Foto Geran De Klerk, Unsplash

OVERVIEW ON TRAFFIC SIMULATION MODELING AT VTI AND LIU, INCLUDING SIMULATION OF 2+1 ROADS AND BIKE TRAFFIC SIMULATION

Johan Olstam

Johan.olstam@vti.se

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Agenda

- Short about me & VTI
- Overview of traffic simulation development and application at VTI and LiU
- Traffic simulation of 2+1 roads
- Traffic simulation of bicycle traffic

Johan Olstam

- Born in 1979
- Moved to Norrköping 1998 to study at Linköping university (LiU)
- M.Sc. in Communication- and transport systems in 2002
- Started at VTI 2002, first with master thesis and PhD student (shared between VTI and LiU)
- Dissertation in 2009 on simulation of surrounding vehicles in driving simulators using microscopic traffic simulation
- Today: senior research leader at VTI and associate professor (30%) at LiU, division for Communication- and transport systems.

VTI is a research institute commissioned by the Swedish Government to conduct research and development within the area of transportation.

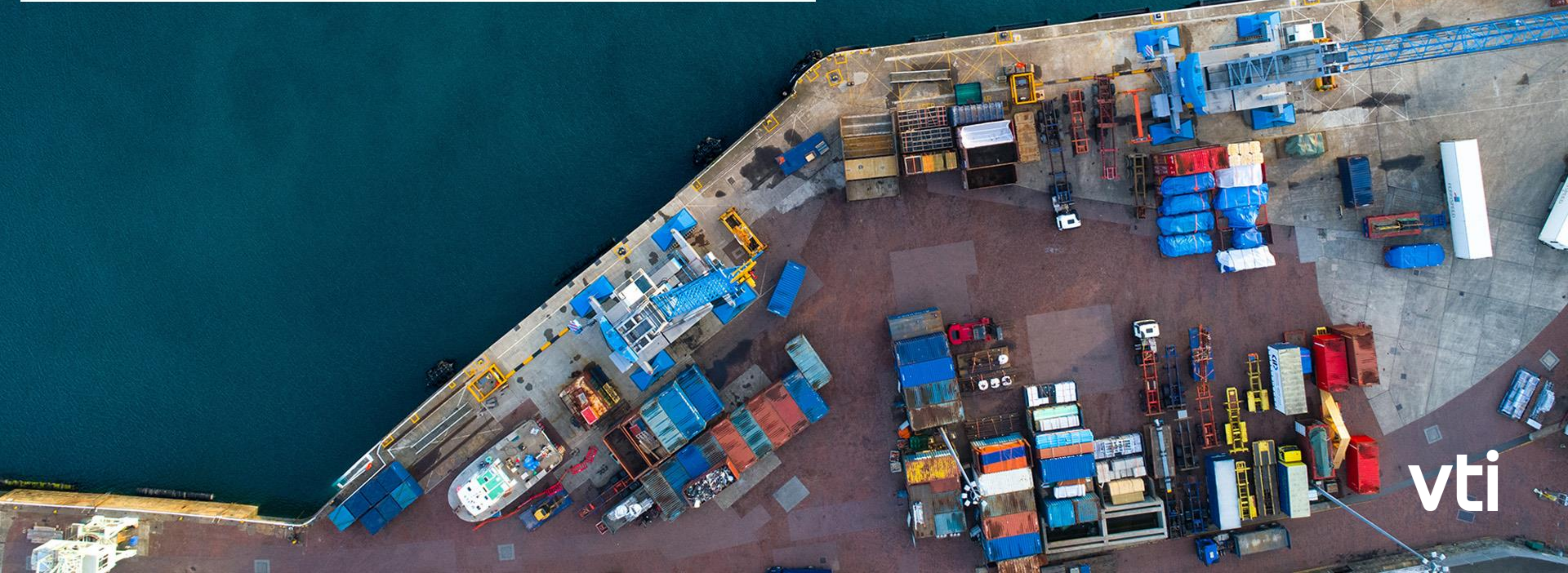
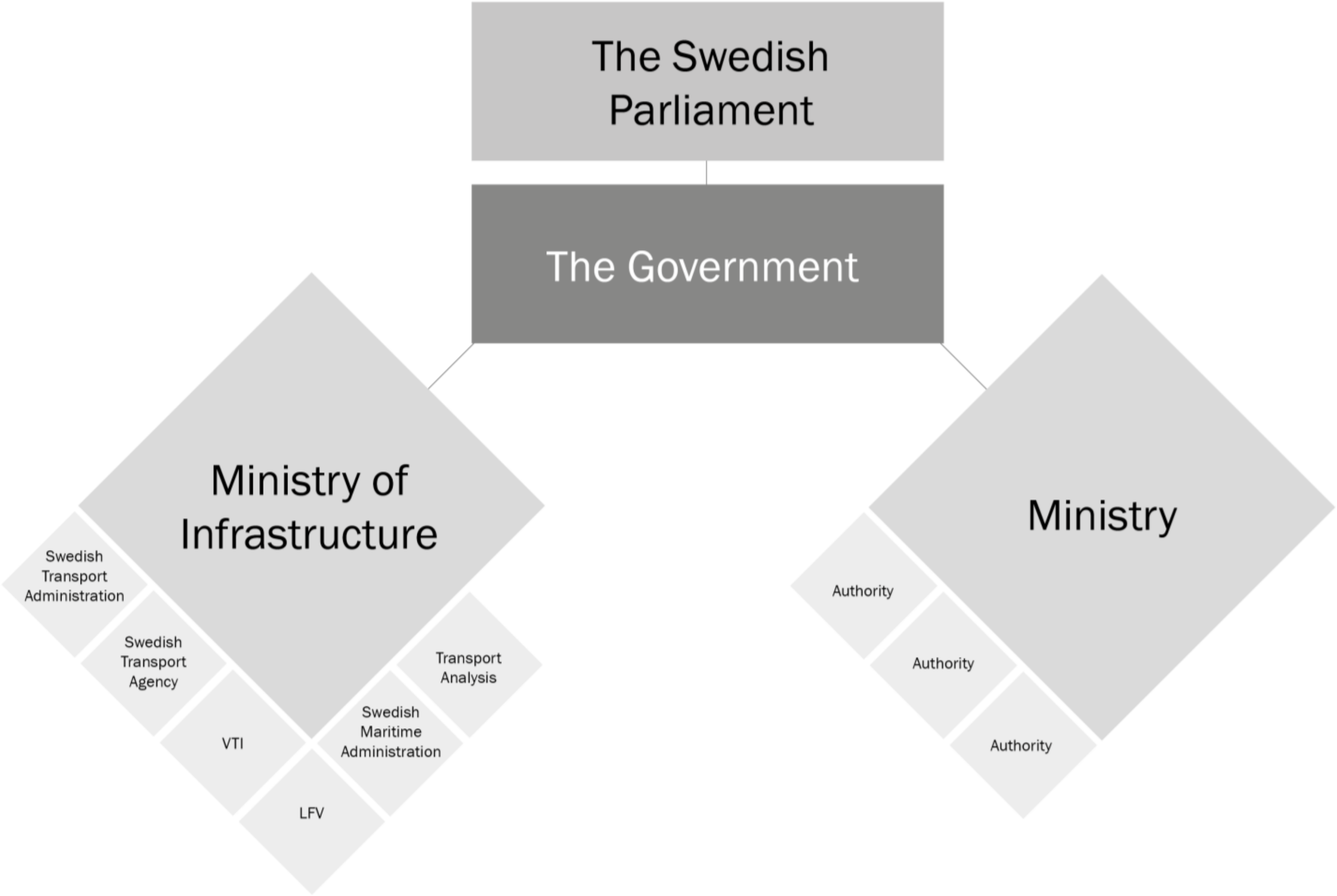


Foto Enrapture Captivating, Unsplash

The swedish parliament, government and authorities



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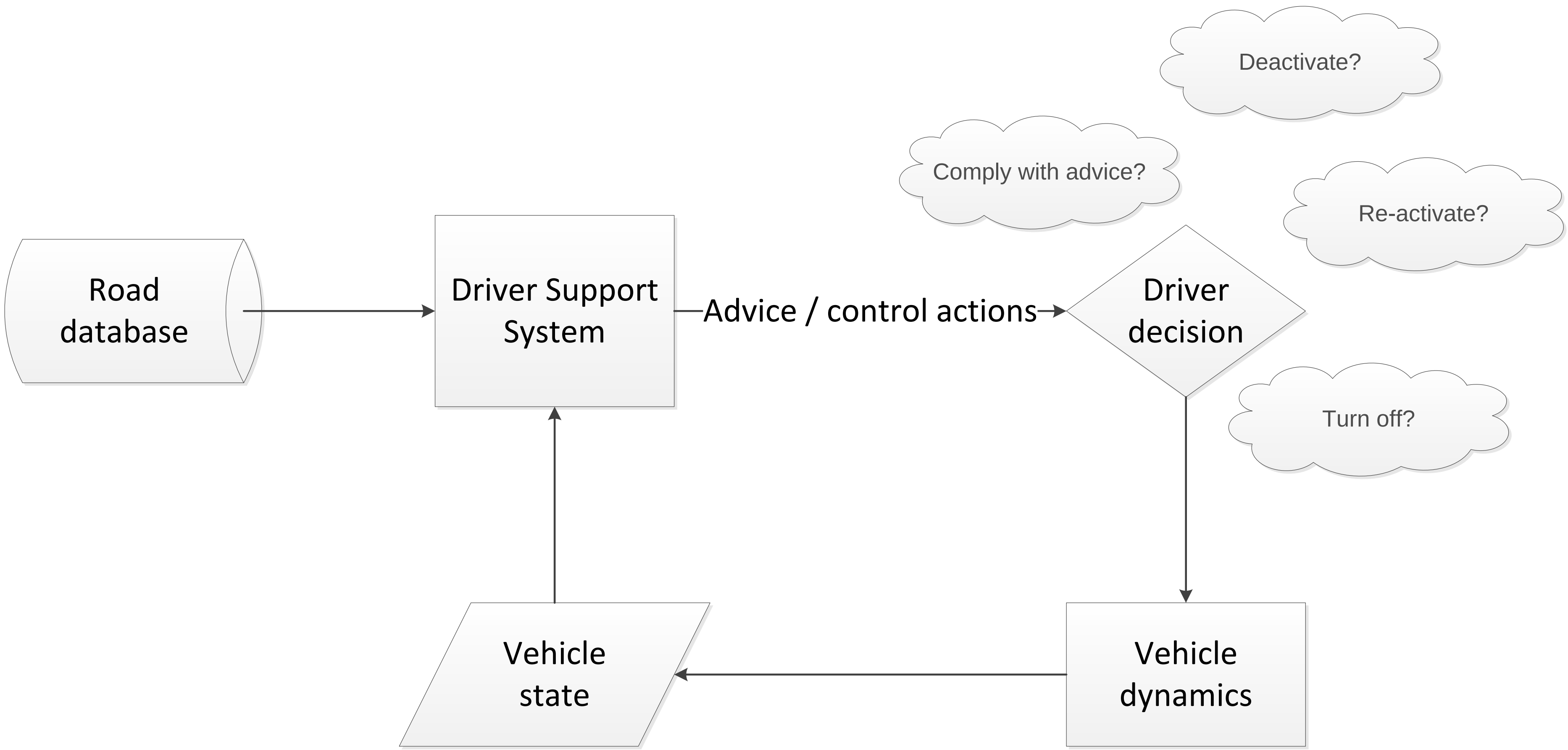
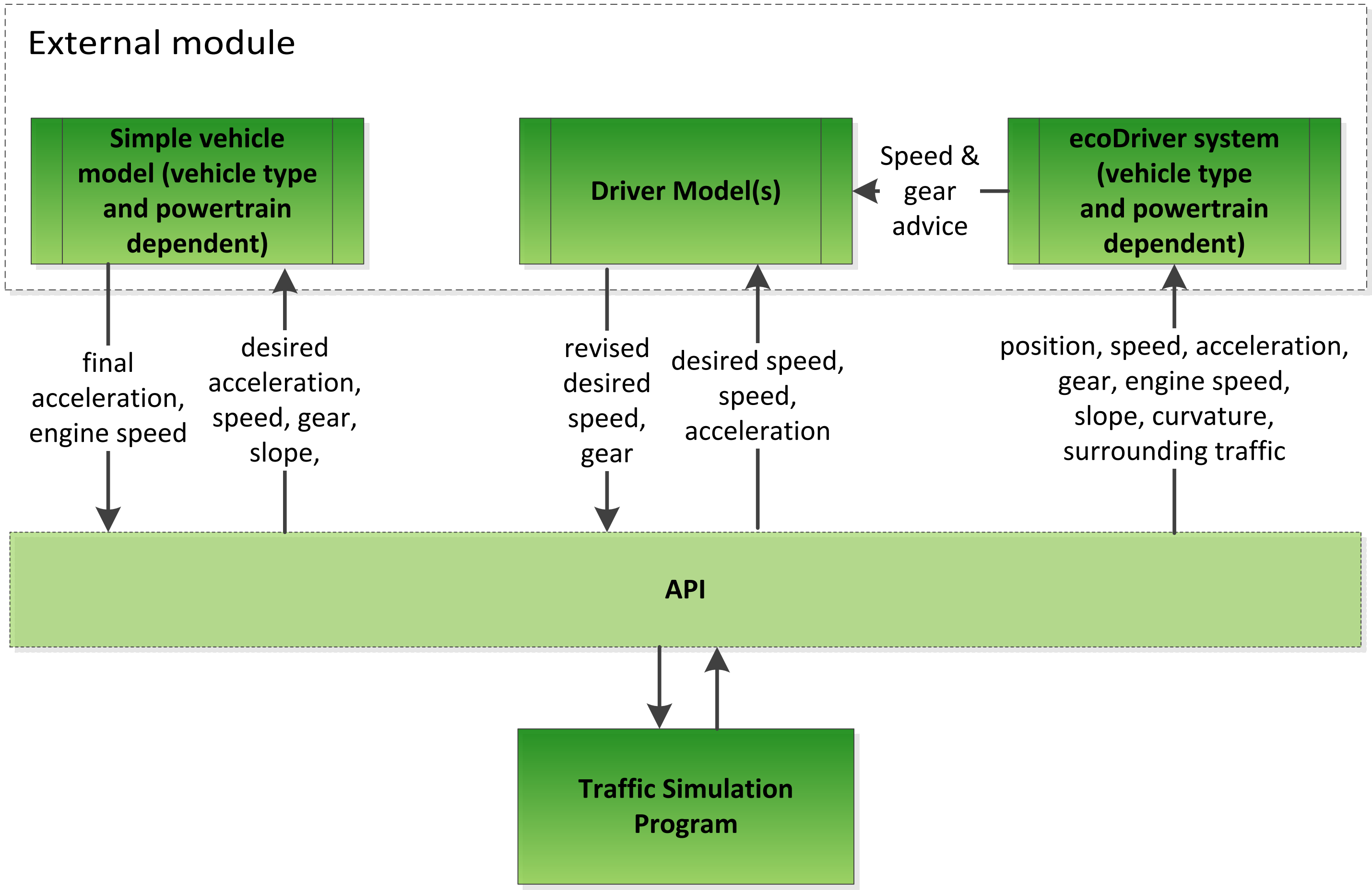
Traffic simulation areas at VTI

- Traffic simulation-based evaluations of traffic control (variable speed limit systems and connected traffic signals) - Ellen Grumert
- Bus terminal and station simulations – PhD project Therese Lindberg
- Pedestrian traffic simulation – Fredrik Johansson
- Traffic simulation-based evaluations of ADAS and automated vehicles
  - PhD project Ivan Postigo
  - EU-projects Johan Olstam
- Model development and application of rural road simulations - Johan Olstam
- Bike traffic simulation - PhD project Guillermo Pérez Castro

Simulation of ADAS requires additional sub-behaviour models



Simulation of ecodriving support system



Olstam, J., Bernhardsson, V., Choudhury, C., Klunder, G., Wilmink, I., and M. van Noort, 2019, Modelling eco-driving support system for microscopic traffic simulation, Journal of Advanced Transportation, Volume 2019, https://doi.org/10.1155/2019/2162568.

