Presentation 5:

Potential customer benefits of Torque Vectoring in Heavy Commercial Vehicles,

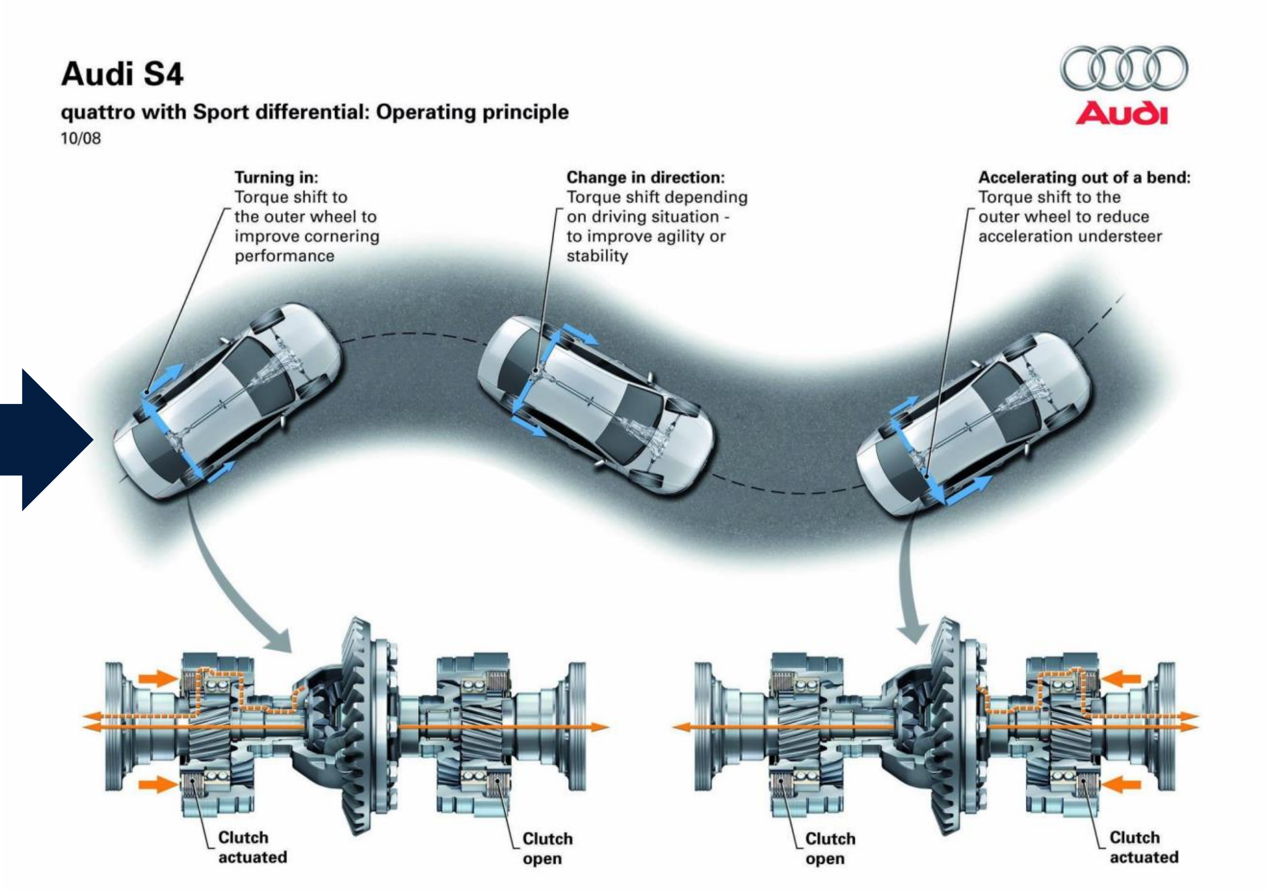
Jolle IJkema, Scania

POTENTIAL CUSTOMER BENEFITS OF TORQUE VECTORING IN HEAVY COMMERCIAL VEHICLES

JOLLE IJKEMA, PROPERTY OWNER HANDLING & STEERING

20+10 MINUTES

Torque vectoring



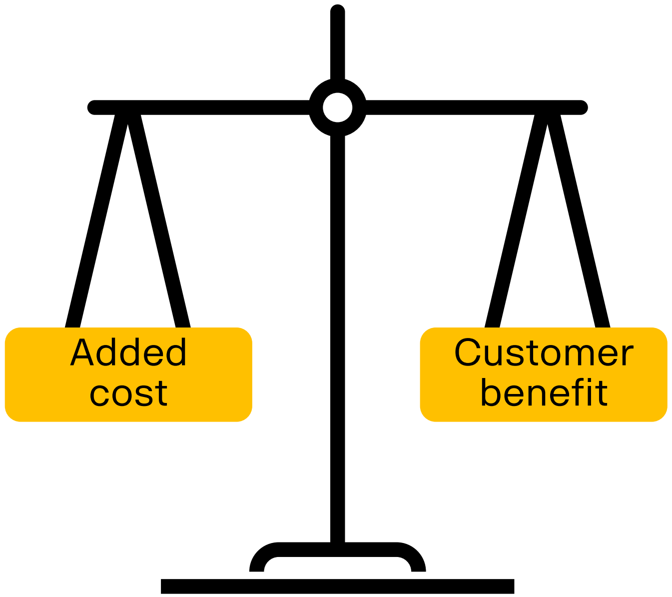
Elon Musk is challenging us: ”Jack-knifing is impossible”

Opportunities increase with introduction of BEVs

Concept	L/R Torque Vectoring	Efficiency	Cost	Complexity
Brake-based	Yes (indirect)	Low	Low	Low
Single motor + TV diff	Yes	Medium	Medium	Medium
Dual-motor AWD	F/R only	High	Medium	Medium
Two motors per axle	Yes	High	High	High
Quad-motor	Yes (max)	High	Very High	Very High

Potential benefits?

- Improved turning radius at low speeds
- Understeer control at low friction
- Oversteer prevention (pro-active Jack-knife prevention)
- Oversteer control at low friction (reactive Jack-knife prevention)
- LKA w/o steering input
- High speed RBS for autonomy
- Side wind / road camber compensation
- Uphill driving on slippery curvy road

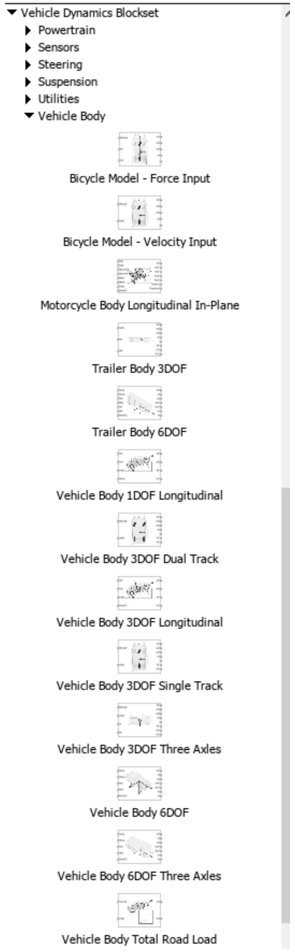


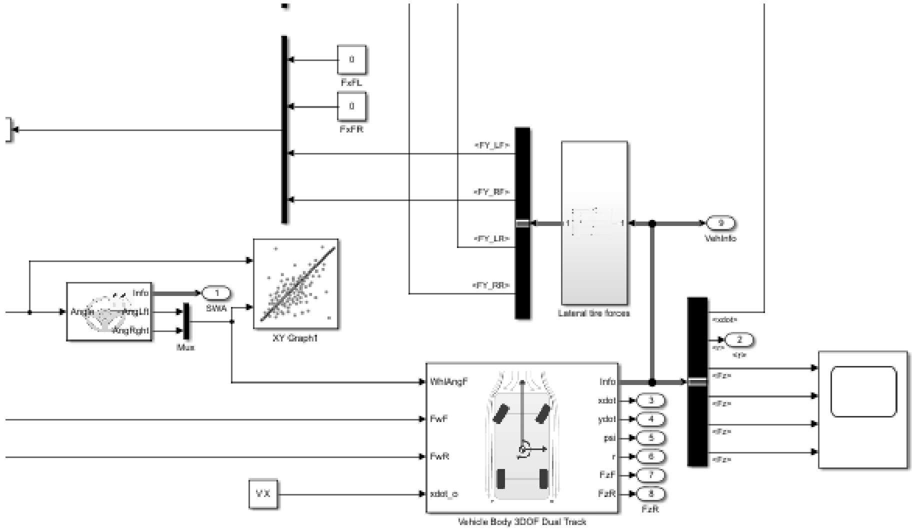
SIMULATION MODELS

Base line vehicle

- Scania B4x2 (RWD)
- Wheelbase 4950 mm
- Axle loads:
  - 6976 kg
  - 11020 kg
- Speed range 10 km/h – 90 km/h

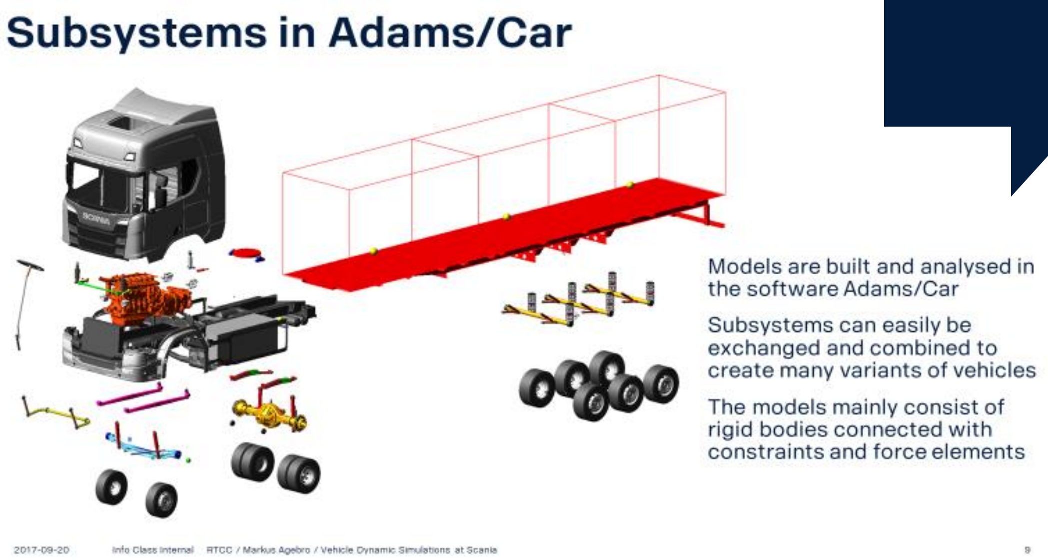
Simulation tools –
Simulink Vehicle Dynamics blockset

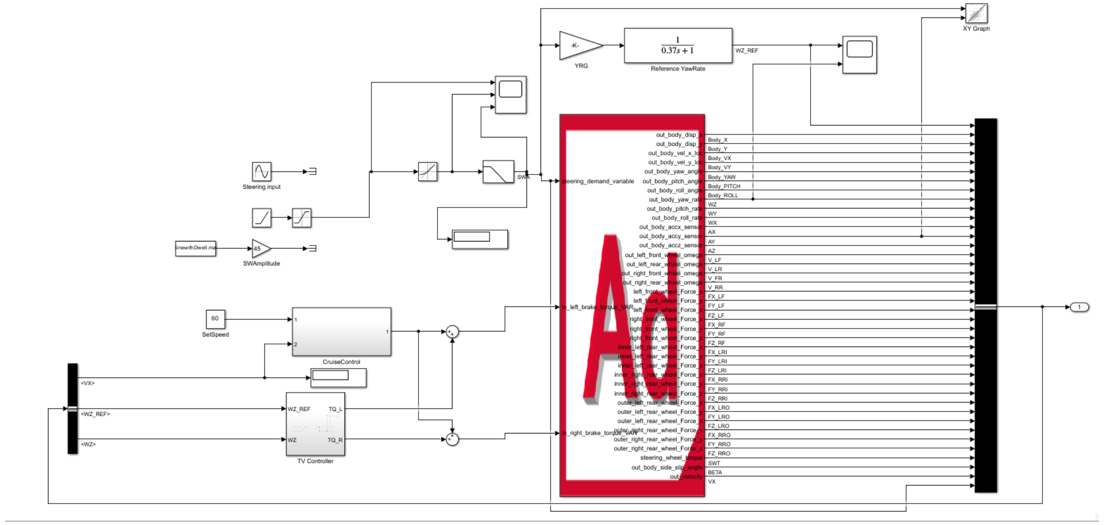




- Fast (~0.2s per second)
- Customizable
- Lo-Fi
- Generic vehicle – not a Scania

Simulation tools –
Simulink with ADAMS FMU





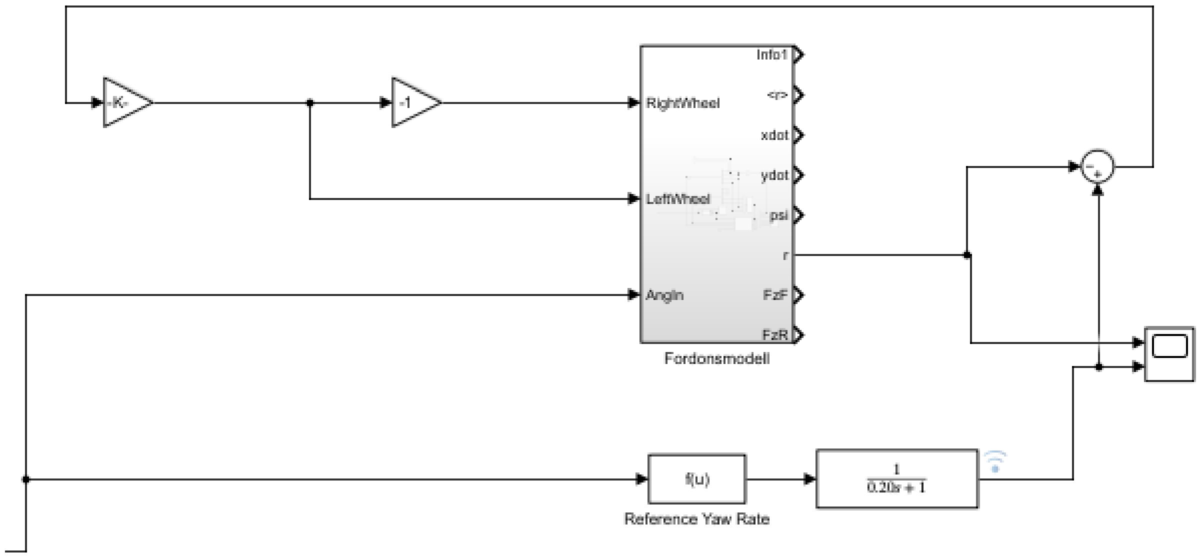
- Slower (~10s per second)
- ADAMS Model parameters are fixed
- Hi-Fi
- Accurate Scania model from ADAMS

SELECTED FEATURES

Understeer mitigation

Understeer at low-μ

- Feed-back controller TV-torque from deviation from desired reference yaw rate
- Simulink VDL model with low-μ tyres
- Open loop Sine wave input at 60 km/h and 0.2 Hz



Understeer at low-μ

Base line

With Torque vectoring

Actual yaw rate follows reference yaw rate better

The lateral acceleration is not increased (friction limit)

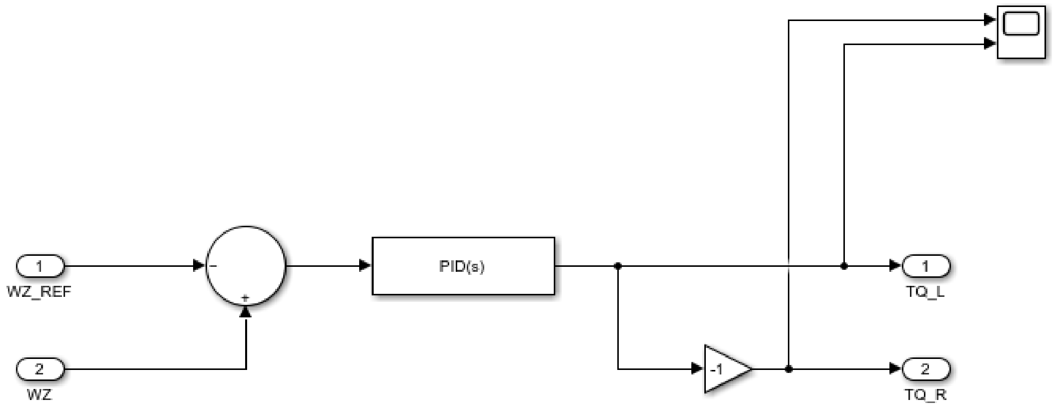
Side slip angle is increasing with TV

- Yaw rate is improved – vehicle turns in well but is still sliding sideways
- Understeer needs speed reduction
- Friction demands at rear axle limiting factor

Oversteer control / Anti-jack knife (reactive)

Oversteer control at low friction
(reactive Jack-knife prevention)

- FMU model with feedback control on deviation from reference yaw rate (ESP control)
- Sine with dwell at 90 km/h

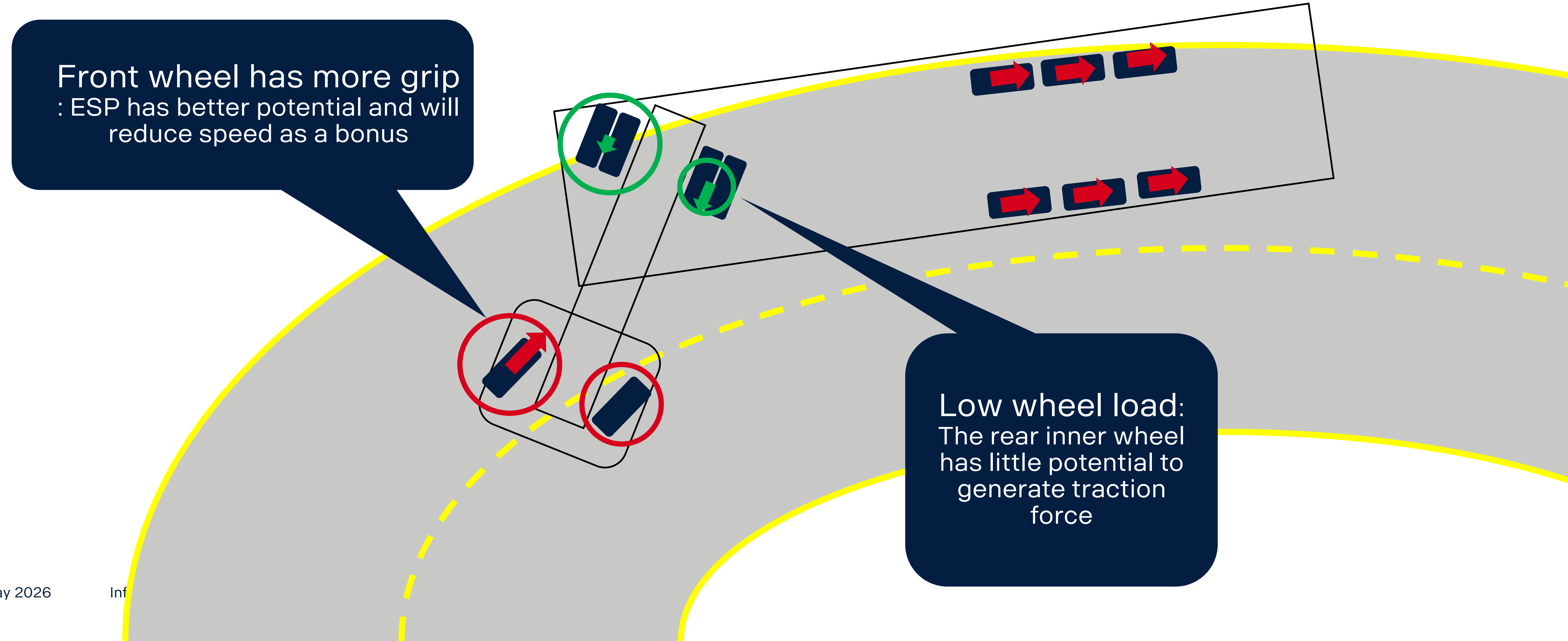


Oversteer control at low friction

(reactive Jack-knife prevention)

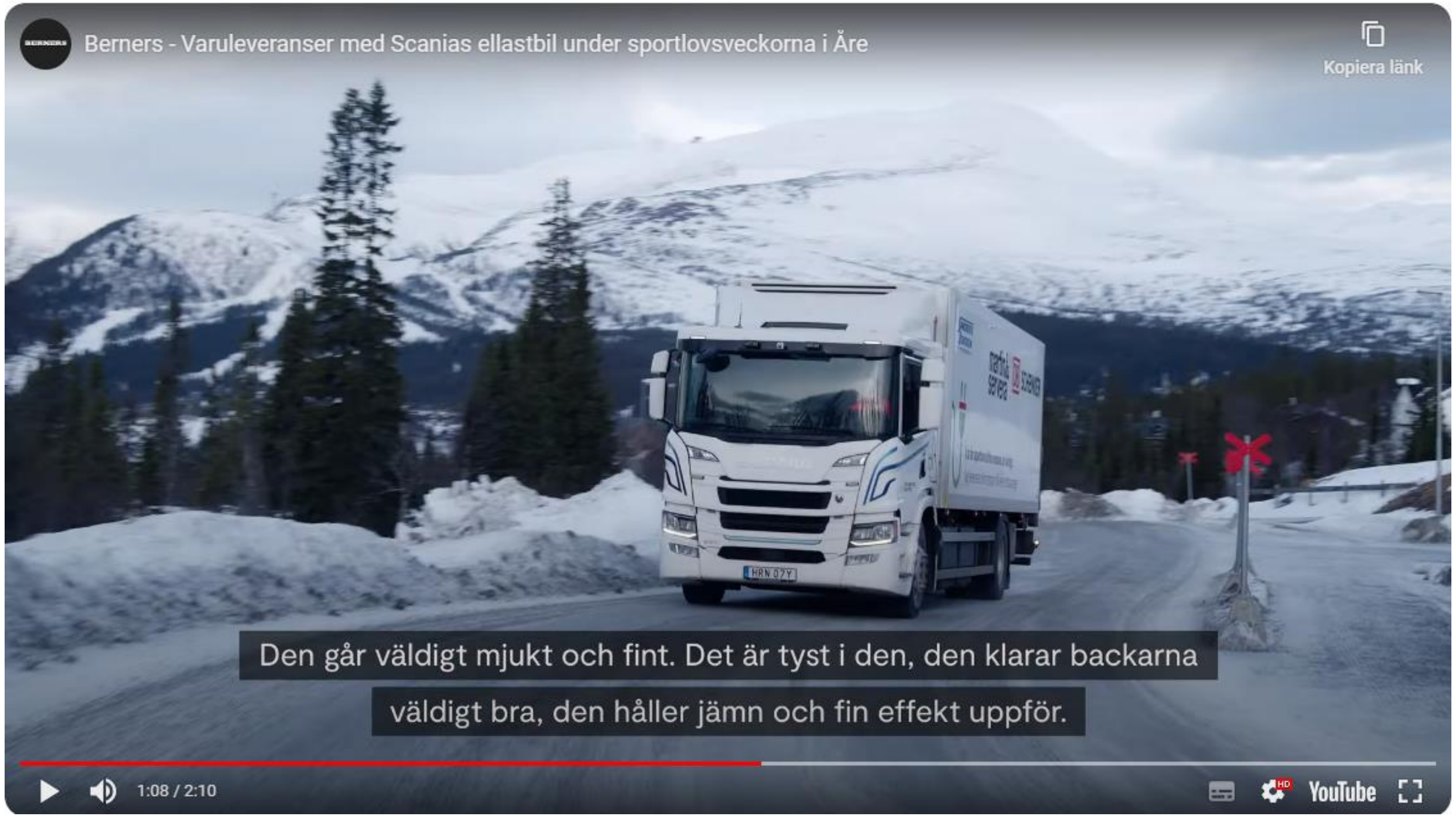
- Little benefit as inner wheel has low vertical load
- ESP that is reacting on the front axle is already effective

Oversteer control at low friction
(reactive Jack-knife prevention)

