Reducing randomness: the advent of self driving cars

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Your speaker

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1986-1990	PhD Queueing models for slotted transmission systems, UT
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1992-2009	Modelling intelligent transport systems, TNO
2003-2009	Part-time professor Driver support system UT
2009-..	Professor Transport Modelling, TU Delft

H-index 17
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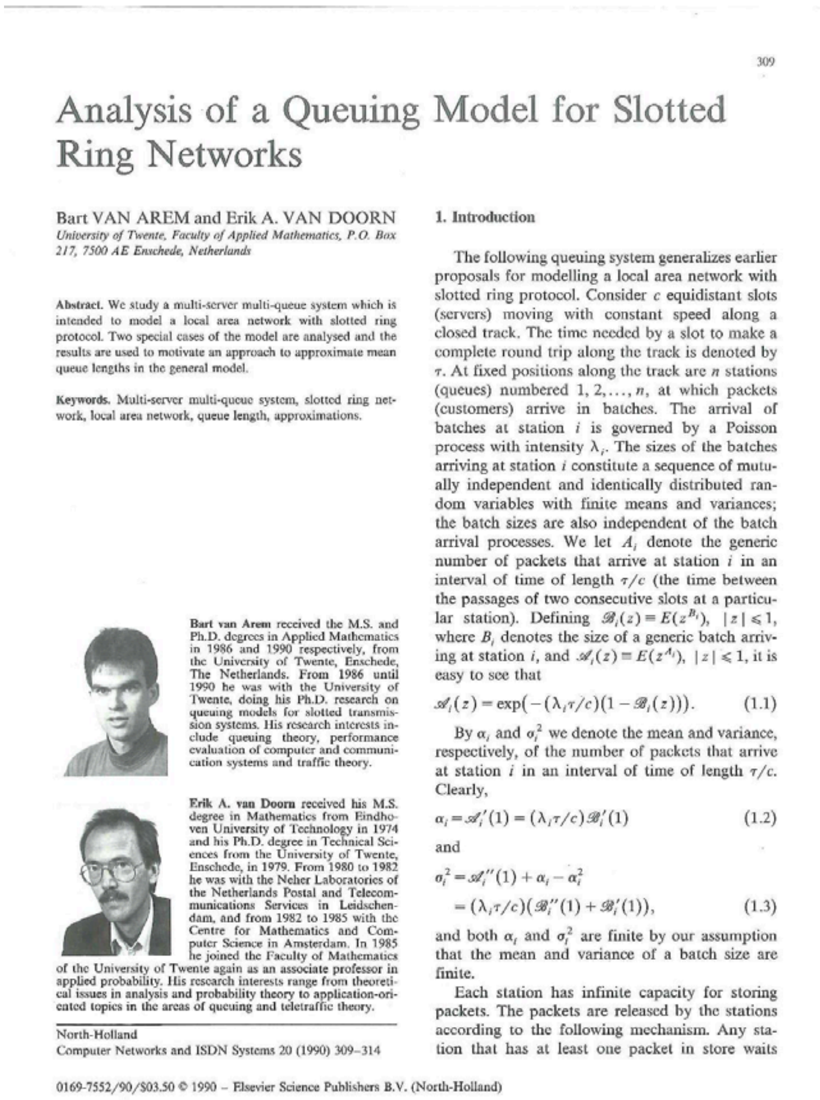
5 PhDs
60 MSc's



Analysis of a Queuing Model for Slotted Ring Networks

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Abstract. We study a multi-server multi-queue system which is intended to model a local area network with slotted ring protocol. Two special cases of the model are analysed and the results are used to motivate an approach to approximate mean queue lengths in the general model.

Keywords. Multi-server multi-queue system, slotted ring network, local area network, queue length, approximations.

Bart van Arem received the M.S. and Ph.D. degrees in Applied Mathematics in 1986 and 1990 respectively, from the University of Twente, Enschede, The Netherlands. From 1986 until 1990 he was with the University of Twente, doing his Ph.D. research on queuing models for slotted transmission systems. His research interests include queuing theory, performance evaluation of computer and communication systems and traffic theory.

Erik A. van Doorn received his M.S. degree in Mathematics from Eindhoven University of Technology in 1974 and his Ph.D. degree in Technical Sciences from the University of Twente, Enschede, in 1979. From 1980 to 1982 he was with the Neher Laboratories of the Netherlands Postal and Telecommunications Services in Leidschendam, and from 1982 to 1985 with the Centre for Mathematics and Computer Science in Amsterdam. In 1985 he joined the Faculty of Mathematics of the University of Twente again as an associate professor in applied probability. His research interests range from theoretical issues in analysis and probability theory to application-oriented topics in the areas of queuing and teletraffic theory.