Traffic simulation of automated vehicles

Challenge:

- No or limited data on first generation of automated vehicle behavior
- No information or data on behavior of future automated vehicle
- Long transition period (at least my guess)

One solution (CoEXist: https://www.h2020-coexist.eu/) :

- Conceptual descriptions of possible driving behavior of automated vehicles
- Scenario based analysis including sensitivity analysis

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Olstam, J. Johansson, F. Alessandrini, A., Sukennik, P., Lohmiller, J., and M. Friedrich, An approach for handling uncertainties related to behaviour and vehicle mixes in traffic simulation experiments with automated vehicles, Journal of Advanced Transportation, Volume 2020, https://doi.org/10.1155/2020/8850591

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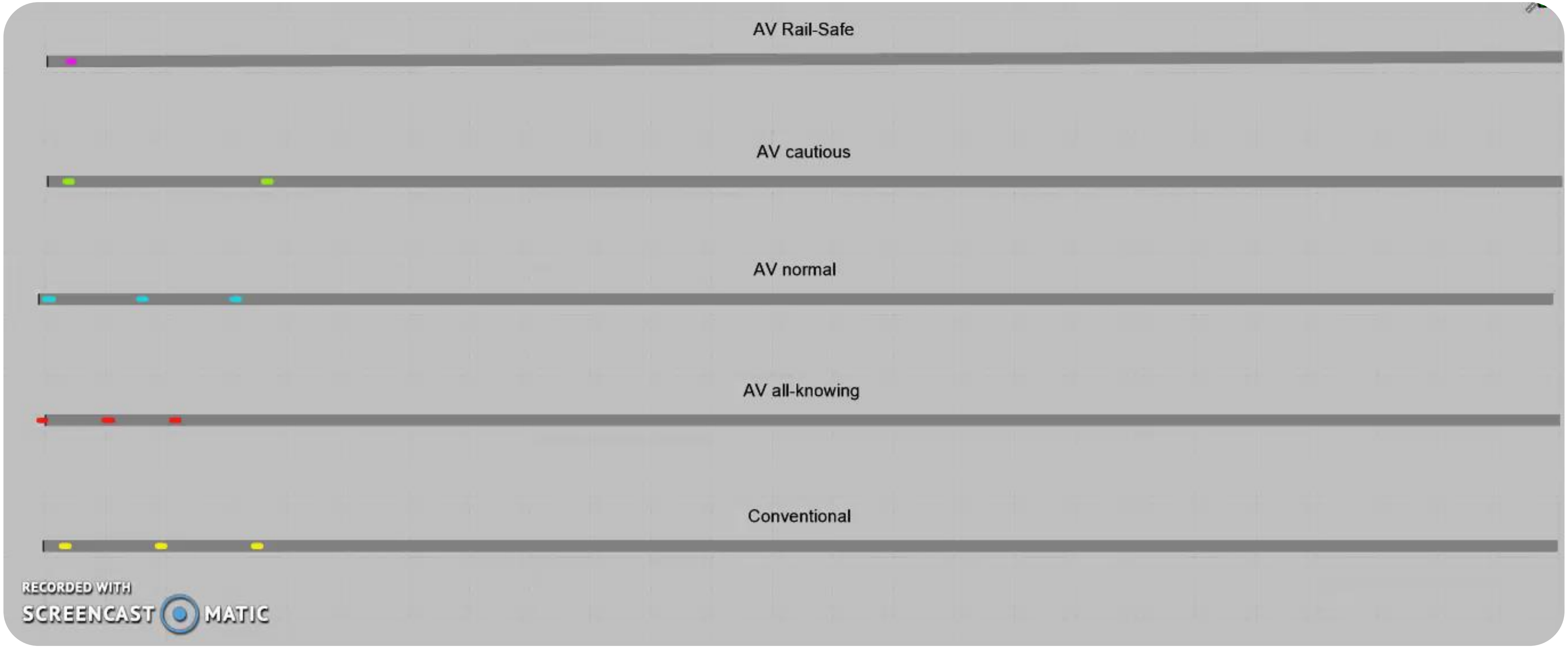
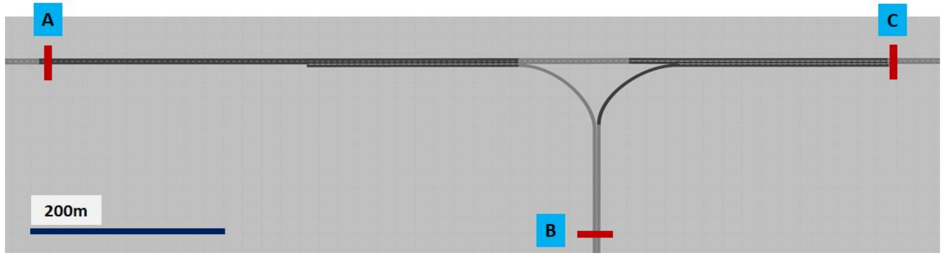
Traffic simulation example of AVs

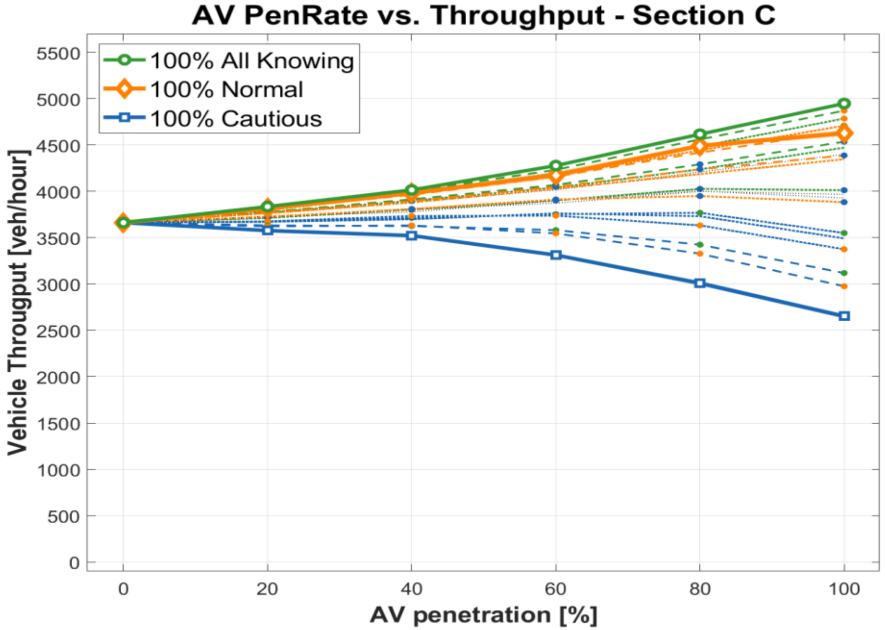


Olstam, J. Johansson, F. Alessandrini, A., Sukennik, P., Lohmiller, J., and M. Friedrich, An approach for handling uncertainties related to behaviour and vehicle mixes in traffic simulation experiments with automated vehicles, Journal of Advanced Transportation, Volume 2020, https://doi.org/10.1155/2020/8850591

Effects on Traffic Performance due to Heterogeneity of Automated Vehicles

- Different generations will coexist on the roads
  → AV heterogeneity
- Vissim simulations using the CoEXist driving logics



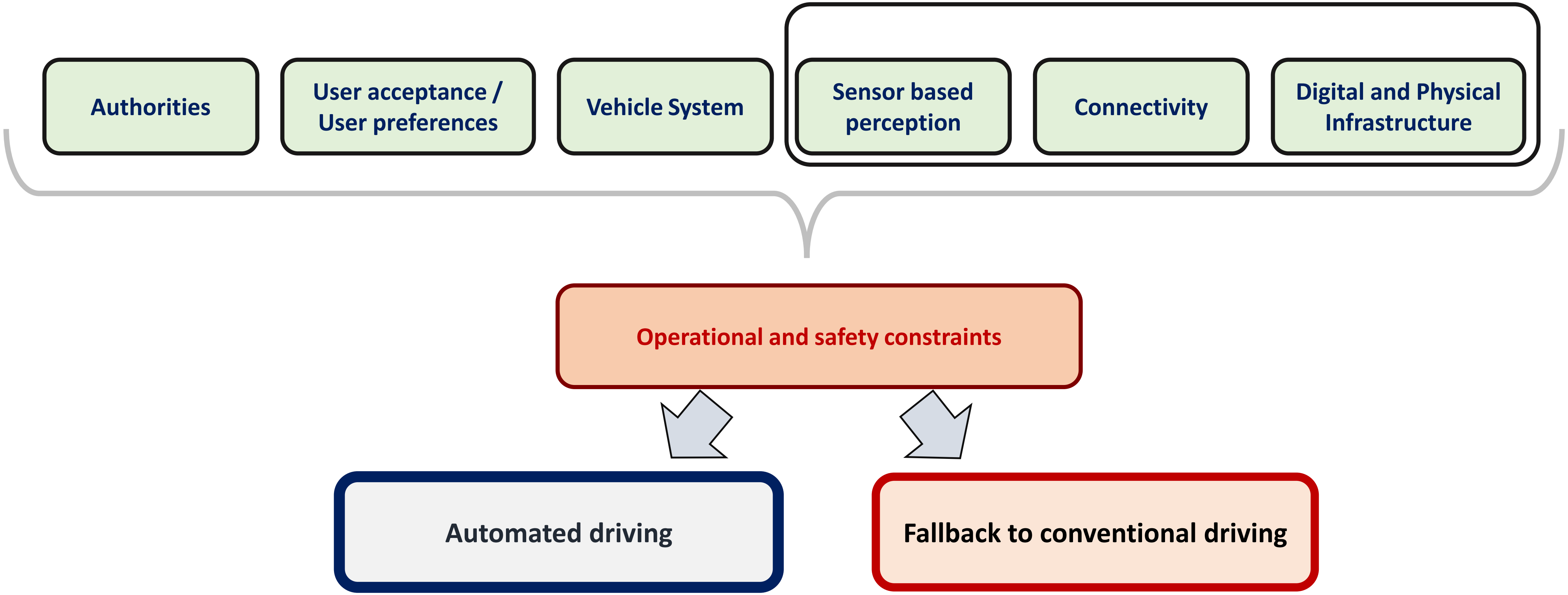


Conclusions:

- More advanced AVs → improved capacity and vice versa
- Cautious driving logics impacts found already at lower demand levels
- Large range in results between driving logics

Postigo, I., Olstam, J. and C. Rydergren, Effects on Traffic Performance due to Heterogeneity of Automated Vehicles on Motorways - A Microscopic Simulation Study, Proceedings of the 7th International Conference on Vehicle Technology and Intelligent Transport Systems - VEHITS, 2021, https://pdfs.semanticscholar.org/

Aspects to consider for modeling automated driving



Farah, H., Postigo, I. Reddy, N., Dong, Y., Rydergren, C., Raju, N. and J. Olstam, Aspects to Consider for Modeling Automated Driving in Microscopic Traffic Simulations: State of the Practice and Research Needs, Submitted to and under review for IEEE Transactions on Intelligent Transport Systems

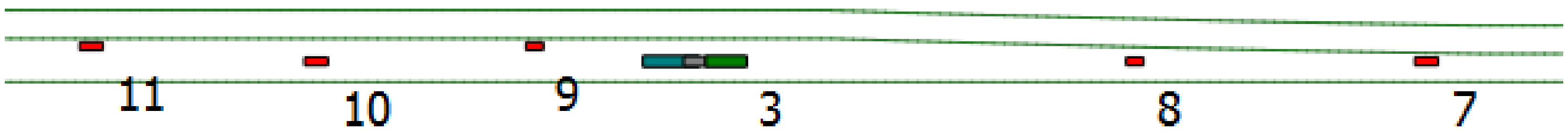
RURAL ROAD TRAFFIC SIMULATION

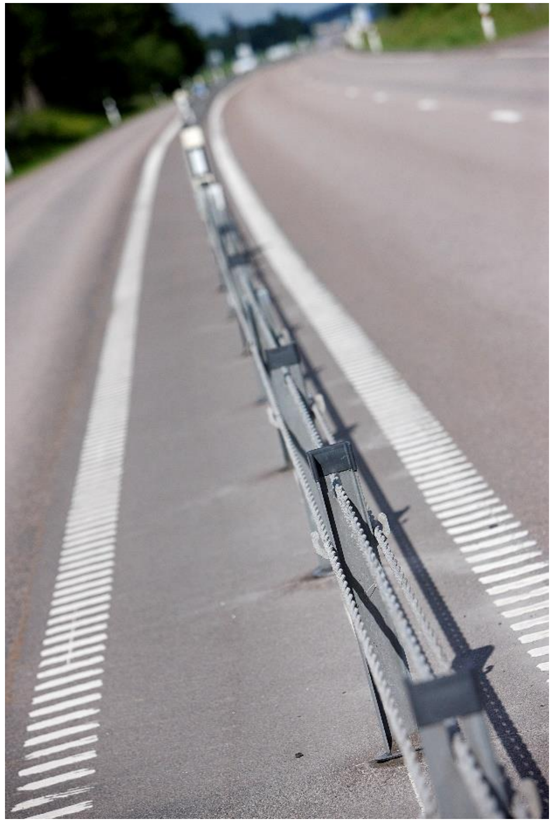
Johan Olstam, Viktor Bernhardsson
and Andreas Tapani

Foto Jonas Jacobsson, Unsplash

RuTSim – The rural road traffic simulator

- A micro-simulation model for traffic on rural highways:
  - Effect of the road geometry on speed
  - Interactions between oncoming traffic
  - Single carriageway two-lane roads
  - 2+1-roads
  - Intersections on rural highways
- Research tool/code developed at VTI

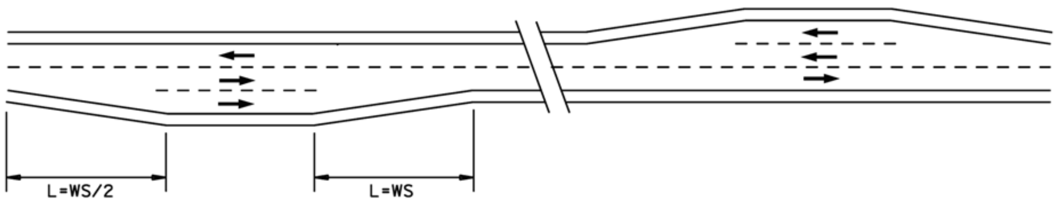


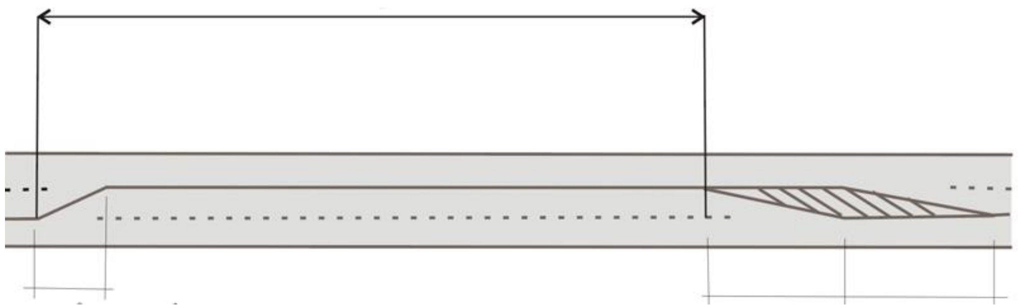


Tapani, A., A Traffic Simulation Modeling Framework for Rural Highways [Internet] [Licentiate dissertation]. Institutionen för teknik och naturvetenskap; 2005. (Linköping Studies in Science and Technology. Thesis). Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-6579

