IMPACTS OF HCT-VEHICLE COMBINATIONS ON TRAFFIC SAFETY

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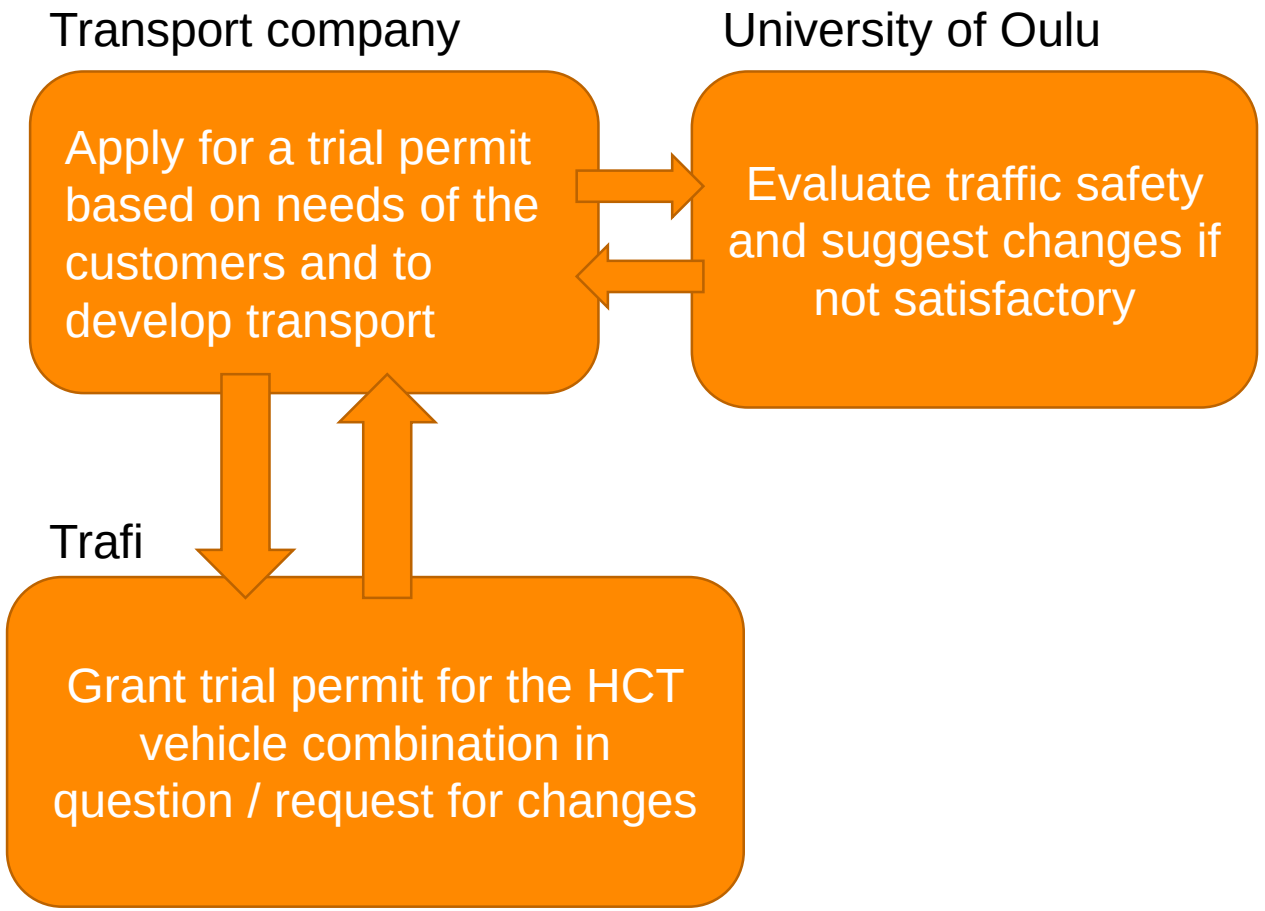
CONTENT

High Capacity Transport (HCT) trials in Finland



- **Transport companies can apply for a permit for the trial use of a HCT vehicle combination from the Finnish Transport Safety Agency, Trafi**
- **In order to get the permit granted, the transport companies have to justify the necessity of the vehicle combination based on the needs of their customers and on the possibility to study different kinds of HCT vehicle combinations**
- **If the HCT vehicle combination differs greatly from other HCT vehicle combinations, the traffic safety of the vehicle combination has to be evaluated**
- **This results in variety of vehicle combination types under HCT trial permit**