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1. Introduction

The following queuing system generalizes earlier proposals for modelling a local area network with slotted ring protocol. Consider c equidistant slots (servers) moving with constant speed along a closed track. The time needed by a slot to make a complete round trip along the track is denoted by τ. At fixed positions along the track are n stations (queues) numbered $1, 2, \ldots, n$, at which packets (customers) arrive in batches. The arrival of batches at station i is governed by a Poisson process with intensity λ_i. The sizes of the batches arriving at station i constitute a sequence of mutually independent and identically distributed random variables with finite means and variances; the batch sizes are also independent of the batch arrival processes. We let A_i denote the generic number of packets that arrive at station i in an interval of time of length τ/c (the time between the passages of two consecutive slots at a particular station). Defining $\mathscr{B}_i(z) = E(z^{B_i})$, $|z| \leq 1$, where B_i denotes the size of a generic batch arriving at station i, and $\mathscr{A}_i(z) = E(z^{A_i})$, $|z| \leq 1$, it is easy to see that

$$\mathscr{A}_i(z) = \exp(-(\lambda_i \tau/c)(1 - \mathscr{B}_i(z))). \qquad (1.1)$$

By α_i and σ_i^2 we denote the mean and variance, respectively, of the number of packets that arrive at station i in an interval of time of length τ/c. Clearly,

$$\alpha_i = \mathscr{A}_i'(1) = (\lambda_i \tau/c)\mathscr{B}_i'(1) \qquad (1.2)$$

and

$$\begin{aligned} \sigma_i^2 &= \mathscr{A}_i''(1) + \alpha_i - \alpha_i^2 \\ &= (\lambda_i \tau/c)(\mathscr{B}_i''(1) + \mathscr{B}_i'(1)), \qquad (1.3) \end{aligned}$$

and both α_i and σ_i^2 are finite by our assumption that the mean and variance of a batch size are finite.

Each station has infinite capacity for storing packets. The packets are released by the stations according to the following mechanism. Any station that has at least one packet in store waits

Reducing randomness…

Road traffic flow strongly heterogeneous and stochastic

First moment of delay depends on second moment of inter arrival times

Randomness of driver/vehicle behaviour in terms of anticipation, speed, reaction time, acceleration

Can self driving vehicles reduce randomness and improve traffic flow efficiency?


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What is automated driving?

Partial automation

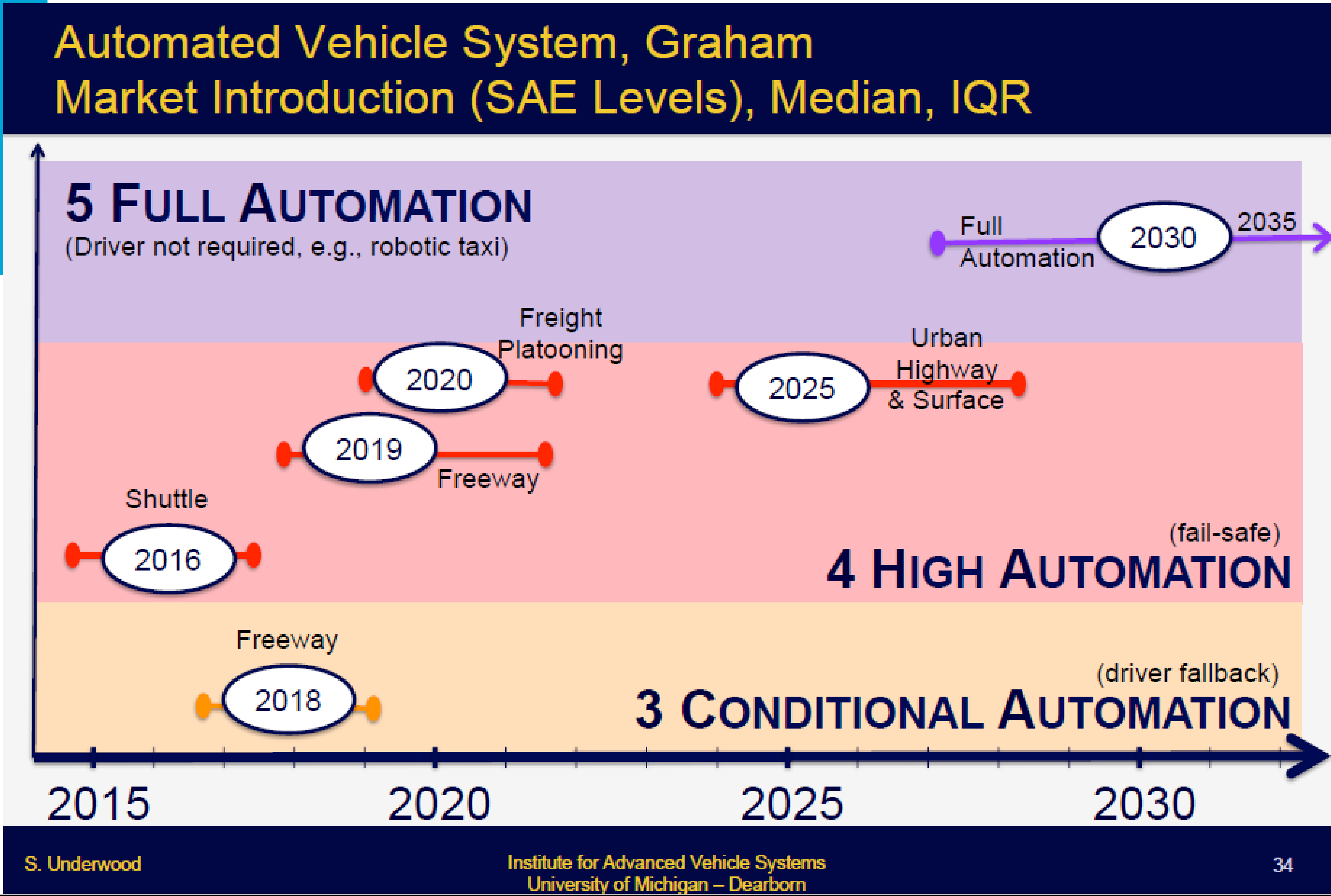
Available,
Mercedes S class
Limited scope