Road designs with overtaking restrictions and periodic overtaking lanes

- 2+1-road, super 2 highway, two-lane expressway





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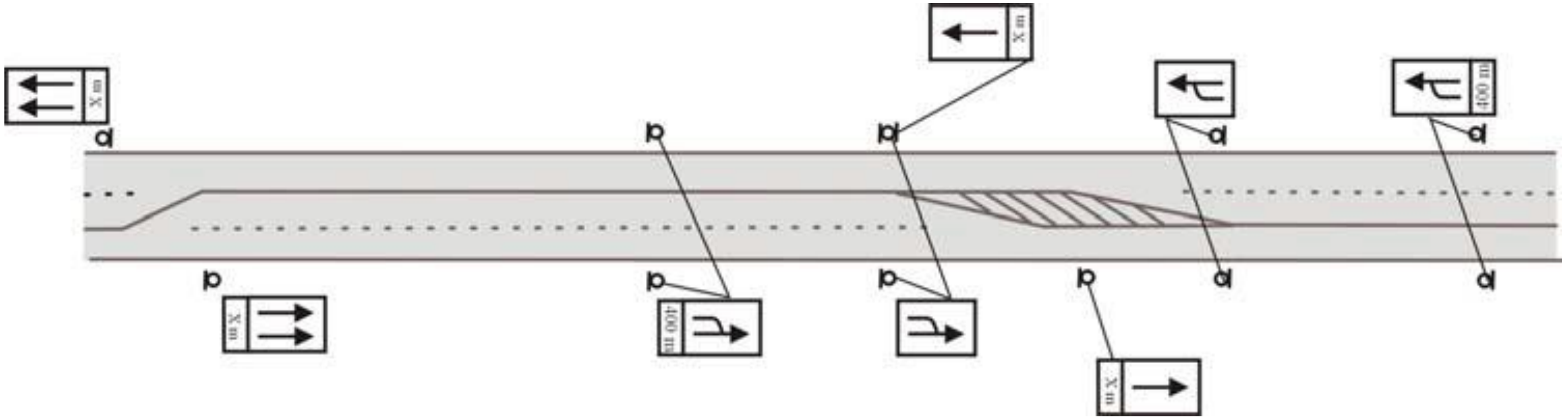
Traffic flow dynamics on 2+1-roads

- Desire to overtake slower vehicles on two-lane sections → increased speeds, differences in speed between right and left lane
- Frequent merging manoeuvres at the end of two-lane sections



Microscopic simulation modelling of traffic on 2+1-roads

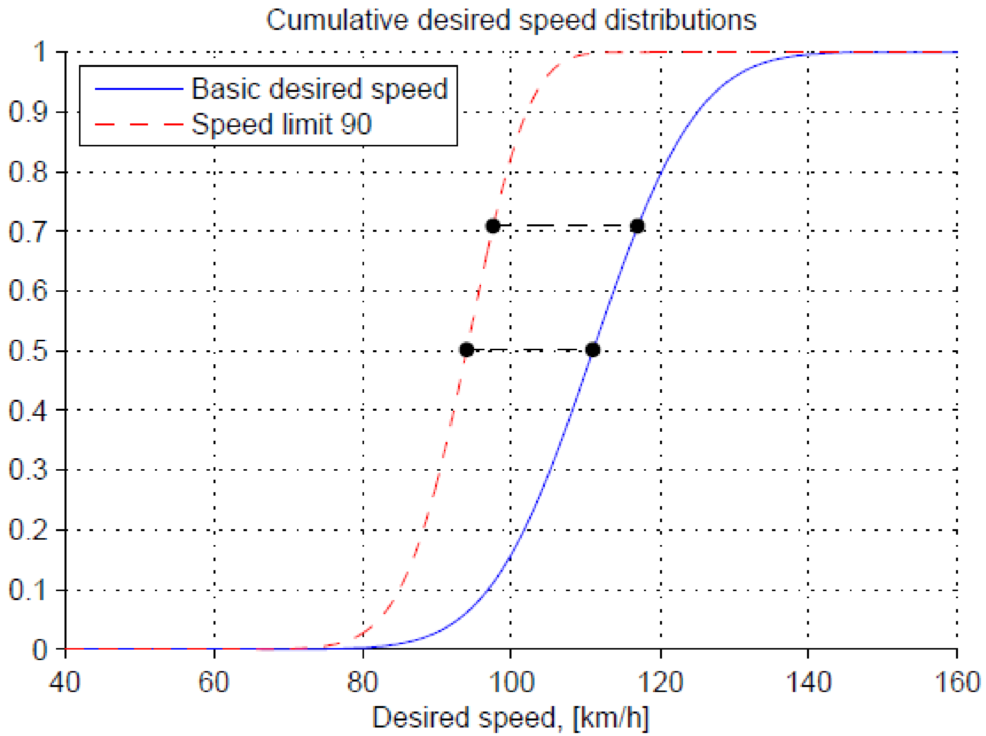
- Speed adaptation
- car-following
- Overtaking decisions
- Merging manoeuvres

Speed adaptation

Effects of

- Speed limit
- Curvature
- Road width

on the desired speed distributions



Effects of slope on the maximum acceleration

$$a_{max} = \frac{p}{v(t)} - C_A v^2 - C_{R_1} - C_{R_2} v - g \cdot i(x)$$

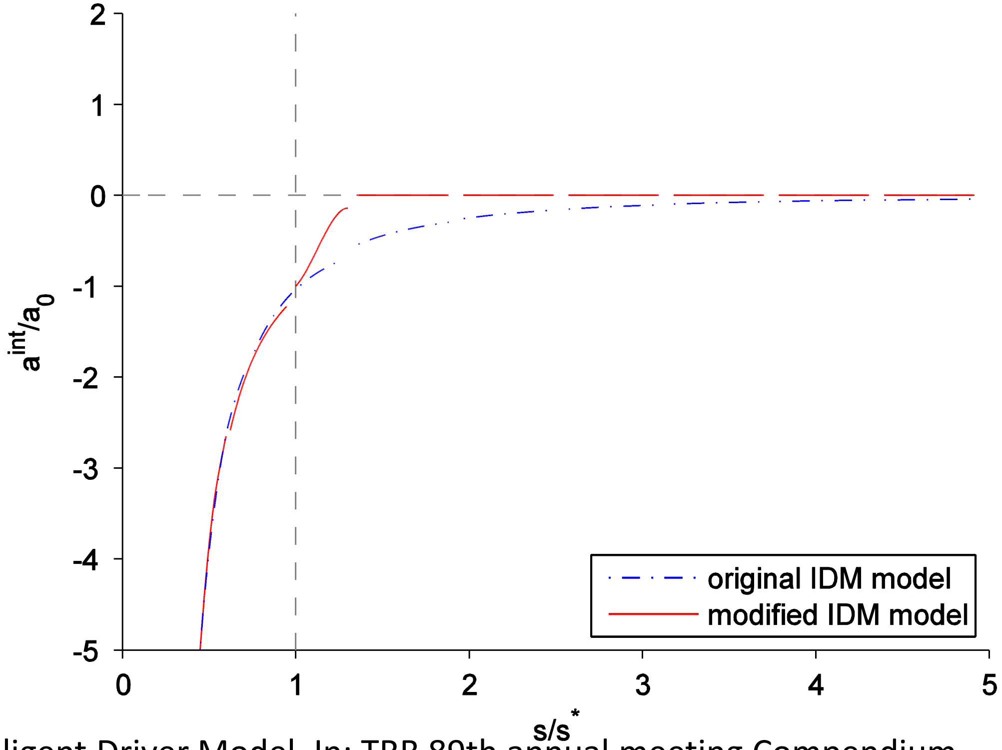
power/weight ratio　air and rolling resistance　slope

Car-following

- Modified Intelligent driver model / Human driver model (IDM/HDM, Treiber et al. 2000, 2006; Olstam and Tapani 2010)

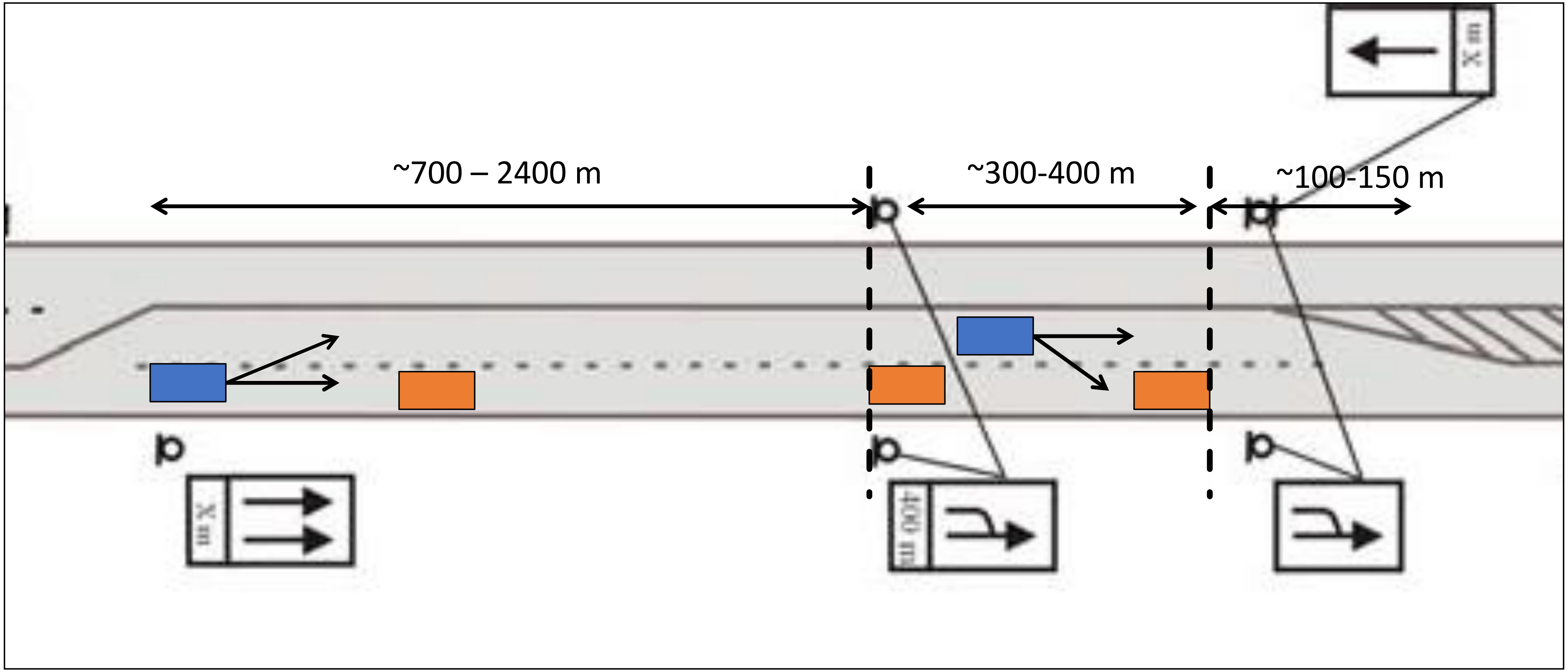
$$a_i\left(t\right)=a_i^{free}\left(t-T'\right)+\sum_{j=i-n}^{i-1}a_{ij}^{int}\left(t-T'\right)$$

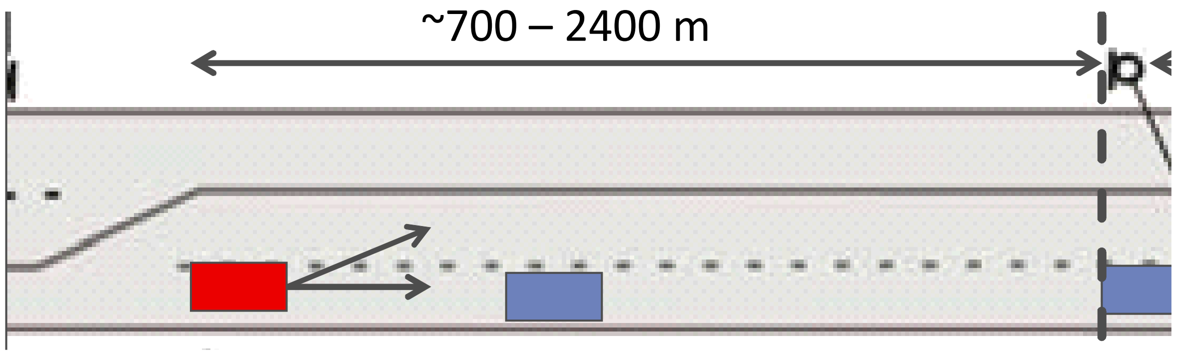
$$a^{int}=-a_0\cdot\begin{cases}\left(\frac{s}{s^*}\right)^{-2}, & \frac{s}{s^*}<1\\ c_1\left(\frac{s}{s^*}-c_3\right)^3+c_2\left(\frac{s}{s^*}-c_3\right)^2+c_4, & 1\leq\frac{s}{s^*}\leq\beta\\ 0, & \frac{s}{s^*}>\beta,\end{cases}$$



Olstam J, Tapani A. Enhancements to the Intelligent Driver Model. In: TRB 89th annual meeting Compendium. Washington D.C.: Transportation Research Board; 2010. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-6584

Driver behaviour on two-lane sections

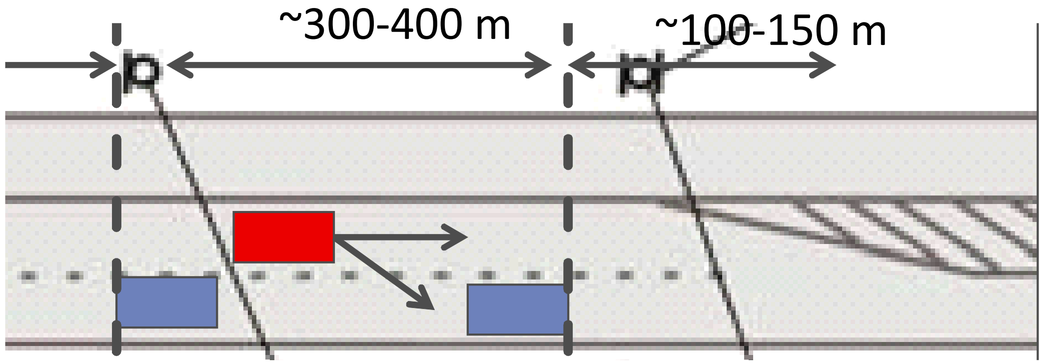




Overtaking manoeuvres

- Overtaking decisions governed by:
  - the length of the two-lane section
  - traffic in the left lane
  - the vehicles ability to overtake the vehicle in front
- Increment in desired speed while in the left lane or if slower vehicle ahead
- Decision whether to stay in left lane to continue overtaking when side-by-side with the vehicle to overtake
- Return to the right-lane when gap equal to the desired gap given by the car-following model

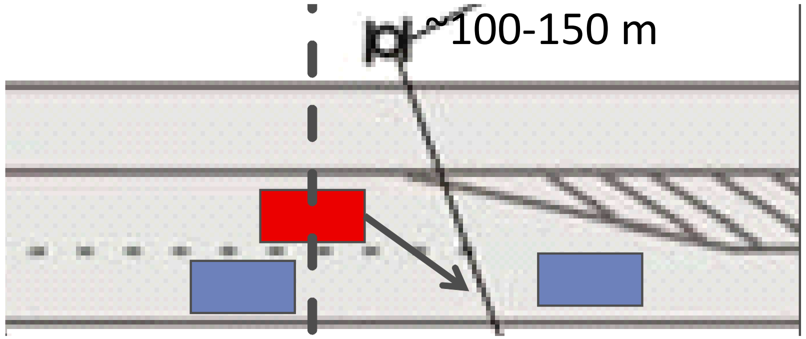
Merging at the end of two-lane sections



First merging zone:

- *Choose gap* in the right lane based on the acceleration needed to reach the desired position, merge acceleration rates determined according to Hidas (2005)
- Change lane when *gap equal to the desired gap* given by the car-following model
- Courtesy deceleration to allow the merging vehicle to change lane

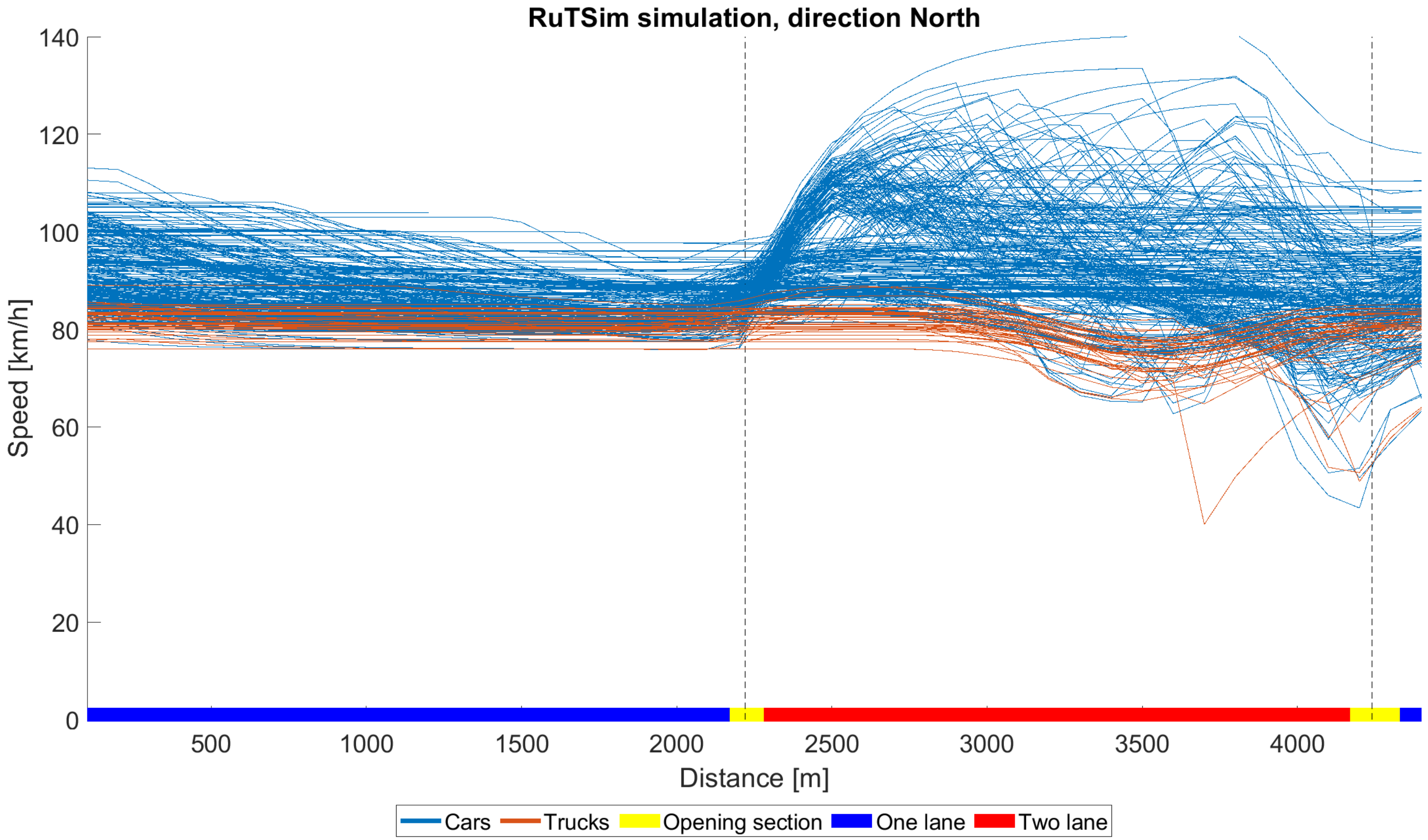
Merging at the end of two-lane sections (cont'd)



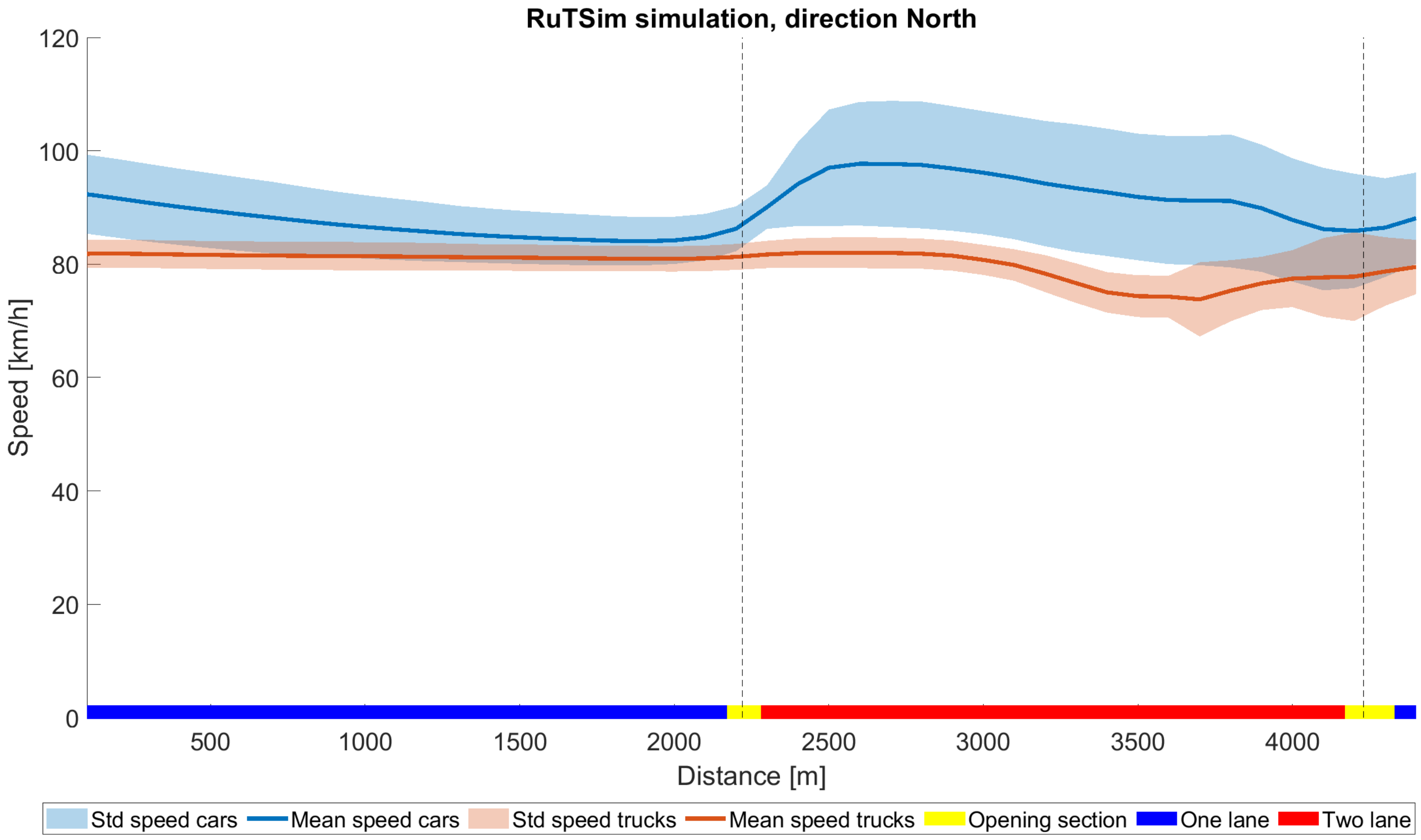
Second merging zone:

- Merge in the gap between follower and leader in the right lane
- Change lane when the *interaction acceleration rates* given by the car-following model are acceptable
- Courtesy deceleration to allow the merging vehicle to change lane

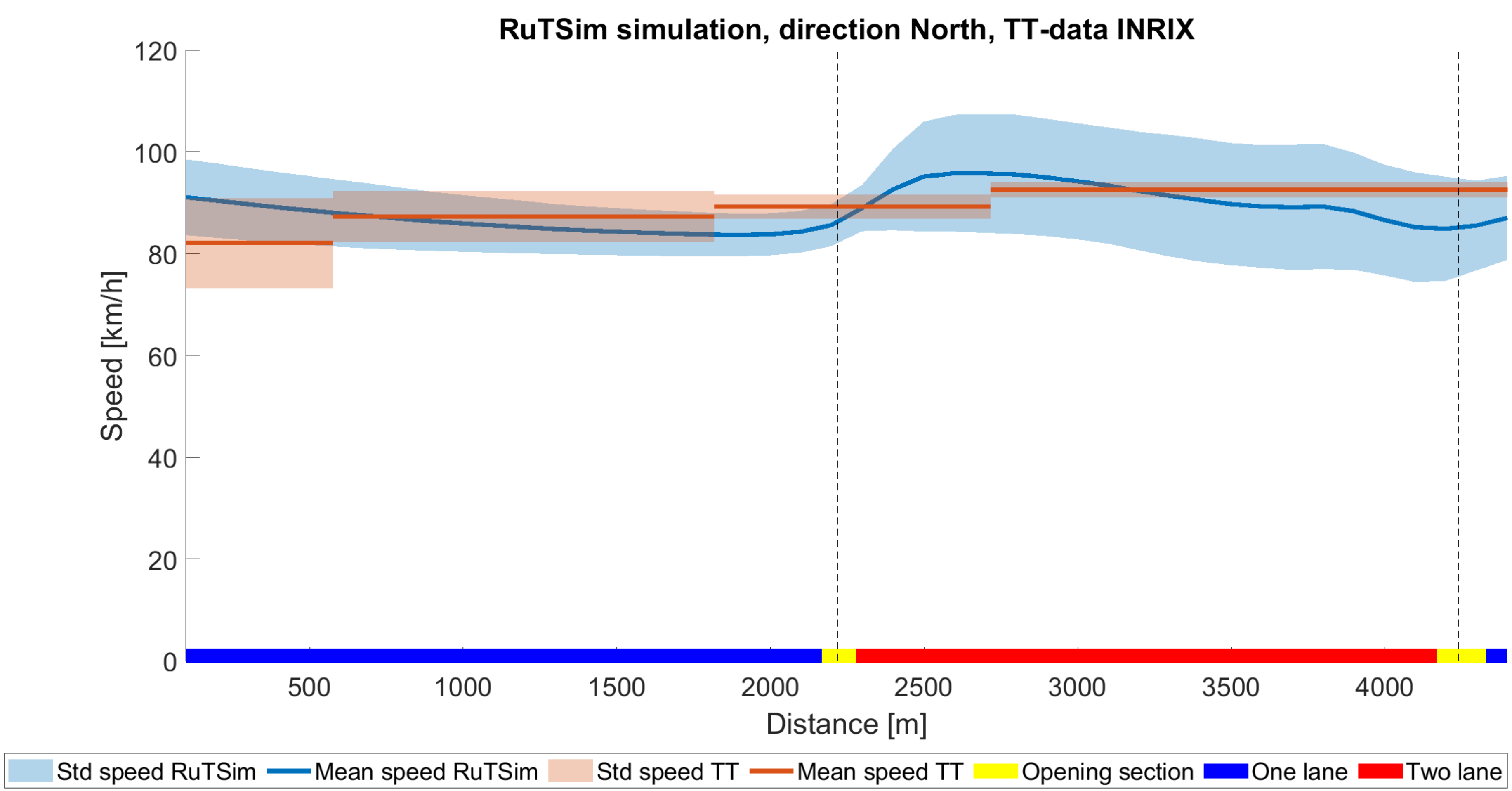
SIMULATED TRAJECTORIES



Traffic flow dynamics on 2+1 roads



Comparison with travel time data from Inrix



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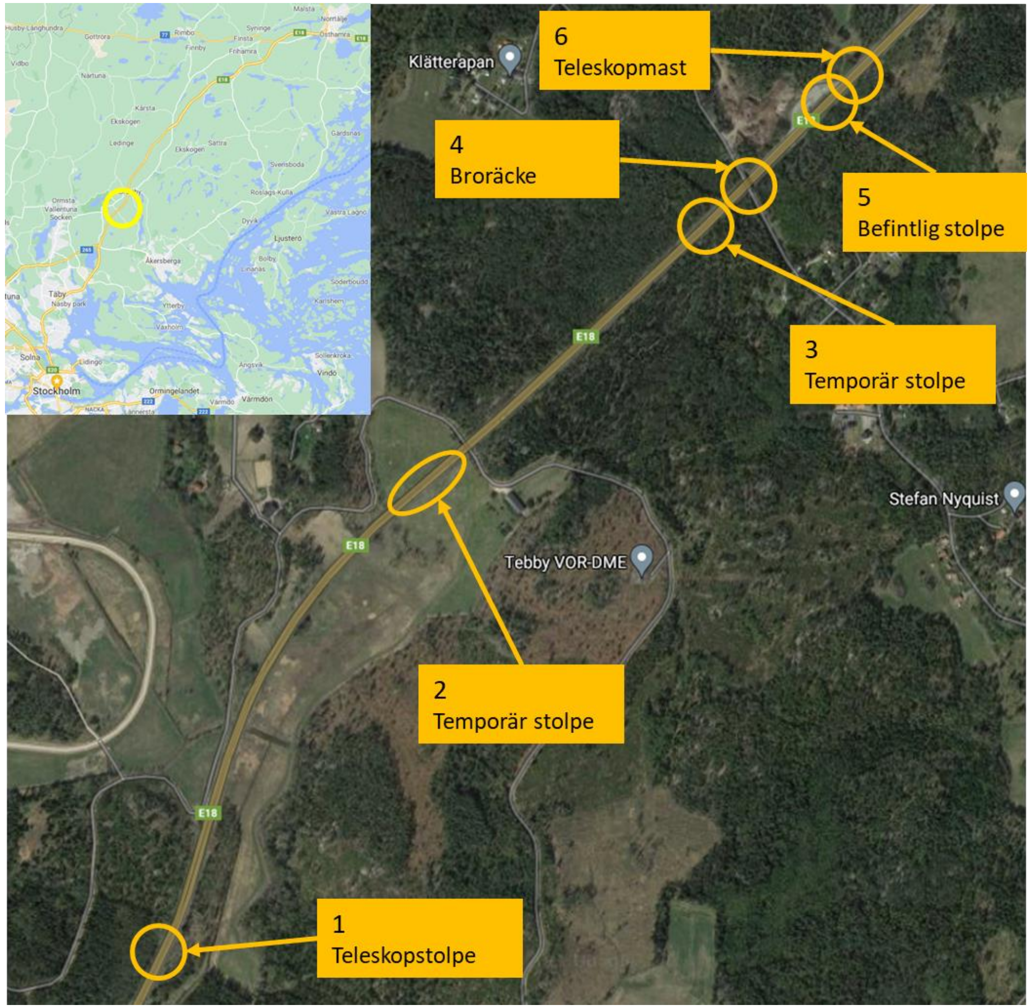
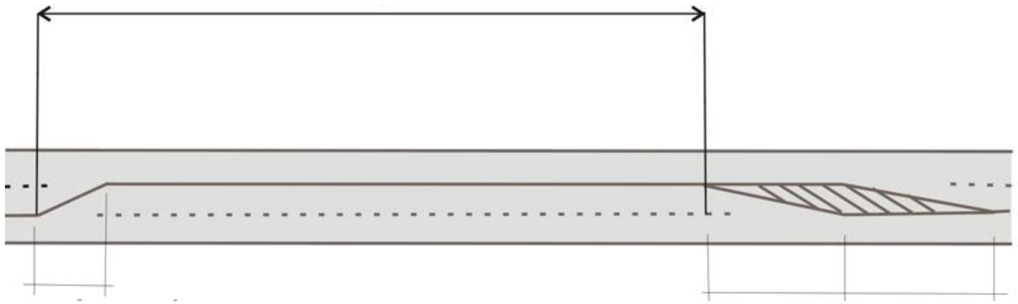
Ongoing collaboration project with Viscando to connect trajectories from several video-based measurements

Sensor 1:

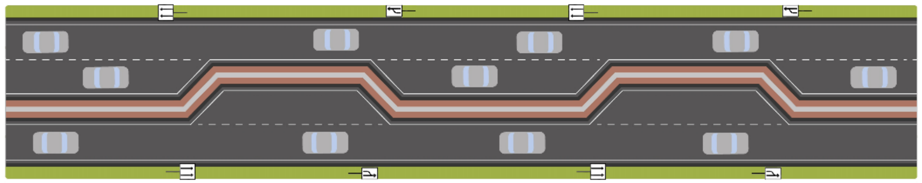
Sensor 2:



What is the optimal length for the two lane segments?