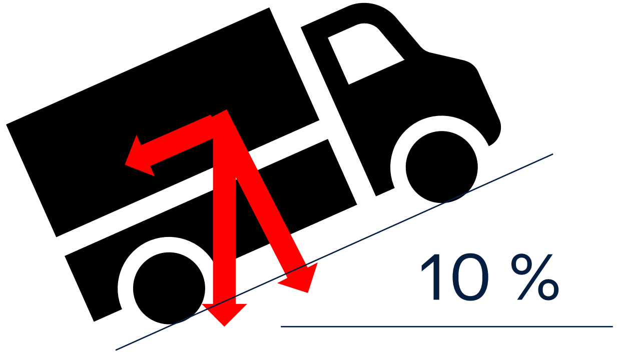


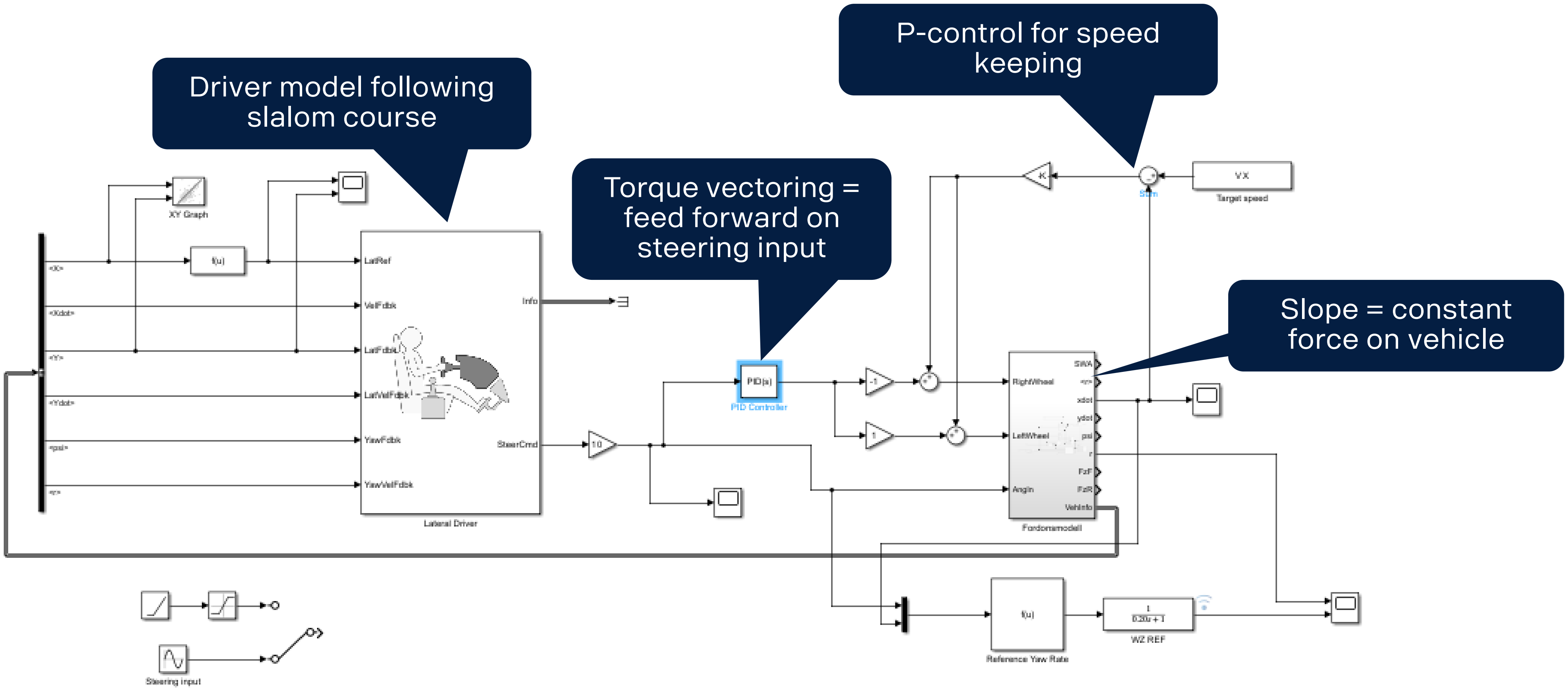
Slippery Slope Traction

Slippery Slope

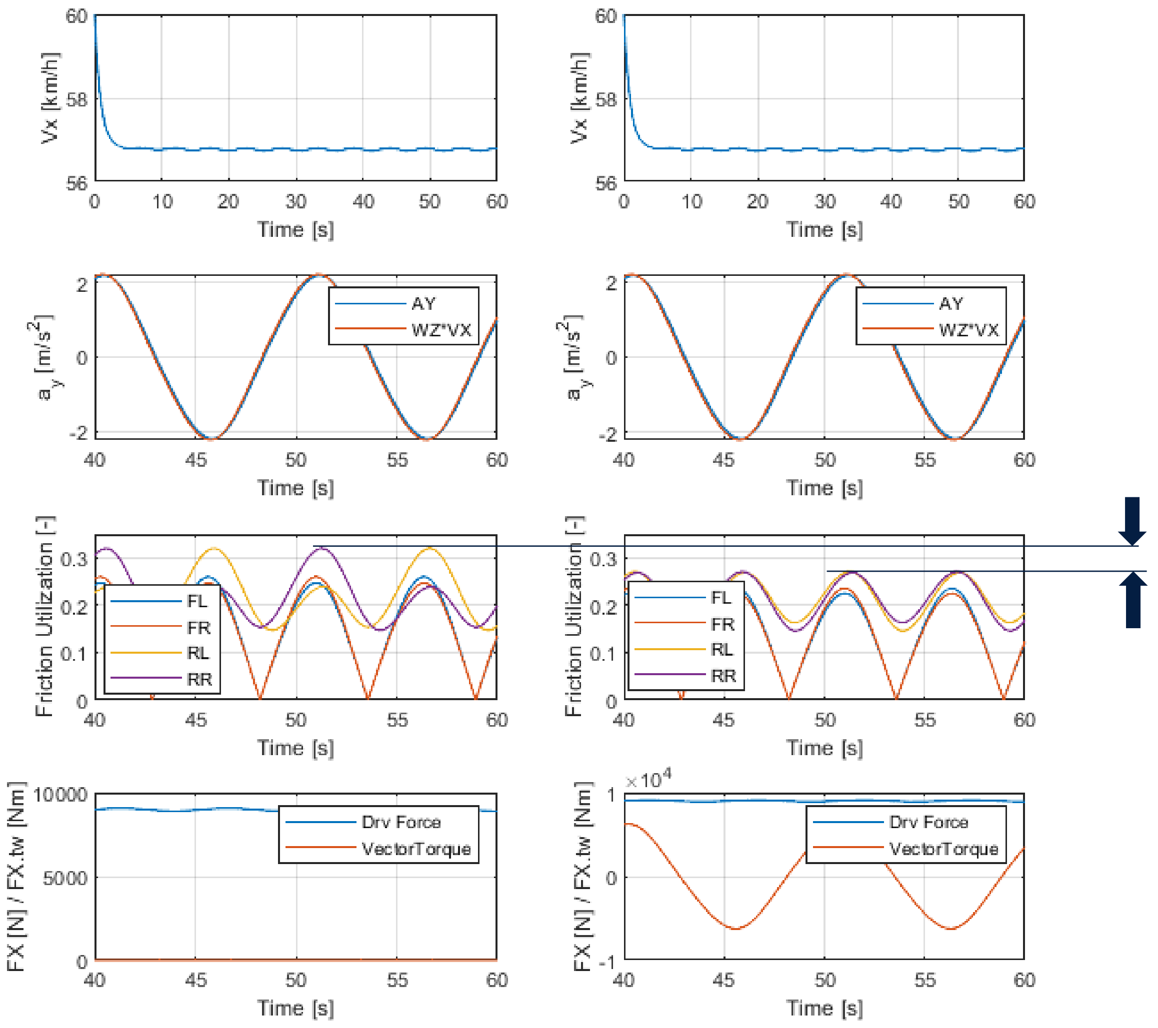


Use Case

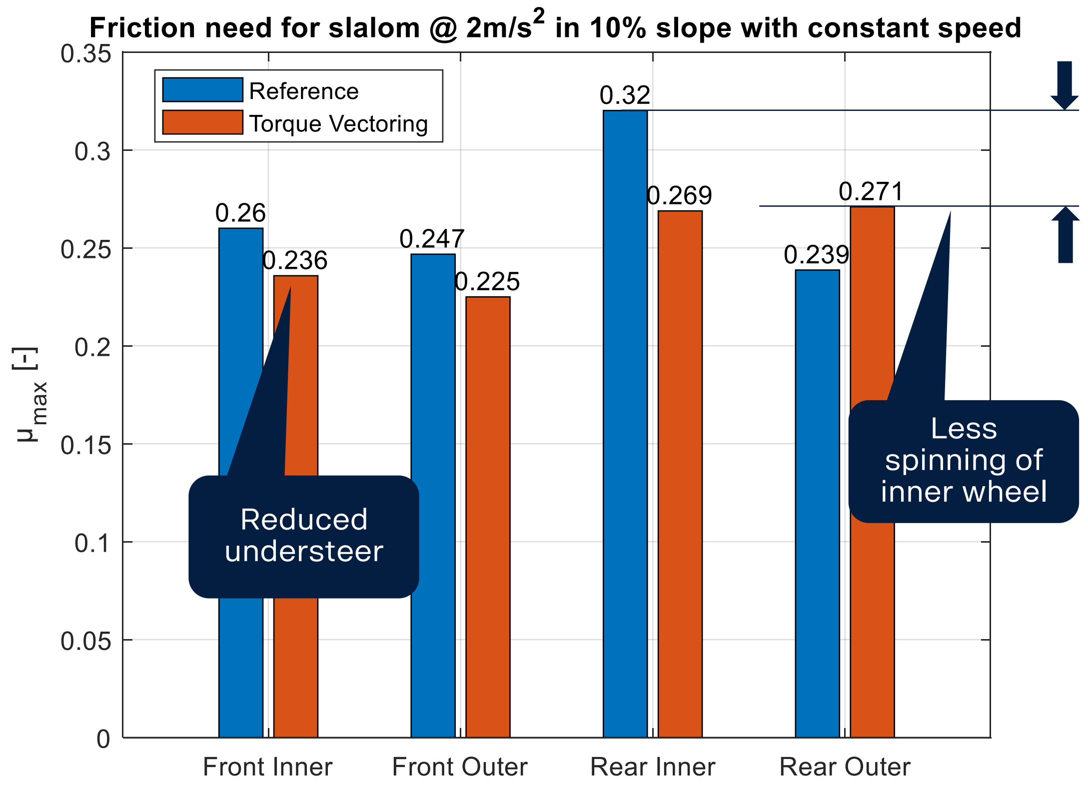



Driver model following slalom course
Torque vectoring = feed forward on steering input
P-control for speed keeping
Slope = constant force on vehicle
XY Graph
f(u)
LatRef
VelFdbk
LatFdbk
LatVelFdbk
YawFdbk
YawVelFdbk
Info
SteerCmd
Lateral Driver
PID(s)
PID Controller
Target speed
RightWheel
LeftWheel
AngIn
Fordonsmodell
Reference Yaw Rate
WZ REF
Steering input

Drive torque is transferred to outer wheel



$$\mu_{max} = \frac{\sqrt{F_x^2 + F_y^2}}{F_z}$$



CONCLUSIONS

Summary

Feature	Evaluation	Comments
Turning radius at low speed	Beneficial at sufficient rear axle load and improves tyre wear on front axle	Requires good rear axle friction. Good function for 6x4
Understeer at low friction	Slides sideways anyway – like shopping cart	Requires good rear axle friction.
Oversteer prevention in DLC (pro-active)	TV could prohibit high lateral accelerations but then the object is not avoided	Stability envelope – but do we want this?
Oversteer control at low friction (reactive)	Little improvement as inner wheel at rear axle has low vertical load	ESP is more effective – reduces speed as a bonus!
LKA / RBS for autonomy	Good performance	Energy consumption?
Lateral drift compensation	See LKA	
More traction on slippery slopes	Improved traction uphill and reduced risk for understeer	Particular for high CoG

“Torque vectoring has benefits for heavy vehicles,
but ESP is more effective in preventing jack-knifing.”

Presentation 6: From Intent to Action:

AI-Assisted Vehicle Dynamics Design Using Validated Modelica Libraries,

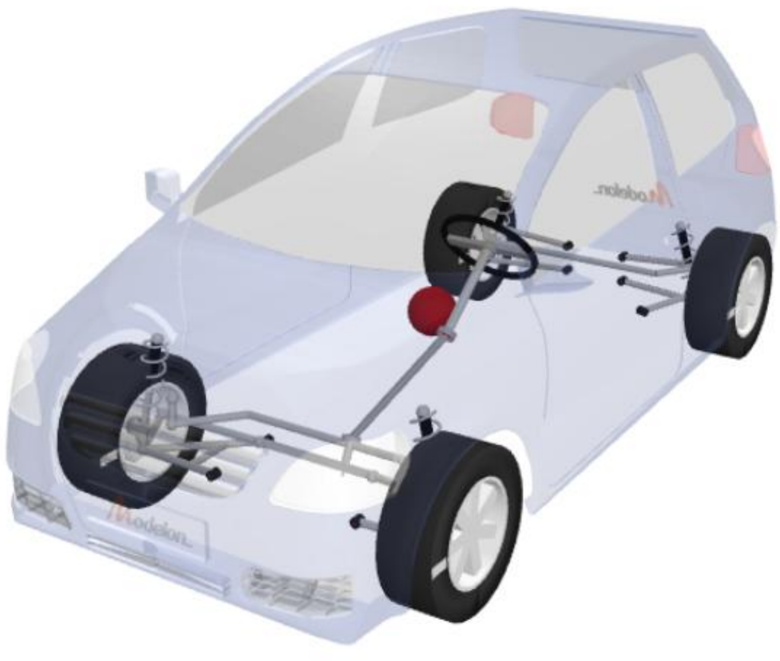
Johan Andreasson, Modelon

From Intent to Action

AI-Assisted Vehicle Dynamics Design Using Validated Modelica Libraries

Johan Andreasson · Modelon · SVEA 2026

Intent: Improve peak lateral acceleration



Compact FWD car example

Validated physics

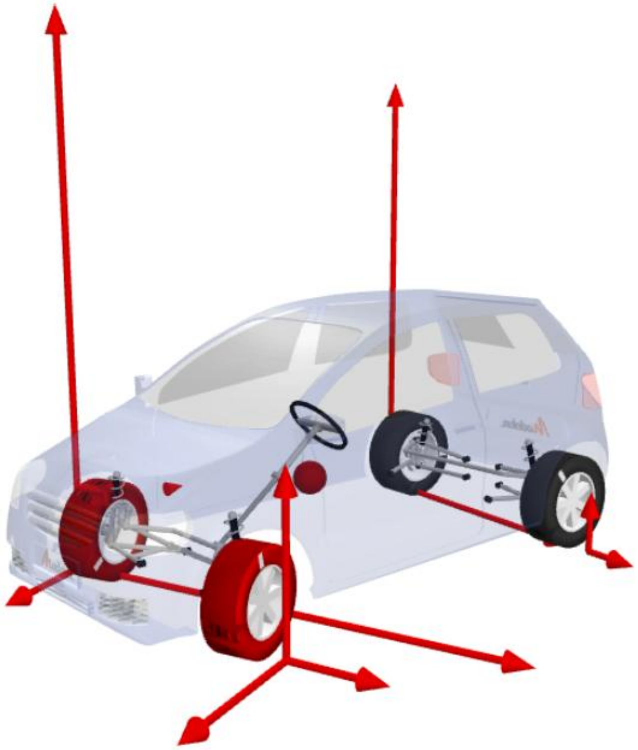
Ramp steer at constant speed

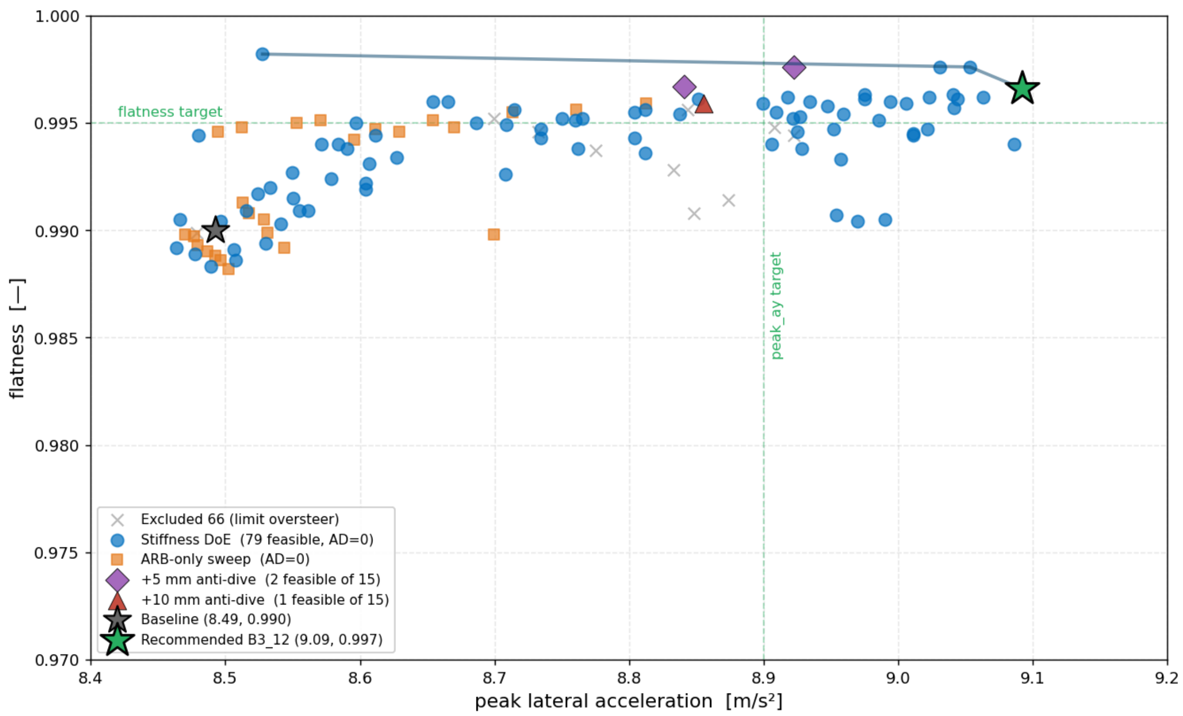
- Max lateral acceleration
- Limit flatness

Design of Experiment or Optimization

- Sensitivity study
- Scatter/pareto plot

Action: DoE finds an optimum, or does it?





How AI changes the workflow

Classical way

Specify the problem, then solve it

- Spec KPI
- Choose factors & define bounds
- Run DoE
- Find pareto front
- Suggest winner
- Inspect
- Re-iterate or re-program

Agentic AI

Discover the problem while solving it

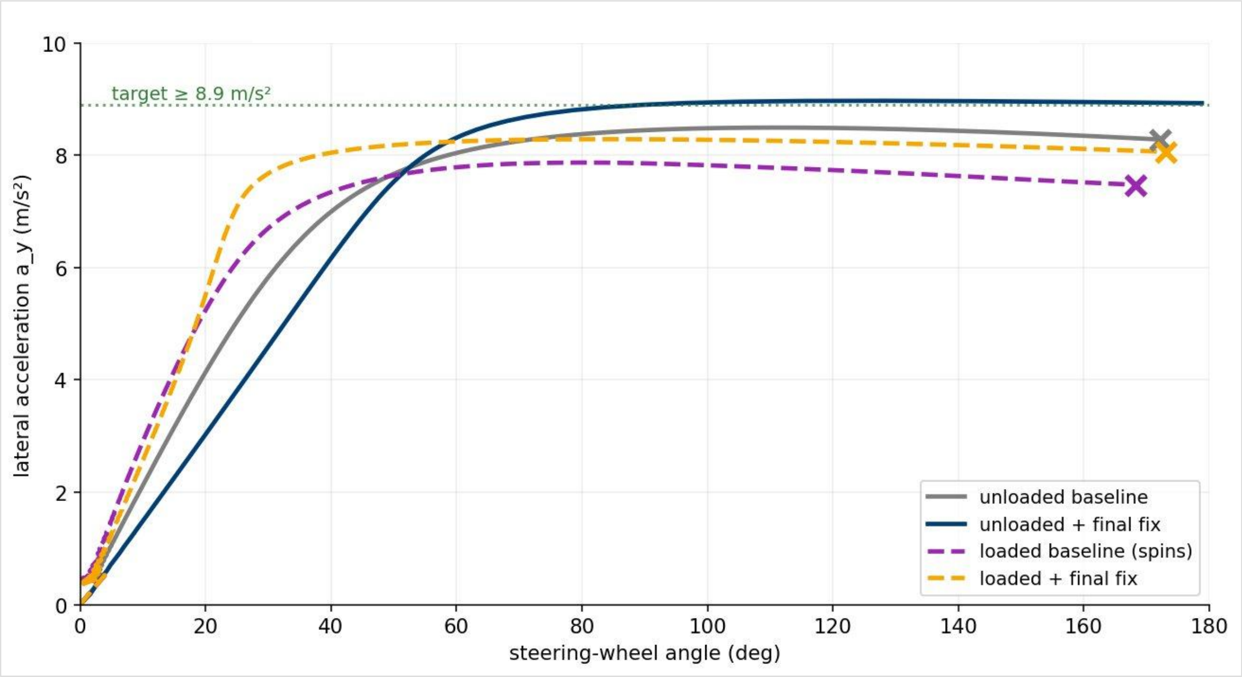
- Agree intent and target KPIs
- Assemble models, run initial sensitivity study and DoE
- Identify limit oversteer for CoG change, strange peak
- Diagnose, 30% camber ceiling
- Geometry and bushing effects
- Include test with payloads in updated DoE
- Dynamic verification
- Report creation and approval

Evolve knowledge base

Result of the AI workflow

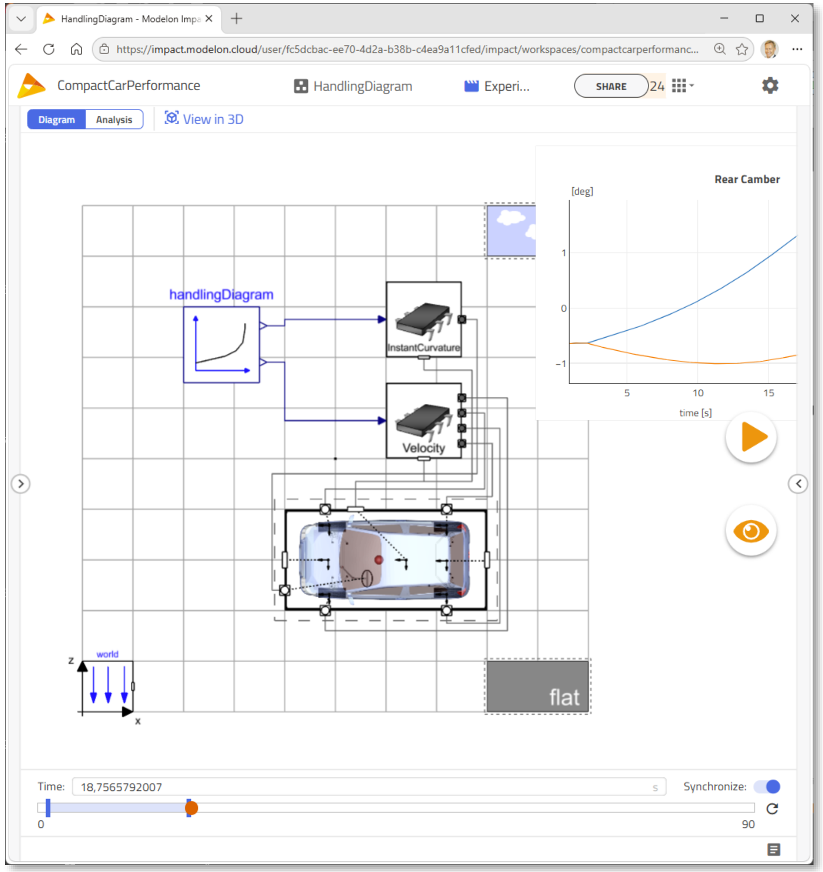
Final design:

- Trailing-arm bushing C × ~5
- Rear ARB +25 %
- Springs, dampers, front ARB, hardpoint geometry: unchanged



The deliverables

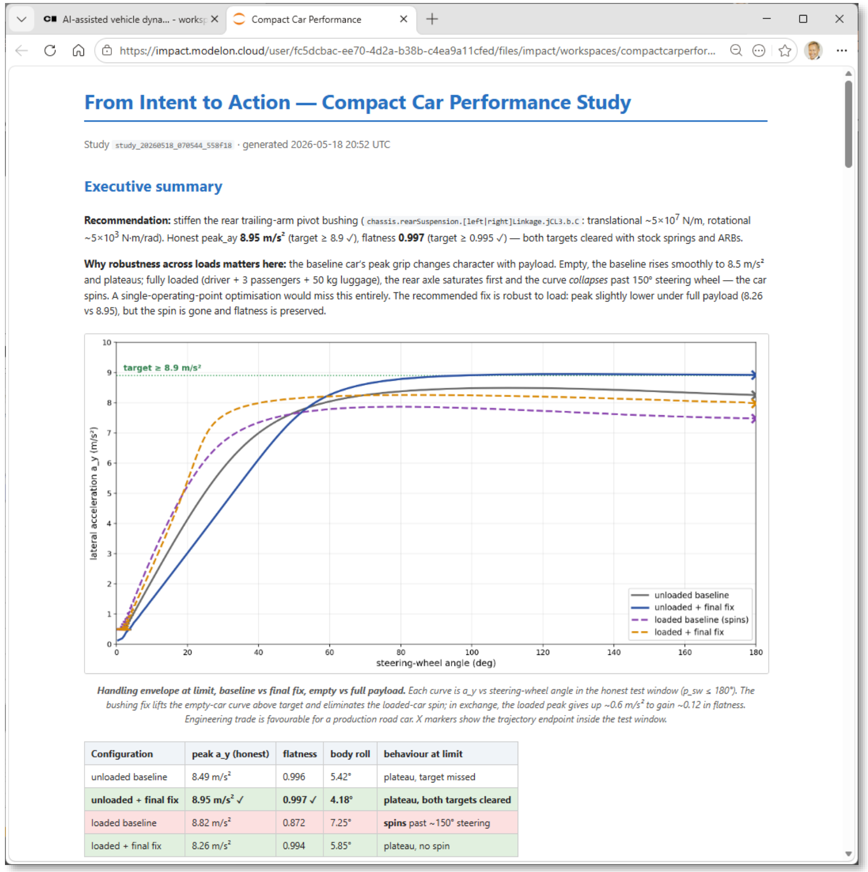
Models and simulation data



Simulation data only

Full reproducibility

Interactive HTML report



What it takes to deliver this

1. Validated models Physics the agent cannot drift from.

2. Good APIs Every action callable, not clickable.

3. Agentic framework with knowledge Domain context, not just tool access.

4. Guiding autonomy A contract up front, an audit trail after.

Takeaways

- Compared to manual work: same methodology, faster cadence
- Compared to automation: more versatile, the plan evolves with learning
- Not a replacement for simulation: still relies on validated physics
- Not a replacement for engineers: result still require human sign-off
- A replacement for scripting and automation?

Presentation 7a:

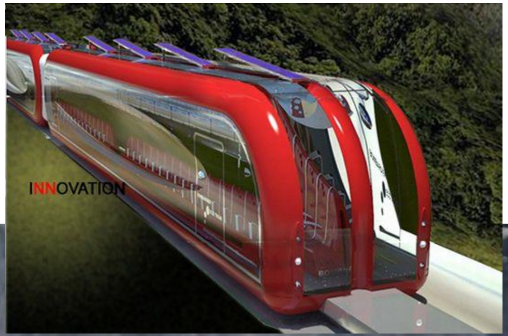
KTH, Vehicle engineering,

Mikael Nybacka, KTH

Master programme in Vehicle Engineering

Mikael Nybacka
Associate Professor in Vehicle Dynamics
Programme Director for Vehicle Engineering

Future of Vehicle Engineering – Exciting and needed transformation going on – requiring engineers!