High automation

Massive worldwide R&D

Full automation

Decades away unless on dedicated infrastructure or driving very slowly


Automated Vehicle System, Graham
Market Introduction (SAE Levels), Median, IQR
5 FULL AUTOMATION
(Driver not required, e.g., robotic taxi)
Full
Automation
2030
2035
Freight
Platooning
2020
2025
Urban
Highway
& Surface
2019
Freeway
Shuttle
2016
(fail-safe)
4 HIGH AUTOMATION
Freeway
2018
(driver fallback)
3 CONDITIONAL AUTOMATION
2015
2020
2025
2030
S. Underwood
Institute for Advanced Vehicle Systems
University of Michigan – Dearborn
34

Potential impacts

Solve traffic jams by increased outflow

Prevent traffic jams by better stability

Better distribution of traffic over network

No accidents (?)

Less congestion delay

Better energy efficiency

Large penetration

Non connected

Decreased throughput by larger headways

Decreased stability by lack of anticipation

Increased risk of congestion

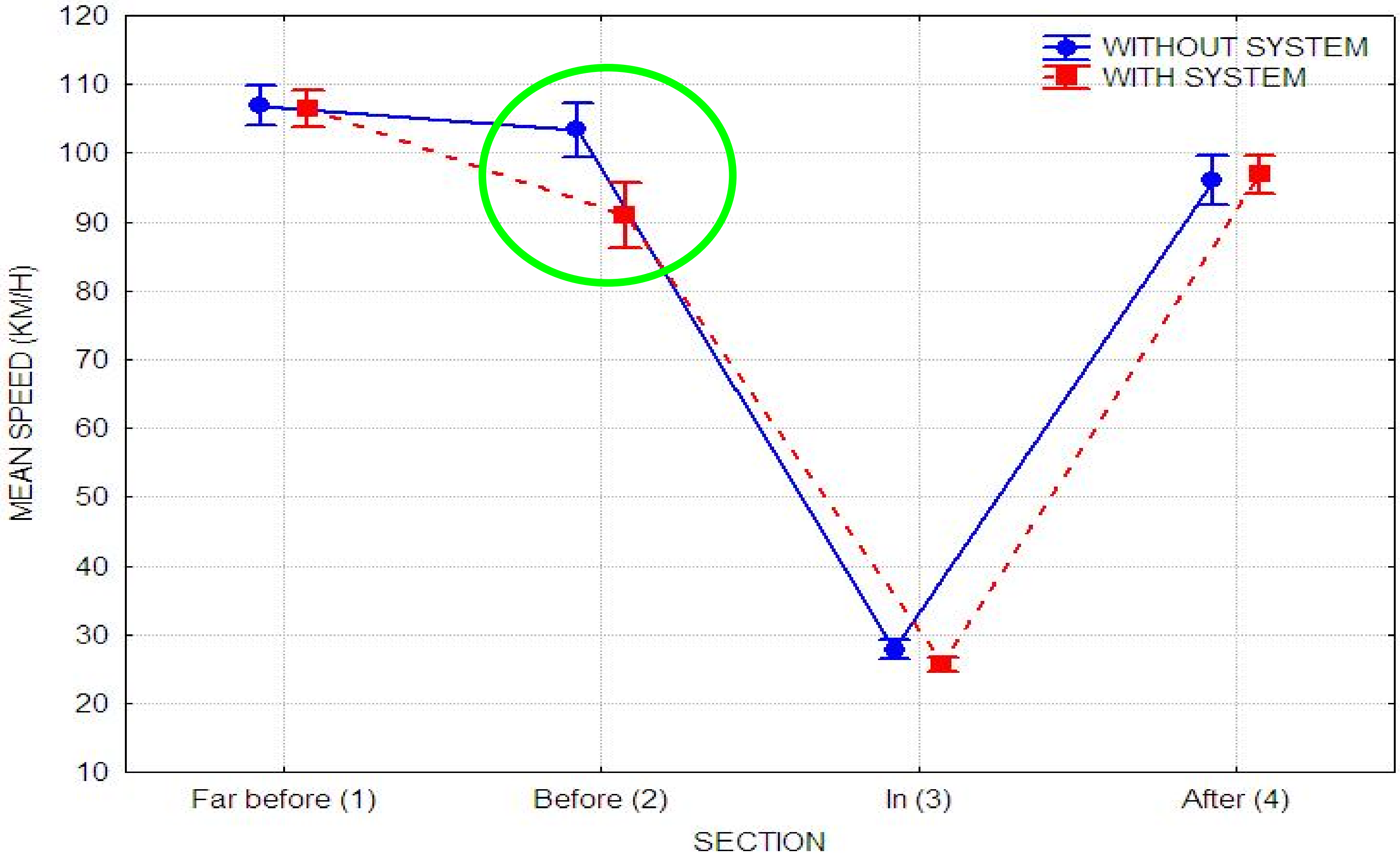
The congestion assistant

- Detects downstream congestion
- Visual and auditive warning starting at 5 km before congestion
- Active gas pedal at 1,5 km to smoothly slow down
- Takes over longitudinal driving task during congestion