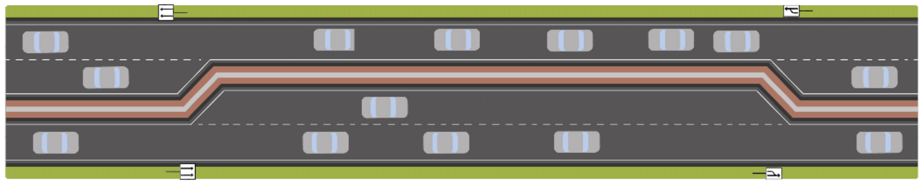
Short passing lanes



+ More recurrent
+ Passing of trucks

- More bottlenecks (weavings)
- Aborted/risky overtakings

Long passing lanes



+ Passing several vehicles
+ Few bottlenecks

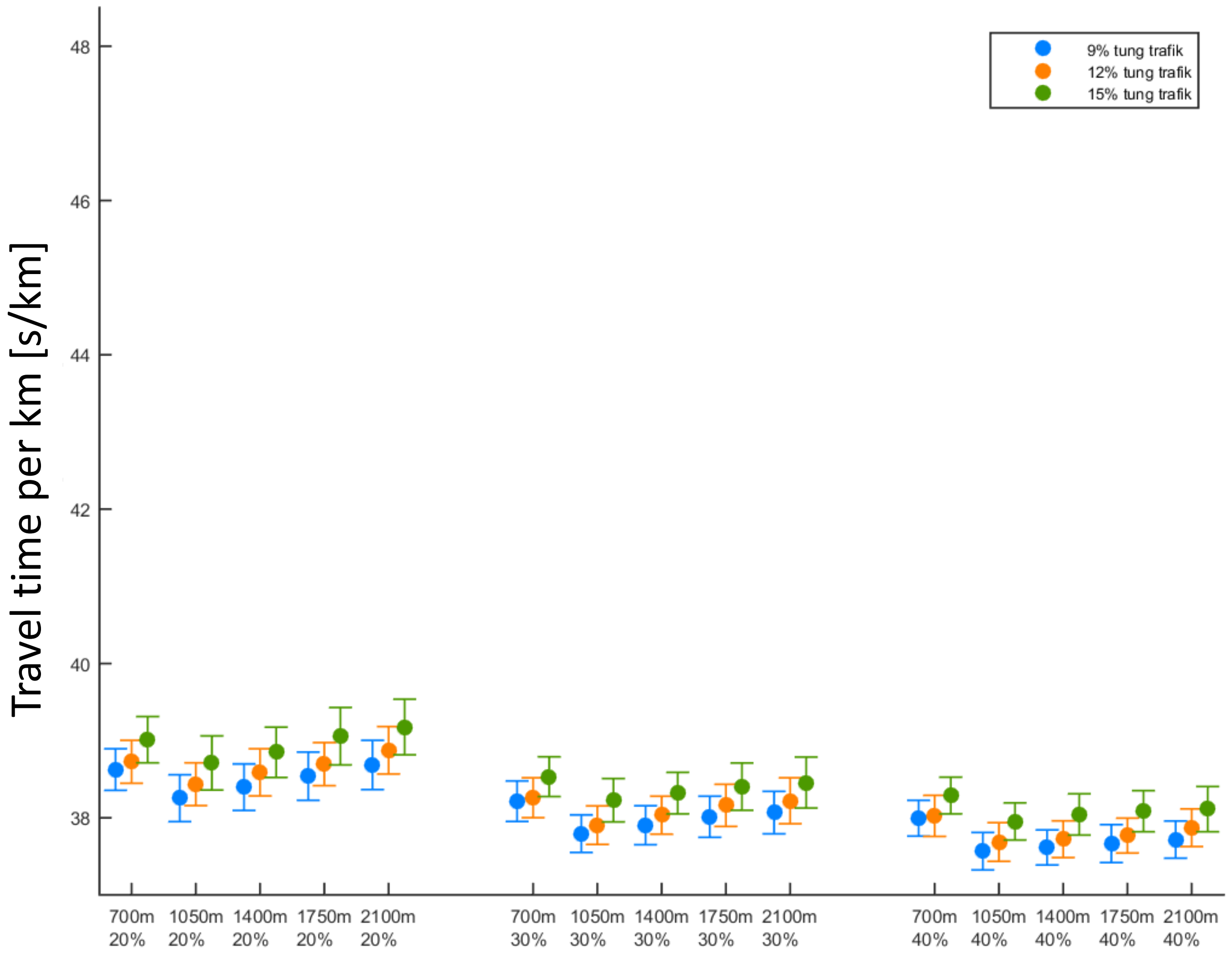
- More catch-ups
- Far between overtaking possibilities

Bernhardsson V, Olstam J. Effektiva omkörningsfält på 2+1-vägar : trafiksimuleringar av olika utformningsalternativ ur ett framkomlighetsperspektiv. Linköping: VTI; 2017. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:vti:diva-12075

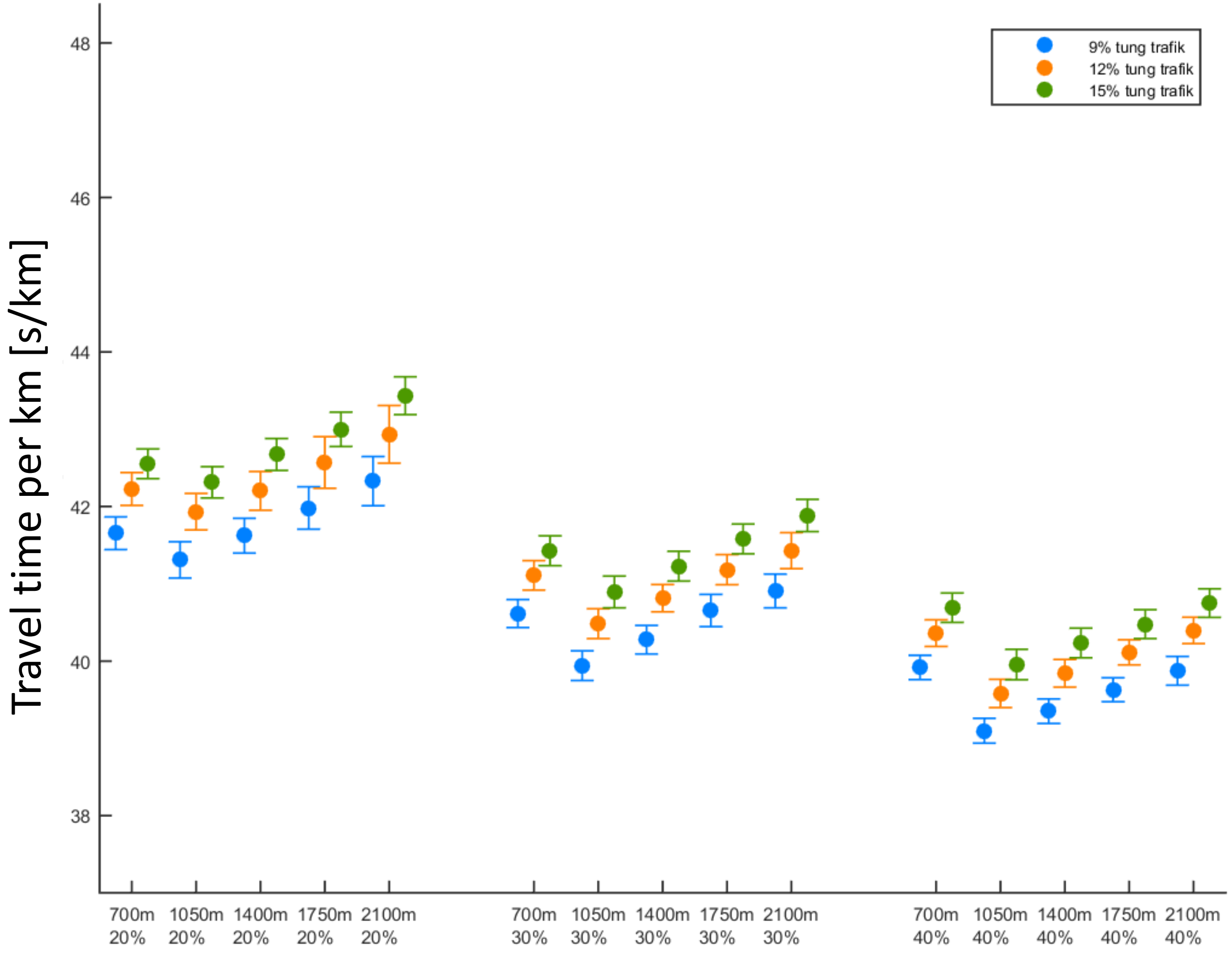
Experimental design of the study

Length of passing lane [m]	Passing lane share [%]	Share of heavy vehicles [%]	Traffic flow [vehicles/h]
700	20	9	100
1050	30	12	400
1400	40	15	700
1750			1000
2100			1300

Travel time at 100 vehicles/h



Travel time at 400 vehicles/h



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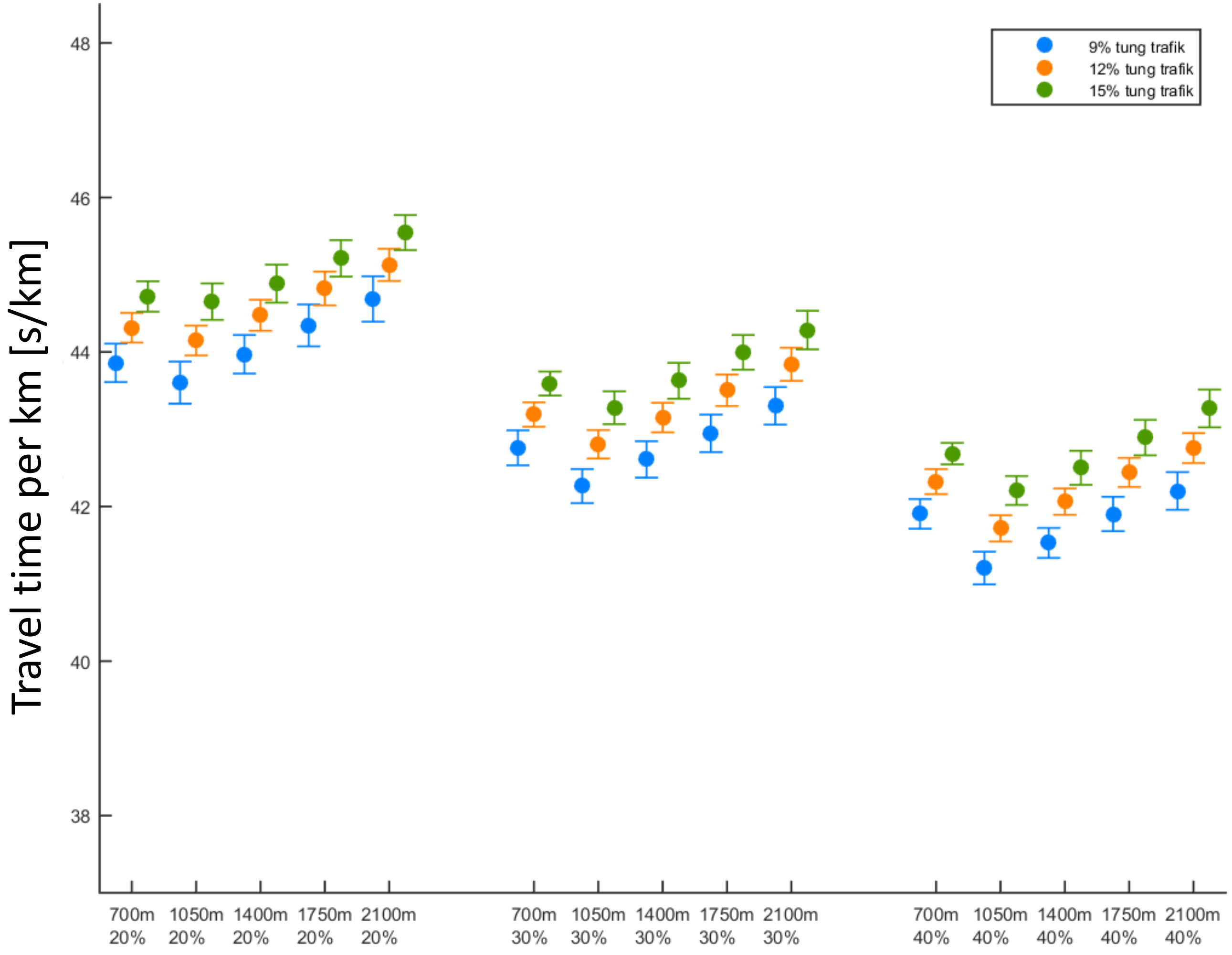
Travel time at 700 vehicles/h