- Flexible
- Environmental friendly
- Safe
- Cheep
- Personal
- Comfortable
- Secure
- Fast
- Integrated
- Just
- …

Master programme in Vehicle Engineering

- Some quick facts

Two-year programme (120 ECTS credits) given in English

Two tracks, **road** and **rail** vehicles

600-700 applicants and ~**300** 1st hand applicants over the last 5 years

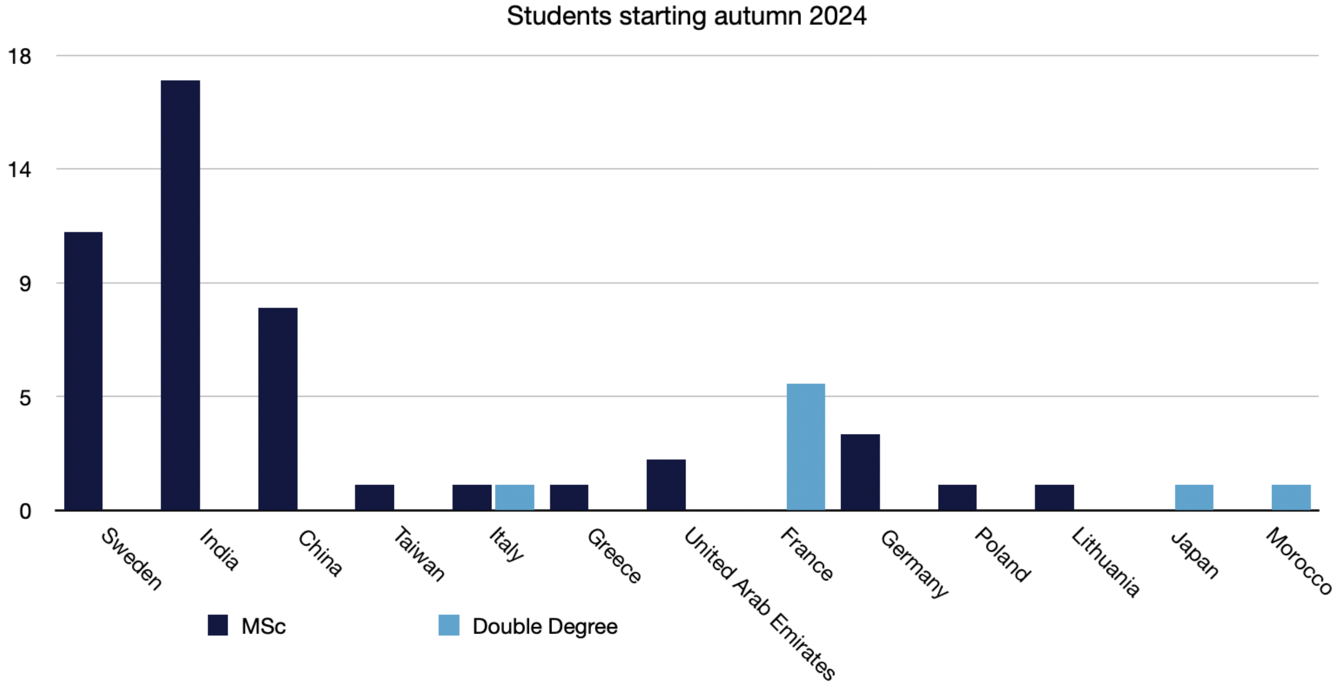
Admitted 45 students 2024 (~**15%** acceptance rate from 1st hand applicants of int. master intake)

Total amount of student / year = **45-55**

Around **1/3 Swedish** and **2/3 international** students

13 Nationalities 2024

~5 female students / year (we want more to apply!)



Entry requirements

- A bachelor's degree or comparable qualification equivalent to a Swedish bachelor's degree from an internationally recognised university. 180 ECTS
- English proficiency, IELTS Academic or IELTS UKVI: An overall score of 6.5, with no selection lower than 5.5
  - Or other like TOEFL, ECPE, PTE, ESOL
- Specific documents for Vehicle Engineering
  - Summary Sheet (IMPORTANT)
- Selection criteria
  - Study results (grades, relevant subjects and English) motivation for studies (motivation letter) and prior education.
  - Prior education is evaluated based on the quality and suitability of the subjects that are relevant for the programme applied to. The merit rating is carried out on a scale of 1-75.

- Specific requirements:
- Mathematics and Programming, equivalent to approximately 25 ECTS credits in total, which must include courses or course modules in differential equations.
- Applied mechanics, equivalent to approximately 20 ECTS credits in total, which must include courses or course modules in solid mechanics.

Mapping of programmes at KTH and prerequisites

- **Farkostteknik**
- **Teknisk fysik**

OK

- **Maskinteknik and Design & Produktframtagning:**
  - Reglerteknik grundkurs
  - (Rekommenderat att även ha läst Strömningslära och Ljud och vibrationer; kan läsas inom Masterprogrammet)

Conditional elective courses in these topic areas, choose any course from any topic area

Vehicle control and robotics
MF2030: Mechatronics basic course
MF2043: Robust mechatronics
MF2007: Dynamics and Motion Control
EL2520: Control Theory and Practice, Adv.
SD2231: Applied Vehicle Dynamics Control
EL2700: Model Predictive Control
SD2230: Vehicle Dynamics Project course (Part 2)

SM2001 Data-driven Methods in Engineering Mechanics 7.5 credits

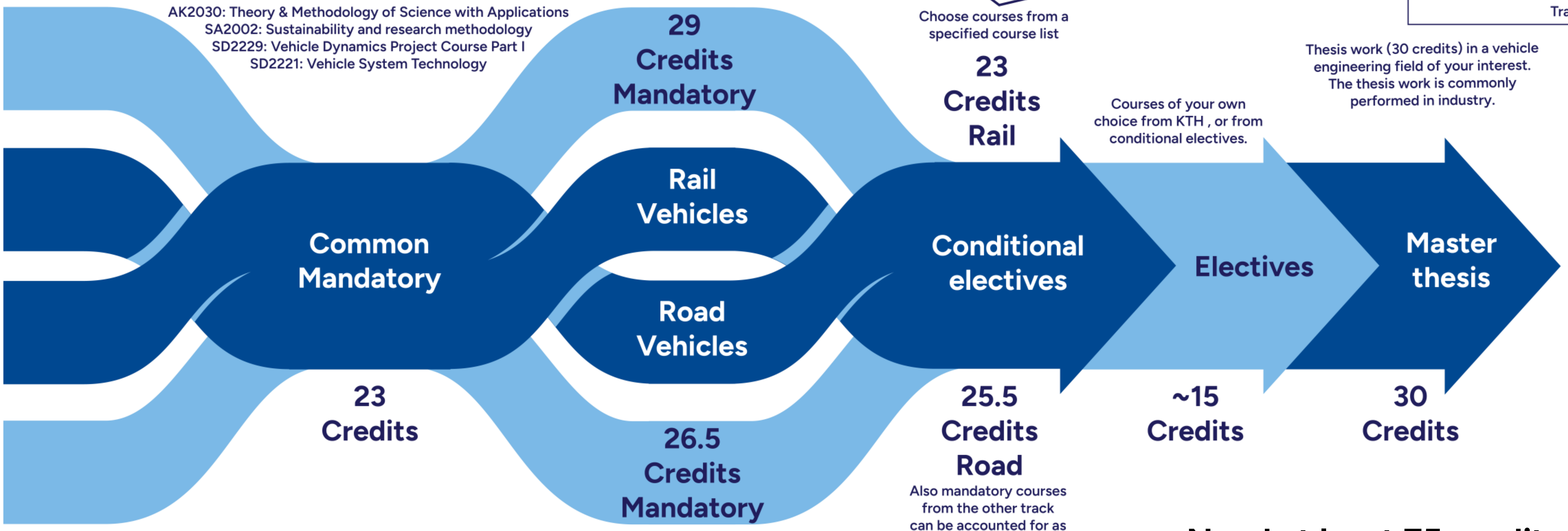
Vehicle structures and design
SD2411: Lightweight Structures and FEM
SD2150: Experimental Structure Dynamics
SD2416: Structural Optimisation and Sandwich Design
SD2190: Vehicle Acoustics and Vibration
SD2111: Engineering acoustics
SD2250: Sustainable vehicle design
SD2230: Vehicle Dynamics Project course (Part 2)

Vehicle aerodynamics and acoustics
SD2155: Flow Acoustics
SG2211: Vehicle Aerodynamics
SD2625: Comp. Vehicle Aerodynamics
SG1217: Fluid mechanics, basic course
SG1220: Fluid mechanics for engineers
SG2214: Fluid Mechanics
SD2250: Sustainable vehicle design
SD2230: Vehicle Dynamics Project course (Part 2)

Transport system
AH2307: Urban modelling and decision
AH2171: Traffic Engineering Management
AH2170: Transport Data Collection and Analysis
AH2174: Traffic Simulation Modelling and Application
AH2173: Public transport

Electric mobility
MF2030: Mechatronics basic course
SD2250: Sustainable vehicle design
CK2300: Batteries
CK2320: Hydrogen
SD2230: Vehicle Dynamics Project course (Part 2)
MJ2506: Energy Technologies for Sustainable Transportation

AH2029: Railway Signalling System
SD2307: Rail Vehicle Technology
SD2313: Rail Vehicle Dynamics
EJ2440: Electric Transportation



Also mandatory courses from the other track can be accounted for as conditionally electives.

SD2222: Vehicle Components
SD2225: Road Vehicle Dynamics
EJ2410: Hybrid Vehicle Drives

Need at least 75 credits Mandatory + Conditional electives

Mandatory courses

ROAD

	Year 1				Year 2			
	1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
ROAD	AK2030 Theory & science 4.5 hp	EJ2410 Hybrid vehicle drives 7.5 hp				SA2002 Sustainable dev. & research methods 3.0 hp	SD221X Master thesis 30 hp	
	SD2221 Vehicle system technology 8 hp	SD2222 Vehicle components 8 hp	SD2225 Road vehicle dynamics 11 hp		SD2229 Vehicle dynamic project Part I 7.5 hp			

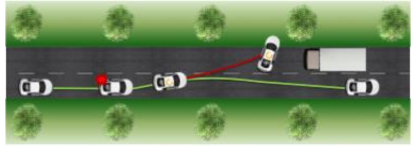
RAIL

	1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
RAIL	AK2030 Theory & science 4.5 hp				AH2029 Railway signalling systems 7.5 hp	SA2002 Sustainable dev. & research methods 3.0 hp	SD231X Master thesis 30 hp	
	SD2221 Vehicle system technology 8 hp	SD2307 Rail vehicle technology 7.5 hp	SD2313 Rail vehicle dynamics 8 hp	EJ2400 Electric traction 6 hp	SD2229 Vehicle dynamic project Part I 7.5 hp			

Legend:
- mandatory
- mandatory, but can be read during 1st or 2nd year
- mandatory, can be read in any study period

Road - Control focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
MF2030 Mechatronics Basic course 6hp	EJ2410 Hybrid Vehicle drives 7.5hp	EL2450 Hybrid and Embedded Control Systems 7.5hp	SD2231 Applied Vehicle Dynamics Control 7.5 hp	EL2700 Model Predictive Control 7.5 hp	MF2007 Dynamics and motion Control 7.5 hp	SD221X Master thesis 30 hp	
AK2030 Theory & science 4.5hp	SA2002 Sustainable dev. research methods 3hp						
SD2221 Vehicle system technology 8 hp	SD2222 Vehicle components 8 hp	SD2225 Road vehicle dynamics 11 hp		SD2229 Vehicle dynamic project Part I 7.5 hp	SD2230 Vehicle dynamic project Part 2 7.5 hp		



Conditionally electives
Free course

Some examples, but can be other Course selections and setups as well

Road - Electric powertrain focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
MF2030 Mechatronics Basic course 6 hp	EJ2410 Hybrid Vehicle drives 7.5hp	CK2320 Hydrogen 7.5 hp	EJ2400 Electric traction 6 hp	SD2250 Sustainable vehicle design 7.5 hp	SD2230 Vehicle dynamic project Part 2 7.5 hp	SD221X Master thesis 30 hp	
AK2030 Theory & science 4.5hp	SA2002 Sustainable dev research methods 3hp						
SD2221 Vehicle system technology 8 hp	SD2222 Vehicle components 8 hp	SD2225 Road vehicle dynamics 11 hp		SD2229 Vehicle dynamic project Part I 7.5 hp	CK2300 Batteries 7.5 hp		

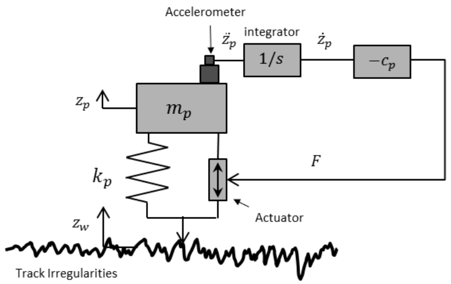
Road - Design focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
SD2111 Engineering Acoustics 6 hp	EJ2410 Hybrid Vehicle drives 7.5hp	SD2125 Experimental structure dynamics 9 hp		SD2250 Sustainable vehicle design 7.5 hp	SD2416 Structural Optimisation and Sandwich Design 6 hp	SD221X Master thesis 30 hp	
AK2030 Theory & science 4.5hp	SA2002 Sustainable dev. research methods 3hp						
SD2221 Vehicle system technology 8 hp	SD2222 Vehicle components 8 hp	SD2225 Road vehicle dynamics 11 hp		SD2229 Vehicle dynamic project Part I 7.5 hp	SD2230 Vehicle dynamic project Part 2 7.5 hp		

KTH VETENSKAP OCH KONST

Rail - Control focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
MF2030 Mechatronics Basic course 6hp AK2030 Theory & science 4.5hp	SA2002 Sustainable dev. & research methods 3 hp	SD2313 Rail vehicle dynamics 8 hp	EJ2400 Electric traction 6 hp	EL2700 Model Pred. Control 7.5 hp AH2029 Railway signalling sys. 7.5 hp	MF2007 Dynamics and motion Control 7.5 hp	SD231X Master thesis 30 hp	
SD2221 Vehicle system technology 8 hp	SD2307 Rail vehicle technology 7.5 hp	EL2450 Hybrid and Embedded Control Systems 7.5hp	SD2231 Applied Vehicle Dynamics Control 7.5 hp	SD2229 Vehicle dynamic project Part I 7.5 hp	SD2230 Vehicle dynamic project Part 2 7.5 hp		



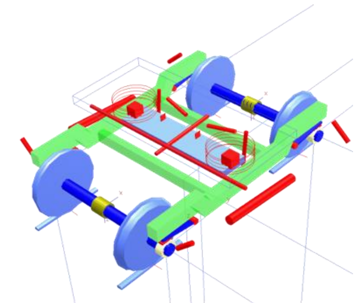
Conditionally electives
Free course

Rail - Traffic focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
AH2170 Transport Data Collection and an. 7.5 hp AK2030 Theory & science 4.5hp	AF2901 Road and Rail. Track Engine. 7.5 hp SA2002 Sustainable dev. research methods 3hp	SD2313 Rail vehicle dynamics 8 hp	EJ2400 Electric traction 6 hp	AH2029 Railway signalling system 7.5 hp	AH2028 Railway traffic market and planning advanced course 7.5 hp	SD231X Master thesis 30 hp	
SD2221 Vehicle system technology 8 hp	SD2307 Rail vehicle technology 7.5 hp	AH2301 Transport Policy and Evaluation 7.5 hp	AH2173 Public Transport 7.5 hp	SD2229 Vehicle dynamics project Part I 7.5 hp	AH2171 Traffic Engineering Managem. 7.5 hp		

Rail - Dynamics focus

1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4
AK2030 Theory & science 4.5 hp	SA2002 Sustainable dev. & research methods 3 hp	SD2313 Rail vehicle dynamics 8 hp	EJ2400 Electric traction 6 hp	AH2029 Railway signalling system 7.5 hp	MF2007 Dynamics and motion Control 7.5 hp	SD231X Master thesis 30 hp	
SD2221 Vehicle system technology 8 hp	SD2307 Rail vehicle technology 7.5 hp	SD2125 Experimental structure dynamics 9 hp		SD2229 Vehicle dynamics project Part I 7.5 hp	SD2230 Vehicle dynamics project Part 2 7.5 hp		



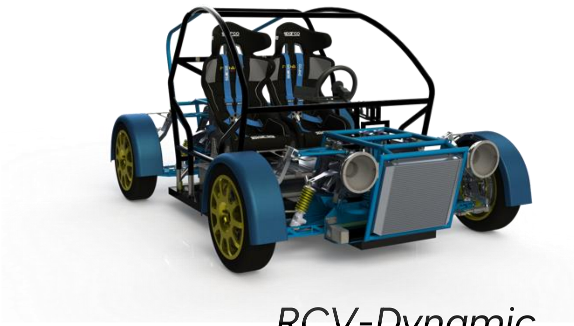
Experimental vehicles, equipment and test tracks

Volvo V60 Plug-in Hybrid

Roller rig

Arlanda test track

Drive Lab 1 and 2



RCV-Dynamic

Research
Concept Vehicles

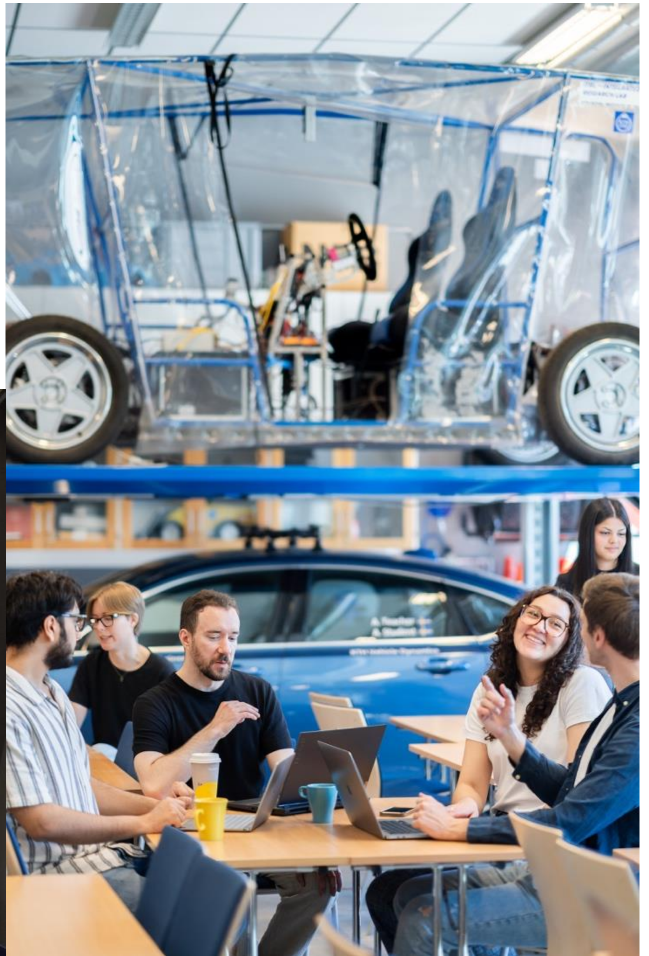
RCV-E

Driving simulators

Lunda flygfält

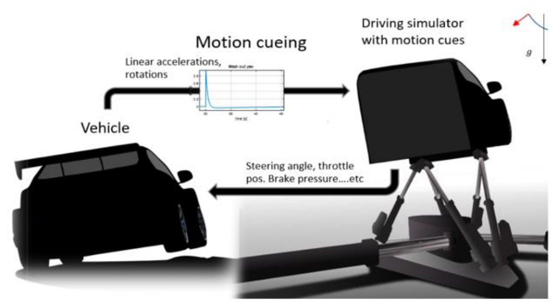
Vehicle Engineering Lab

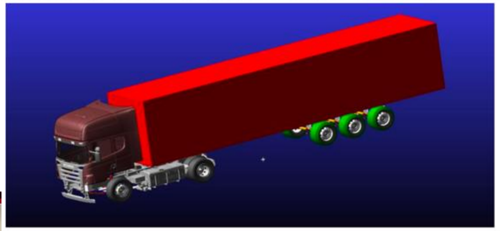
- Education
- Experiments
- Computer exercises
- Studies on your own

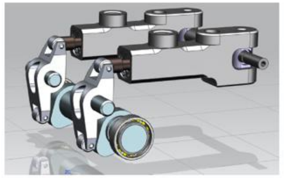


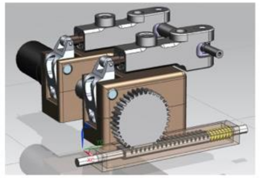
Project course final year

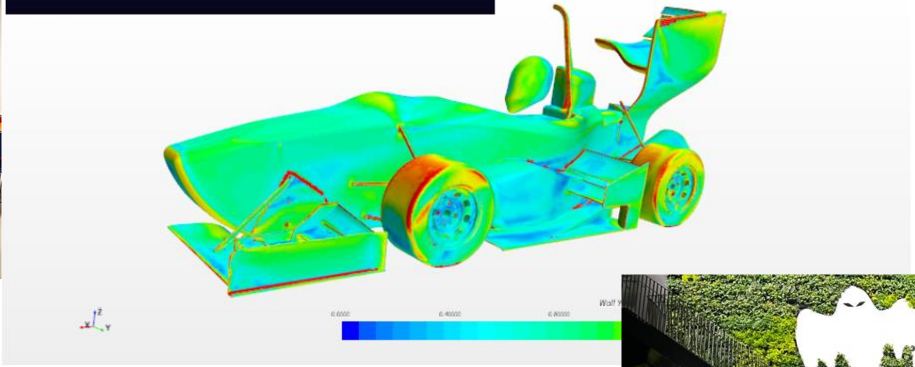
Companies send project ideas to mnybacka@kth.se in June the latest

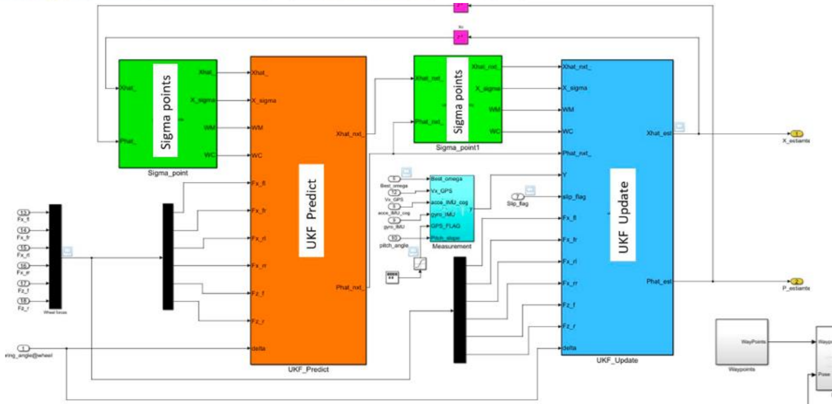


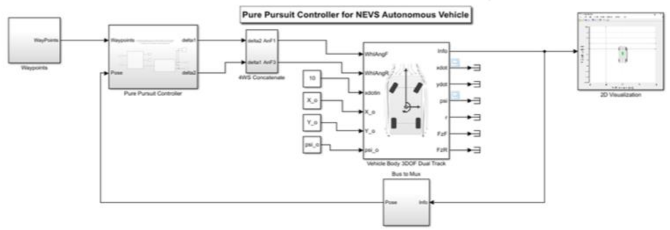


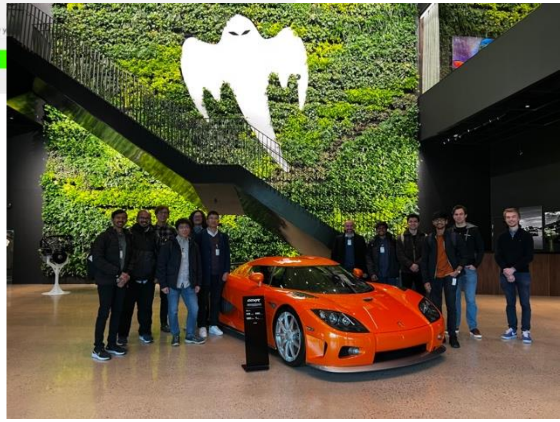












Exchange

- There are several universities around the world you can choose from on the link below, but you need to check that they have courses that are similar to the programme courses that period:
  - https://www.kth.se/student/studier/utlandsstudier/utbyte/utbytesuniversitet-skolan-for-teknikvetenskap-1.590700

- Best period for exchange is autumn second year.

- Best period for exchange is Autumn in second year.
  - Austria: Technische Universität Graz
  - Netherlands: Technische Universiteit Delft
  - Netherlands: Technische Universiteit Eindhoven: Universitat Politècnica de Catalunya
  - Italy: Politecnico di Torino
  - Spain: Universitat Politècnica de Catalunya
  - Tyskland: Technische Universität Berlin
  - Tyskland: Technische Universität Braunschweig
  - Tyskland: Technische Universität München
  - Tyskland: Universität Stuttgart
  - USA: University of Illinois at Urbana-Champaign
  - USA: University of Texas at Austin
  - …
- New double degree exchange programme with Beijing Jiaotong University (BJTU)
  - One year at KTH and one year at BJTU
- Contact: exchange-out@sci.kth.se

Questions?

Mikael Nybacka
Programme director

mnybacka@kth.se

Research groups ***Rail vehicles***, ***Vehicle dynamics***, ***Aero dynamics*** and ***Conceptual vehicle design***
At the division of Vehicle Engineering and Solid Mechanics

info@kth.se – accommodation, KTH user account, anything else.

master@sci.kth.se – study plans, courses, etc.

www.kth.se/en/studies/master/vehicleengineering

Presentation 7b:

Chalmers, Mobility engineering & Systems, Control and Mechatronics,

Jonas Bärgman and Jonas Fredriksson,
presented by Bengt Jacobson, Chalmers

Chalmers gives 2 MSc programmes

These slides and presentation is by Bengt Jacobson,
based on some relatively new presentations from: **Dag Henrik Bergsjö** and **Jonas Fredriksson**

Presentation scope:

- for Chalmers' MSc programme update for starters **from autumn 2027**
- with **explicit automotive (road & ground vehicle) contents**.