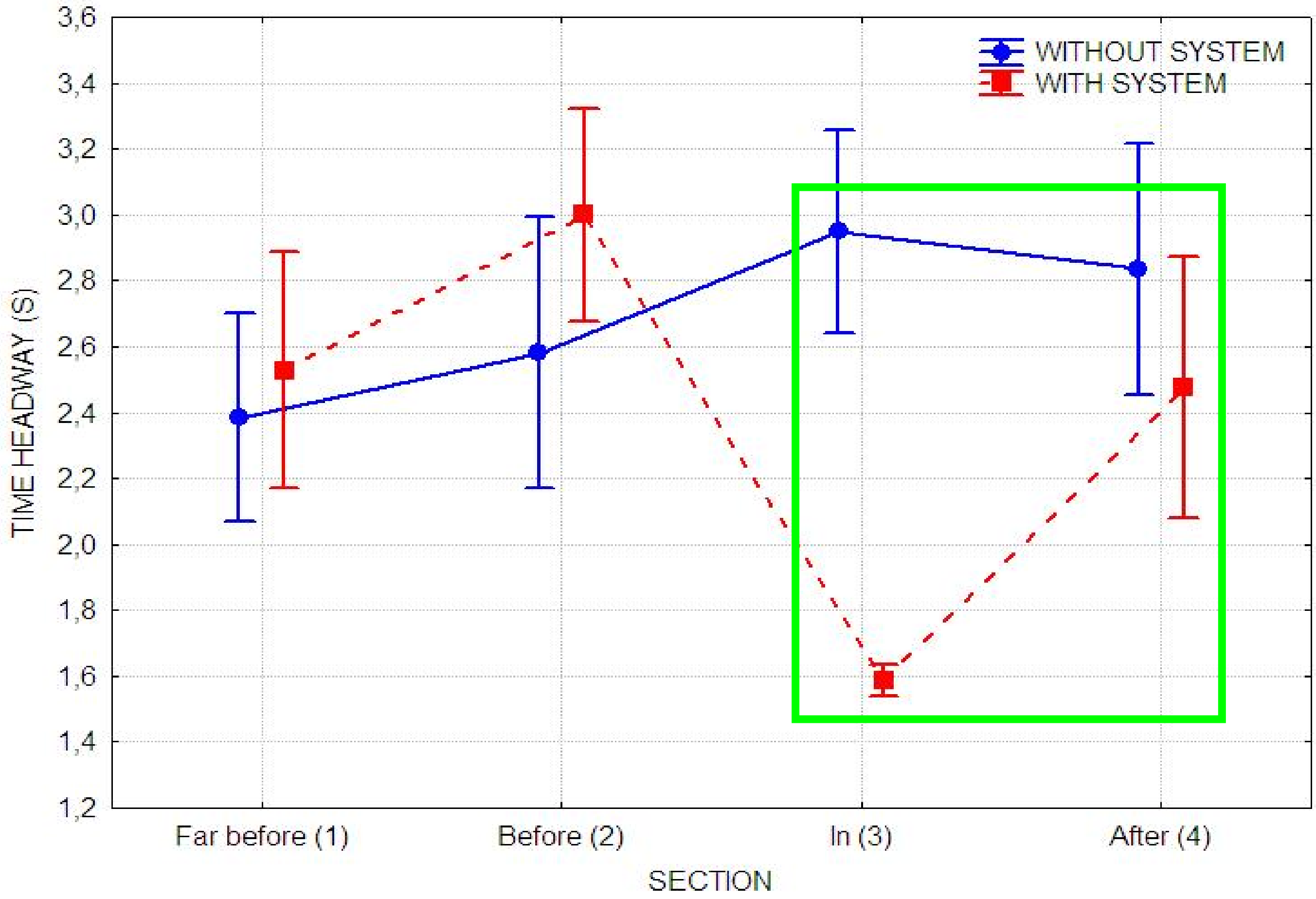
Impacts on driving behaviour

Motorway scenario with congestion
Impacts on driving behaviour
Acceptance

Effects on mean speed

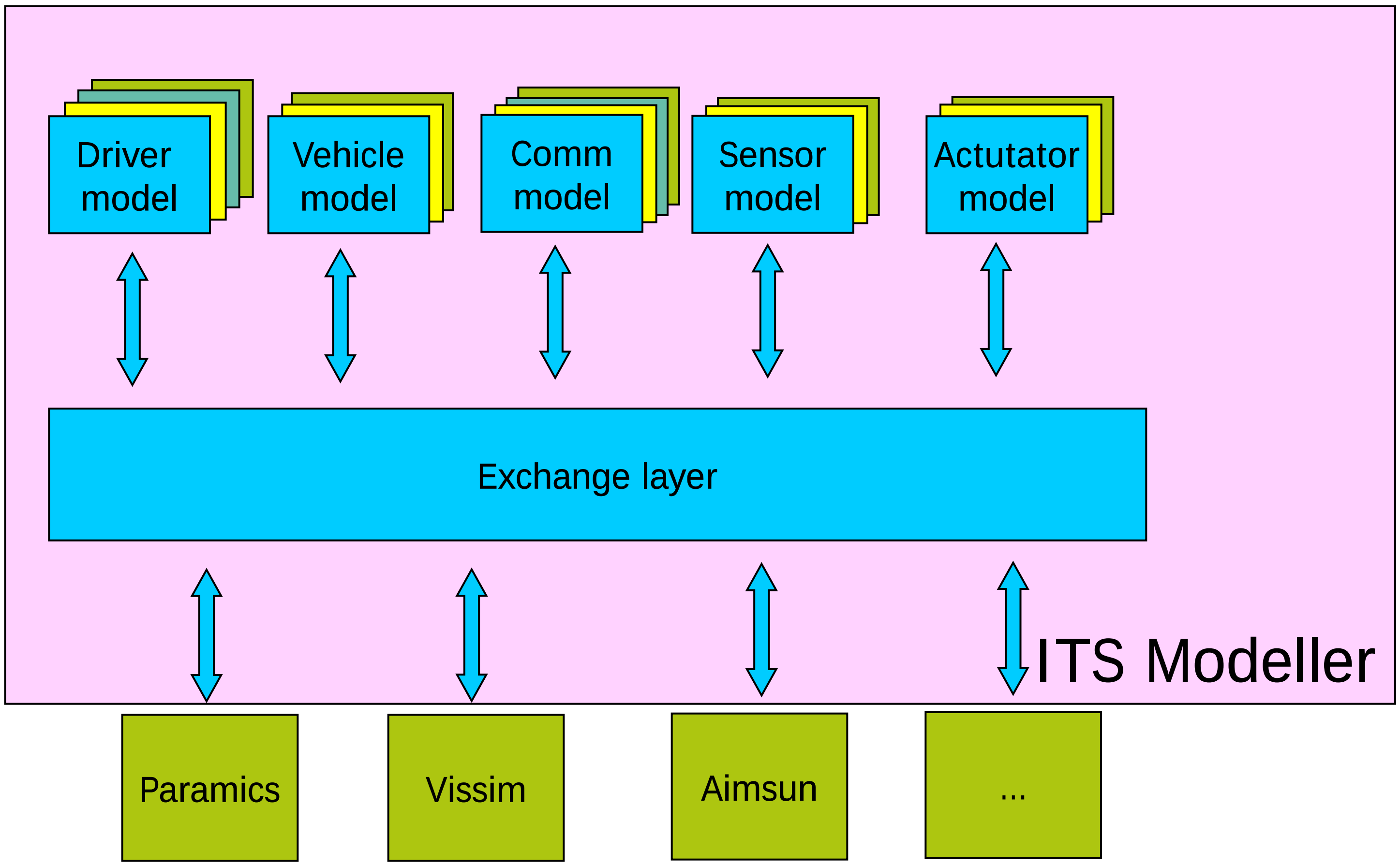


Effects on time headway



