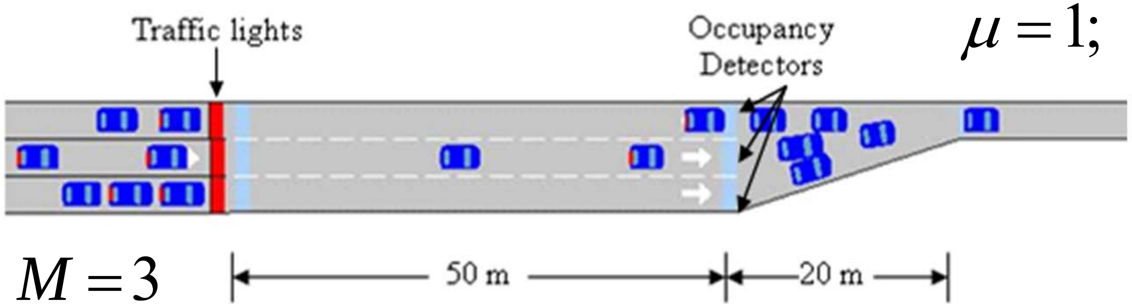


$$M = 15$$

$$\mu = 5; \quad q_{cap} = 10,500\text{veh/h}$$

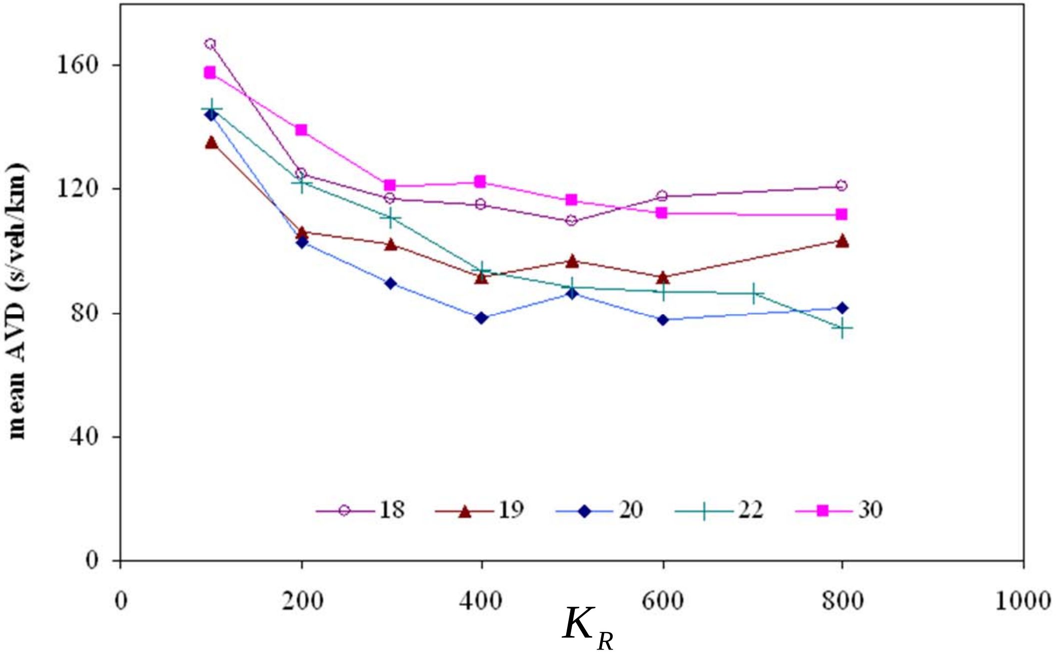


Work Zone Control

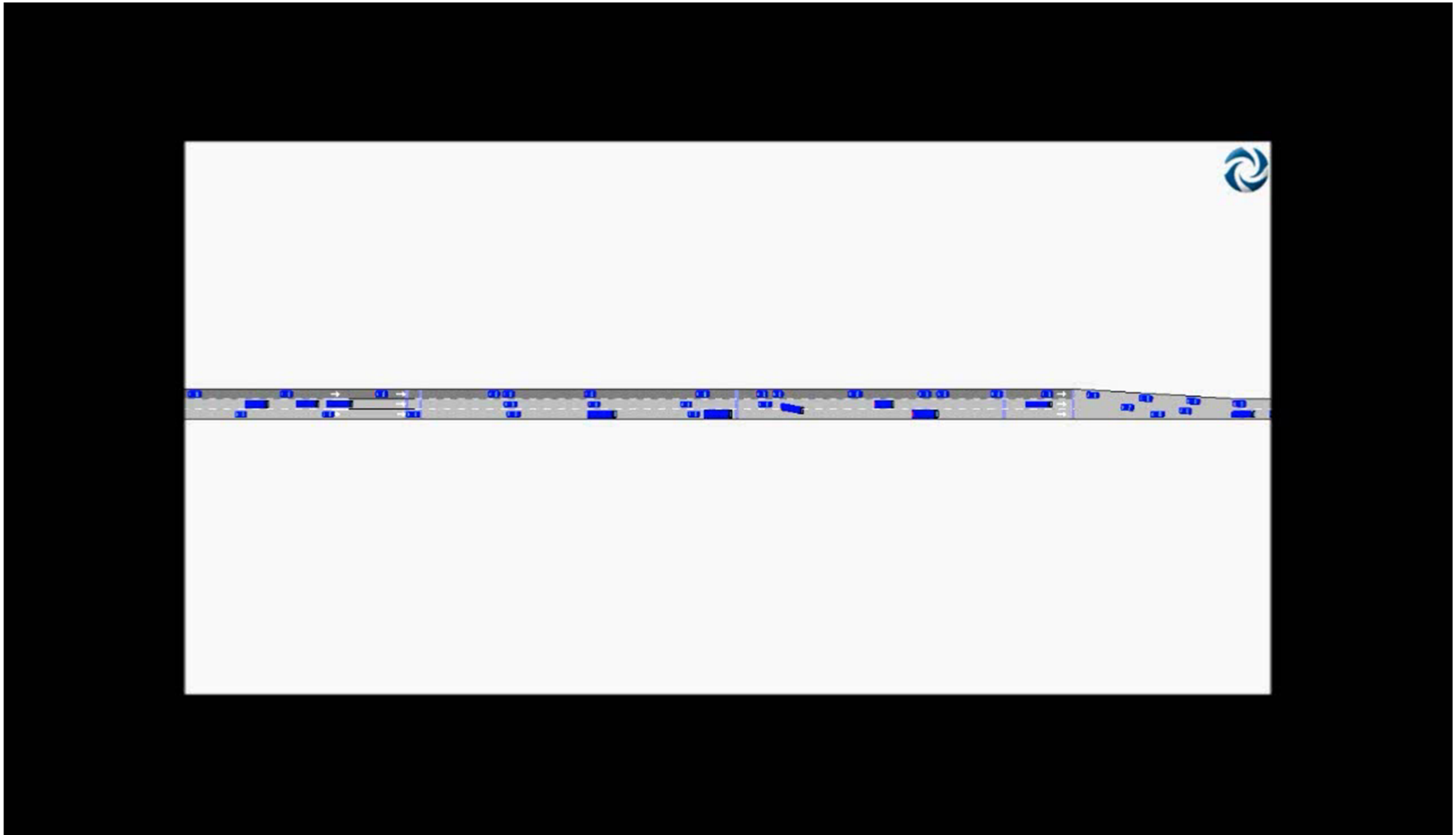


$\mu = 1; \quad q_{cap} = 2{,}300\text{veh/h}$