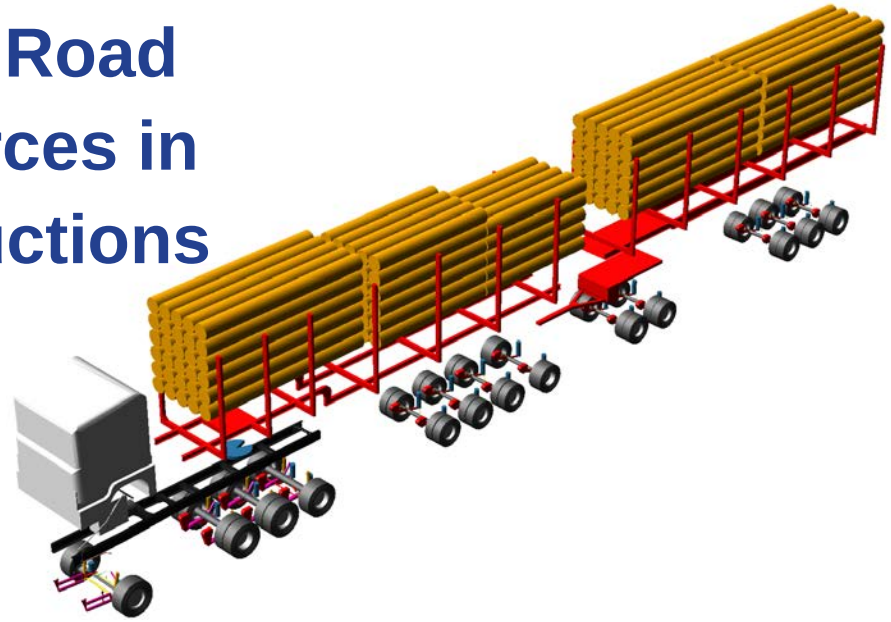
Traffic Safety Research of HCT-Vehicle Combinations

HCT-Research Project aim is to explain vehicle dynamics and relationships with traffic safety of HCT-vehicle combinations

1 Measurements of Vehicle Dynamics

- **Double-Lane Changes ISO-3888-1 and Single–Lane Changes ISO- 14791 on test field**
- **Braking decelerations and Braking distances**
- **Monitoring of Vehicle Dynamics on the Road**

2 Measurements of Deformations and Forces in Drawbar, Fifth Wheel and Vehicle Constructions



Traffic Safety Research of HCT-Vehicle Combinations

3 Adams- Modeling and Simulations of Vehicle Combinations and Model Verification between Measurements

4 Tire research

- Tire Laboratory Measurements and Tire Modeling in Adams-program

5 Road Construction Measurements

Conclusions in research results: Evaluations of HCT-vehicle combination's traffic safety and vehicle dimensioning, driver training for HCT-combinations, Road construction Measurements

Research Group of Vehicle Engineering: Researchers Miro-Tommi Tuutijärvi (Adams-Modeling and Simulations), Ville Pirnes (Experimental Measurements, Driving Tests), Veikko Pekkala (road construction measurements), Perttu Niskanen (Project Manager)

HCT-timber vehicle combination monitoring

Research project: 1.1.2015 - 31.12.2017 (European Regional Development Fund (ERDF) , Metsäteho ja Nokia Heavy Tires)

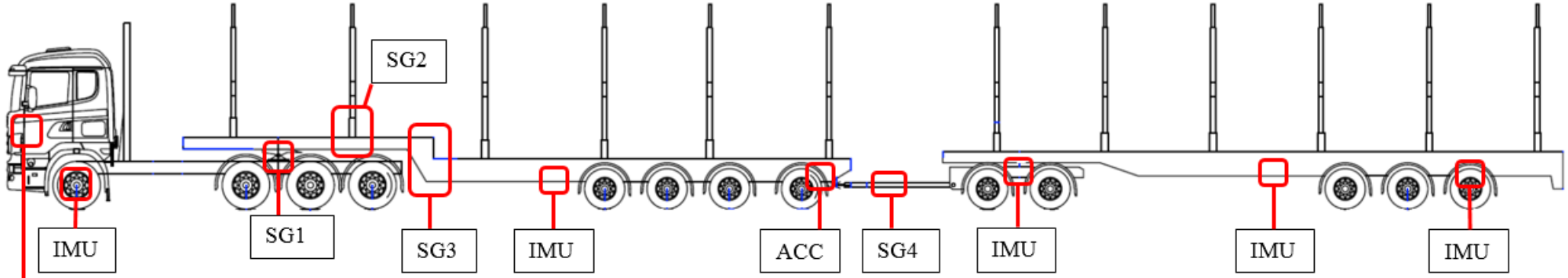
HCT Timber Vehicle Combinations:

- 13-axle timber combination with 4-axle truck (8x4) and 4-axle semi-trailer and 5-axle full trailer. Total mass 104 tonnes, payload about 78 tonnes.
- 10-axle timber combination with 5-axle truck (10x4) and 5-axle full trailer. Total mass 84 tonnes, payload about 60 tonnes.