May 31, 2006

ITS Modeller



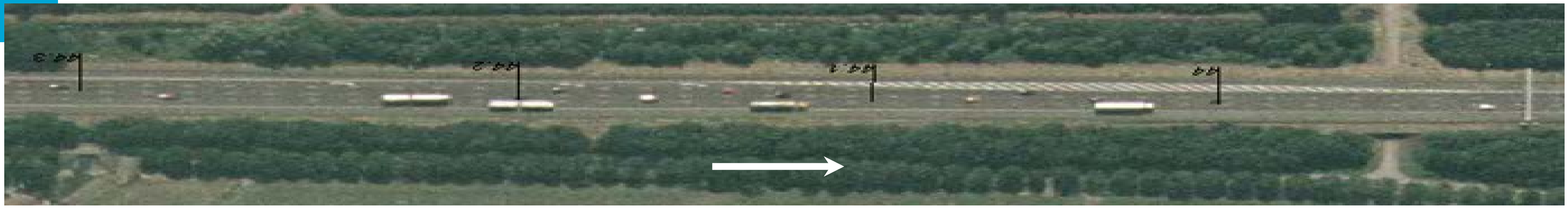
Longitudinaal bestuurdersmodel

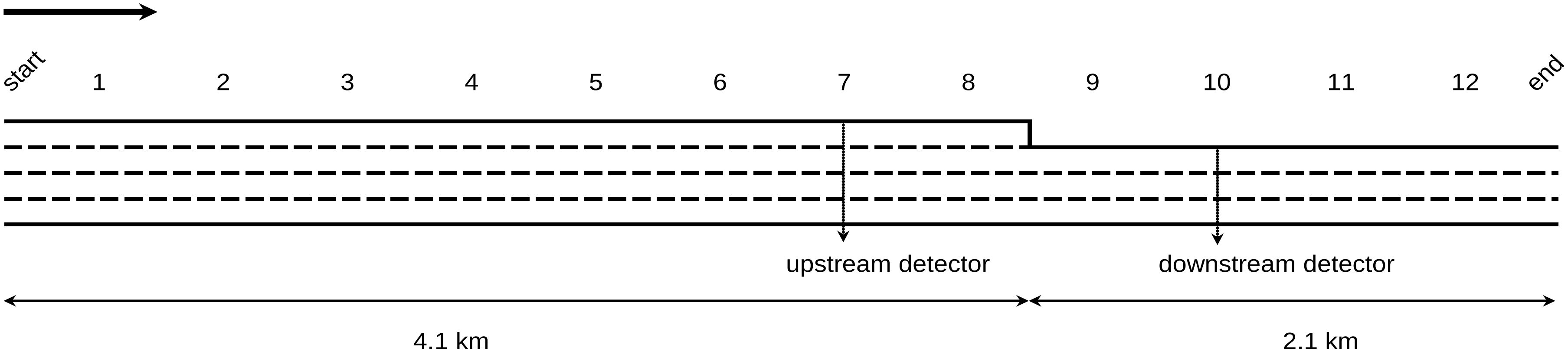
$$a_{ref\_v} = r \cdot \left(v_{ref} - v\right)$$