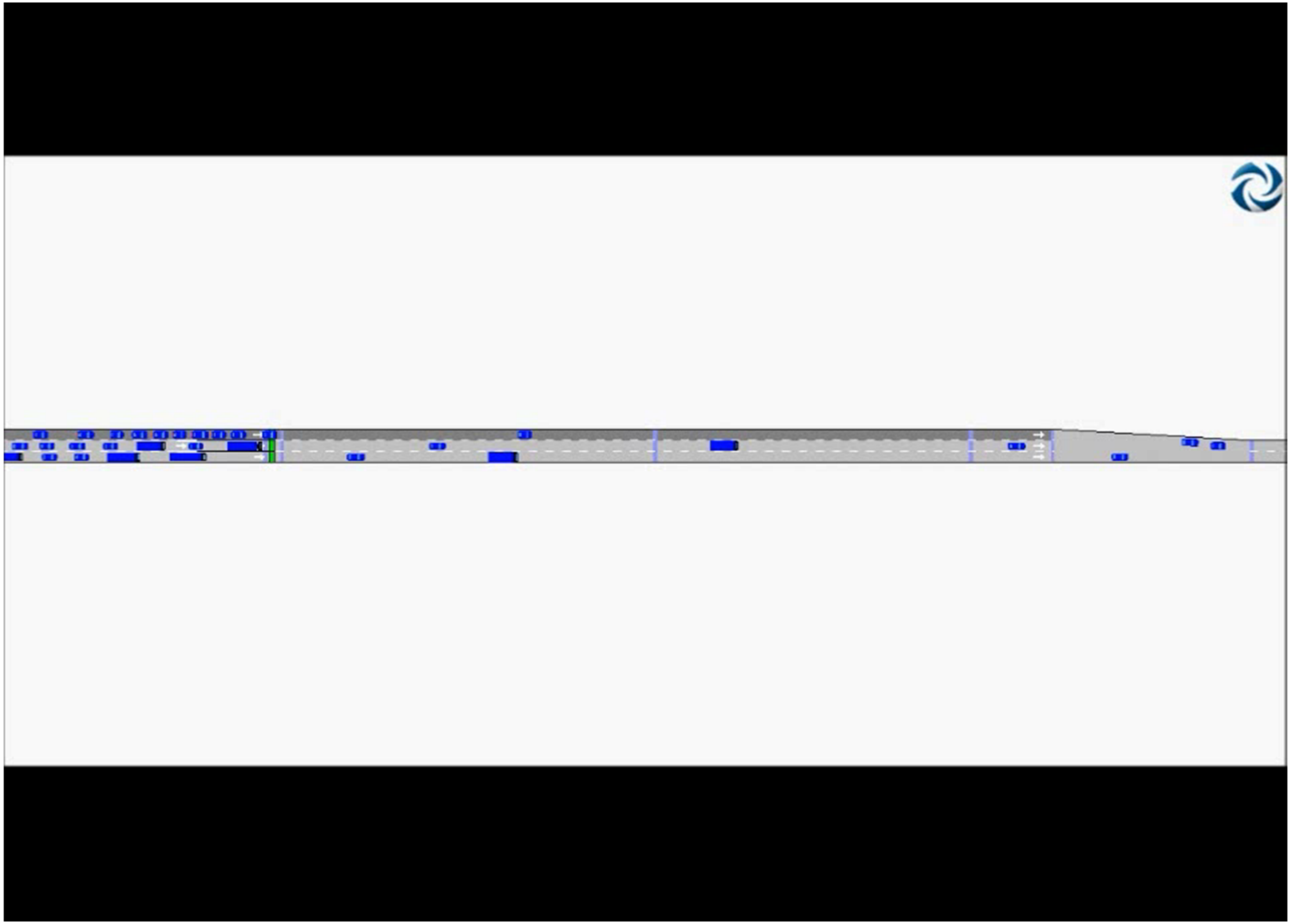
$M = 3$



Different layout (now using PI-ALINEA)



WZ No Control video



WZ Control video

8. Conclusions

- Traffic flow can be substantially improved (in some cases -50% travel times) via traffic control
- Technological giants with a baby brain
- Methodological zombies
- Nothing is more practical than a good theory
- As simple as possible as complex as necessary
- General applicability, high efficiency
- Field applications needed