MSc programmes:	**Mobility engineering, MSc** 120 credits	**Systems, control and mechatronics, MSc** 120 credits

***Specializations:**	**Aerospace engineering** **Automotive engineering** **Specialization: Marine technology** **Specialization : Railway technology**	**...** **...** **Vehicle Dynamics Control** **...**

*) *Formalized (!) from 2027*

MPMOB and MPSYS with Compulsory courses

	year 1 (or 3)				year 2 (or 5)			
	period 1	2	3	4	1 (sept-oct)	2	3	4 (apr-may)
MPMOB	Systems and mechatronics for mobility engineering; Introduction to propulsion and energy systems for transport						Master Thesis	
MPSYS	Modelling and learning for dynamical systems; Applied signal processing	Linear control systems		Design of cyber-physical systems			Master's thesis	

Courses for **MPMOB.Automotive**

Compulsory

- Systems and mechatronics for mobility engineering
- Introduction to propulsion and energy systems for transport
- Vehicle Motion Engineering
- Vehicle and traffic safety

Elective | Elective | Elective | Elective

Elective | Elective | Elective | Elective

Master Thesis

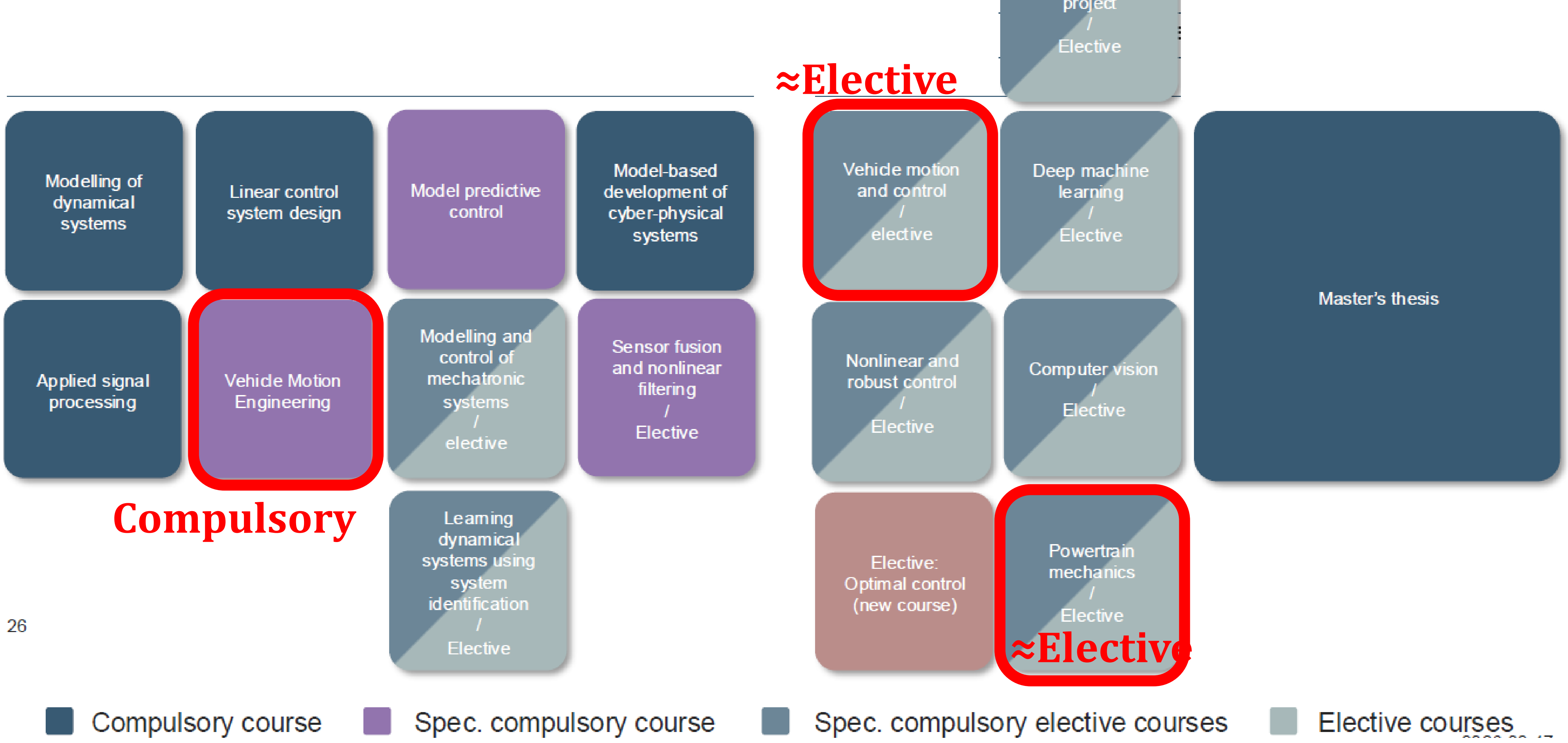
Examples of "**Elective**" from MPMOB:

(Note: also course from MPSYS are Elective for MPMOB)

- **Vehicle Motion and Control**
- **Powertrain mechanics**
- **Road Vehicle Aerodynamics**
- **Electric and Hybrid Vehicles**
- **Chalmers formula student**
- **Automotive Engineering Project**

MPSYS.VehicleDynamicsControl

Courses from MPMOB in red



Reserve slide: Courses for MPMOB.Automotive

Course code	Course Name (linked)	Examiner	In specialisaiton:	credits
MMS196	Introduction to propulsion and energy systems for transport	Tomas Grönstedt	MPMOB Compulsory	7,5 hp
EEN130	Systems and mechatronics for mobility engineering	Jonas Fredriksson	MPMOB Compulsory	7,5 hp
MMS210	Connected fleets in data-driven engineering	Ola Benderius	MPMOB Generic	7,5 hp
EEN140	Electric drive systems for vehicles and vessels	Stefan Lundberg	MPMOB Generic	7,5 hp
EEN135	Electric machines for vehicles and vessels	Sonja Lundmark	MPMOB Generic	7,5 hp
IMS105	Fundamentals of systems engineering	Dag Bergsjö	MPMOB Generic	7,5 hp
TME192	Active safety	Marco Dozza	Automotive Engineering	7,5 hp
TME180	Automotive engineering project	Alexey Vdovin	Automotive Engineering	15,0 hp
TME047	Chalmers formula student	Björn Pålsson	Automotive Engineering	15,0 hp
TME095	Electric and Hybrid Vehicles	David Sedarsky	Automotive Engineering	7,5 hp
TME196	Impact biomechanics	Johan Davidsson	Automotive Engineering	7,5 hp
MTF242	Internal combustion engines	Petter Dahlander	Automotive Engineering	7,5 hp
TME170	Powertrain mechanics	Petter Dahlander	Automotive Engineering	7,5 hp
MTF236	Road vehicle aerodynamics	Simone Sebben	Automotive Engineering	7,5 hp
TME202	Vehicle and traffic safety	Jonas Bärgman	Automotive Engineering	7,5 hp
TME102	Vehicle motion and control	Mats Jonasson	Automotive Engineering	7,5 hp
MMF062	Vehicle motion engineering	Bengt Jacobson	Automotive Engineering	7,5 hp

Course code	Course Name (linked)	Examiner	In specialisaiton:	credits
MMS196	Introduction to propulsion and energy systems for transport	Tomas Grönstedt	MPMOB Compulsory	7,5 hp
TME180	Automotive engineering project	Alexey Vdovin	Automotive Engineering	15,0 hp
TME047	Chalmers formula student	Björn Pålsson	Automotive Engineering	15,0 hp
MMA169	Structural engineering	Jonas Ringsberg	Naval Architecture	7,5 hp
SJO747	Wave loads and seakeeping	Martin Schreuder	Naval Architecture	7,5 hp

Reserve slide 1(of2): MPSYS.VehicleDynamicsControl

Specialisations

Communication and sensing - Create reliable, high-performance systems that sense the world and communicate information seamlessly.

Decision and control - Master the methods that power high-performance control and real-time decision-making in dynamic systems.

Electromobility - Shape the future of electric transportation by mastering battery systems, electric drives, and vehicle control.

Intelligent automation - Develop advanced automation solutions using high-level planning, simulation, and optimisation for modern industry.

Mechatronics - Design smart electro-mechanical systems by integrating mechanics, electric drives, control, and energy storage.

Robot learning - Build intelligent robots that can sense, plan, and act autonomously in real-world environments.

Vehicle dynamics control - Engineer safe, stable, and intelligent vehicles through advanced modelling, estimation, and control of vehicle dynamics.

Reserve slide 2(of2): MPSYS.VehicleDynamicsControl

The specialisation focuses on applying control to vehicle dynamics, a key foundation for designing modern automotive systems such as active safety functions and automated driving. This includes how sensing, decision-making, and actuation work together to ensure safe and stable vehicle motion. The courses provide in-depth knowledge of vehicle modelling, estimation, and control methods used in applications ranging from stability control to autonomous driving.

Compulsory courses:

- Model predictive control (SSY286)
- Sensor fusion and nonlinear filtering (SSY345)
- Vehicle motion engineering (MMF062)

Compulsory elective courses (at least 1 out of):

- Capstone project in Systems, Learning and Control (SSY226, new name)
- Computer vision (EEN020)
- Deep machine learning (SSY340)
- Learning dynamical systems using system identification (SSY230)
- Modelling and control of mechatronic systems (SSY156)
- Optimal control (new course)
- Powertrain mechanics (TME170)
- Vehicle motion and control (TME102)

Vehicle dynamics control

Year 1				Year 2			
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Modelling and learning for dynamical systems	Linear control systems	Model predictive control	Design of cyber-physical systems	Vehicle motion and control / elective	Optimal control / Elective	Master's thesis	
Applied signal processing	Vehicle Motion Engineering	Modelling and control of mechatronic systems / elective	Sensor fusion and nonlinear filtering	Nonlinear and robust control / Elective	Computer vision / Elective		
		Learning dynamical systems using system identification / Elective		Deep machine learning / Elective	Powertrain mechanics / Elective		
					Capstone project / Elective		

Compulsory course | Spec. compulsory course | Spec. compulsory elective courses | Elective courses

Slide <u>not</u> planned for presentation; maybe input to Q&A

Automotive outside MSc programmes:

- **First 3 years** in civilingenjörs education does hardly contain any automotive
  - Even if we try to dedicate some **BSc thesis** (kandidatarbeten) to automotive

- **PhD** graduate schools (e.g. Machine and Vehicle Systems)
- **PhD** courses
- Courses given **for industry in industry**
- **Stand-alone/single courses** can be taken by engineers in industry

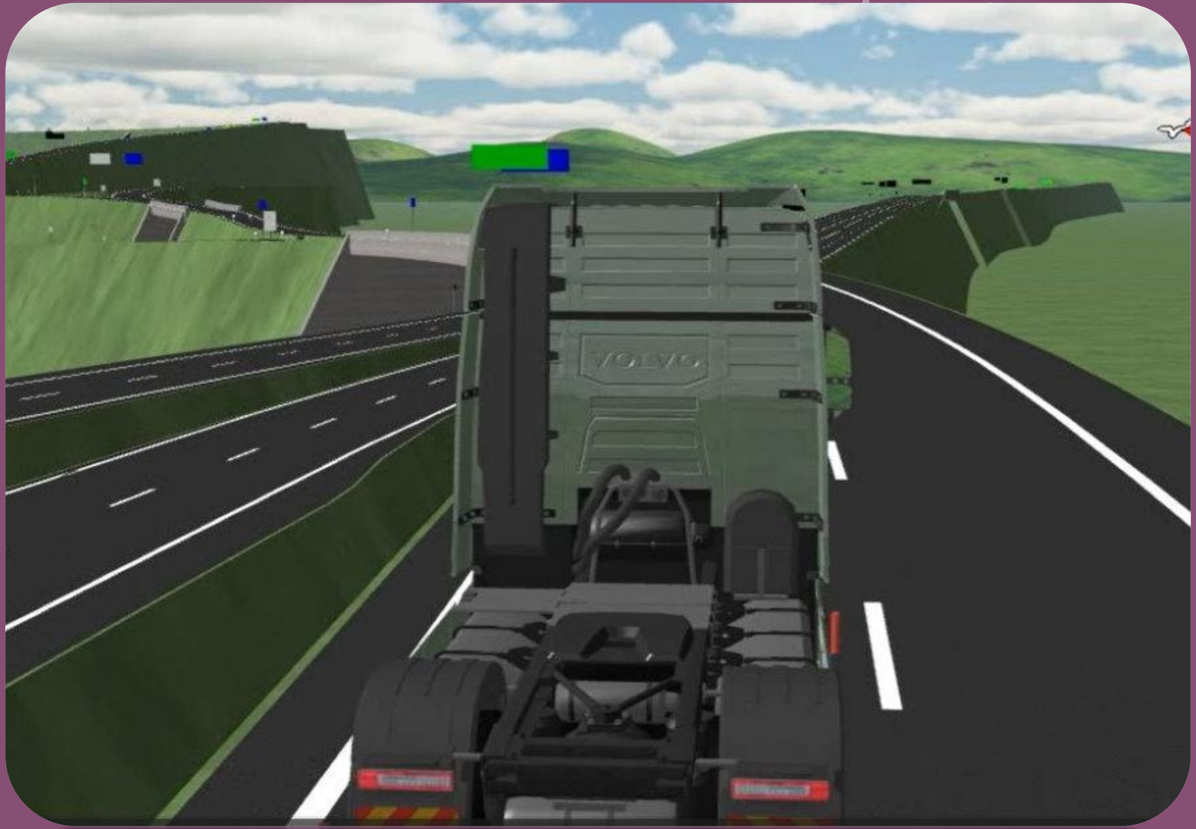
- **Double degree**, mainly MSc degree, but also PhD degree exists
- Master theses can be ways to cooperate (or “steal” students) **between universities**.
  - Examples (from Chalmers.VehDyn):
    - KTH.VehDyn and Chalmers.VehDyn
    - HAN.Automotive and Chalmers.VehDyn
    - TU Delft and Chalmers.VehDyn

Poster 1:

Development environments for route based functions in road vehicles,

Victor Andersson, Chalmers

Development environments for route based functions in road vehicles



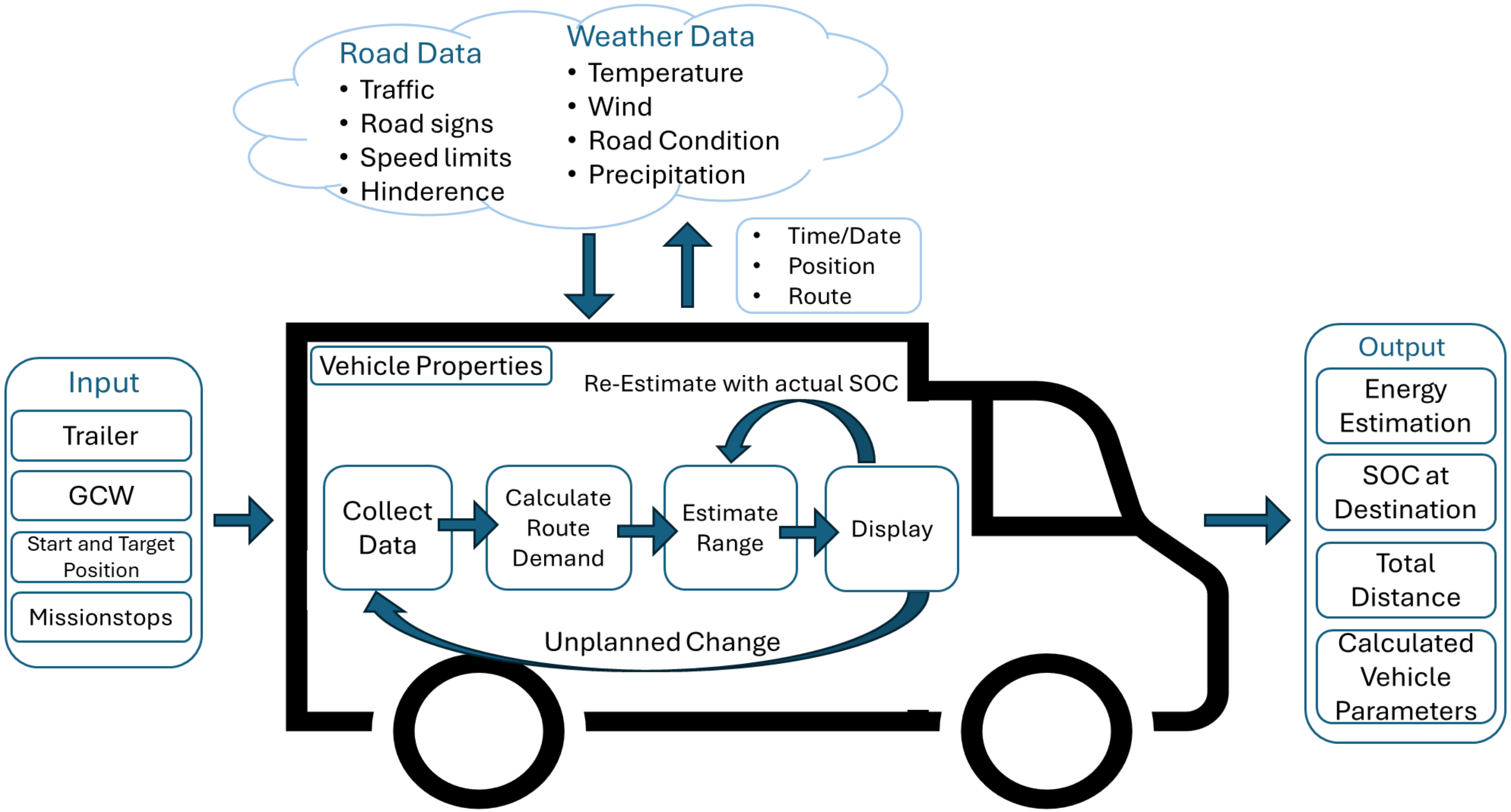
Victor Andersson
Master’s Programme in Mobility Engineering
Chalmers university of technology

CHALMERS

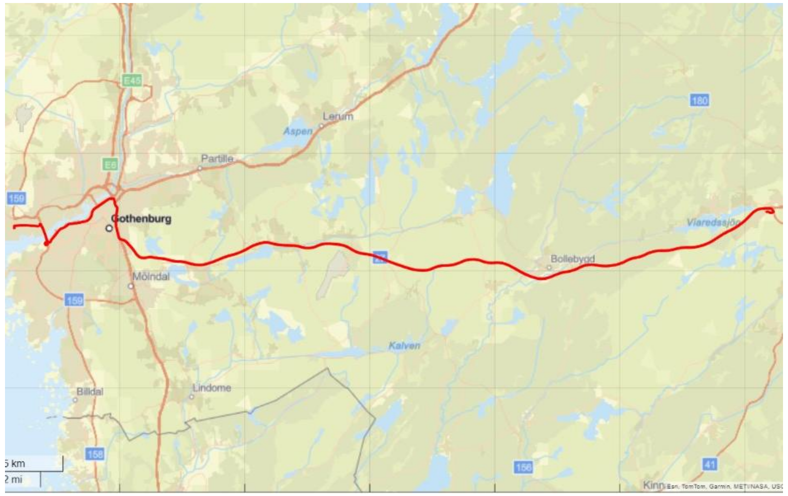
Short Description

- Uses road data from HERE
- Simulation environment in TruckMaker for route-based energy prediction
- Predicts vehicle range and state of charge (SoC) from road data
- Analyzes impact of re-estimation frequency on accuracy
- Investigates effects of parameter changes
- Develop testbench for real vehicle

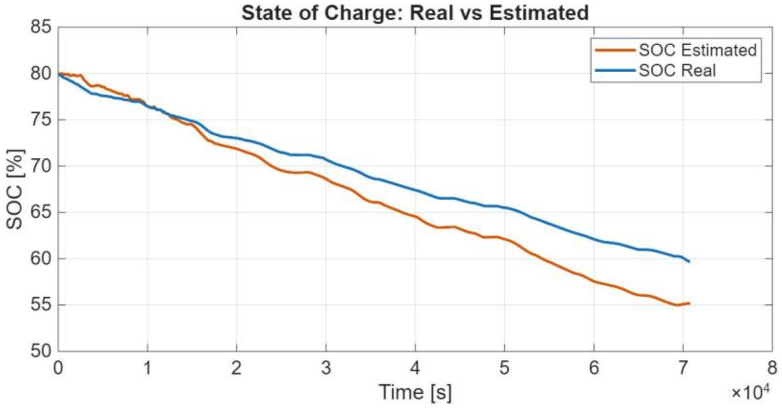
Considerations for range estimators

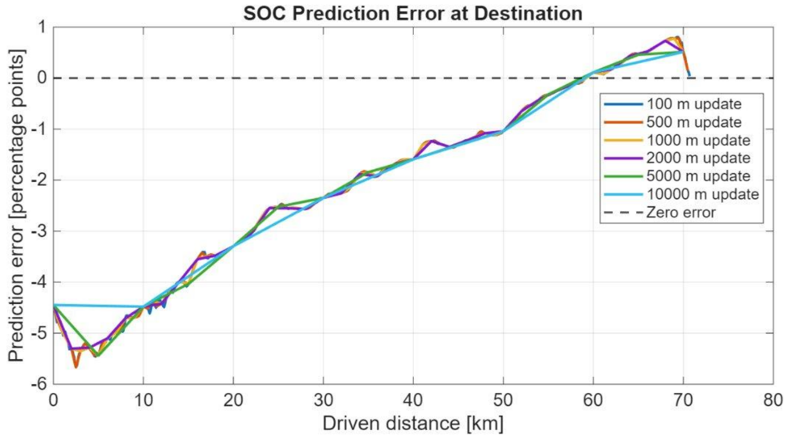


Results


Gothenburg
Partille
Lerum
Aspen
Mölndal
Bollebygd
Kalven
Lindome
Billdal


Vehicle Speed: Real vs Estimated
Speed Estimated
Speed Real
Speed [km/h]
Time [s]
×10^4


State of Charge: Real vs Estimated
SOC Estimated
SOC Real
SOC [%]
Time [s]
×10^4


SOC Prediction Error at Destination
100 m update
500 m update
1000 m update
2000 m update
5000 m update
10000 m update
Zero error
Prediction error [percentage points]
Driven distance [km]

Development environments for route based functions in road vehicles

Examiner: Bengt Jacobson   Supervisor: Carl Emvin

CHALMERS

Victor Andersson
Chalmers Tekniska Högskola
Mobility Engineering
Contact:
Victoand@chalmers.se
Tel: 072 310 61 93

Background

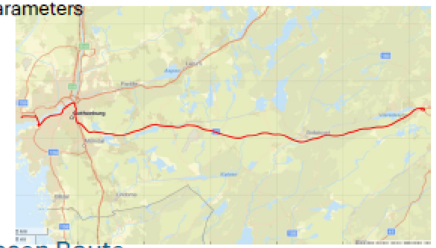
The transition to battery-electric heavy-duty trucks is accelerating, but adoption remains limited due to concerns about range, charging infrastructure, and operational reliability. Haulage companies face uncertainties regarding charging availability, battery capacity, and vehicle performance, creating significant "range anxiety" and slowing the shift toward sustainable freight transport.

Problem Definition

Accurate range prediction is essential for planning electric truck operations and reducing perceived risk. Energy consumption depends on factors such as payload, topography, weather, driving behavior, and auxiliary systems, making prediction difficult with simple models. This project aims to develop and evaluate a predictive, data-driven range estimation framework and test environment for battery-electric heavy-duty trucks, supporting more reliable and efficient transport operations.

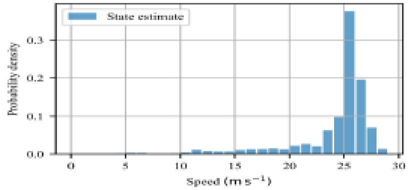
Aim/Objective

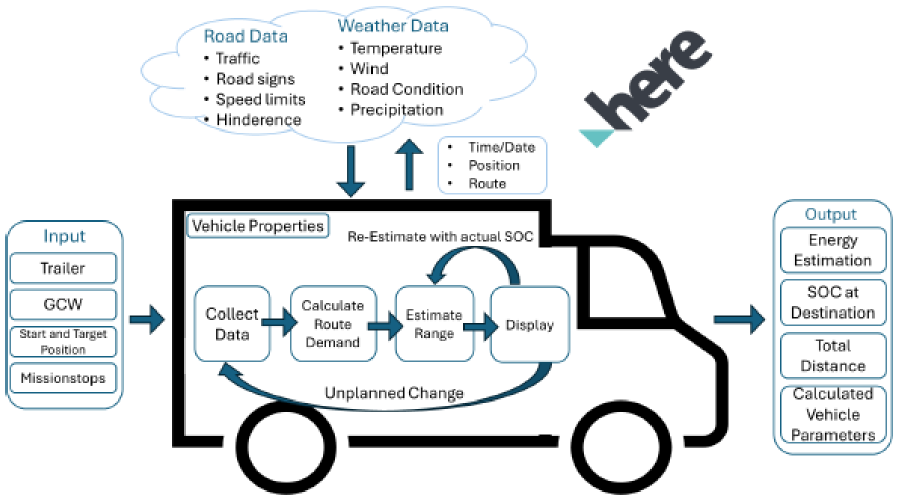
- Developed a simulation environment in TruckMaker for route-based energy prediction
- Integrated road and map data from HERE Technologies
- Predicted vehicle range and battery state of charge (SoC)
- Evaluated how re-estimation frequency affects prediction accuracy
- Investigated the impact of varying vehicle and environmental parameters



Chosen Route

The chosen route is Gothenburg harbour to Viared near Borås. This route is chosen since it is a common driven route that is not too long to simulate, but also long enough to get different conditions and valid results



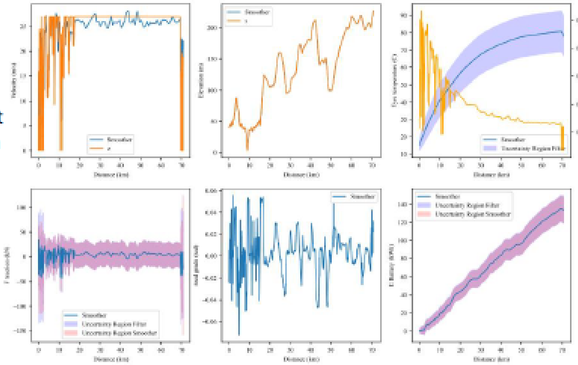


Simulation Platform (TruckMaker)

A predictive range estimation framework was developed in TruckMaker using a Simulink-based heavy-duty vehicle model. The environment enabled route-based energy prediction using road and mission data from HERE Technologies under varying operating conditions.

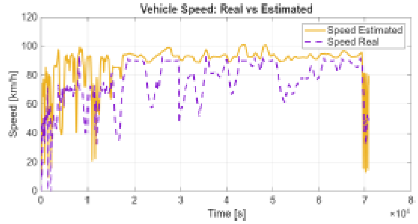
Range Estimator

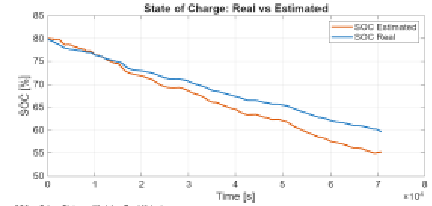
The predictive range estimator was developed based on research conducted within the U-Feel project at Chalmers University of Technology. The main estimation framework and algorithms build upon previous work by PhD student Carl Emvin on energy consumption estimation for battery-electric heavy-duty vehicles. The estimator predicts vehicle energy consumption and remaining state of charge along a planned route using route, vehicle, and environmental data.

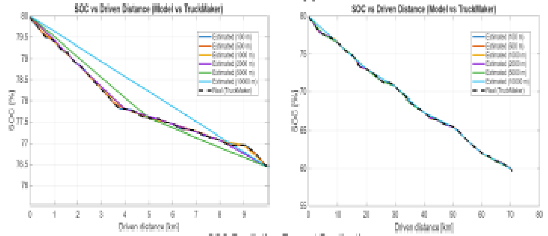


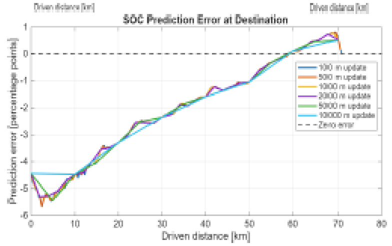
Results

The results show that estimation accuracy is influenced by re-estimation frequency, route conditions, and varying vehicle and environmental parameters.