Traffic: Ivalo-Rovaniemi-road network
Ketosen Kuljetus Oy
P&A Trans Oy

Measurement System of Vehicle Combination

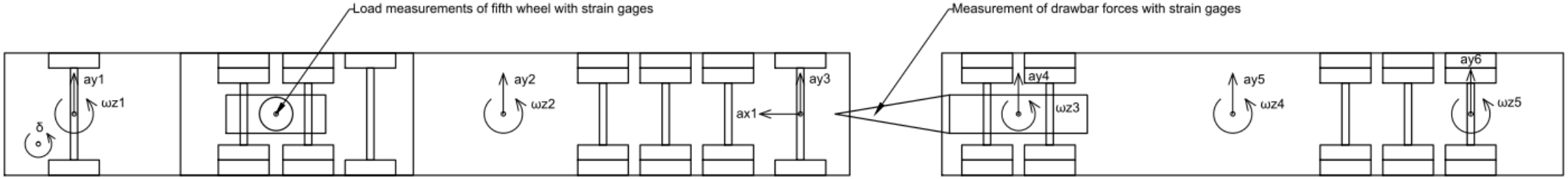
GPS
FMS-connection (vehicle's CAN-bus)
Data logger
Fitlet miniPC (for transferring data)



Steering wheel angle

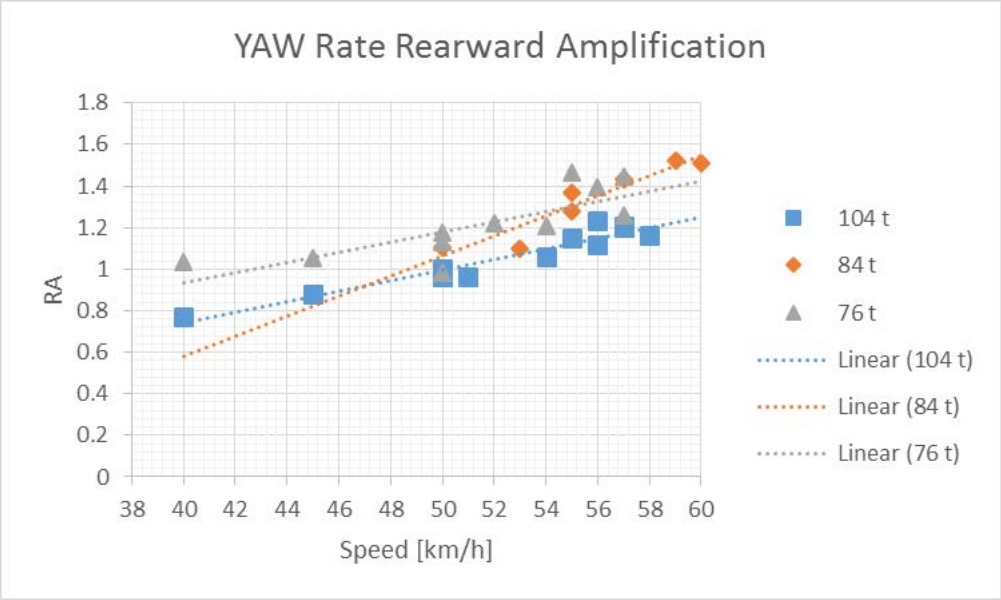
ACC: Longitudinal and lateral acceleration measurements
IMU: Lateral acceleration and yaw rate measurements
SG1: Load measurement in fifth wheel (strain gages)
SG2: Strain measurement of a timber bunk
SG3: Strain measurement of trailer frame
SG4: Measurement of drawbar forces
Information from the CAN-bus of the truck: wheel speed, engine rpm, fuel consumption, brake pedal position (on/off), gas pedal position etc.

ai = acceleration measurement
ωi = angular rate measurement
δ = measurement of steering wheel angle