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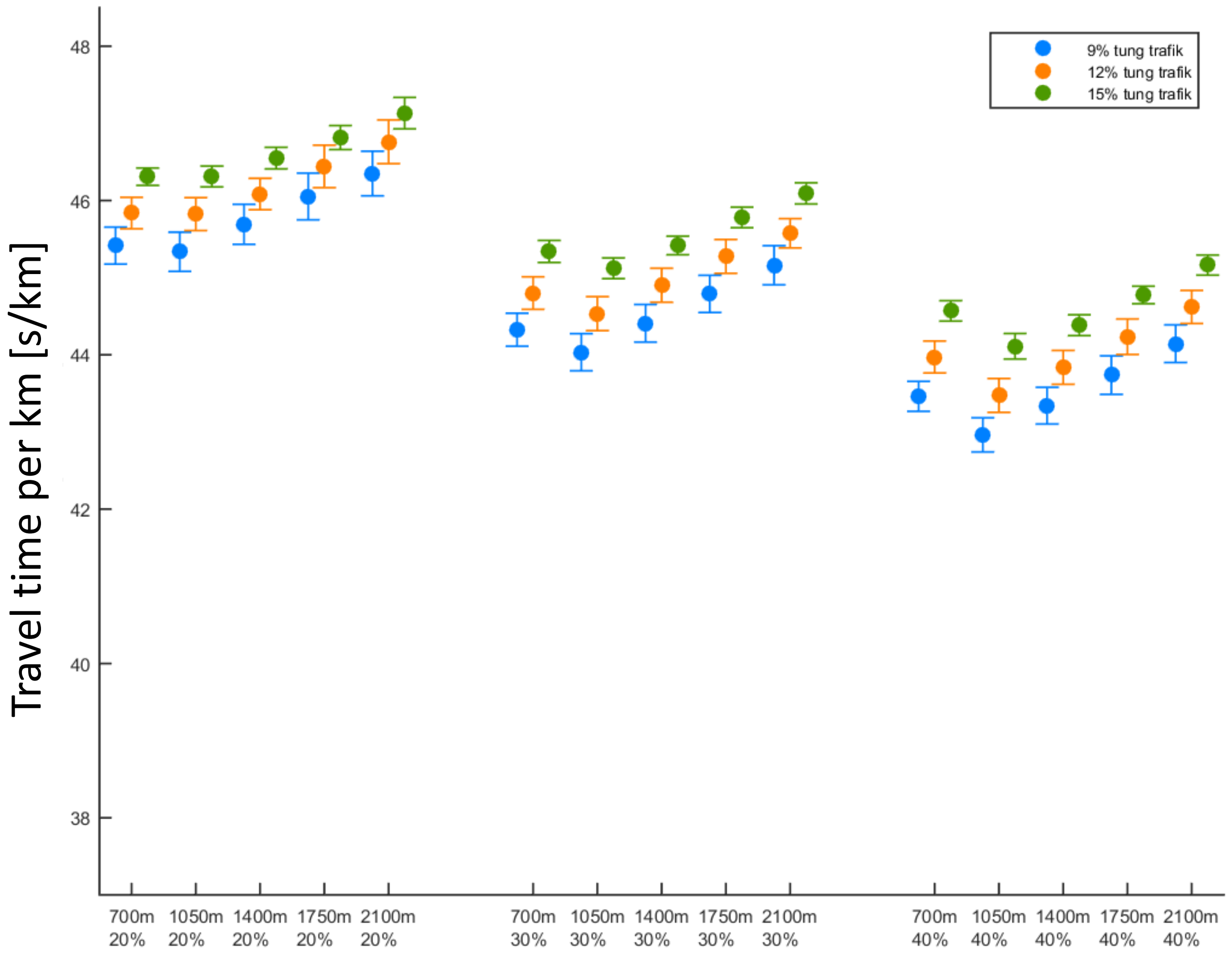
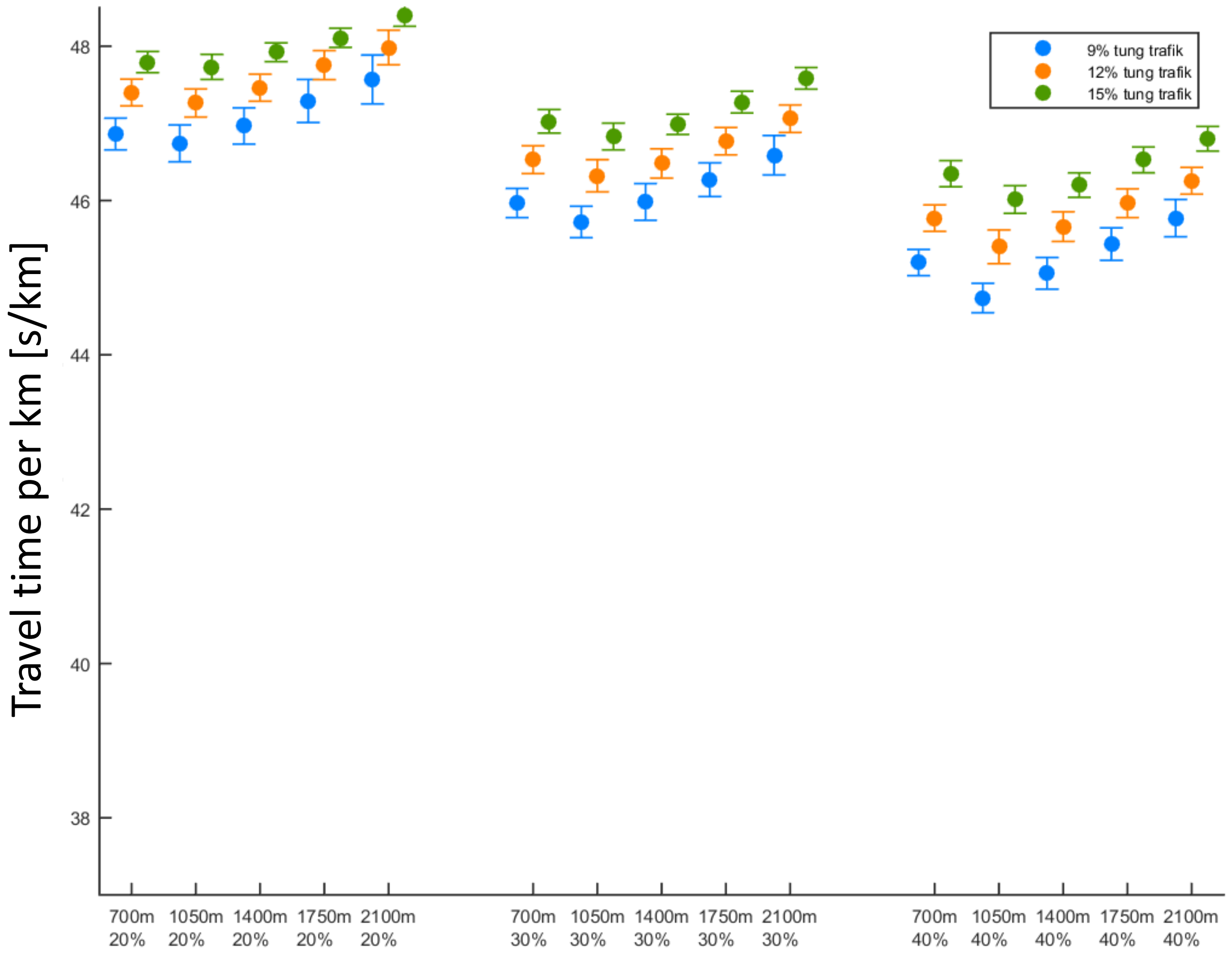
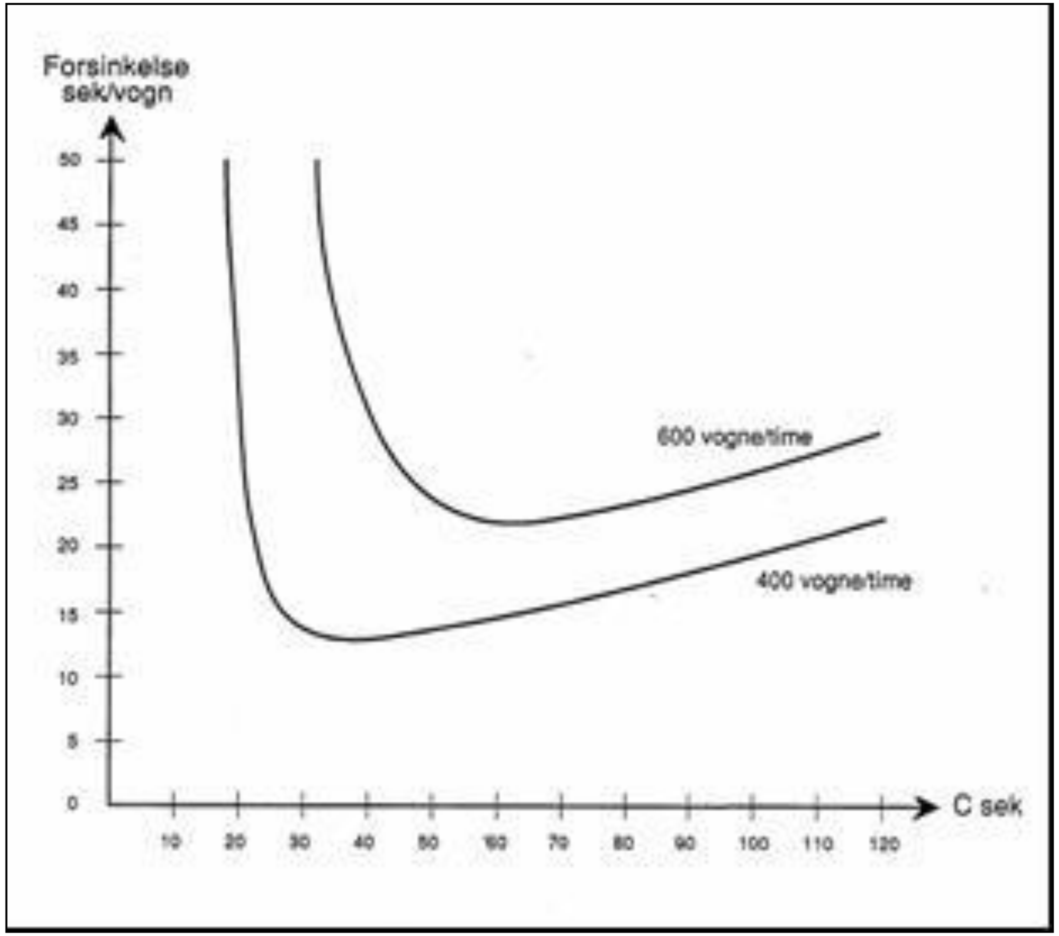
Travel time at 1000 vehicles/h

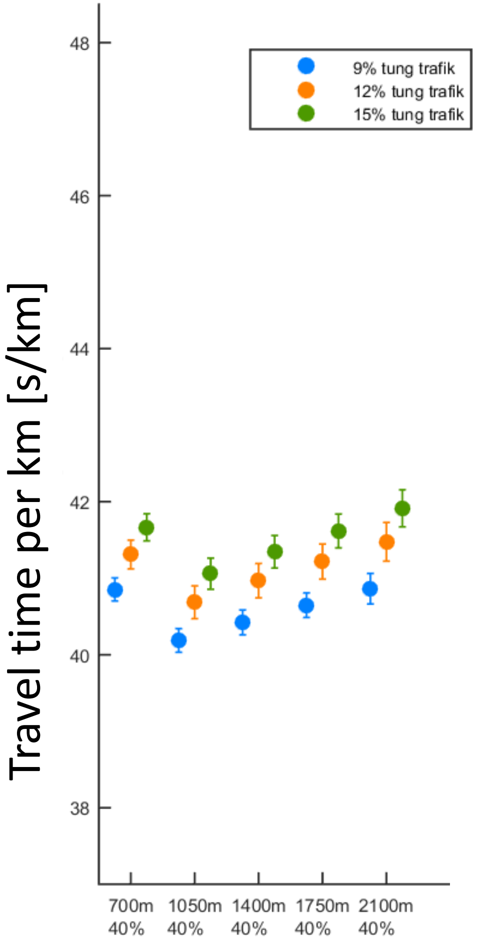


Travel time at 1300 vehicles/h



Comparison with cycle length in traffic signals





BICYCLE TRAFFIC SIMULATION

PhD project by Guillermo Pérez Castro
Johan Olstam, Fredrik Johansson

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Foto Jonas Jacobsson, Unsplash

PURPOSE

- To investigate, develop, and evaluate microscopic traffic models for simulating the behavior of cyclists
  - Including interactions between cyclists, and with the cycling infrastructure
- To improve microscopic traffic simulation analysis for bicycle traffic

Foto Louis Lo, Unsplash

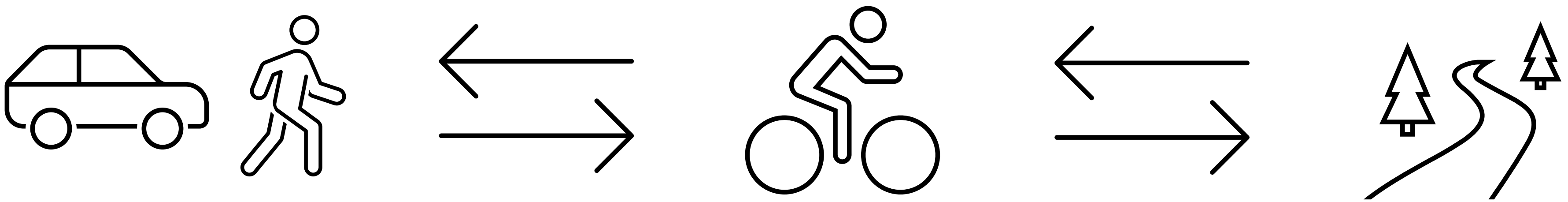
WHY MODELLING BICYCLE TRAFFIC?

- To cope with the expected/intended increase in demand of bike trips
  - Need for better planning and design of bicycle infrastructure

- Traffic models
  - To support the planning of an efficient transport system
  - Evaluate the effect of changes in the traffic system
  - To predict behavior of bicycle traffic streams

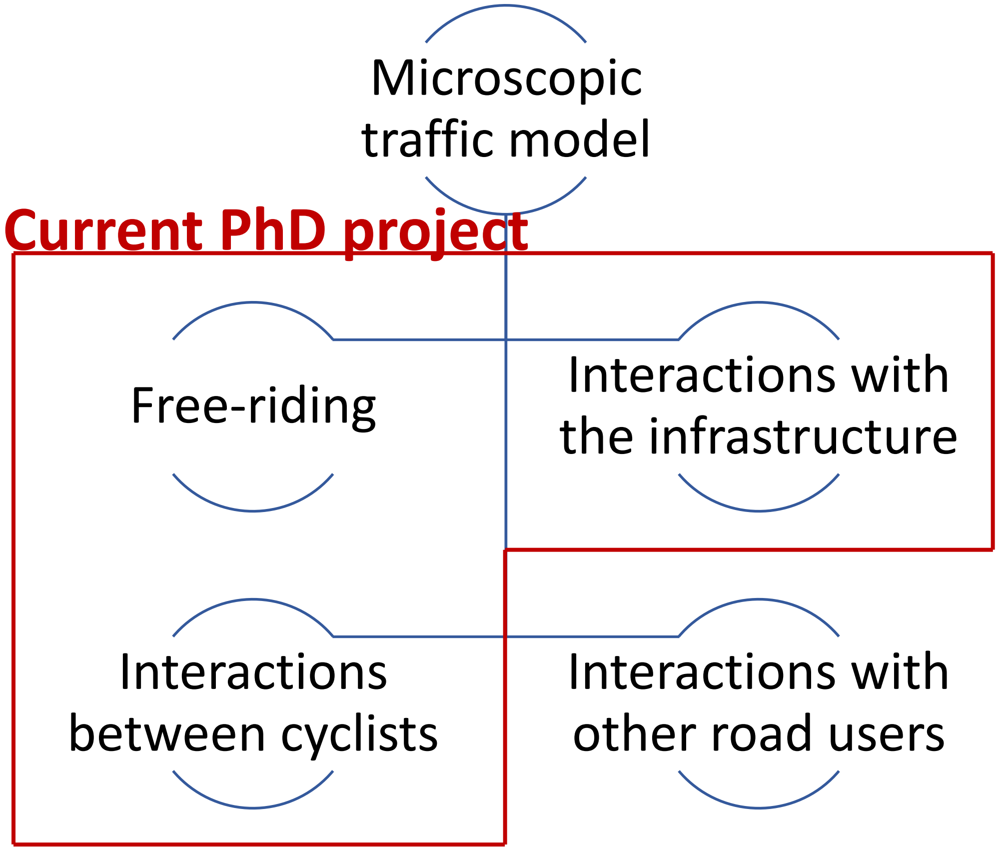
WHY IS MICROSCOPIC TRAFFIC SIMULATION NEEDED IN BICYCLE TRAFFIC?