Future Work

- Compare with log from Revere
- Validate both simulation model and Range Predictor, Try different routes
- Possibly try real truck at REVERE
- Changing parameters mid route, ex. Stops, GCW etc.
- Add real weather data

Development environments for route based functions in road vehicles

Examiner: Bengt Jacobson Supervisor: Carl Emvin

Victor Andersson
Chalmers Tekniska Högskola
Mobility Engineering
Contact:
Victoand@chalmers.se
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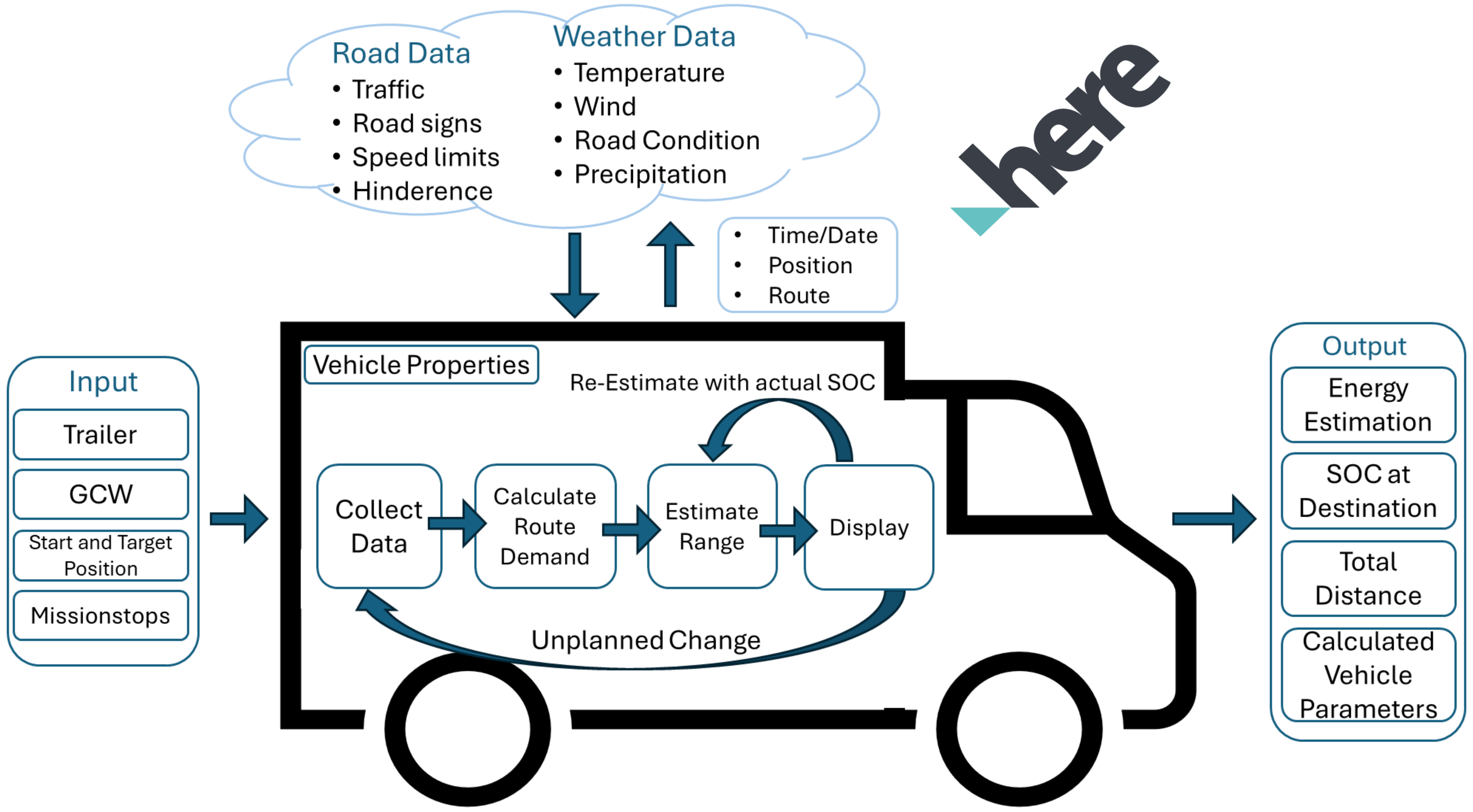

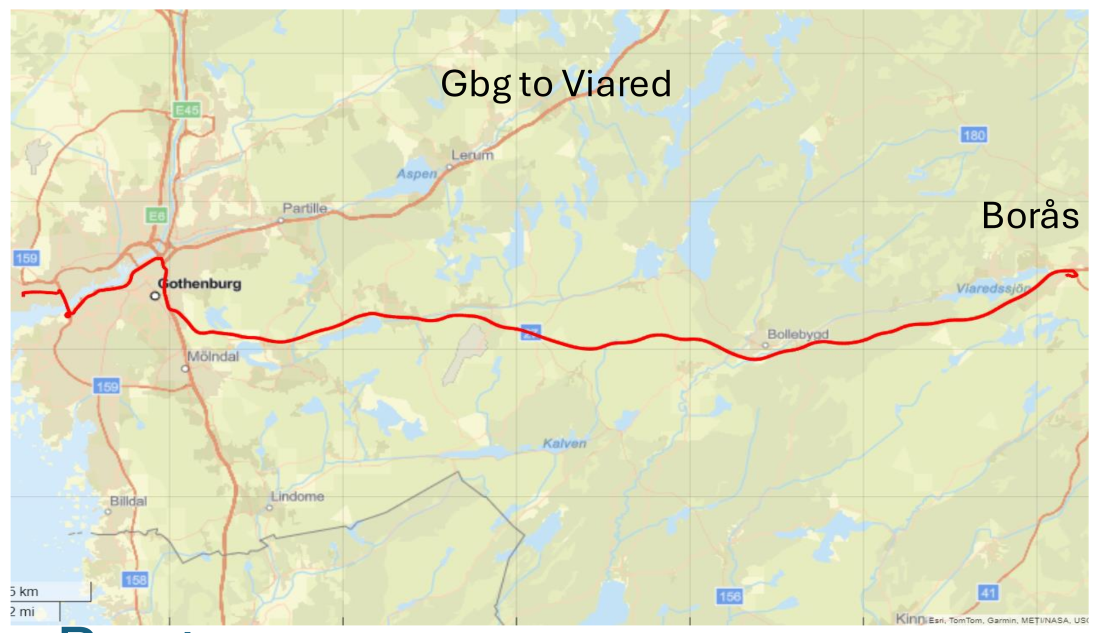

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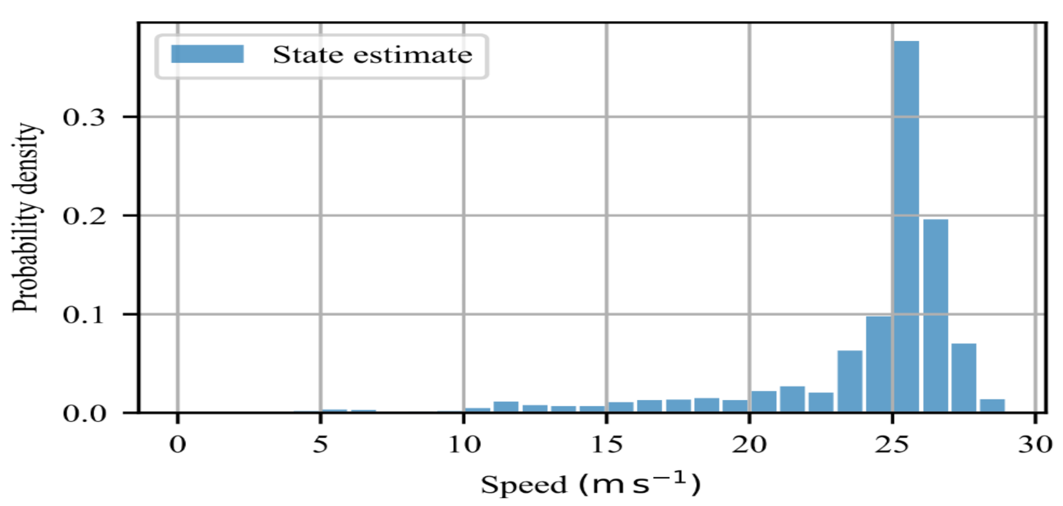

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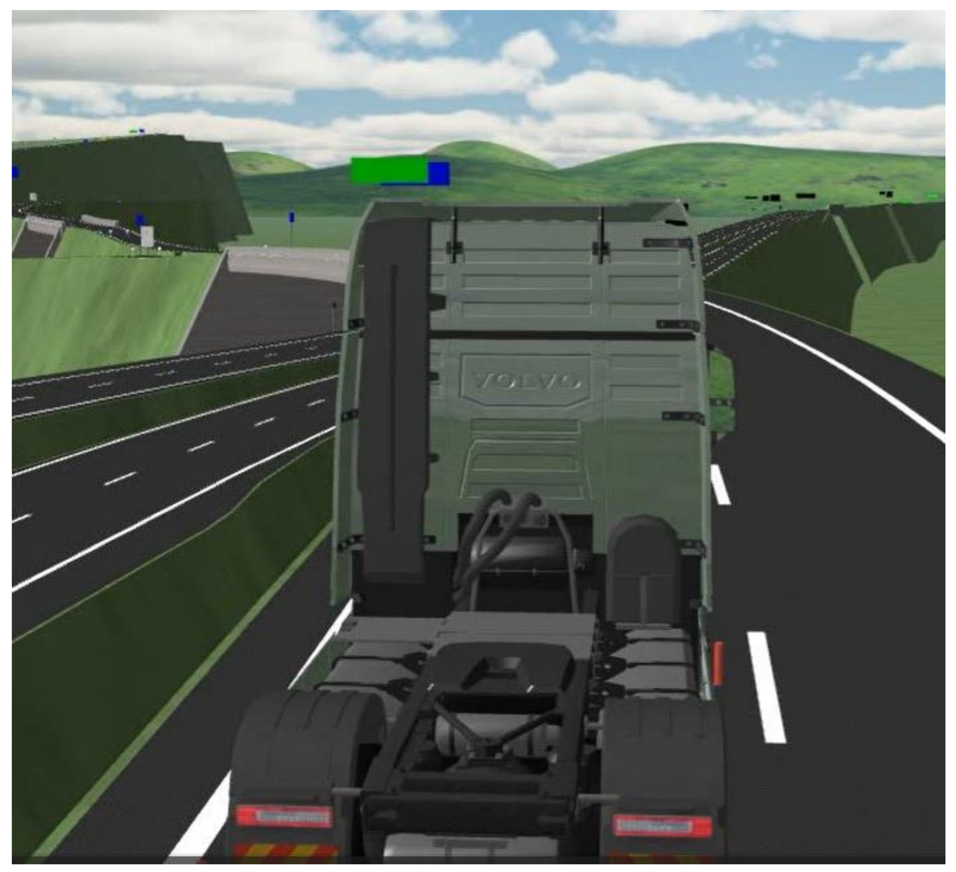

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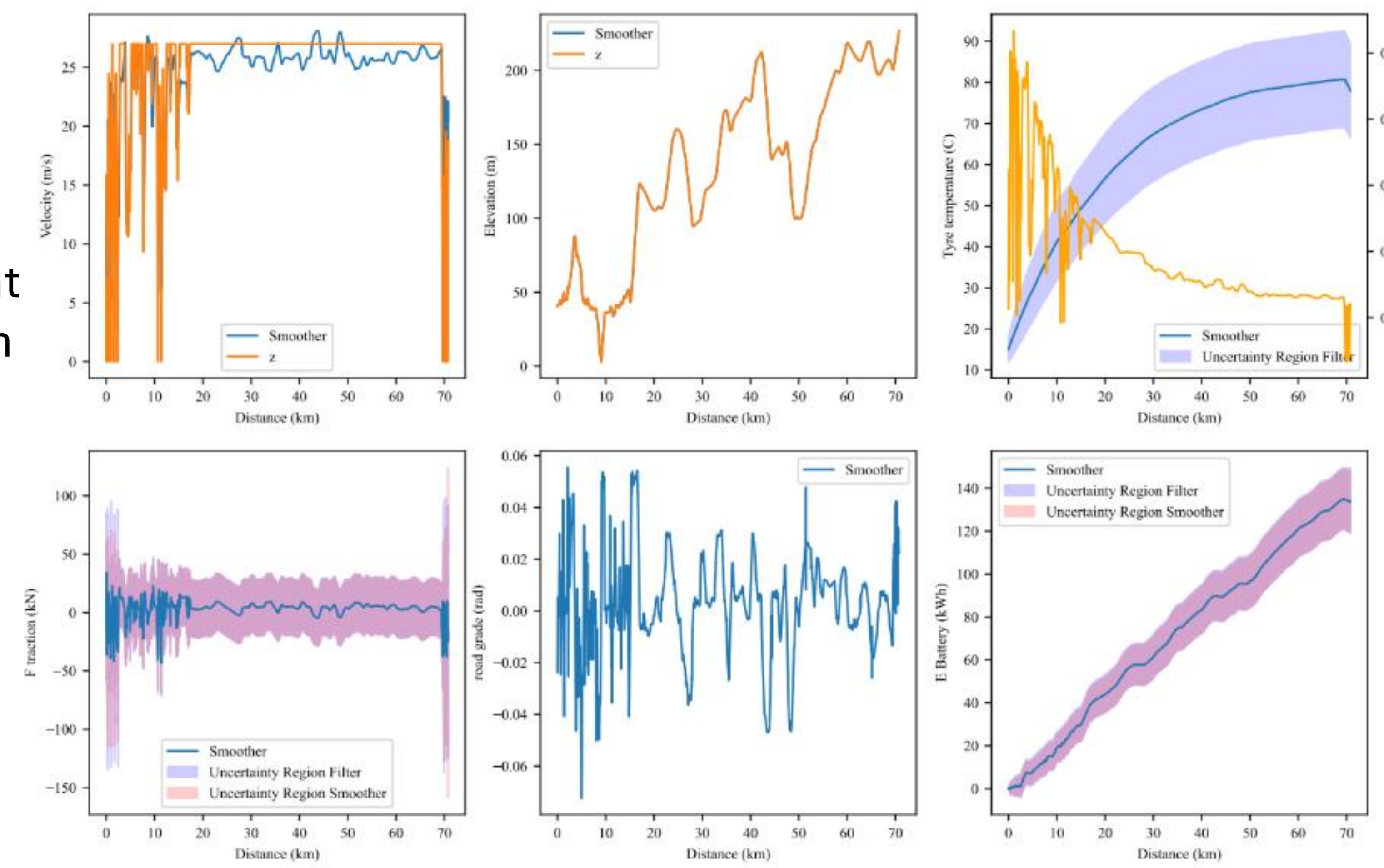

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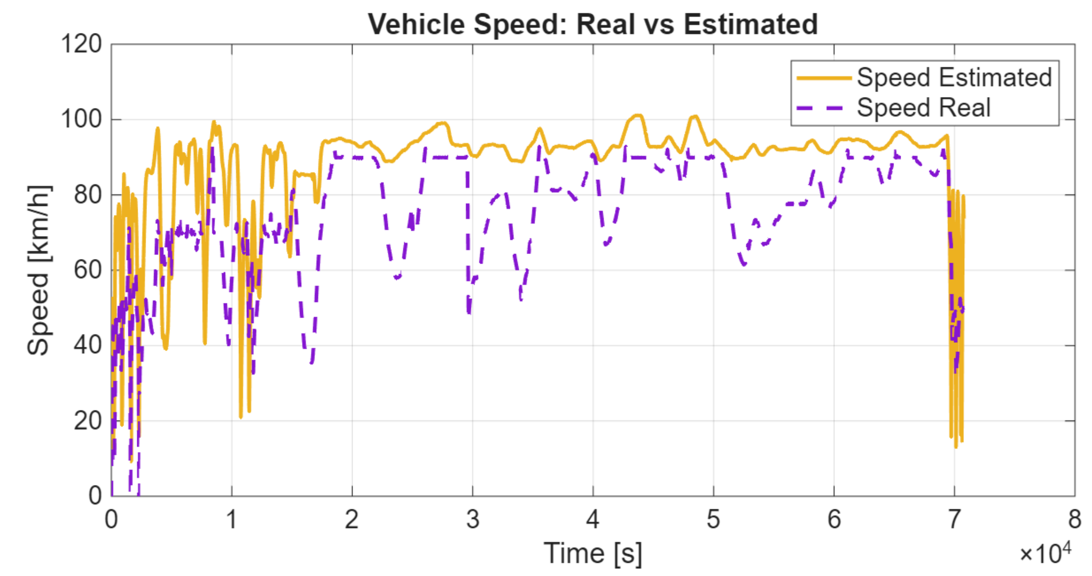

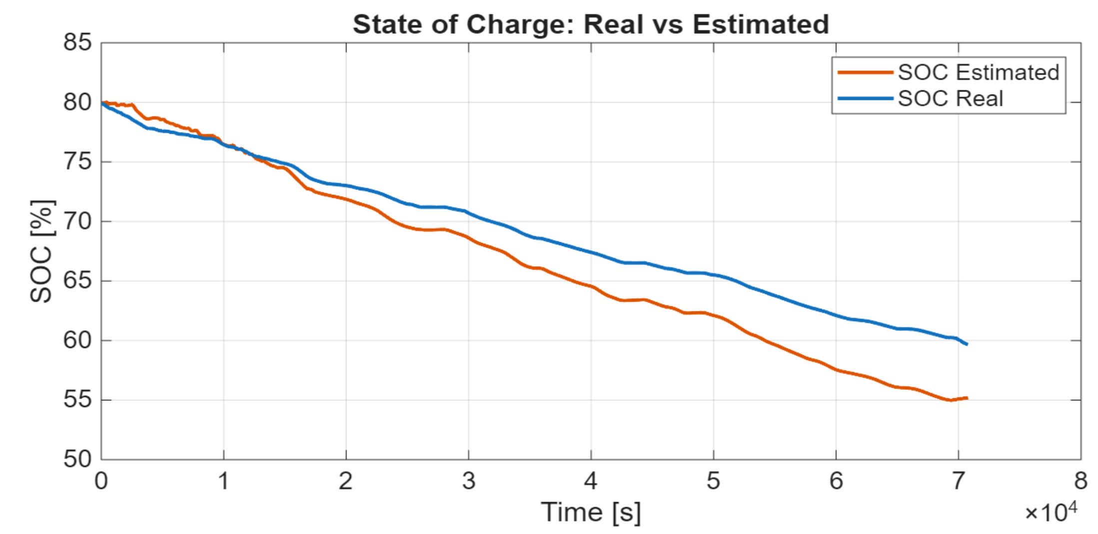

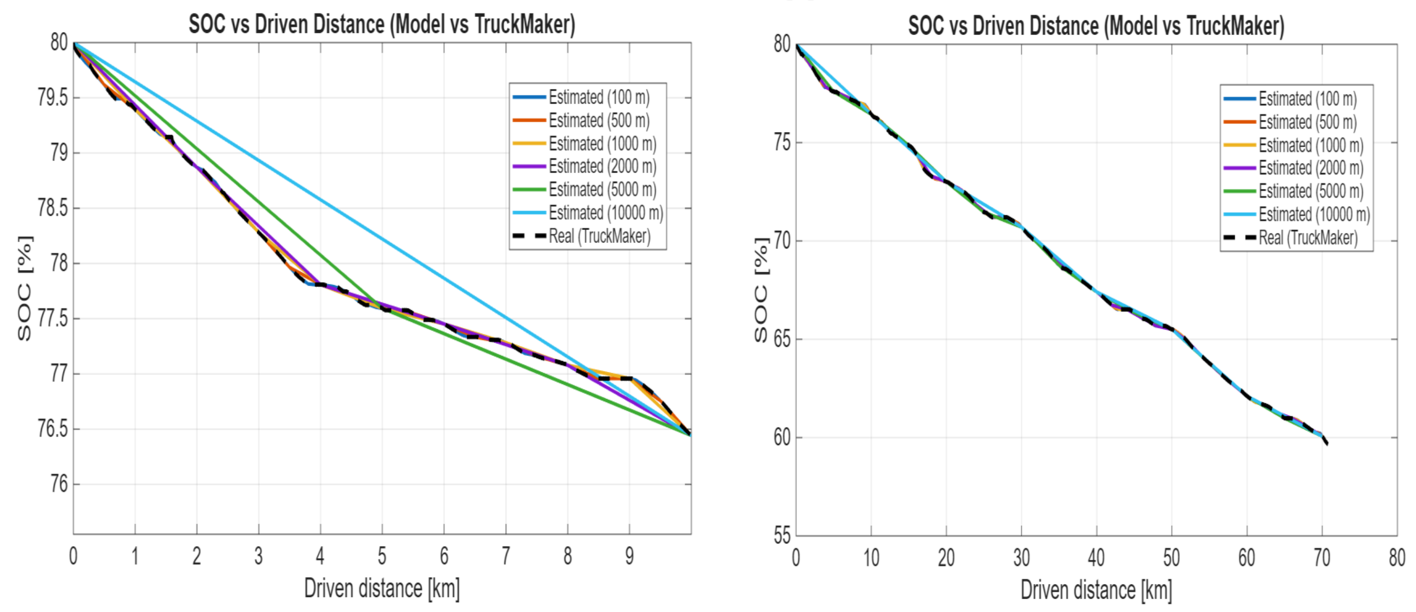

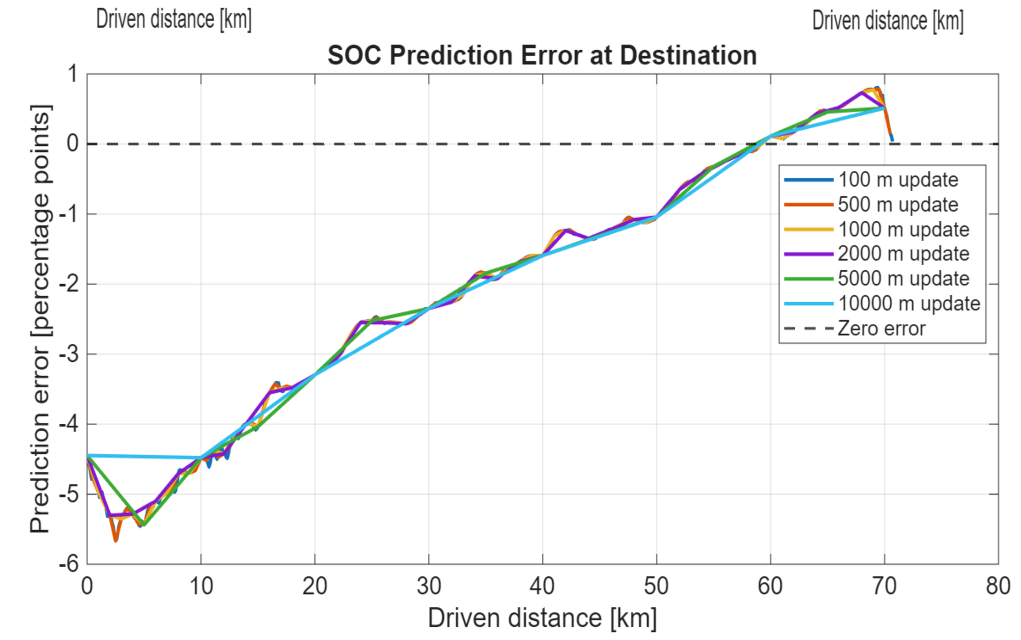

Future Work

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- Validate both simulation model and Range Predictor, Try different routes
- Possibly try real truck at REVERE
- Changing parameters mid route, ex. Stops, GCW etc.
- Add real weather data

Poster 2:

Turbulence signal approximation at unsimulated yaw angles,

William Kumlien, Chalmers & VCC

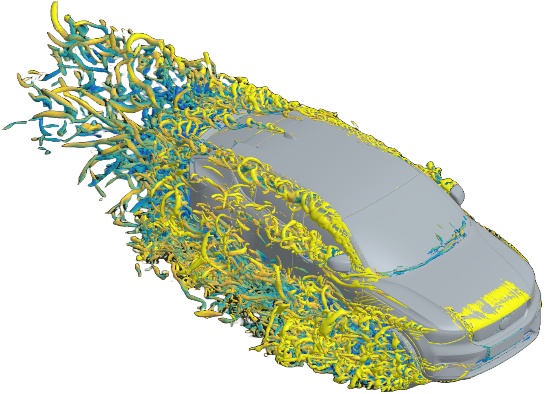
Simulating Transient Crosswind Aerodynamics

Enhancing Realism in the Volvo Cars Driving Simulator

William Kumlien

Lund University & Volvo Cars

The Reality of Crosswinds



- Flow separation
- Coherent vortex shedding
- **Transient load shocks**

The Computational Bottleneck

- High-fidelity CFD

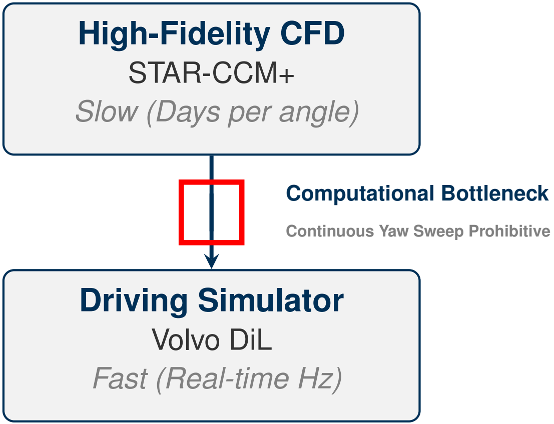
  Accurate but prohibitively slow

- Driving Simulator

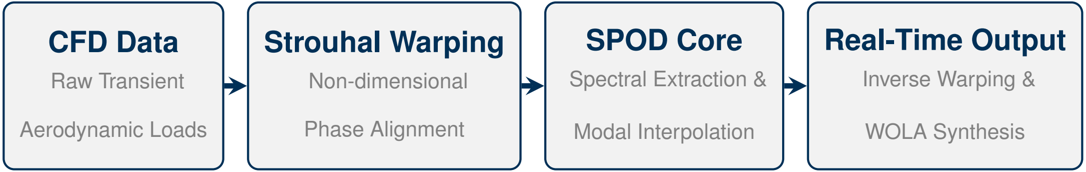
  Requires instantaneous data

- **The Gap:**

  Continuous Yaw Angles



Bridging the Gap: Data-Driven SPOD



Result: Computationally inexpensive, continuous turbulence synthesis.

Impact: The Volvo Cars Simulator

- Driver-in-the-Loop validation
- True transient stability analysis
- **Safer, predictable handling**

Thank You

Questions?