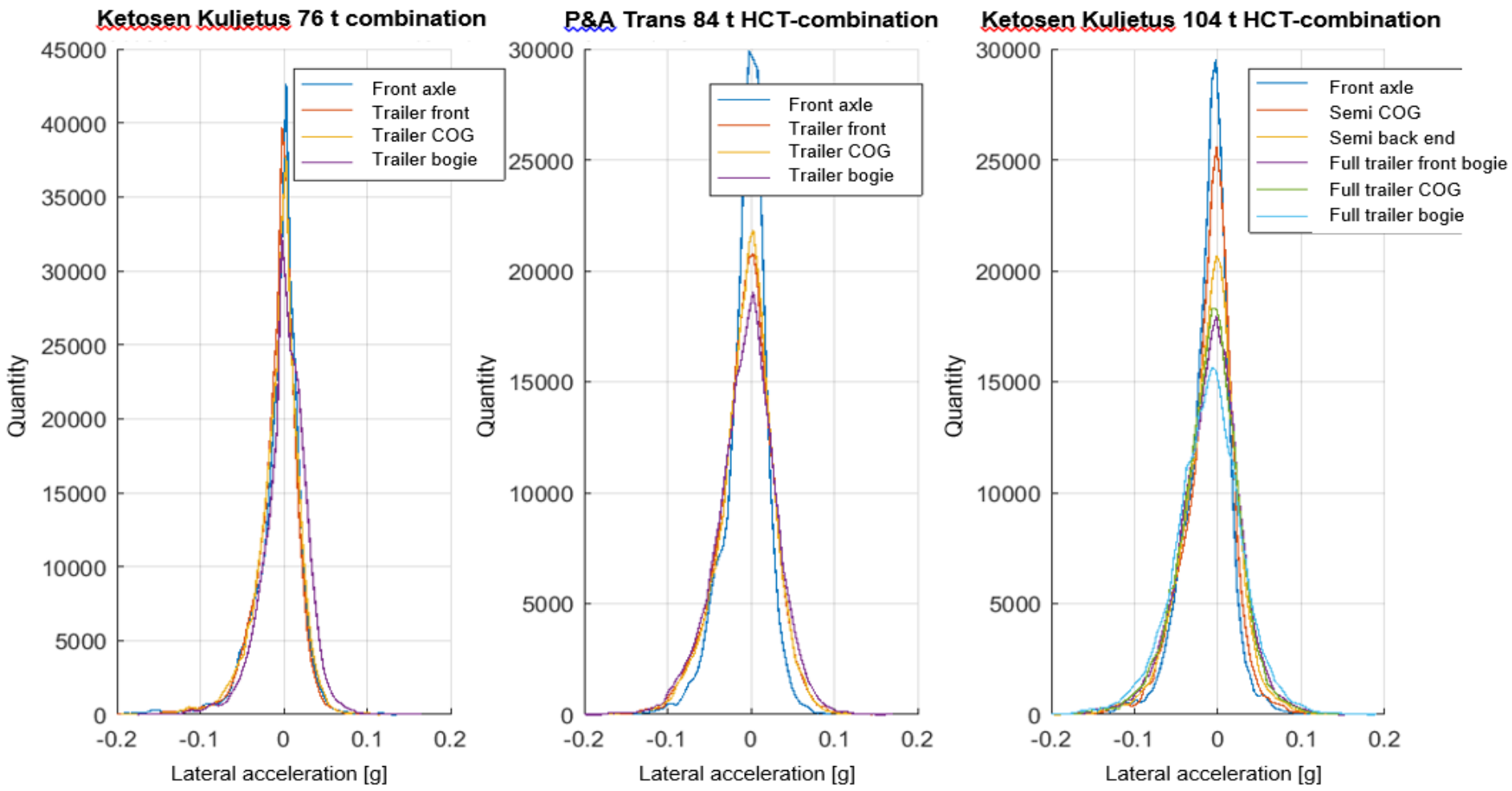
Results of Experimental Methods – 104 t and 84 t Double Lane Change in summer conditions

- Double Lane Change test according to ISO 3888-1
- Tests were carried out in September at Ivalo
- Purpose was to compare the results between different combination vehicles
- HCT vehicles performed well at the used speeds



Driving Monitoring on Ivalo-Rovaniemi Road : Distribution of Lateral Accelerations (Summer Season)

Measured trail 57 km



Measured results in Ivalo–Rovaniemi-road January 2016 (104 t. combination)