- A population of cyclist is highly diverse
  - Microscopic traffic simulation focus on modelling individual entities and their interactions



- Increased bicycle traffic flows lead to more congestion and delays
  - Need to evaluate bicycle traffic performance (e.g., platoon formations, delays, queue length, etc.):
    - Effects of infrastructure design on bicycle traffic… and redesign
    - Effects of types of bicycles: electric, cargo, etc.
  - Provide support for large-scale analysis (e.g., route choice, socio-economic evaluations)

A MICROSCOPIC BICYCLE TRAFFIC MODEL

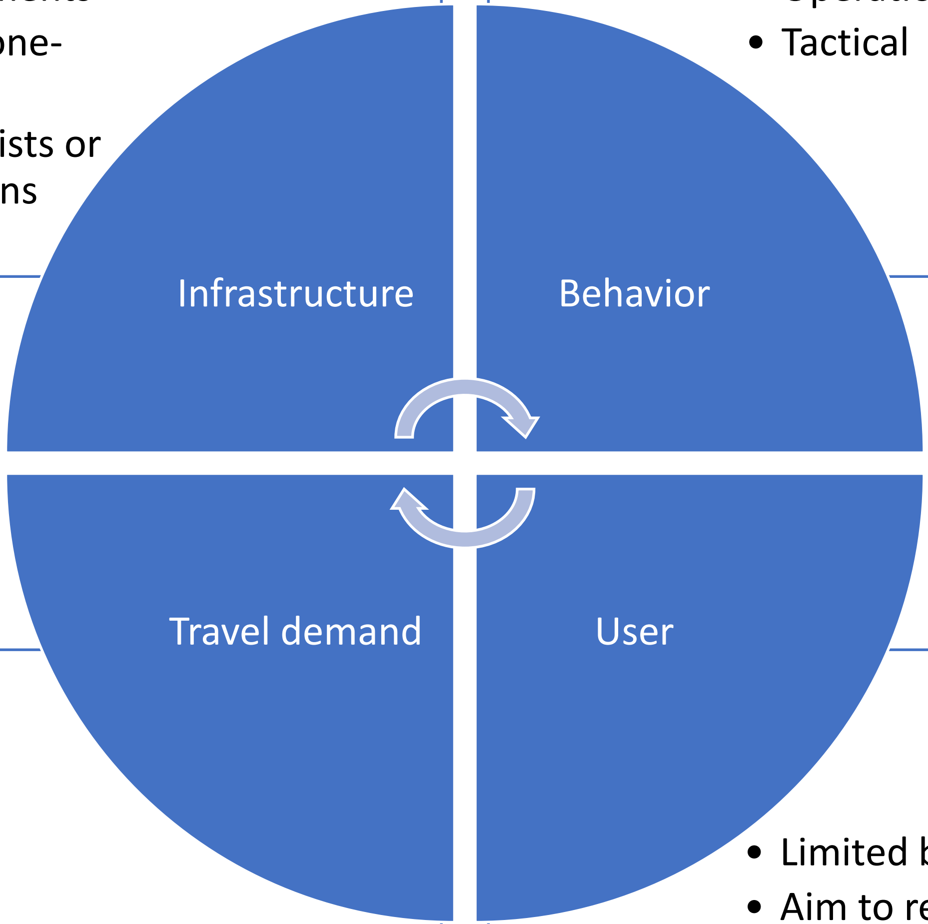


- **Sub-project 1: Cyclist-infrastructure interaction (Ongoing)**
  - What is the effect of gradient on the speed and acceleration?
  - How can we model the gradient effects?
    - Uphill and downhill models
- **Sub-project 2: Heterogeneous bicycle traffic (Ongoing)**
  - What cyclists' characteristics and preferences are relevant to predict bicycle traffic performance?
  - How do they vary among a population of cyclists and how can we model heterogeneity?
- **Sub-project 3: Cyclist-cyclist interactions (Ongoing)**
  - How do cyclists interact with other cyclists, in terms of following and passing behavior?
  - How can we model cyclist-cyclist interactions?

SCOPE

- Bicycle path segments
- Bidirectional or one-directional
- Exclusive for cyclists or shared pedestrians

- Operational
- Tactical

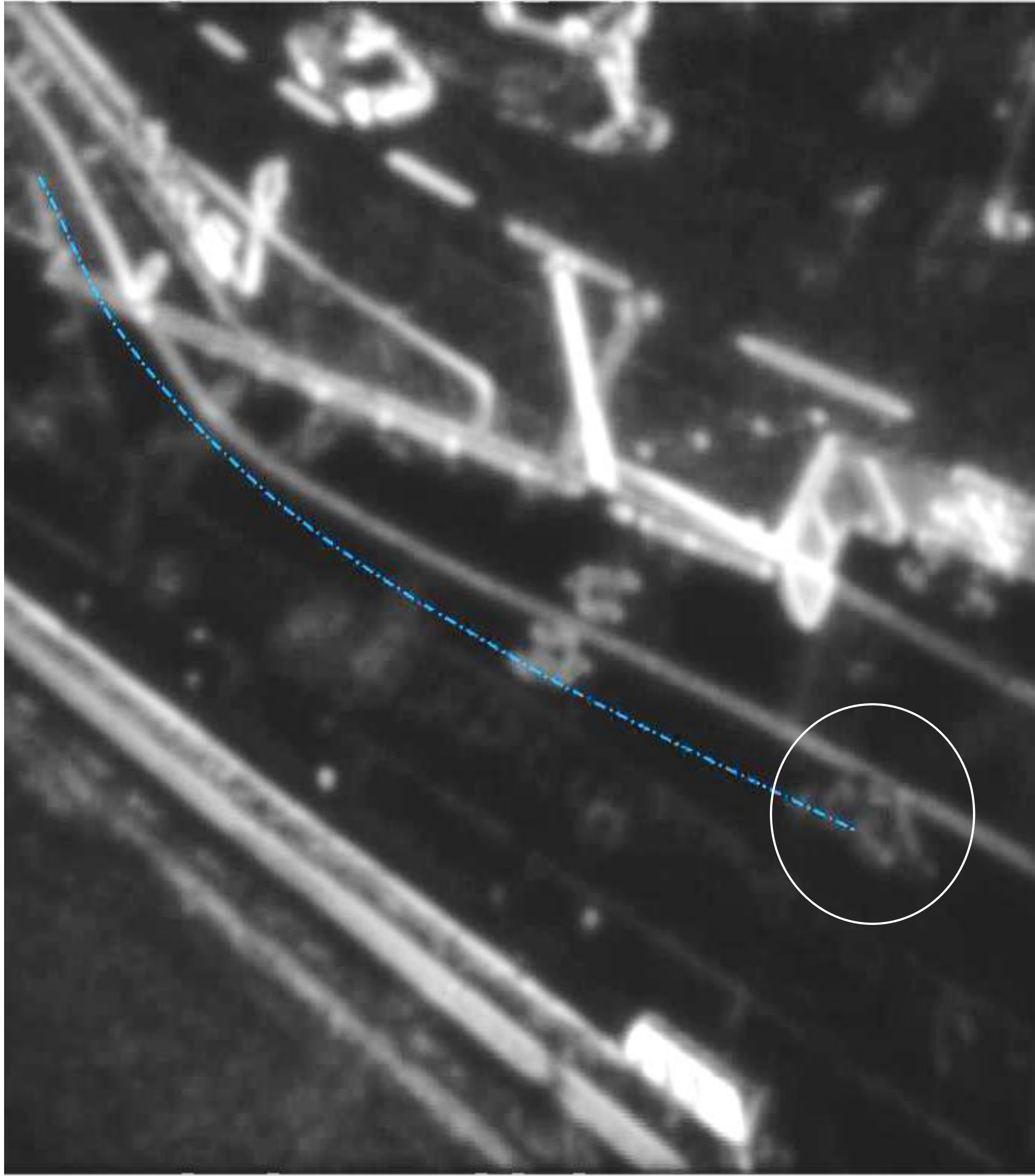


- High flows

- Limited by the data
- Aim to represent heterogeneity

DATA

- Need for detailed information about cyclists (behavior/interactions)
- Trajectory data
  - Manual tracking: T-Analyst (Johnsson et al. 2018)
  - Automated tracking: Viscando OTUS3D System (Viscando AB, 2013)



DATA

Data set 1 (Stockholm)

- September 2020, Munkbron, Stockholm
- Bidirectional path (exclusive for cyclists)
- Viscando OTUS3D System (anonymized video)
- In total, 45 779 trajectories

Data set 2 (Stockholm)

- September 2021, Norr Mälarstrand, Stockholm
- Bidirectional path (exclusive for cyclists)
- Viscando OTUS3D System + Wind measurements
- Anonymized video (anonymized video)
- In total, 41 607 trajectories

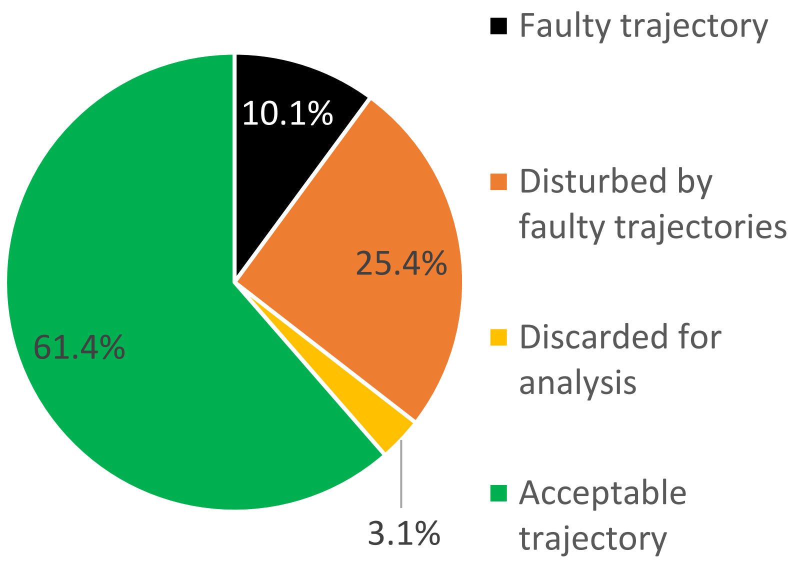
Data set 3 (Lund)

- October 2020, Lund
- Bidirectional path (exclusive for cyclists)
- Drone Phantom 4 Pro V2.0
- Manually tracked trajectories
- In total, 135 trajectories

Data set 4 (Stockholm, Gothenburg and Linköping)

- Cross-sectional measurements in various locations (2018, 155 183 cyclists)

In the complete data set 1



28 117 trajectories, which almost 40% belong to peak-hour periods

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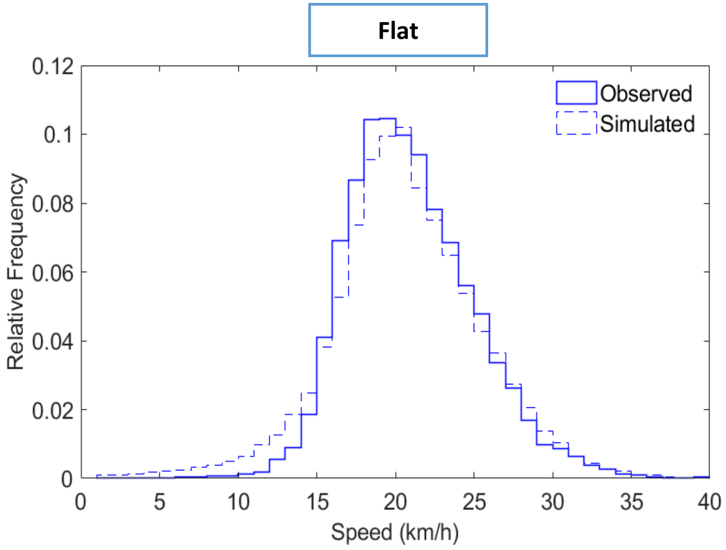
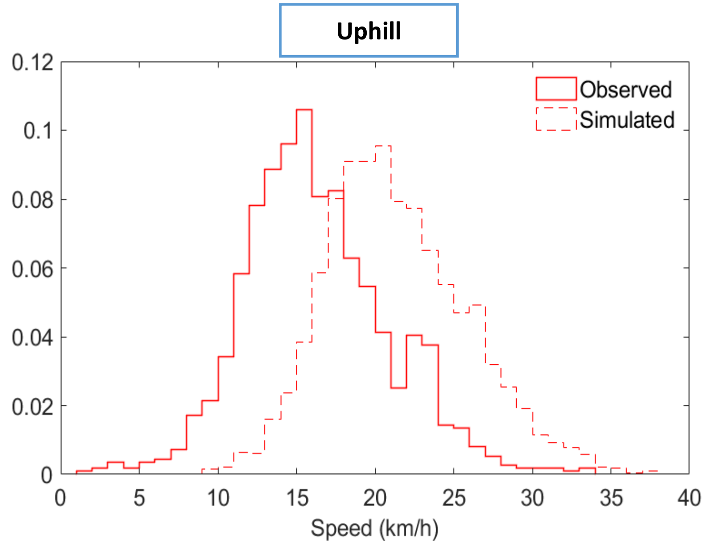
PRE-STUDY / MASTER THESIS

How accurate is it to apply a car traffic inspired approach to bicycle traffic simulation? (in Vissim)

- Location: Munkbron, Central Stockholm
- Bidirectional bicycle path (3-meter-wide) - Fully separated from other traffic
- Main finding: Vissim represents partially bicycle traffic but there is problem to capture the effect on the gradient





Pérez Castro G. Modelling behavior of cyclists to evaluate bicycle traffic performance. Master Thesis TRITA ABE-MBT-20696. KTH Royal Institute of Technology; 2020.
https://www.diva-portal.org/smash/get/diva2:1466509/FULLTEXT01.pdf

HOW TO MODEL THE EFFECT OF GRADIENT ON BICYCLE TRAFFIC IN MICROSCOPIC TRAFFIC SIMULATION?

- Purpose: Explore how to simulate the effect of longitudinal gradient of a bicycle path on the speed of cyclists
  - In Vissim (default driver behavioral model)
- Data: Cross-sectional measurements of speed at one location
  - 3 week-days, September 2018
  - Viscando OTUS3D System
  - Focus: AM peak, from 7-9 h (9 111 observations)

Pérez Castro G., Johansson, F. and J. Olstam How to Model the Effect of Gradient on Bicycle Traffic in Microscopic Traffic Simulation?, 2022, Presented at TRB annual meeting 2022 and Accepted for publication in Transportation Research Record