$$a_{ref\_d} = c_d \cdot \left(d\left(t - t_r\right) - d_{ref}\right) + c_{v\_p} \cdot v_{rel\_p}\left(t - t_r\right) + c_{v\_pp} \cdot v_{rel\_pp}\left(t - t_r\right)$$

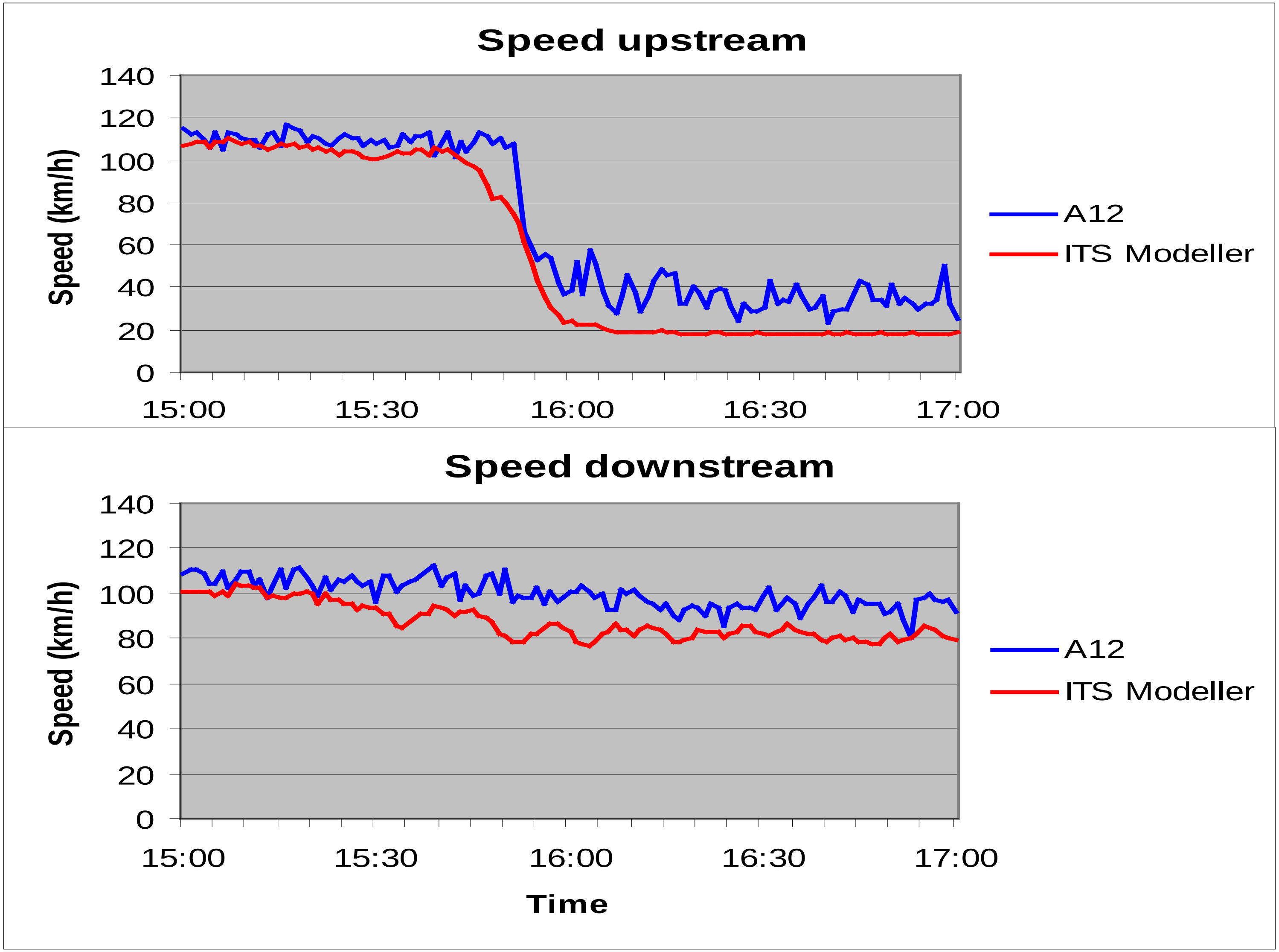
$$d_{ref} = c_1 + c_2 \cdot v + c_3 \cdot v^2$$