Table 1: Lateral acceleration values on winter rutted roads

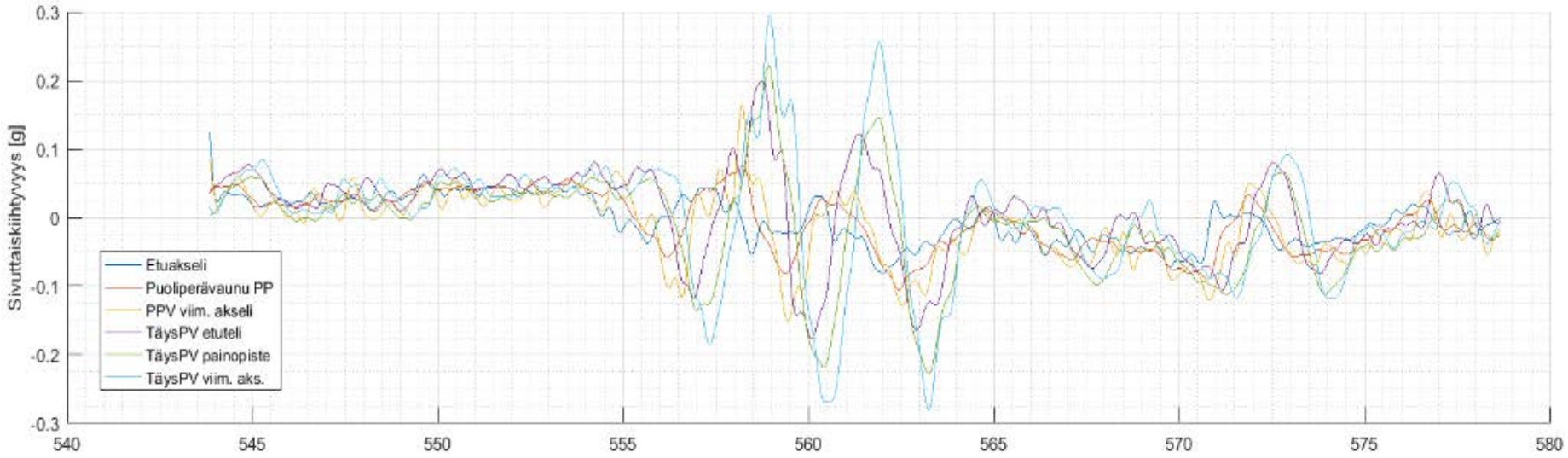
Measuring objects	Unloaded 17.1.2016	Full loaded 18.1.2016
Front axle	-0,137–0,128	-0,101–0,079
Semitrailer (CG)	-0,133–0,120	-0,124–0,102
Semitrailer last axle	-0,170–0,136	-0,163–0,095
Full Trailer front axle	-0,144–0,140	-0,133–0,370
Full trailer (CG)	-0,149–0,123	-0,149–0,119
Full trailer, last axle	-0,162–0,151	-0,182–0,144

Table 2: Lateral acceleration values on a road with hard compressed snow layer

Measuring objects	Unloaded 17.1.2016	Full loaded 18.1.2016
Front axle	-0,039–0,065	-0,024–0,044
Semitrailer (CG)	-0,039–0,072	-0,036–0,051
Semitrailer last axle	-0,070–0,062	-0,079–0,048
Full Trailer front axle	-0,037–0,095	-0,057–0,090
Full trailer (CG)	-0,051–0,073	-0,058–0,066
Full trailer, last axle	-0,049–0,093	-0,079–0,087

Results – 104 t Evasive Maneuver in the Highway

- Vehicle combination had to make an evasive maneuver in order to evade colliding into a deer.
- Peak lateral accelerations at the last axle of the full trailer were almost 0,3 g.
- In slippery conditions traction in the full trailers last axles could have been lost.