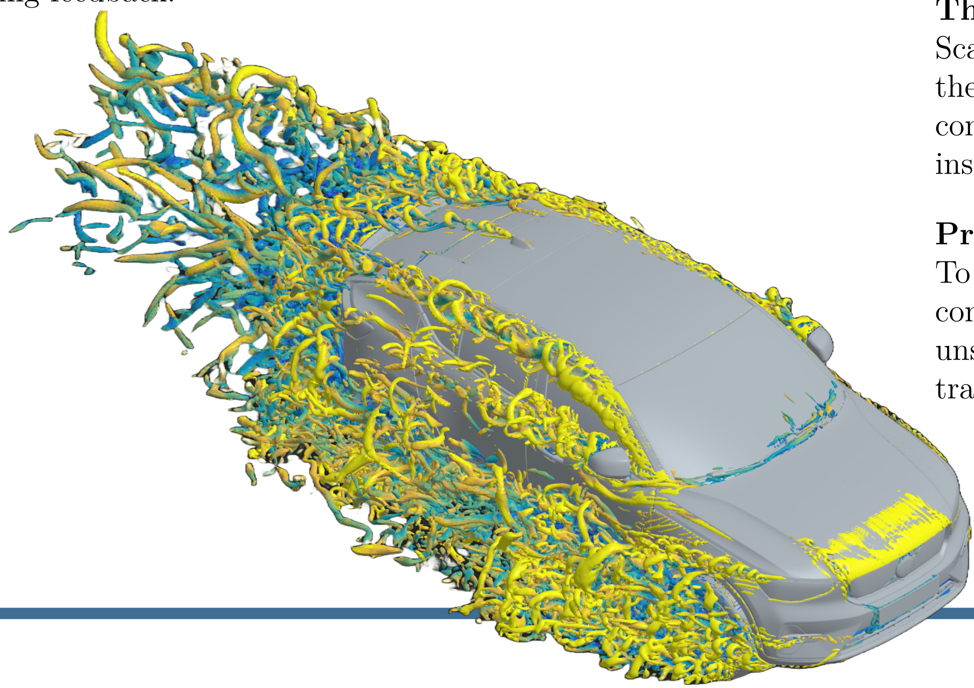
Data-Driven Reduced Order Modeling of Transient Vortex Shedding Across Continuous Yaw Angles

William Kumlien
Lund University & Volvo Cars

The Simulator Challenge

Vehicle aerodynamic restrictions traditionally rely on time-averaged ("mean") forces due to the extreme difficulty of measuring high-frequency turbulence in physical wind tunnels.

However, real-world crosswinds cause bluff-body flow separation, resulting in highly periodic and energetic vortex shedding. These transient forces and moments heavily impact vehicle stability and steering feedback.



The Computational Barrier

Scale-resolving CFD (e.g., STAR-CCM+ DES/LES) captures these physics accurately but is computationally prohibitive for continuous yaw sweeps. Real-time driving simulators require an instantaneous, continuous aerodynamic surrogate model.

Project Objective

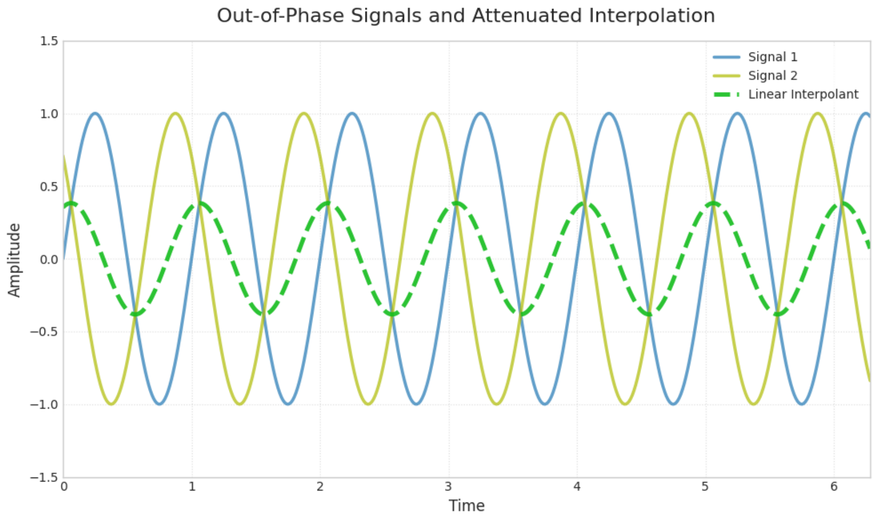
To develop a data-driven Reduced Order Model (ROM) that reconstructs full time-history turbulence signals at any continuous, unsimulated yaw angle, empowering engineers to evaluate true transient stability in real-time.

The Frequency-Yaw Dependency

Vortex shedding frequencies shift non-linearly with the vehicle's yaw angle due to the changing effective bluff-body width (L). This is governed by the Strouhal relationship:

$$St = \frac{f_{St} L}{U_\infty}$$

The Phase Barrier: Direct temporal interpolation between discrete yaw angles averages mismatched phases (e.g., combining a peak with a trough), causing destructive interference and artificial amplitude attenuation.



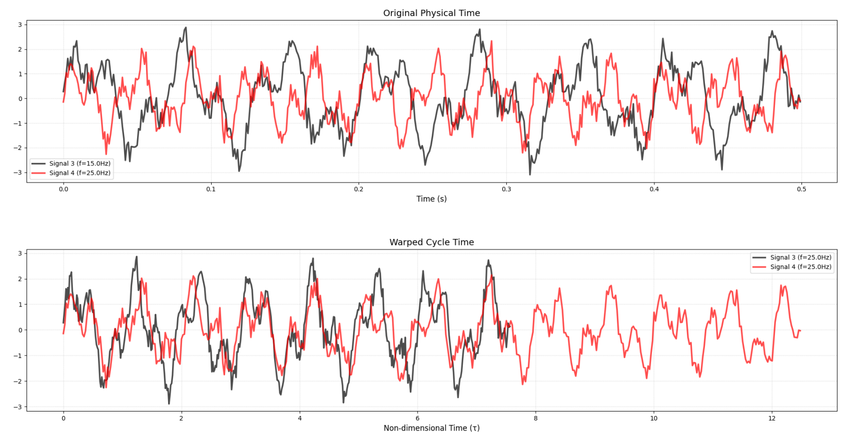
Amplitude Attenuation due to Phase Mismatch.

Dynamic Time Warping

To synchronize the shedding cycles, the physical time vector t is non-dimensionalized into a phase variable τ (Strouhal Scaling):

$$\tau = f_{St}(\theta) t \implies \tilde{y}(\tau, \theta) = y\left(\frac{\tau}{f_{St}(\theta)}, \theta\right)$$

Independent CFD training runs are first cross-correlated to a 0° reference angle to ensure all arrays commence at the identical shedding phase.



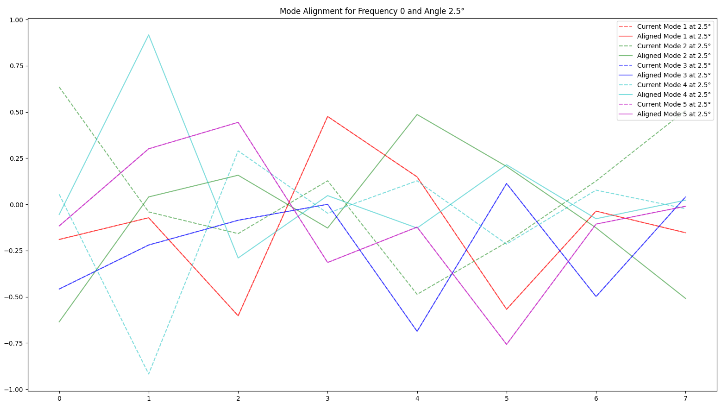
Frequency alignment via Strouhal scaling.

Spectral Proper Orthogonal Decomposition

Unlike spatial POD, SPOD enforces strict temporal coherence by operating on Welch frequency-domain blocks ($\hat{\mathbf{Q}}_f$). Because the system is bounded by 8 macroscopic aerodynamic coefficients, the spatial cross-spectral density matrix is a tractable 8×8 system. The spatial modes ($\mathbf{U}_f$) and temporal coefficients ($\mathbf{A}_f$) are extracted via the economy SVD for numerical stability:

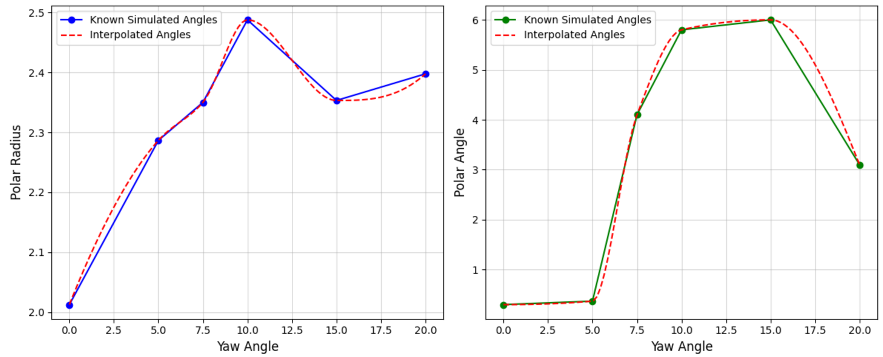
$$\frac{1}{\sqrt{K-1}}\hat{\mathbf{Q}}_f = \mathbf{U}_f \boldsymbol{\Sigma}_f \mathbf{V}_f^*$$

Eigenmodes are globally phase-aligned to prevent polar interference, and then interpolated across yaw in polar coordinates.



Eigenmodes before and after phase-alignment.

These modes represent a coherent coupling pattern between forces and moments at a given frequency.



Interpolation of the 1st singular value across yaw.

Weighted Overlap-Add (WOLA)

To prevent boundary discontinuities caused by modal truncation, the reconstructed Inverse-FFT blocks are double-windowed. The global signal is normalized by the squared window envelope (satisfying the COLA constraint) to strictly conserve physical kinetic energy:

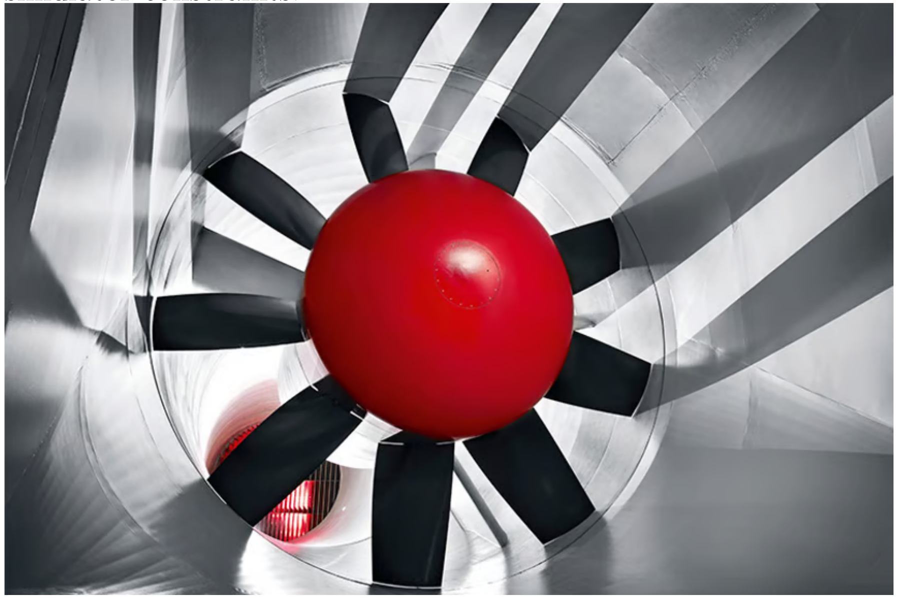
$$y_{final}(\tau, \theta^*) = \frac{\sum \mathbf{q}_b(\tau, \theta^*) w(\tau - \tau_b)}{\sum w^2(\tau - \tau_b)}$$

The Real-Time Reconstructor Algorithm

To deploy the generated aerodynamic signals into the Volvo Cars' Driving Simulator, a real-time explicit time-stepping algorithm—the *Reconstructor*—was developed.

While the dynamic signals could theoretically be implemented using multi-dimensional lookup tables, storing and querying massive arrays of time-series data is highly memory-intensive and computationally prohibitive for real-time hardware.

To circumvent this, the Reconstructor synthesizes continuous time-domain aerodynamic coefficients (C_l, C_d, C_{mz}, etc.) directly from the predicted signal frequency parameters (A, ϕ, f_k). To preserve physical stability during continuous yaw maneuvers, it utilizes a time-dependent linear cross-fading mechanism that enforces continuity between states. Optimized for deterministic execution, the module strictly uses pre-allocated static arrays to satisfy rigid simulator constraints.



Driver-in-the-Loop Evaluation

Because mathematical error does not always map linearly to human perception, ultimate validation is performed by a professional test driver.

The driver will evaluate the following methodologies:

1. Direct Temporal Interpolation
2. Direct Spectral Interpolation
3. Strouhal-Scaled Temporal
4. Harmonic Component Extraction
5. Standard Snapshot POD
6. Spectral POD

Conclusion

By effectively bridging high-fidelity computational fluid dynamics with real-time hardware constraints, this data-driven framework successfully captures the fundamental mechanics of transient vortex shedding without sacrificing spatio-temporal coherence.

Coupled with the Reconstructor algorithm, the system synthesizes highly realistic aerodynamic buffeting across continuous, unsimulated yaw angles. This novel approach circumvents the reliance on static mean loads and memory-intensive lookup tables, ultimately empowering engineers to evaluate true transient vehicle stability and steering feedback in a dynamic simulation environment.

Poster 3:

Steer-by-wire with closed-loop yaw rate control,

Mohammad Faddawi and Elmer Janmark, VCC

Steer-by-wire yaw rate disturbance rejection

Mohammad Faddawi – MPSYS Chalmers
Elmer Janmark – MPSYS Chalmers
Supervisor: Matthjis Klomp

Biography

Elmer Janmark
ejanmark@volvocars.com

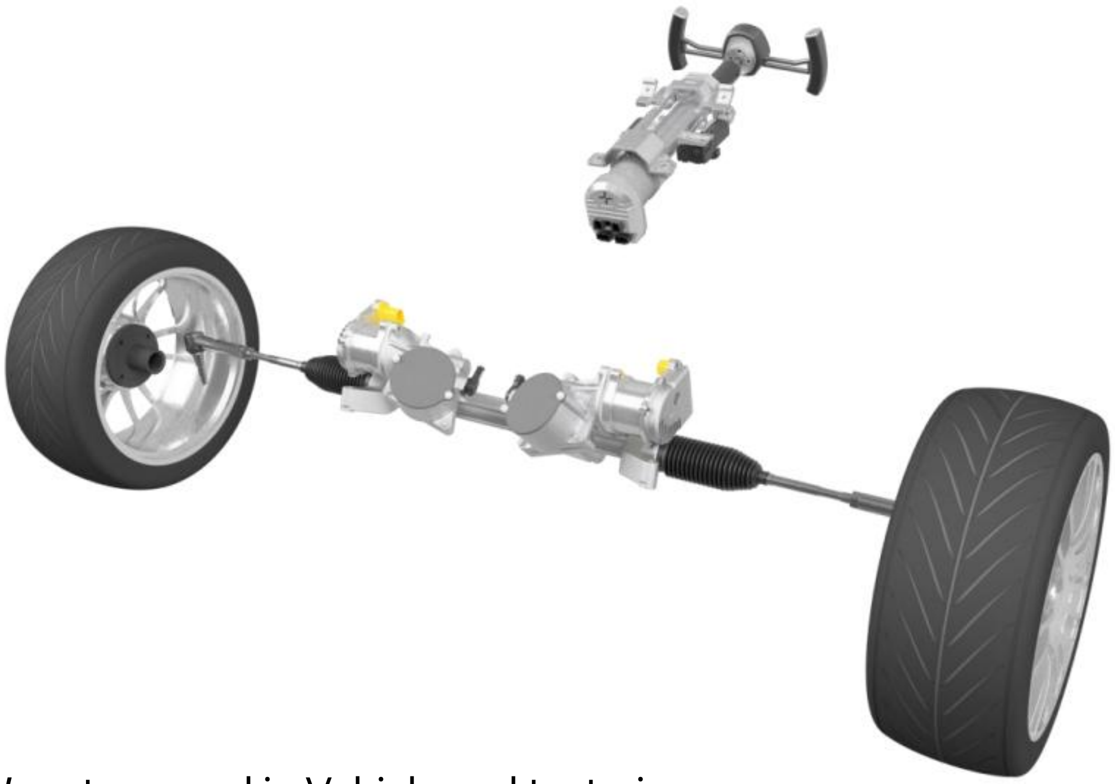
Mohammad Faddawi
mfaddawi@volvocars.com

- Master thesis students from Systems, Control & Mechatronics (MPSYS) at Chalmers
- Currently doing our master thesis at Volvo Cars, dept Steering

- We will present the results and findings from our thesis work on SbW yaw rate control.

Steer-by-Wire (SbW)

- No mechanical connection between steering wheel and the road wheels.
- Road wheels can be steered independently from the steering wheel
- Using Angle overlay



SbW system used in Vehicle and test-rig

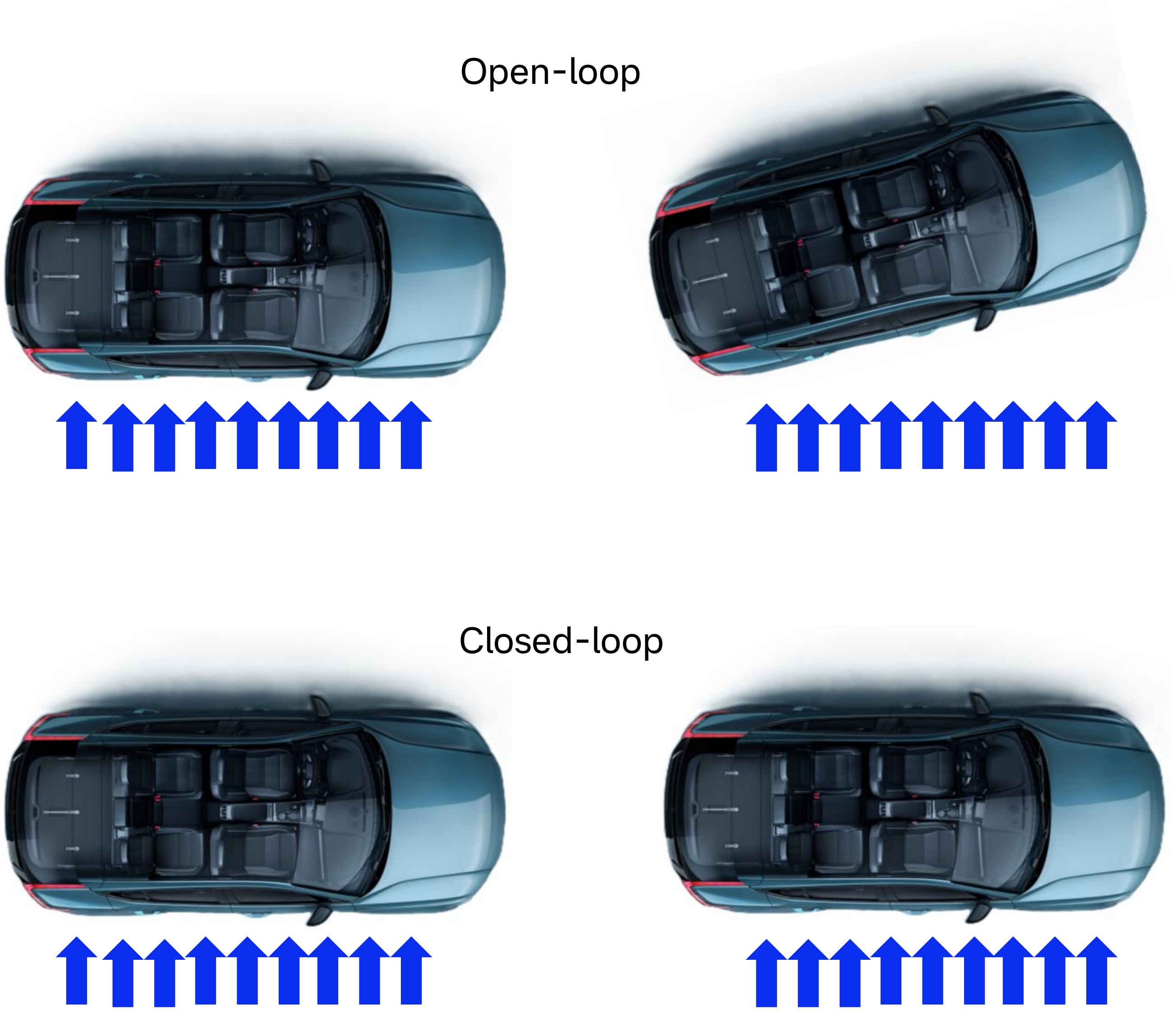
Challenge

Problem:

- Current open-loop lack ability to filter out body disturbances on the car (e.g, crosswinds)

Solution:

- Design a **closed-loop yaw rate controller** to apply corrective steering action (without affecting the steering wheel angle) to **counteract disturbances**



Reference model

- Based on the linear single track (bicycle) model
- System identification
- Model validation

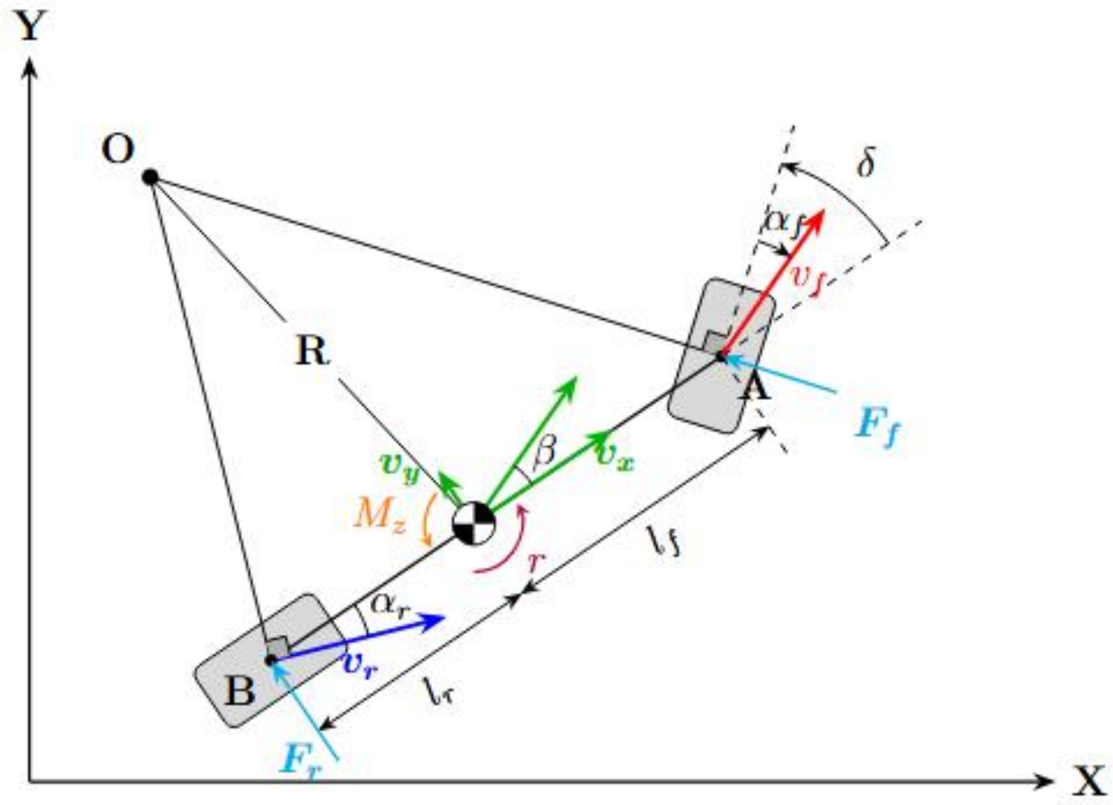
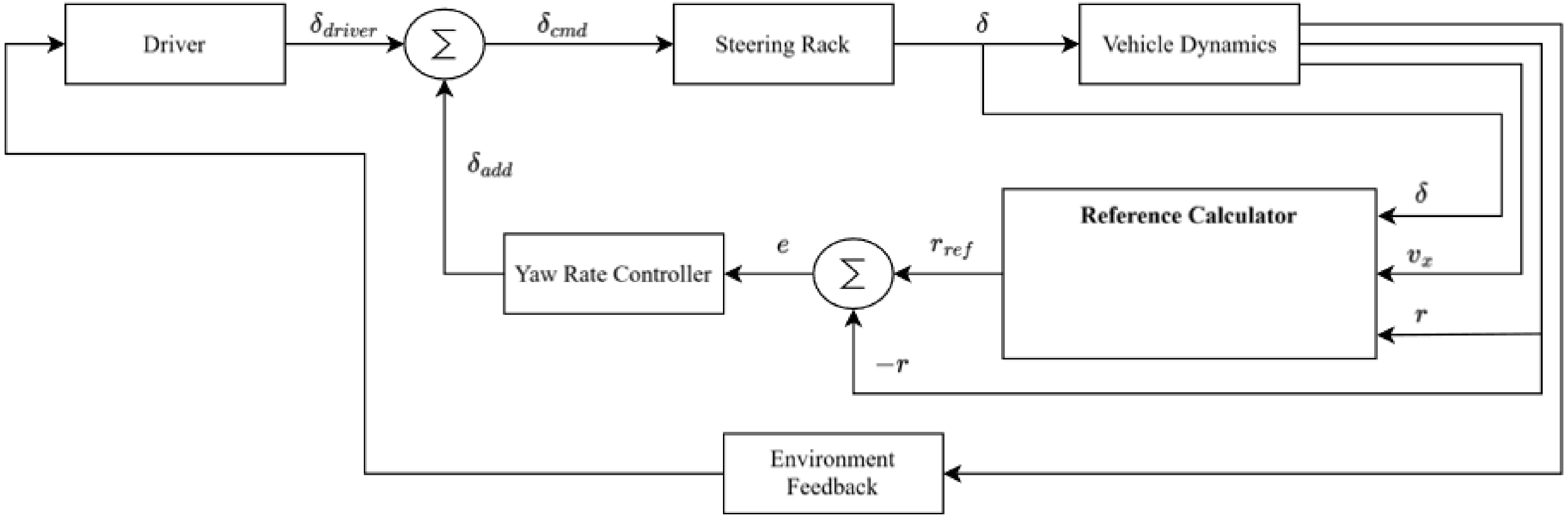