Study area: merging area A12 motorway, Woerden, the Netherlands





Calibratie


Speed upstream
Speed (km/h)
140
120
100
80
60
40
20
0
15:00
15:30
16:00
16:30
17:00
A12
ITS Modeller
Speed downstream
Speed (km/h)
140
120
100
80
60
40
20
0
15:00
15:30
16:00
16:30
17:00
Time
A12
ITS Modeller

Model file assistent

Actief gaspedaal: $$a_{ac} = \frac{v_j^2 - v^2}{2 \cdot x}$$

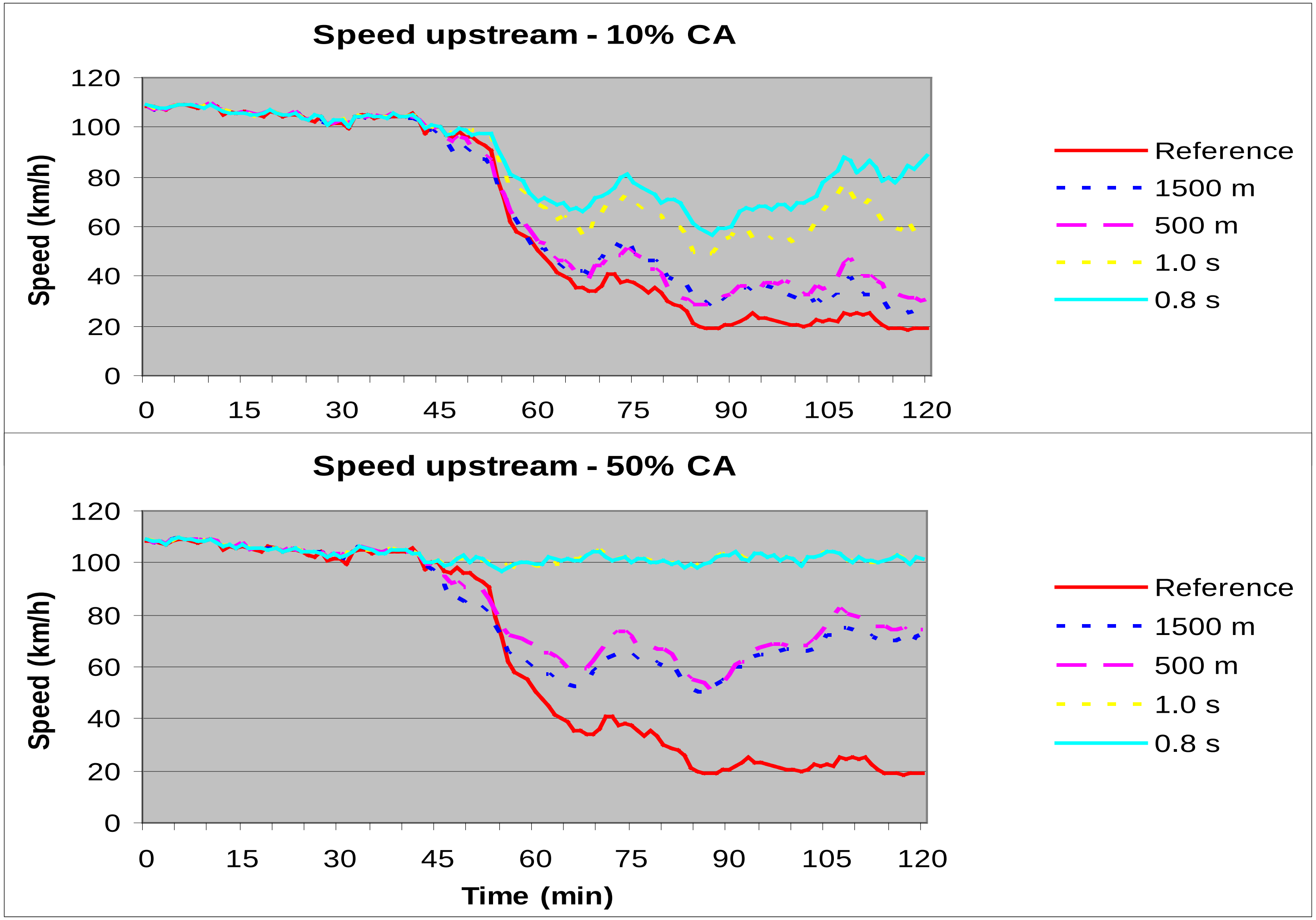
Stop & Go

$$d_{st} = d_0 + t_{st} \cdot v$$

$$a_{st\_v} = r_{st} \cdot \left(v_{\text{int}} - v\right)$$

$$a_{st\_d} = k_a \cdot \left(k_d \cdot \left(d - d_{st}\right) + k_v \cdot v_{rel\_p}\right)$$