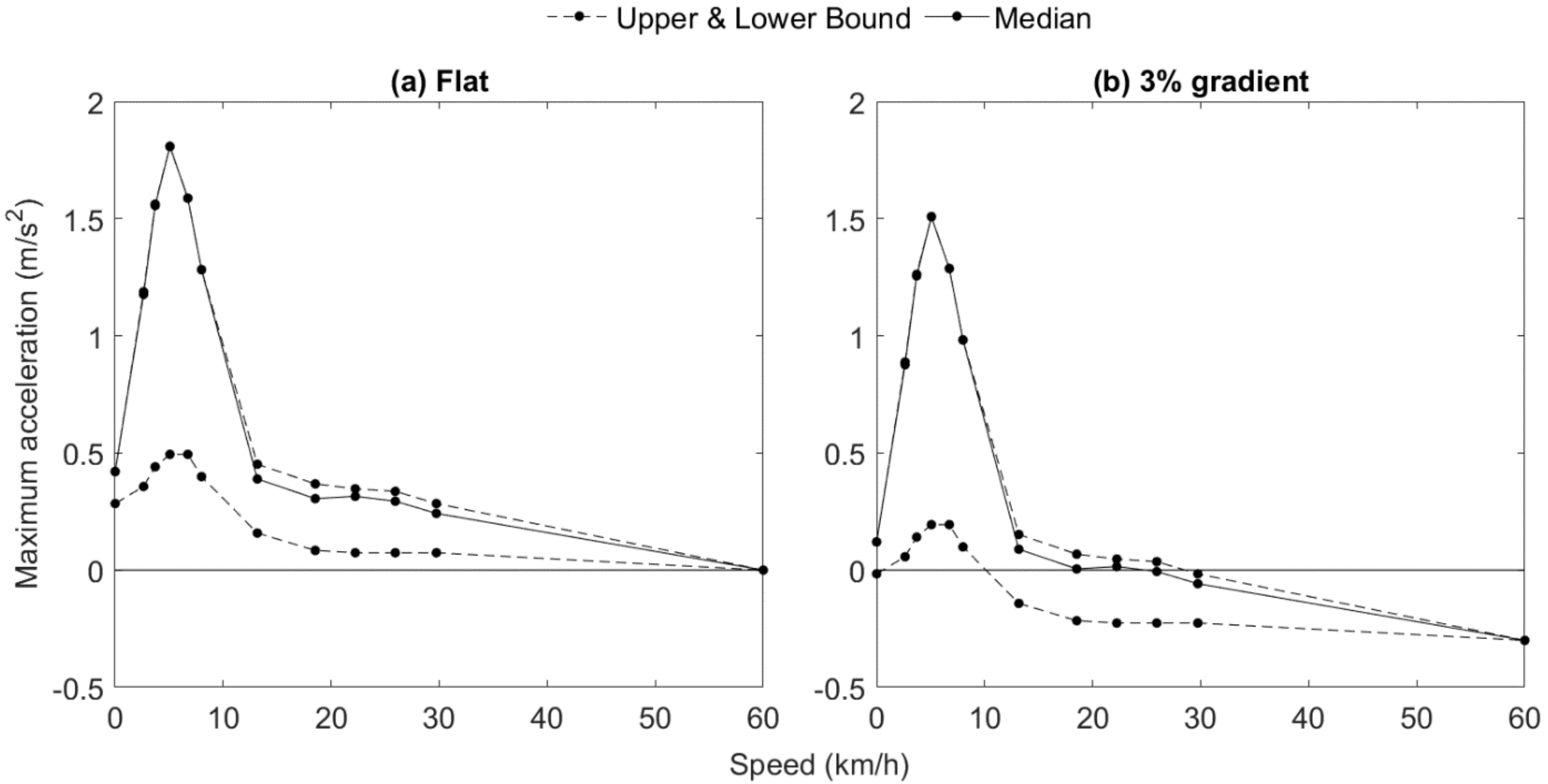
BICYCLE TRAFFIC MODELLING IN VISSIM

Gradient ⤵ Maximum acceleration function

Gradient-Acceleration parameter
+/- 0.1 m/s² per 1% gradient

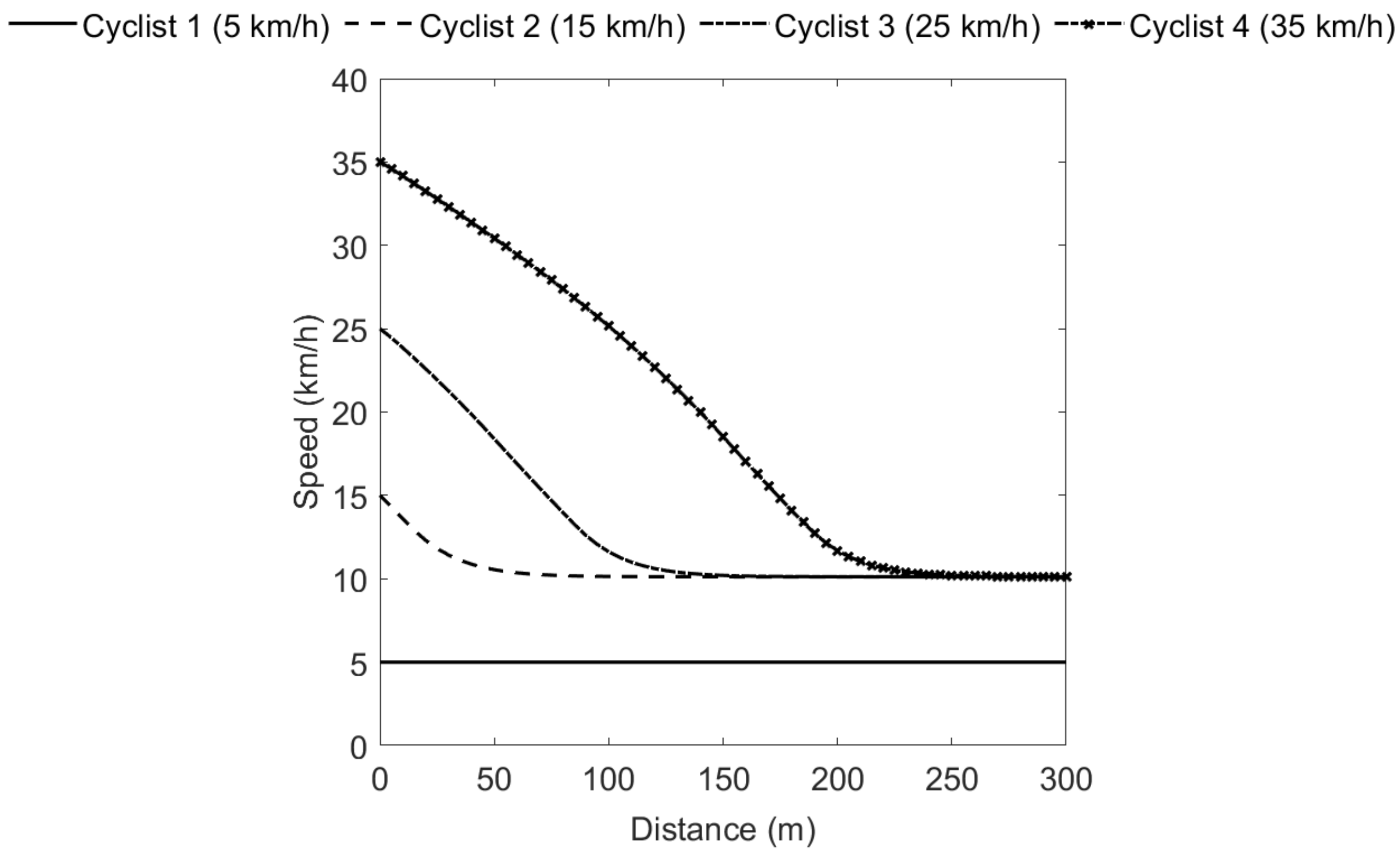
cf. rural road simulation approach

$$a_{max} = \frac{p}{v(t)} - g \cdot i(x)$$



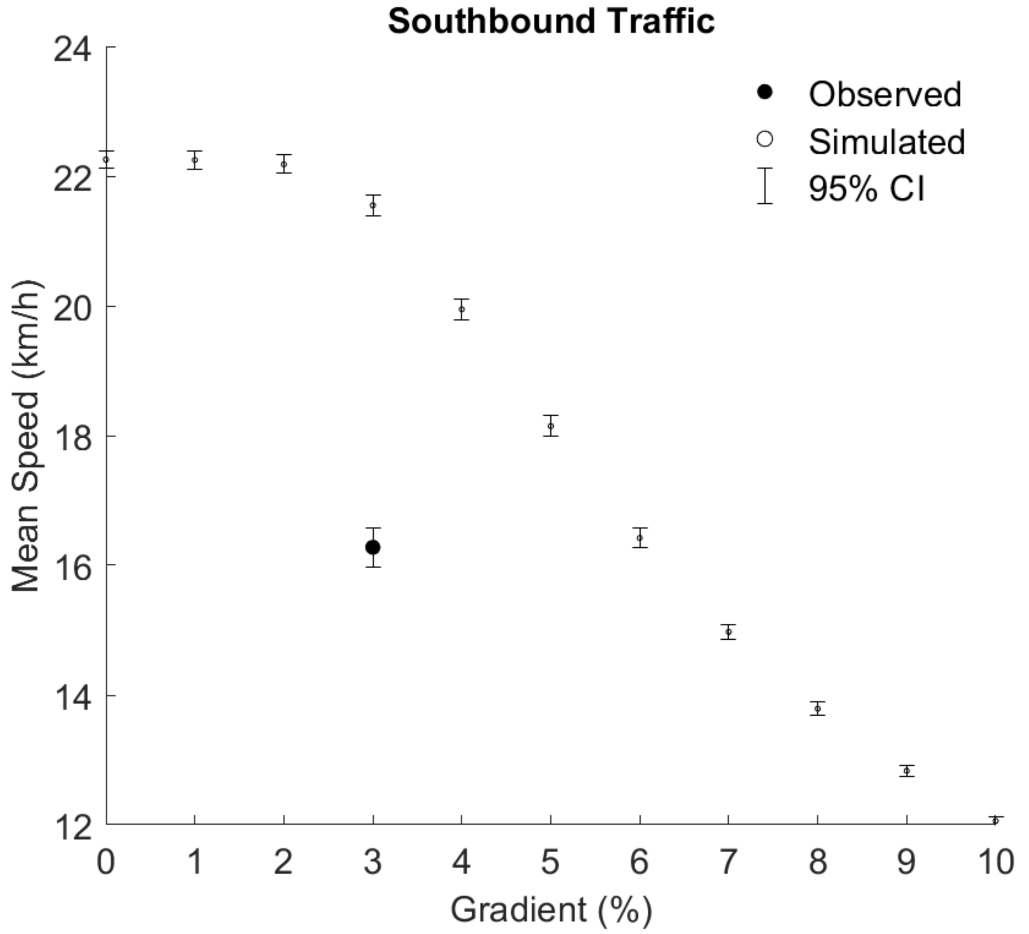
RESULTS

- A hypothetical case: an infinite 3% uphill and 4 cyclists with different desired speeds
  - Cyclists with a low desired speed are not affected by the gradient



RESULTS

- Small impact at real-world gradient… gradient should be twice the real-world gradient



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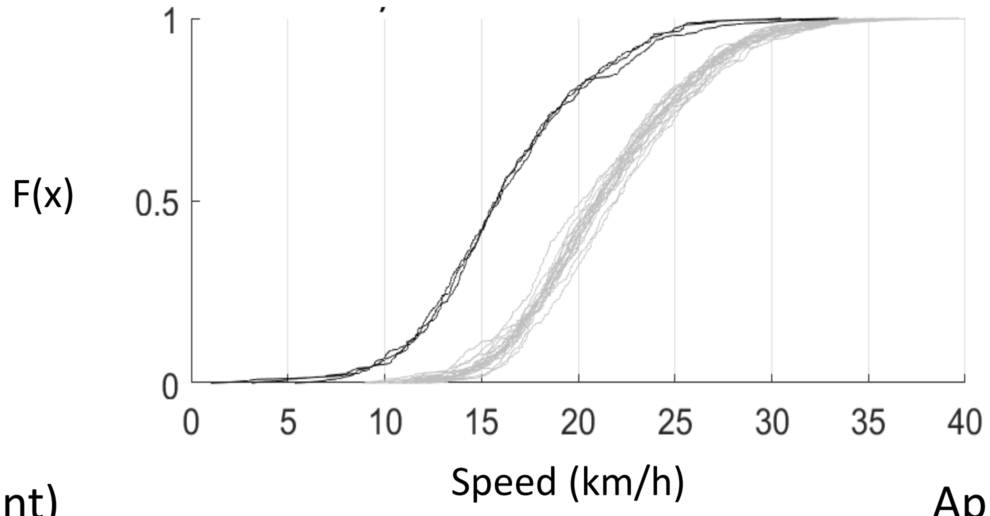
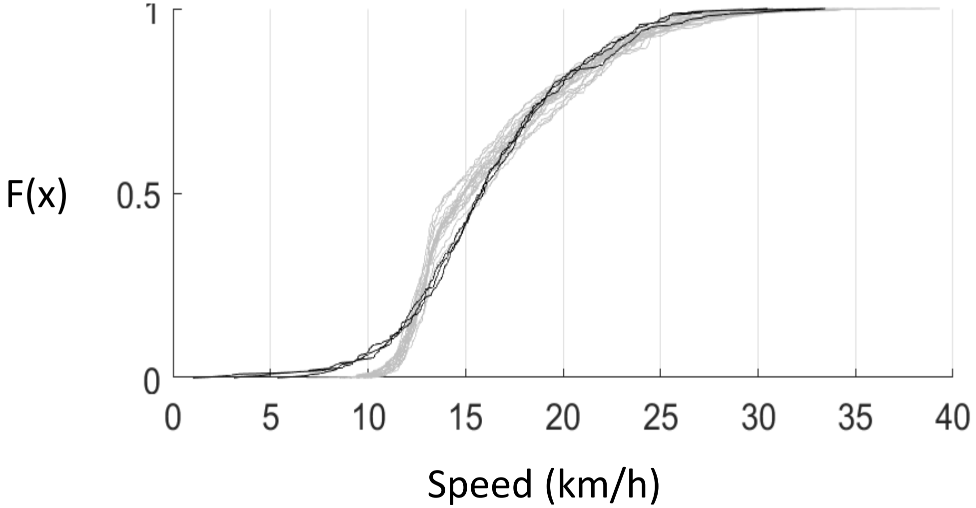
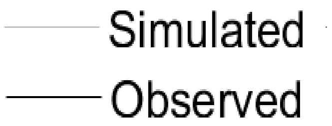
RESULTS

Base scenario (no changes)

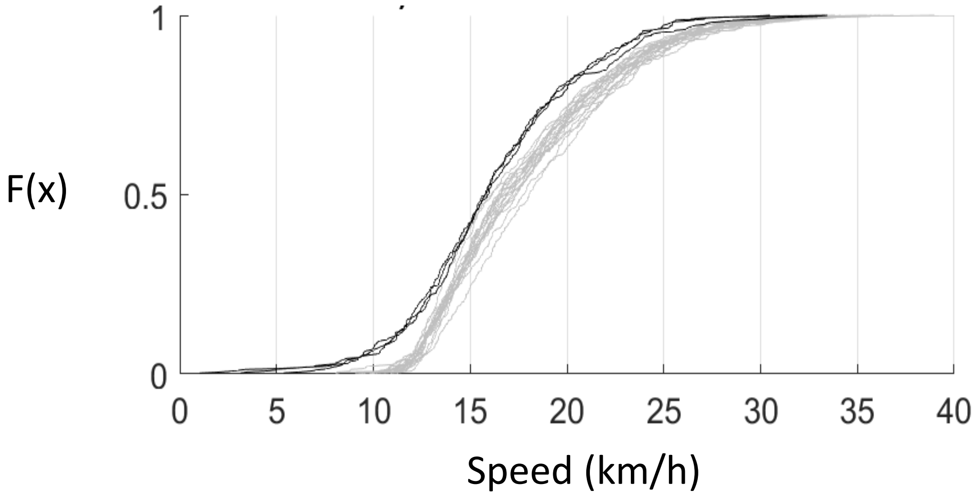


Approach A (6% gradient)





Approach B (cal. max. acc. function)



Conclusions

- A car-traffic modelling approach (Vissim) could reproduce the bicycle traffic speed… at flat conditions
- In Vissim, we could reproduce the mean speed on the slope… but fails to reproduce accurate speed distributions
- Underestimation of the effect of gradient on cyclists' speed
- Having a maximum acceleration function (as in Vissim) is complex
- There is a clear need for investigating other (more appropriate for bicycle traffic) approaches

Pérez Castro G., Johansson, F. and J. Olstam How to Model the Effect of Gradient on Bicycle Traffic in Microscopic Traffic Simulation?, 2022, Presented at TRB annual meeting 2022 and Accepted for publication in Transportation Research Record

Next steps

- **Sub-project 1: Cyclist-infrastructure interaction (Ongoing)**
  - What is the effect of gradient on the speed and acceleration?
  - How can we model the gradient effects?
- **Sub-project 2: Heterogeneous bicycle traffic (Ongoing)**
  - What cyclists' characteristics and preferences are relevant to predict bicycle traffic performance?
  - How do they vary among a population of cyclists and how can we model heterogeneity?
- **Sub-project 3: Cyclist-cyclist interactions (Ongoing)**
  - How do cyclists interact with other cyclists, in terms of following and passing behavior?
  - How can we model cyclist-cyclist interactions?

Mostphotos