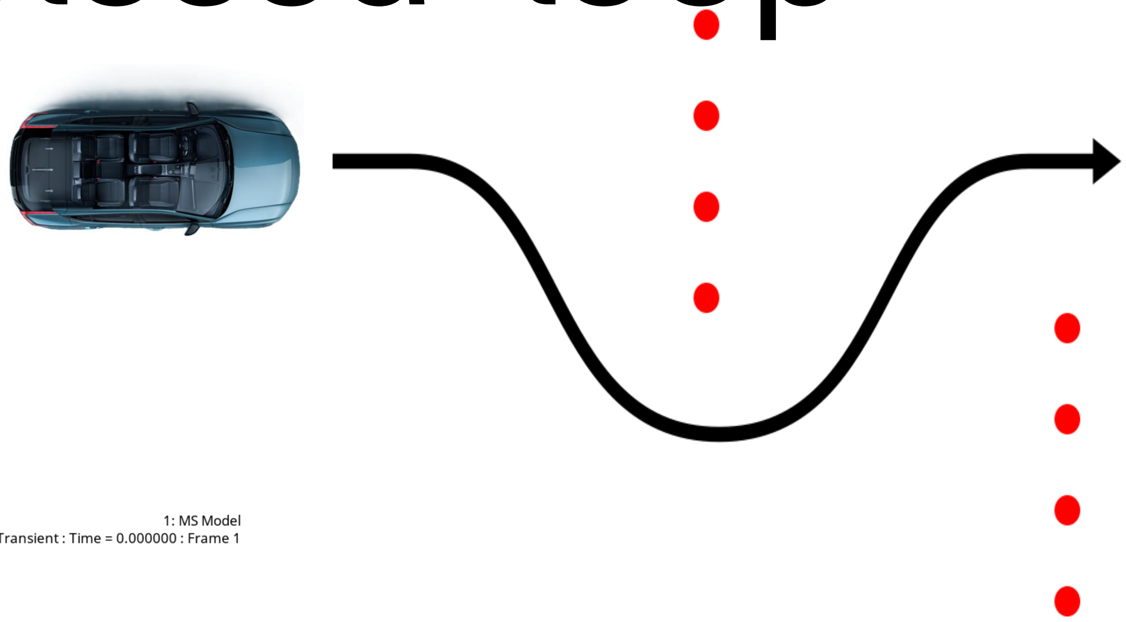
Figure 2.1: Linear Bicycle Model

Controller design

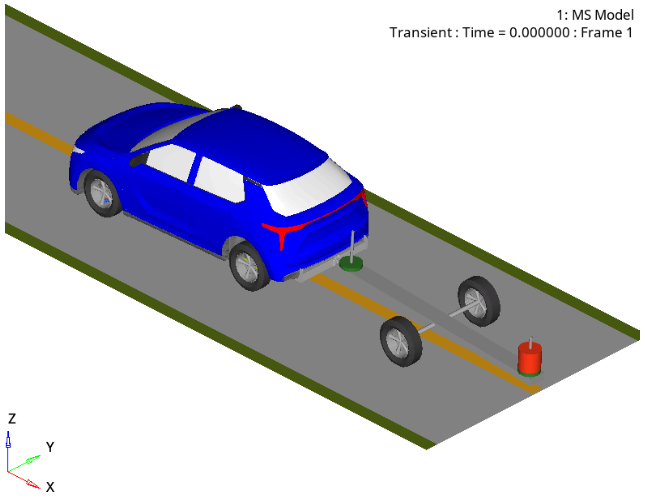
- P-controller using steady state as reference and IMU measurements to calculate error.
- Controller will add steering angle overlay based on calculated error
- Implemented using CANoe



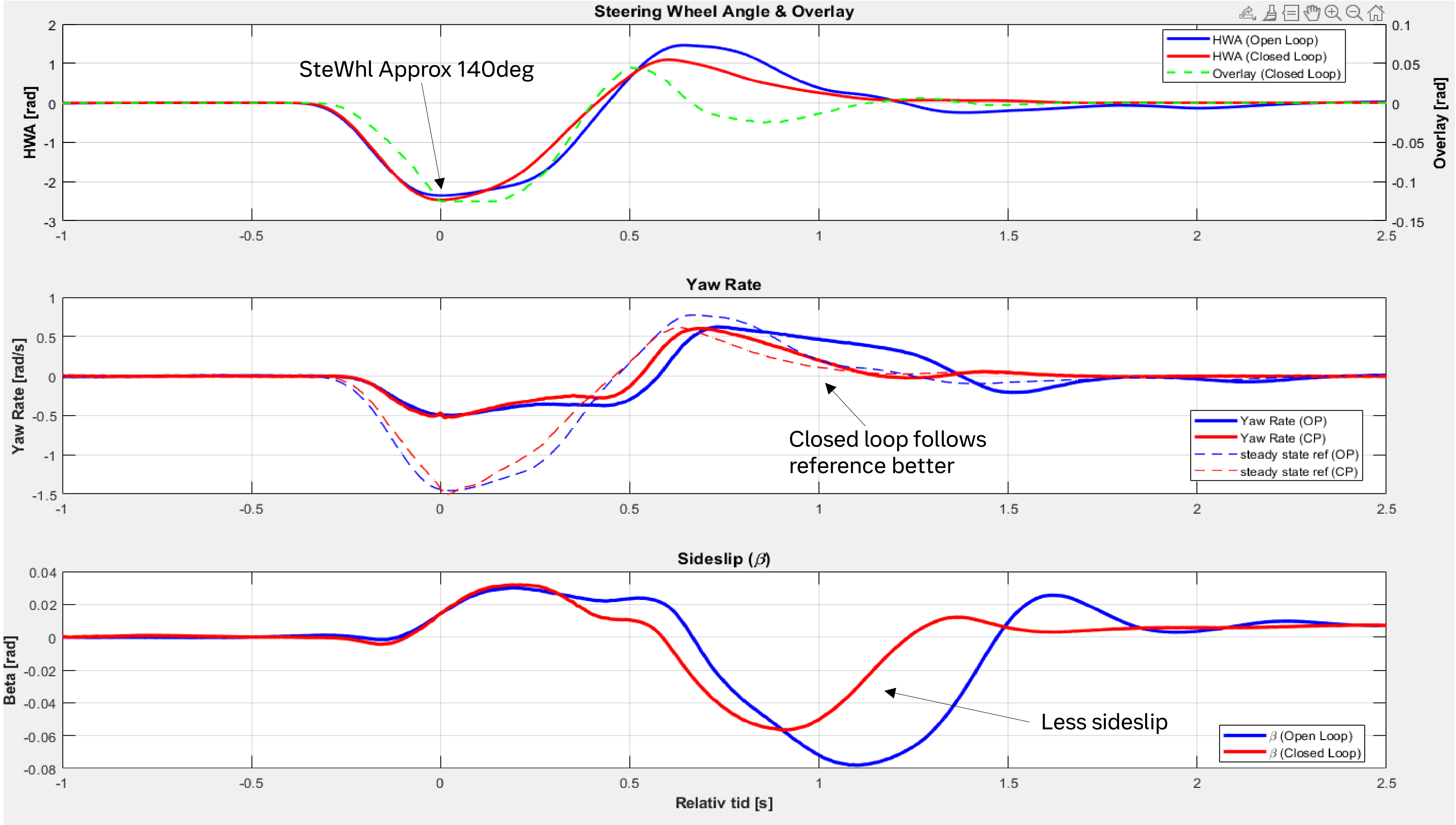
Open-loop vs Closed-loop evaluation



- Lane changes
- Step-steers
- Phase-delay comparison
- Unstable trailer



Aggresive Lanechange 80km/h



Trailer test setup

- Weight of trailer with cage and weights: 750kg
- Driving on TT-track 80km/h doing random input manuevers
- Trailer acts as a disturbance

Two test cases:

- Normal loaded
- Back heavy load, negative tow hook pressure

Normal load

Back heavy load

Table 3.9: Quantitative performance comparison between the open-loop baseline and the active closed-loop controller during the dynamic trailer towing maneuvers.

Performance Metric	Open-Loop	Closed-Loop	Improvement
Load Configuration 1 (Standard Load)			
Mean RMS Error (rad/s)	0.01944	0.01466	24.6 %
Mean Peak Error (rad/s)	0.04208	0.04393	-4.4 %
Mean Phase Delay (s)	0.091	0.058	37.0 %
Load Configuration 3 (Rear-Biased Load)			
Mean RMS Error (rad/s)	0.0252	0.0159	36.8 %
Mean Peak Error (rad/s)	0.0815	0.0593	27.2 %
Mean Phase Delay (s)	0.098	0.056	42.5 %

Thank you for your attention, see you at our poster!

VOLVO

ejanmark@volvocars.com
mfaddawi@volvocars.com

Steer-by-wire yaw rate disturbance rejection

Mohammad Faddawi – MPSYS Chalmers (mfaddawi@volvocars.com)
Elmer Janmark – MPSYS Chalmers (ejanmark@volvocars.com)
Supervisor - Matthjis Klomp

VOLVO

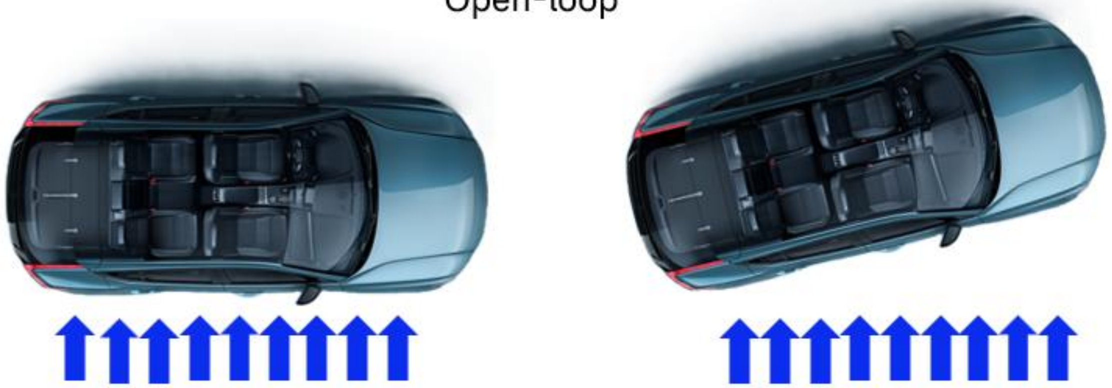
Problem:

- Current open-loop lack ability to filter out body disturbances on the car (e.g, crosswinds)

Aim:

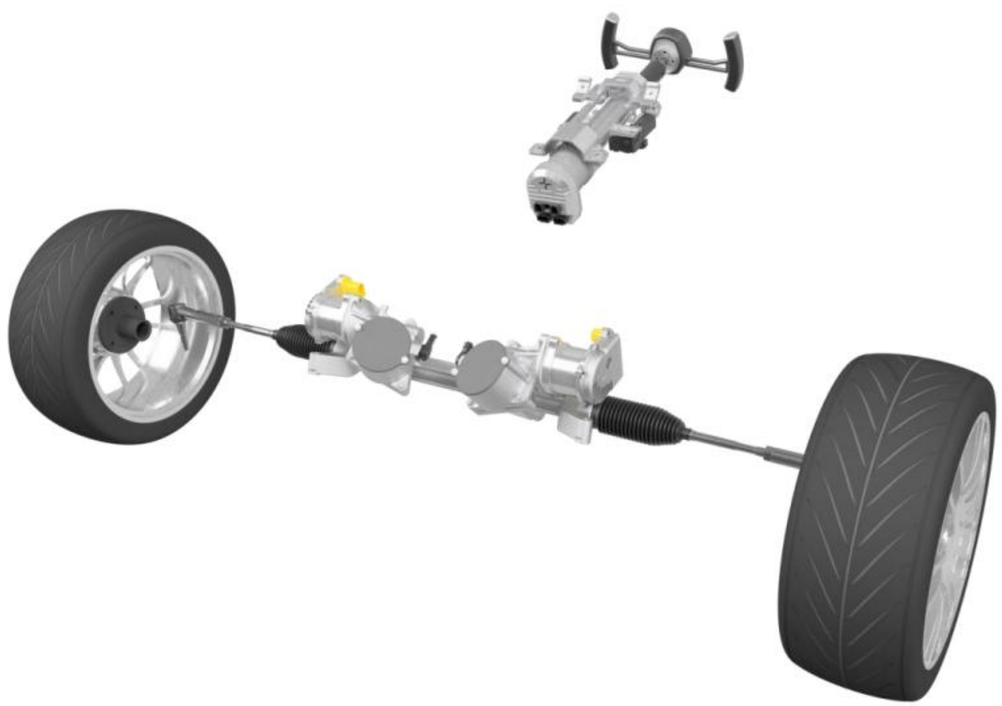
- Design a **closed-loop yaw rate controller** to apply corrective steering action (without affecting the steering wheel angle) to **counteract disturbances**

Open-loop



Closed-loop

SbW system used in Vehicle and test-rig



- No mechanical connection between steering wheel and the road wheels.
- Road wheels can be steered independently from the steering wheel
- Using angle overlay

Modelling and System Identification

Reference model: Linear single track model

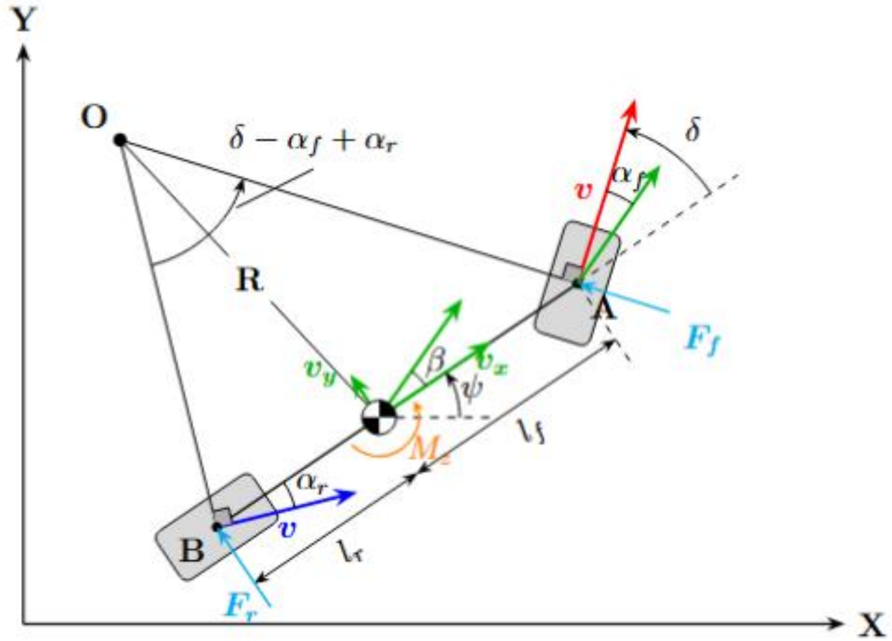
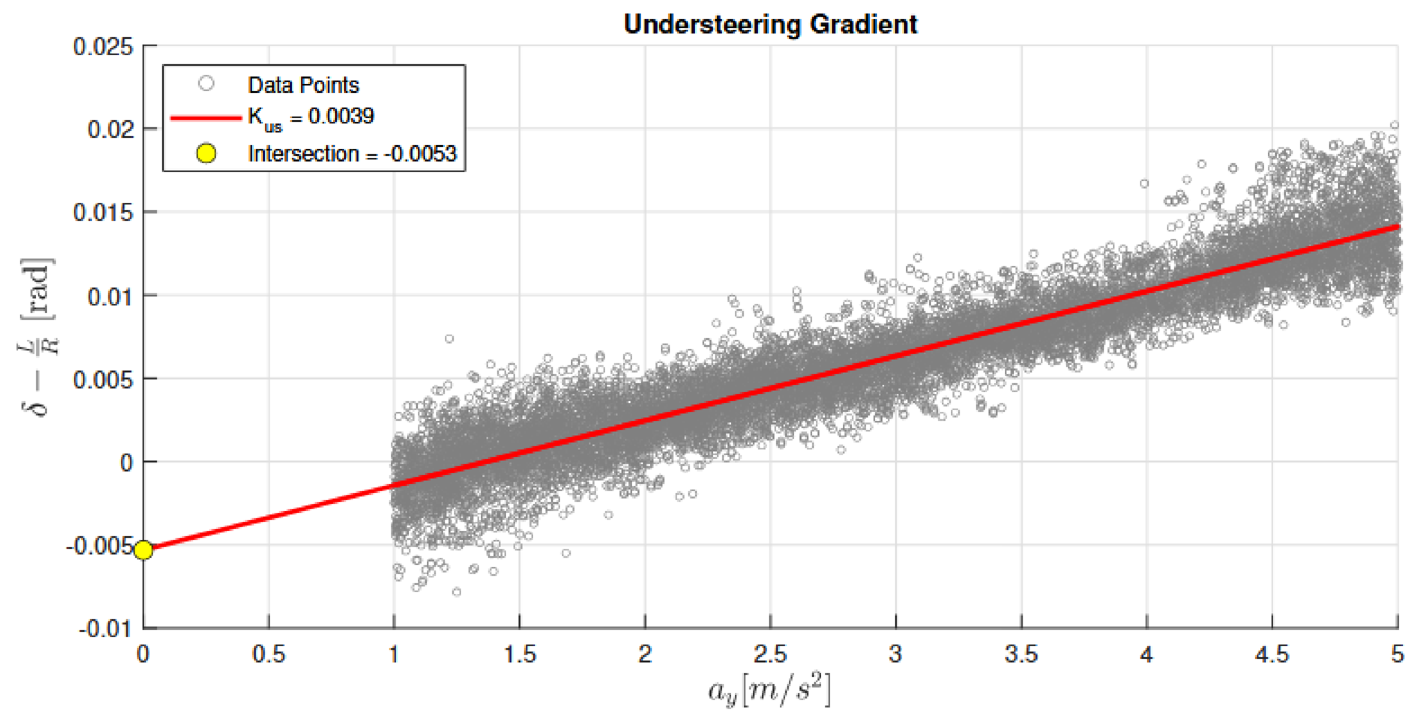
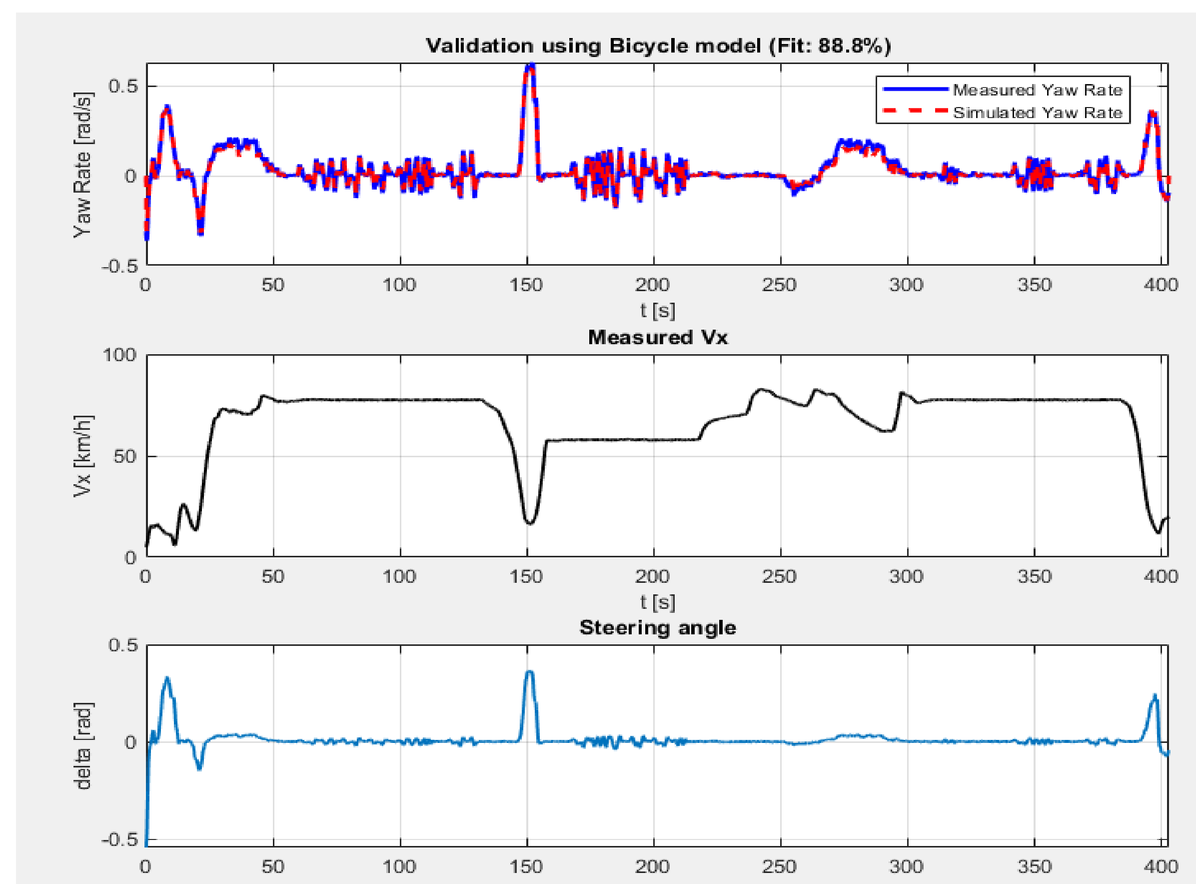


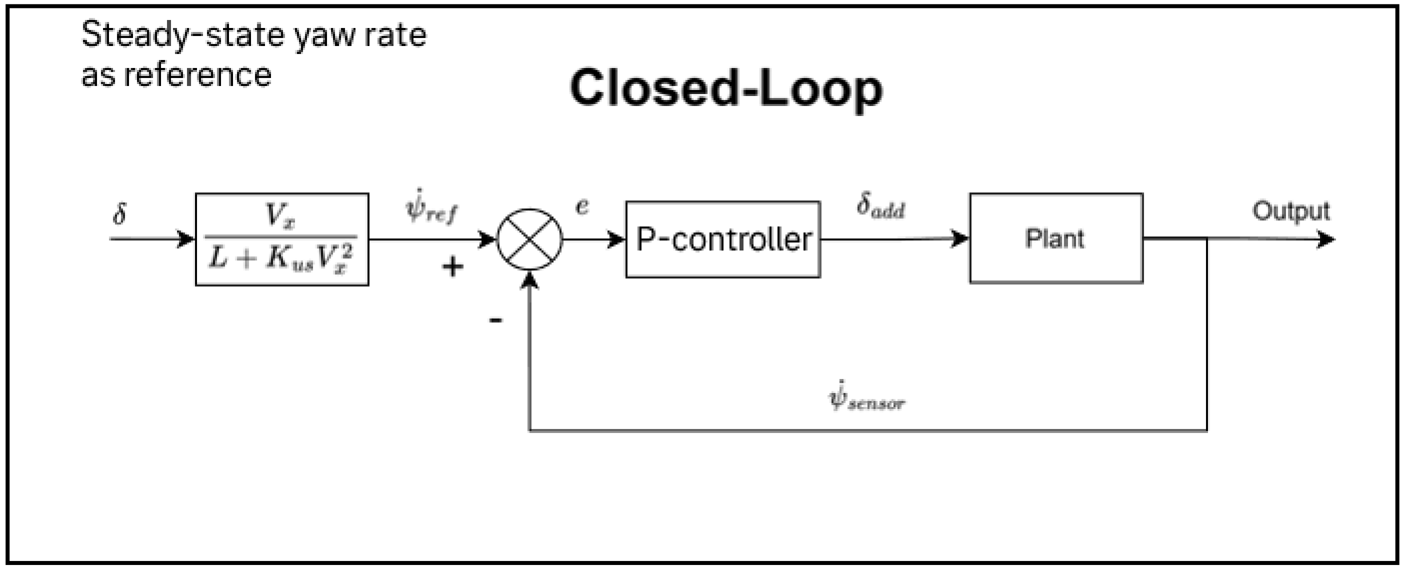
Figure 2.1: Linear Bicycle Model



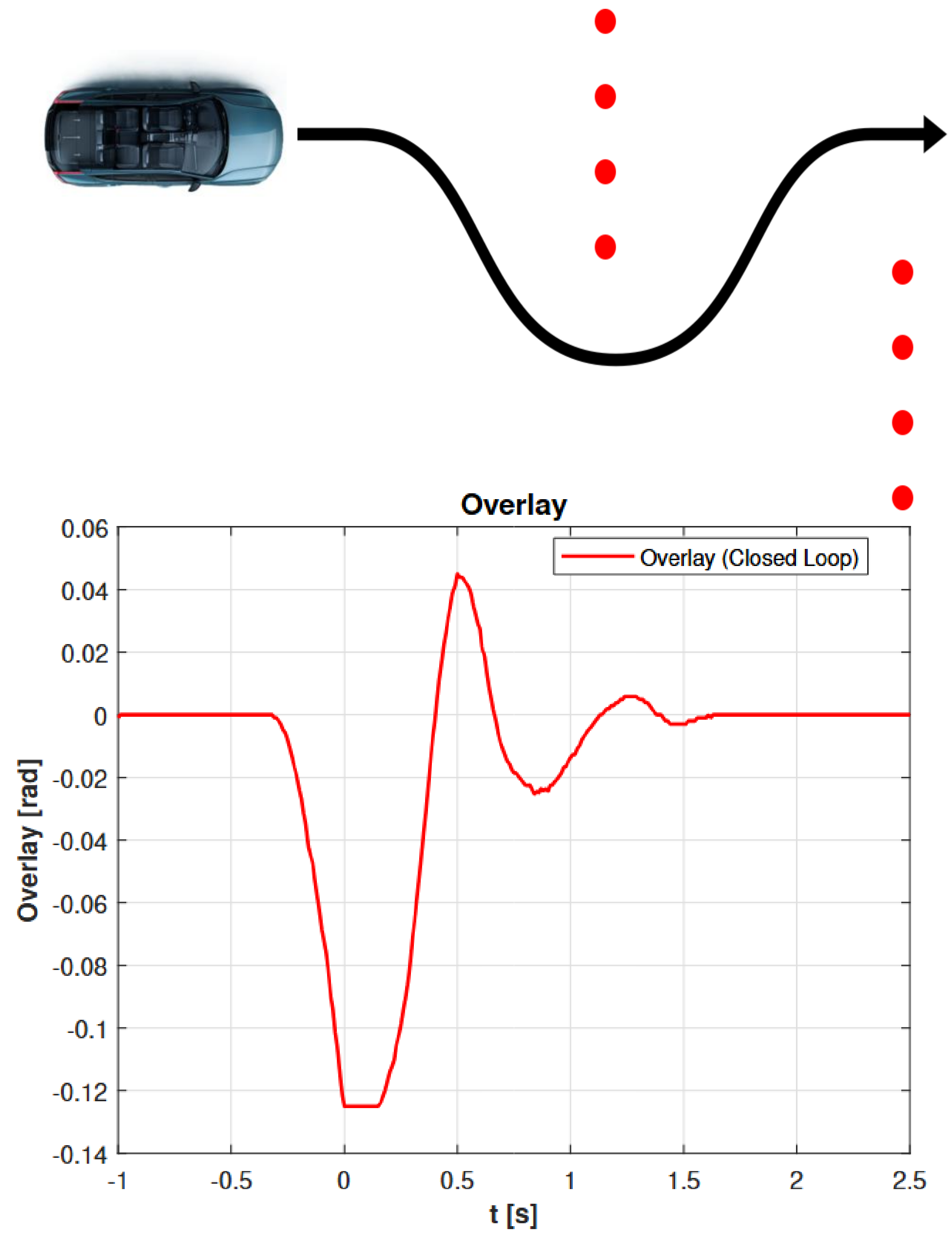
Validation of model:



- Reference model: Linear single track model
- Steady-state circular driving to find Understeer Gradient
- Sinus-Sweep Driving to find the vehicle parameters for cornering stiffness (Cf, Cr). To be used in simulation and tuning.
- Independent data-set for validation



Aggresive lane change
80km/h test



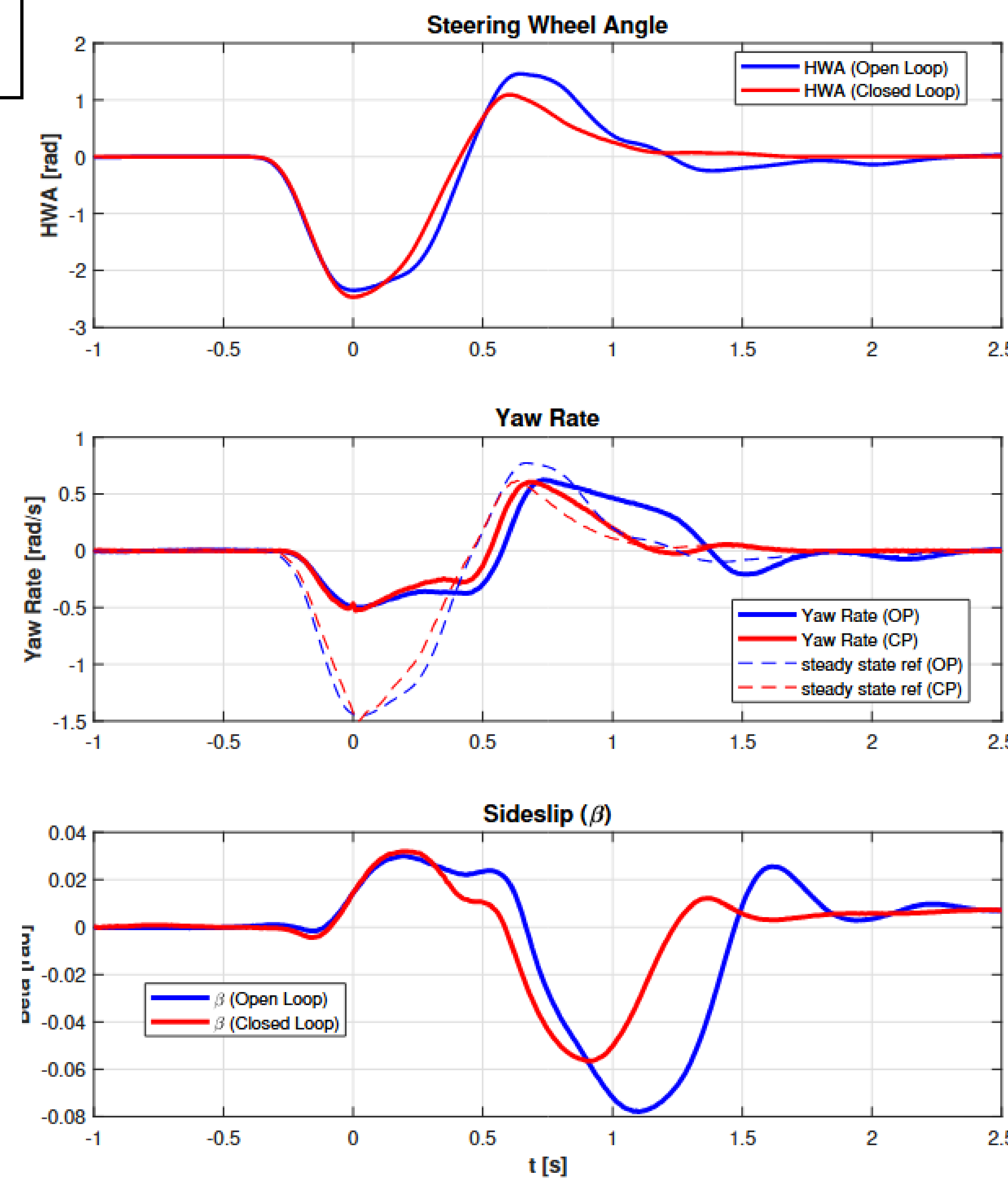


Figure 3.18: Active steering overlay (δ_{add}) applied by the controllers during the lane change maneuver demonstrating strict compliance with the $\pm 7°$ hardware limit.