Resultaten

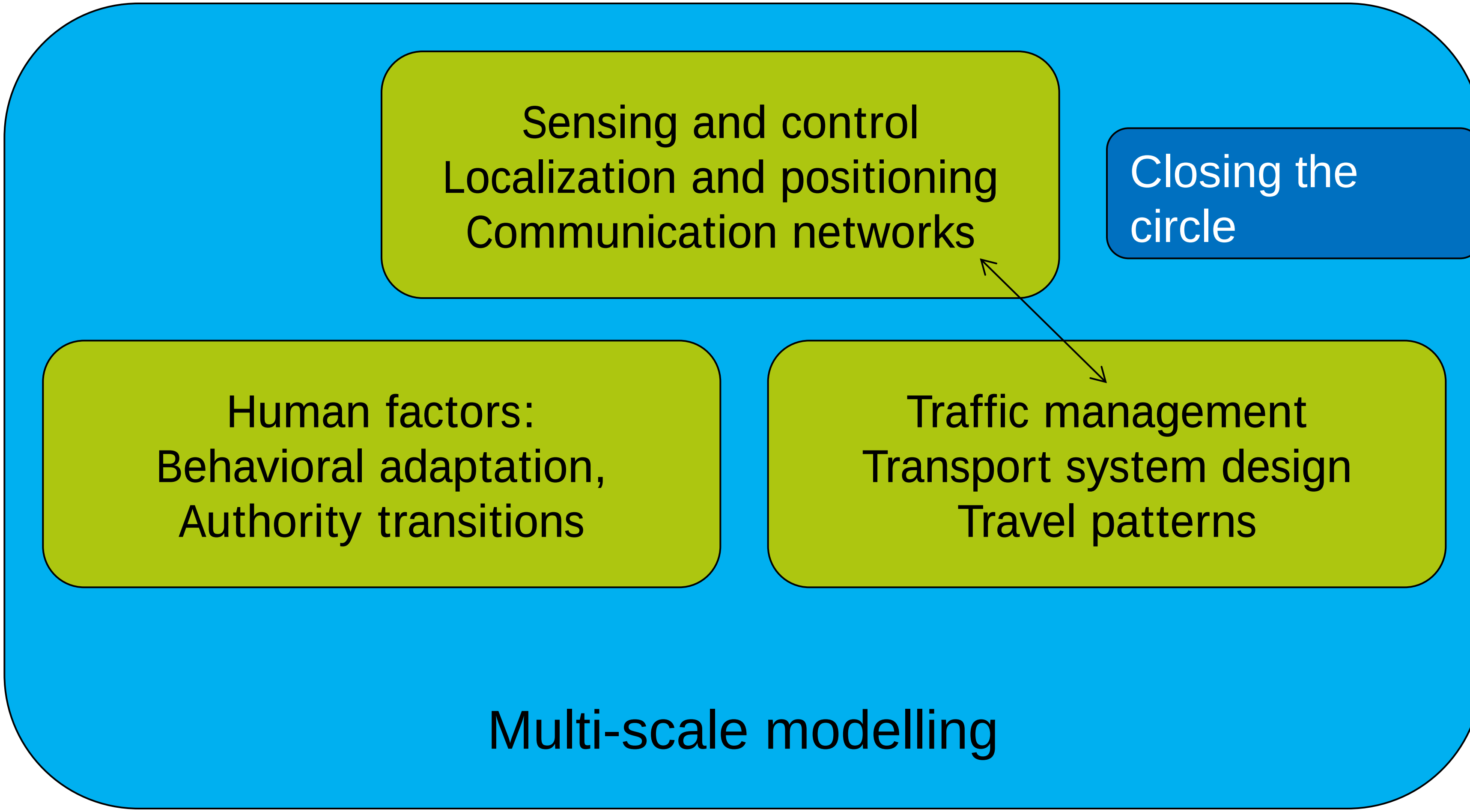


Speed upstream - 10% CA
Speed (km/h)
120
100
80
60
40
20
0
0
15
30
45
60
75
90
105
120
Reference
1500 m
500 m
1.0 s
0.8 s
Speed upstream - 50% CA
Speed (km/h)
120
100
80
60
40
20
0
0
15
30
45
60
75
90
105
120
Time (min)
Reference
1500 m
500 m
1.0 s
0.8 s

Resultaten-2

	Travel time (min)	Delay (min)	Delay reduction
Free flow (110 km/h)	3.4	-	-
Reference	5.7	2.3	-
500 m / 0.8 s (10%)	5.0	1.6	30%
500 m / 0.8 s (50%)	4.3	0.9	60%

Challenges


Sensing and control
Localization and positioning
Communication networks
Closing the circle
Human factors:
Behavioral adaptation,
Authority transitions
Traffic management
Transport system design
Travel patterns
Multi-scale modelling

Lessons from Erik

- Always careful, precise
- Straight feedback
- Committment
- Humor
- Heen en weer blocnote
- Right drink at the right time