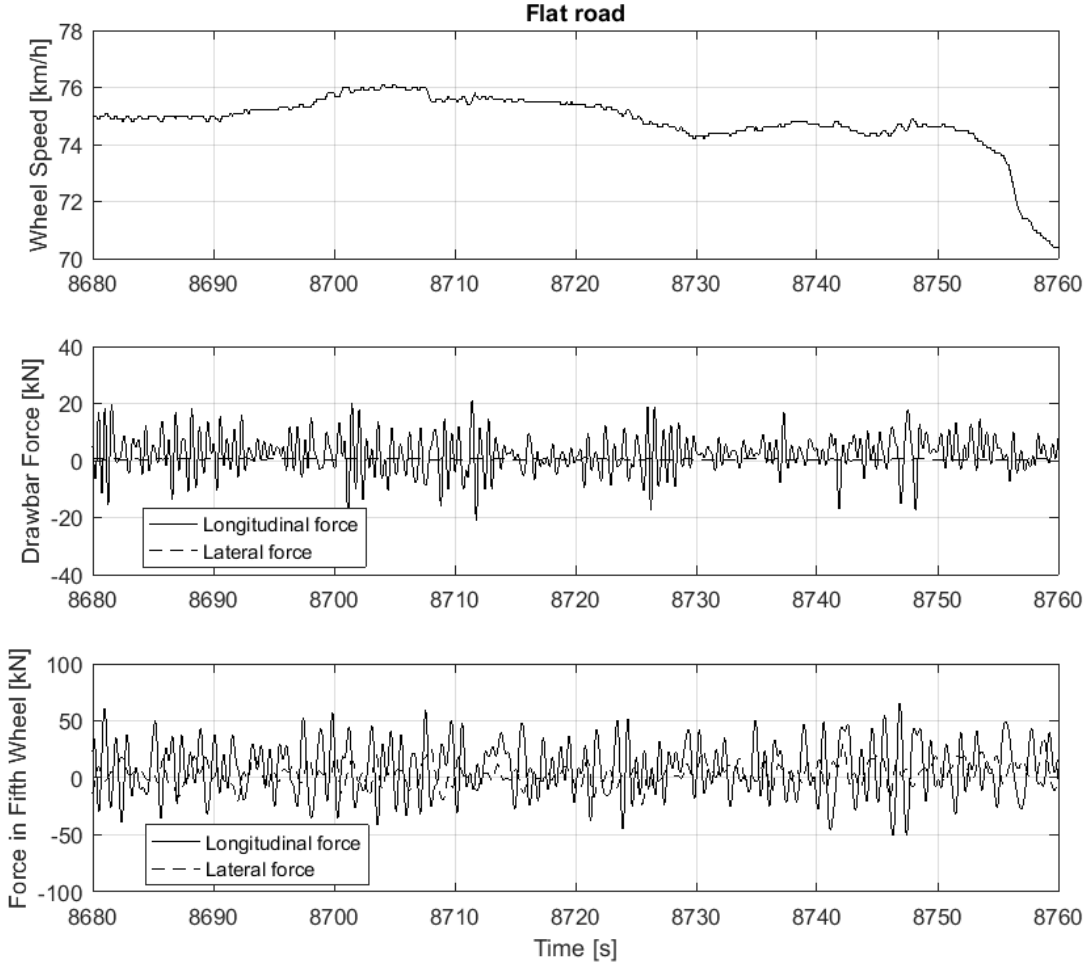


Force Measurements in Drawbar

– Strain gages for longitudinal and lateral forces

- Measurement of normal and bending strains
- 4 gages for a direction => temperature effects and unwanted strains are compensated