Trailer as yaw rate disturbance test

Normal load

Back heavy load

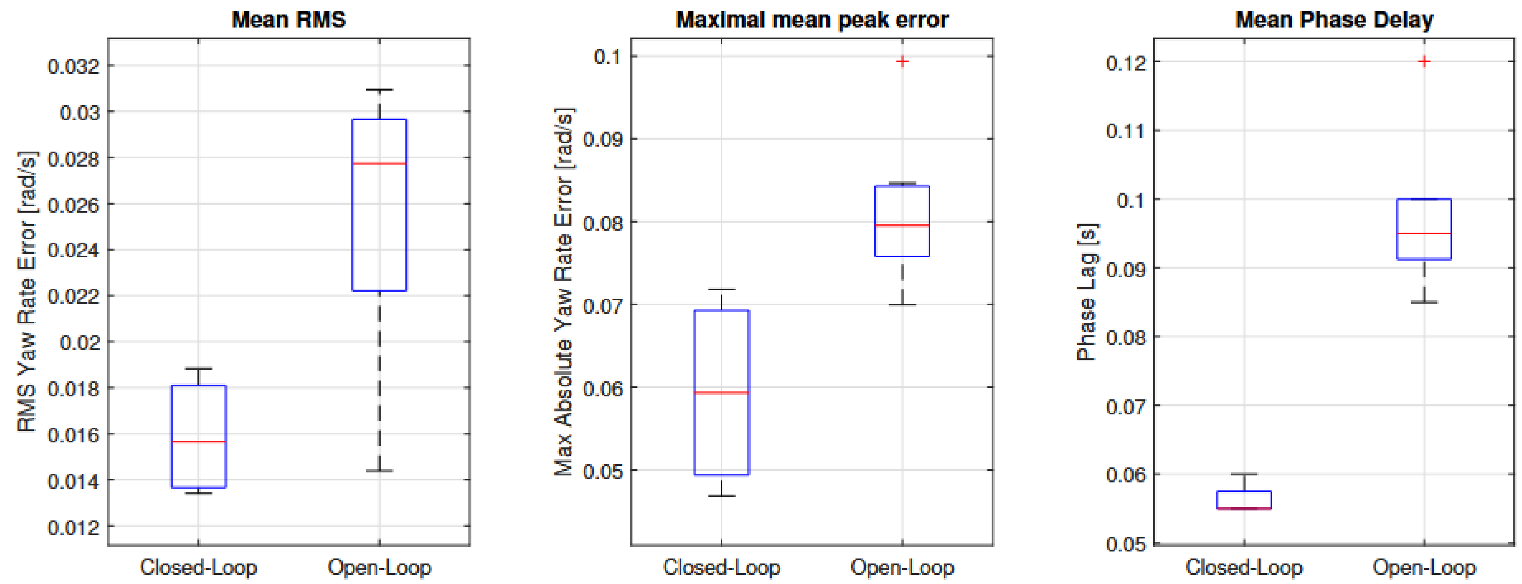


Figure 3.20: Boxplots illustrating the performance metrics when subjected to severe trailer sway induced by the negative tow hook weight (Configuration 2).

Conclusion

- SbW controller can be used to minimize disturbances on vehicle
- Limited to linear single track model but still improvement outside linear region
- Parameters Variations: The controller was able to compensate for the variations by providing a suitable reference

Table 3.9: Quantitative performance comparison between the open-loop baseline and the active closed-loop controller during the dynamic trailer towing maneuvers.

Performance Metric	Open-Loop	Closed-Loop	Improvement
Load Configuration 1 (Standard Load)			
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Mean Phase Delay (s)	0.098	0.056	42.5 %

Poster 4:

Experimental validation of road friction and slope estimation models for enhanced AEB performance in heavy trucks,

Malte Håkanson, KTH & Scania/Traton

Road friction and slope estimation in a heavy truck

For improved Advanced Emergency Braking system performance with experimental validation

Degree project, in Vehicle Engineering, second level

Who am I?

- Malte Håkanson
- Degree Programme in Vehicle Engineering at KTH Royal Institute of Technology
  - Master in Vehicle Engineering
- Degree project, in Vehicle Engineering
  - In collaboration with TRATON R&D/Scania

Advanced Emergency Brake system (AEB)

What is the AEB?

- Detects potential forward collision
- Full emergency braking
- Mandatory since 2013

Limitations

- Assumes perfect conditions
- Risk of braking too late when slippery/downhill

Scope of thesis

- Implement friction and slope estimation model in heavy truck
- Validate during real-world driving
- Investigate threshold parameter for potential adaptive AEB system

Model implementation

Estimator inputs

- Vehicle speeds and acceleration
- Brake cylinder pressures
- Engine torque and gear
- Mass

Model framework

- $\sum F = ma$
- Dugoff tire model
- Recursive Least Square (RLS)
- Kalman filter

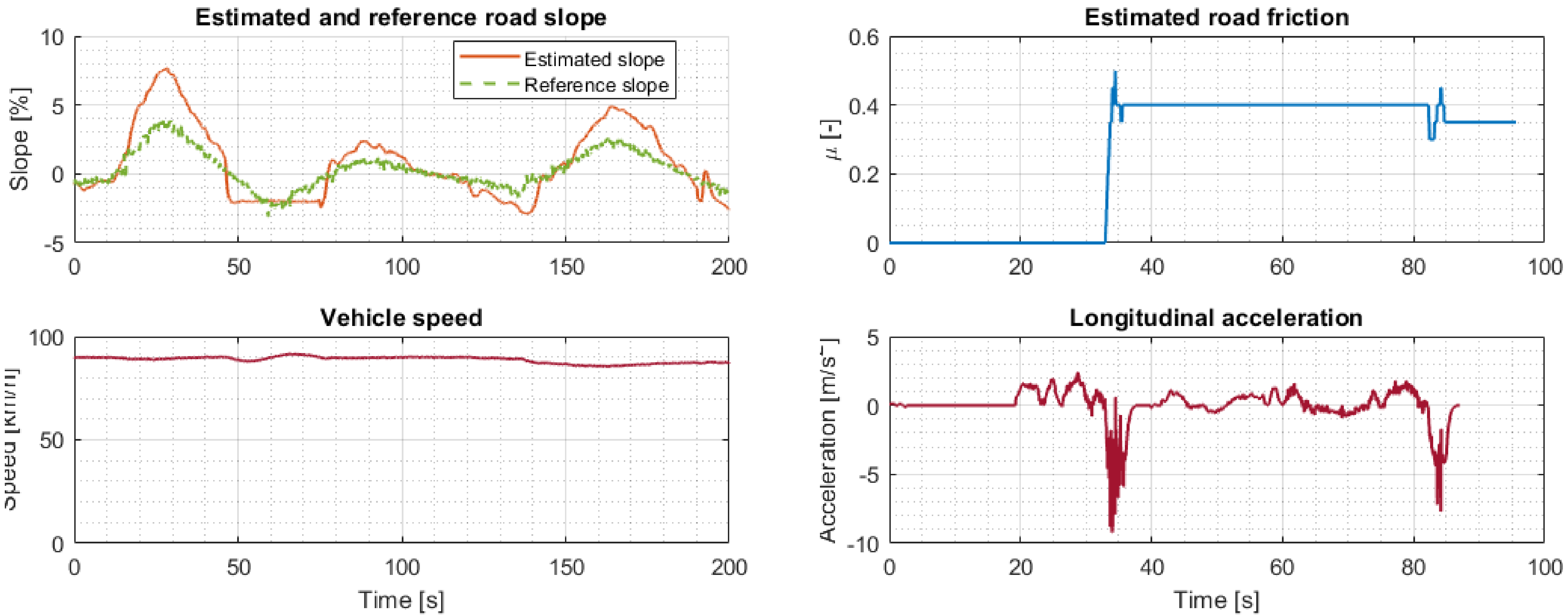
Inputs
$\omega_i, v, a, p_{brake,i}, T_{engine}, i_{gear}, m$

→ Slope estimate β

→ Friction estimate μ

→ $a_{x,max} = g\sin(\beta) + \mu g cos(\beta)$

Result highlights



System performance and conclusion

Slope estimation error

Driving case	Slope MAE [percentage points]
Mixed driving	1.319
Highway driving	1.120

Acceleration estimation error

Surface	Braking level	Peak a_x [m/s^2]	Estimated $a_{x,\text{max}}$ [m/s^2]	Δa_x [m/s^2]
Gravel	Full	4.0	3.0	1.0
Gravel	Almost full	3.8	3.4	0.4
Cobblestone	Full	5.0	4.0	1.0
Cobblestone	Almost full	4.5	4.0	0.5
Asphalt	Full	6.0	7.8	-1.8
Asphalt	Full	5.8	6.0	-0.2
Asphalt	Soft	0.5	6.0	0*
Asphalt	Soft	1.8	7.5	-1.5*

* Error calculated using the peak acceleration from the full braking event on asphalt (6.0 m/s^2).

Limitations

- Adaptive AEB system not yet implemented
- Robustness needs improvement

Conclusion

- Friction and slope estimation validated in real-world driving
- Promising results for AEB implementation
- Relevant for use in other vehicle dynamics areas

Experimental validation of road friction and slope estimation models for enhanced AEB performance in heavy trucks

Advanced Emergency Braking system (AEB)

- Detects targets with radar and lidar
- Automatically brakes if collision is unavoidable
- AEB has been mandatory for new trucks in the EU since 2013

Presenter: Malte Håkanson

- Degree Programme in Vehicle Engineering at KTH
- Master Thesis in collaboration between Scania/Traton and KTH

Problem

- Assumes ideal conditions

Objectives

- Implement friction and slope estimation in a heavy truck.
- Use the estimates to calculate maximum available longitudinal acceleration
- Evaluate the signals as potential inputs to adaptive AEB

Key takeaway: The work focuses on making road condition information available for a potential adaptive AEB decision logic.

Method and Implementation

Estimator inputs

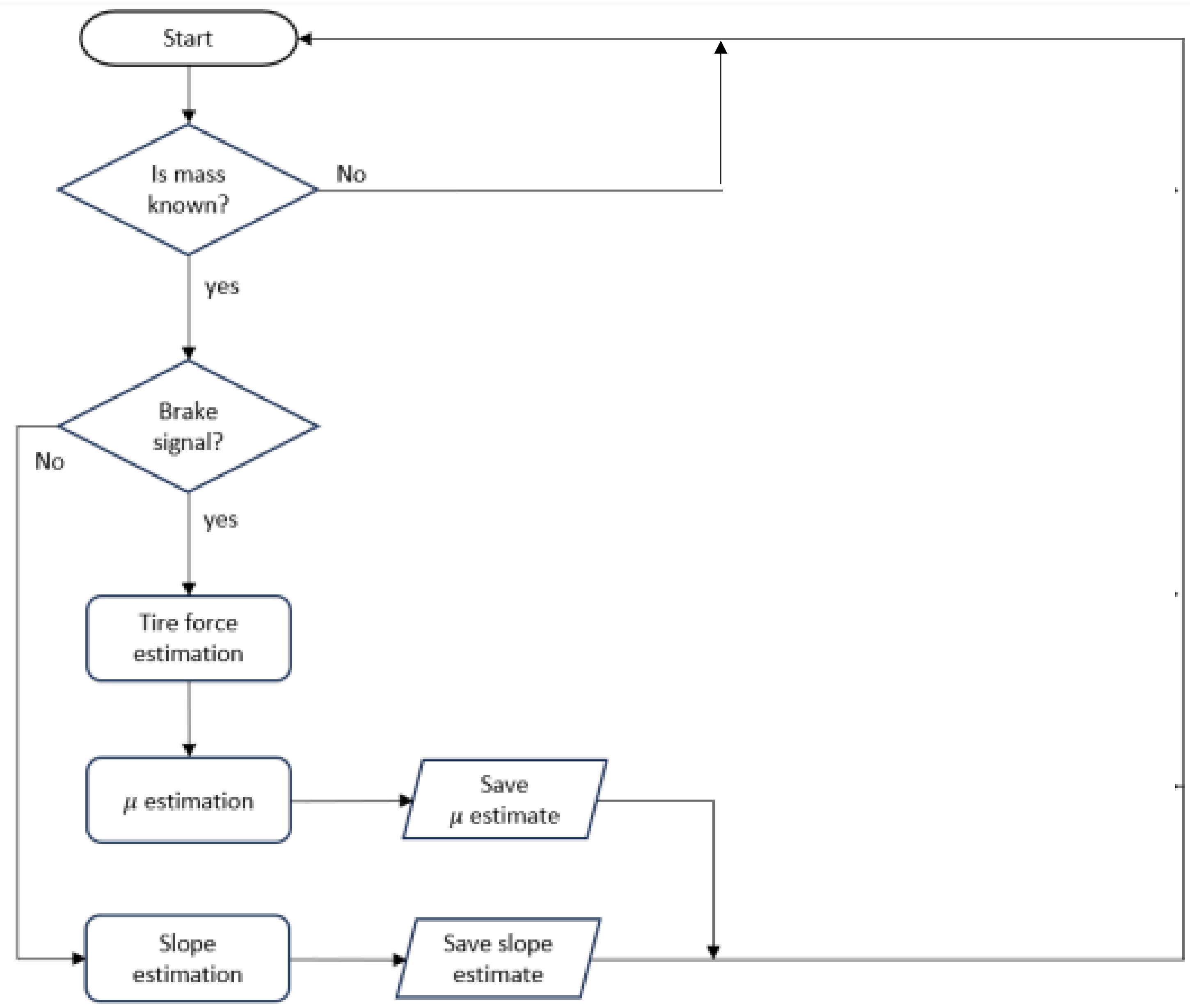
- Vehicle speed and acceleration
- Brake cylinder pressures
- Engine torque and gear
- Mass

Implementation flow

Inputs → Slope estimate β → Friction estimate μ → $a_{x,max} = g\sin(\beta) + \mu g\cos(\beta)$

Model framework

- $\sum F = ma$
- Dugoff tire model
- Recursive Least Square
- Kalman filter

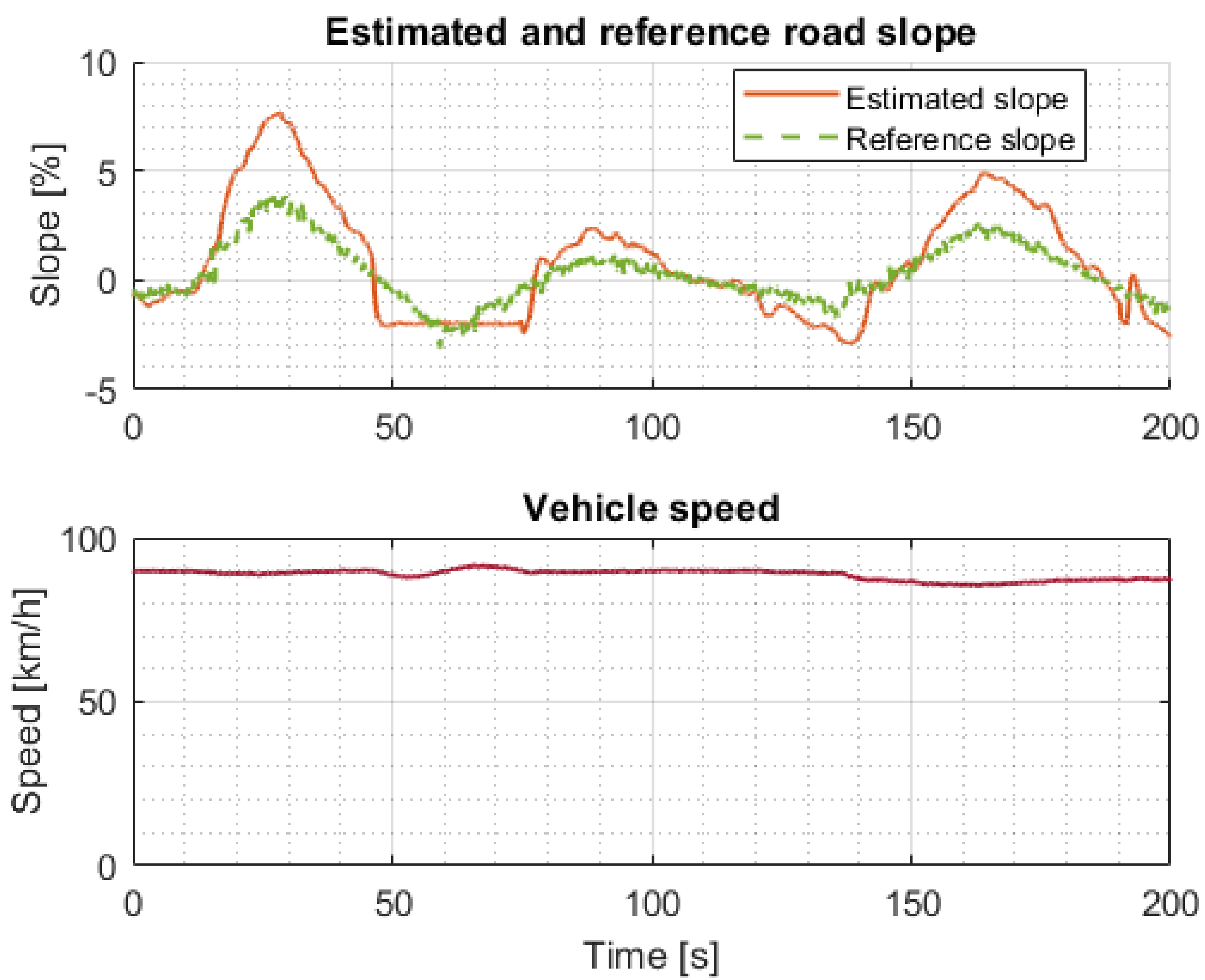


Test setup

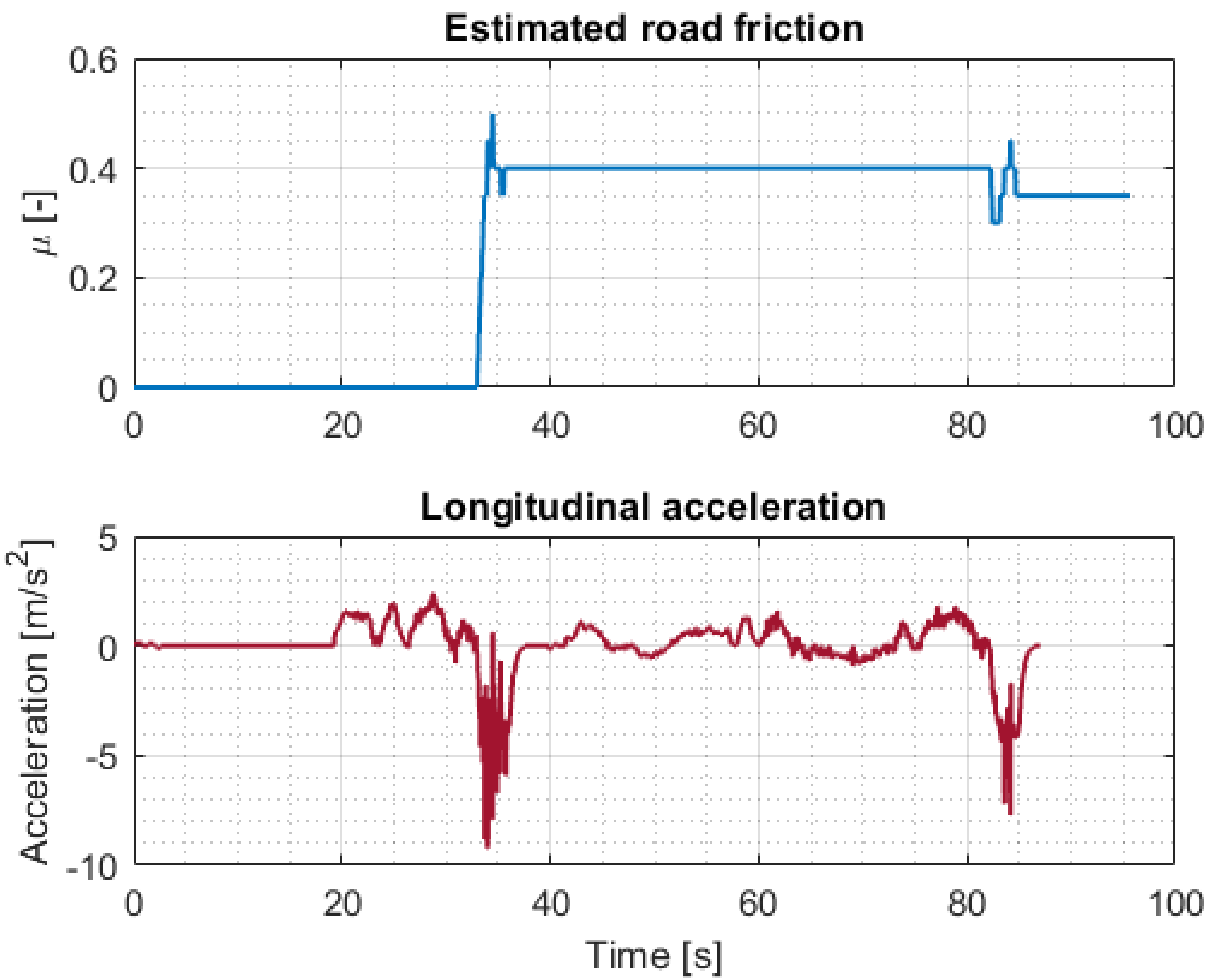
- Models deployed on heavy truck
- Signals logged during real-world driving.
- Controlled braking events on asphalt, gravel, and cobblestone
- Mixed surfaces: asphalt, cobble stone, gravel

Key takeaway: The implemented on a truck ECU

Slope estimation on highway



Friction estimation on low friction surface (gravel)



The estimated slope Mean Average Error (MAE) for both highway and mixed driving

Driving case	Slope MAE [percentage points]
Mixed driving	1.319
Highway driving	1.120

Key takeaway: Both friction and slope estimation models are validated in real-world conditions

System performance

- The right column shows how close the estimation is to the measured peak acceleration
- System shows good accuracy but robustness is relatively low

Surface	Braking level	Peak a_x [m/s^2]	Estimated $a_{x,\max}$ [m/s^2]	Δa_x [m/s^2]
Gravel	Full	4.0	3.0	1.0
Gravel	Almost full	3.8	3.4	0.4
Cobblestone	Full	5.0	4.0	1.0
Cobblestone	Almost full	4.5	4.0	0.5
Asphalt	Full	6.0	7.8	-1.8
Asphalt	Full	5.8	6.0	-0.2
Asphalt	Soft	0.5	6.0	0*
Asphalt	Soft	1.8	7.5	-1.5*

* Error calculated using the peak acceleration from the full braking event on asphalt (6.0 m/s^2).

Conclusions

- Friction and slope estimation works in certain conditions
- Estimated maximum acceleration ($a_{x,max}$) could be used as threshold variable in adaptive AEB system

Future work

- Tuning of parameters for improved performance
- Improve robustness during low-excitation driving.
- Implement adaptive AEB system

Summary

This master thesis implements and evaluates road friction and slope estimation on a heavy truck, with the estimates used to calculate the maximum available braking acceleration in real time. The results indicate that this signal can be used as the threshold variable for a potential adaptive AEB system, although full AEB intervention testing was outside the scope of the work.

Key takeaway: Final message: road-condition-aware braking information can support future adaptive AEB decisions.