Results of Force Measurement – Usual Driving

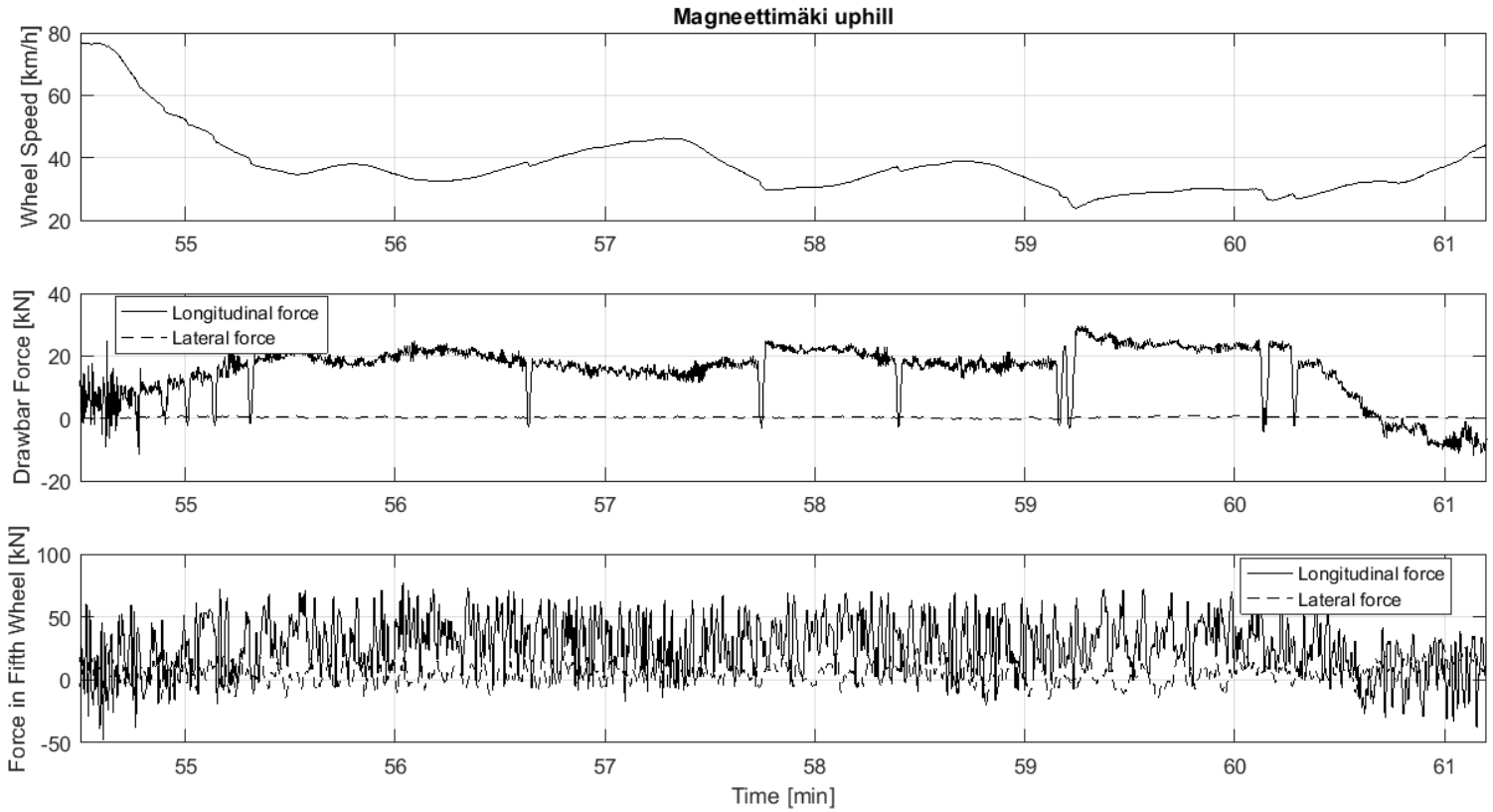


- **Drawbar, unloaded combination:**
  - Highway
    - Fx = ± 5 kN, Fy = ± 0,5 kN
  - Streets
    - Fx = ± 15 kN, Fy = ± 2,5 kN
- **Drawbar, loaded combination:**
  - Highway
    - Fx = ± 45 kN, Fy = ± 2 kN
  - Streets:
    - Fx = ± 30 kN, Fy = ± 7 kN
- **Measurements in fifth wheel problematic**
  - Varying vertical load affects both longitudinal and vertical measurements

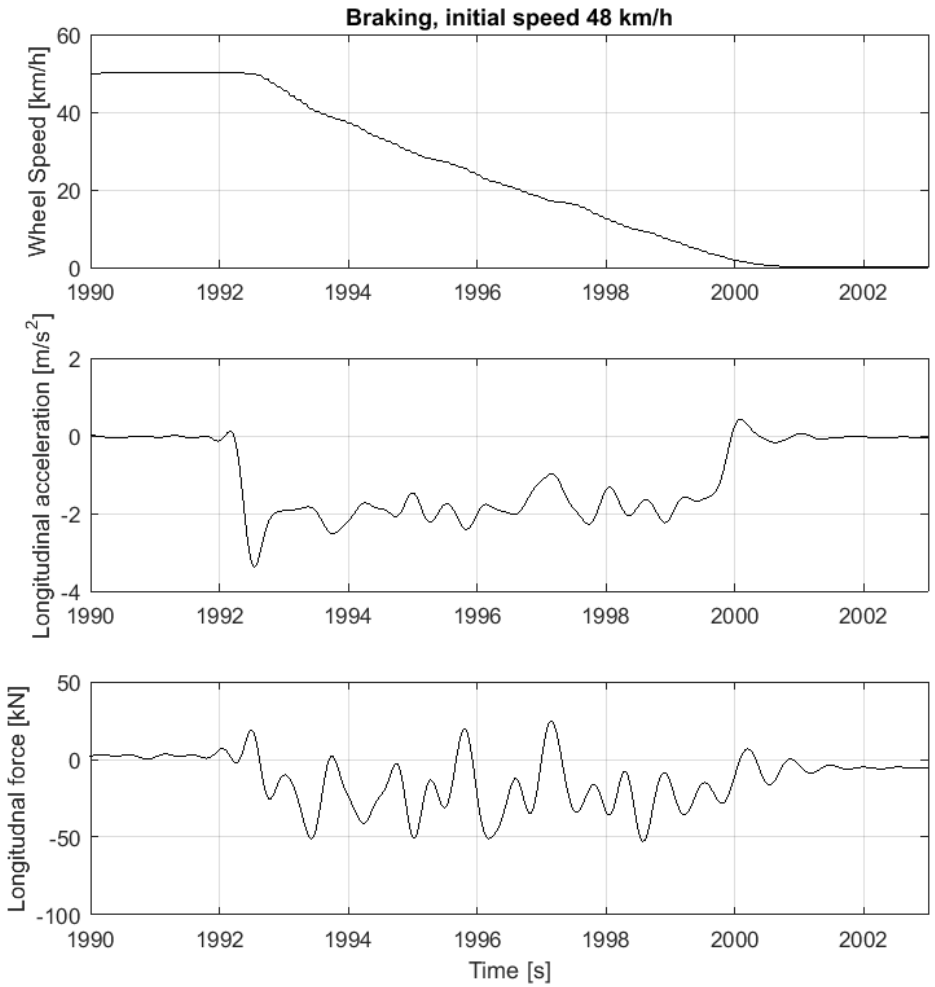
Results of Force Measurement – Usual Driving

Magneettimäki hill

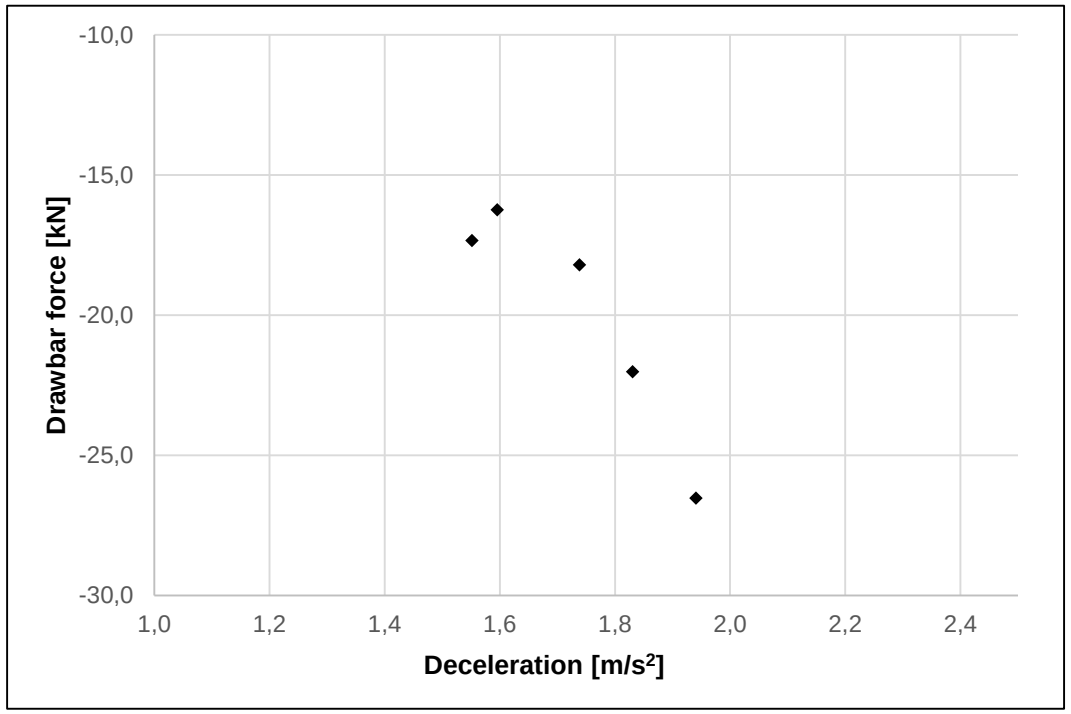
- Length 3 600 m, height difference 160 m
- Average speed 32,8 km/h
- Average Fx 19,7 kN; maximum Fx 30 kN
- Calculated climbing resistance + rolling resistance ≈ 20 kN



Results of Force Measurement – Braking

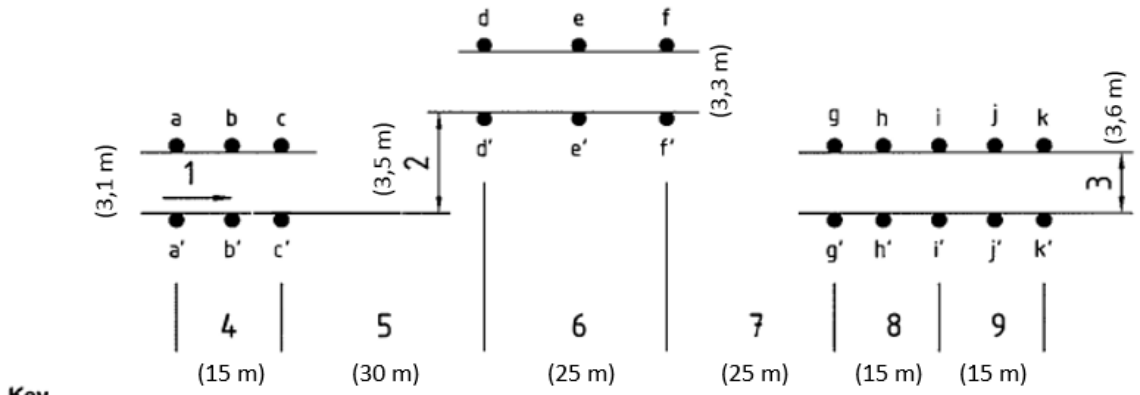


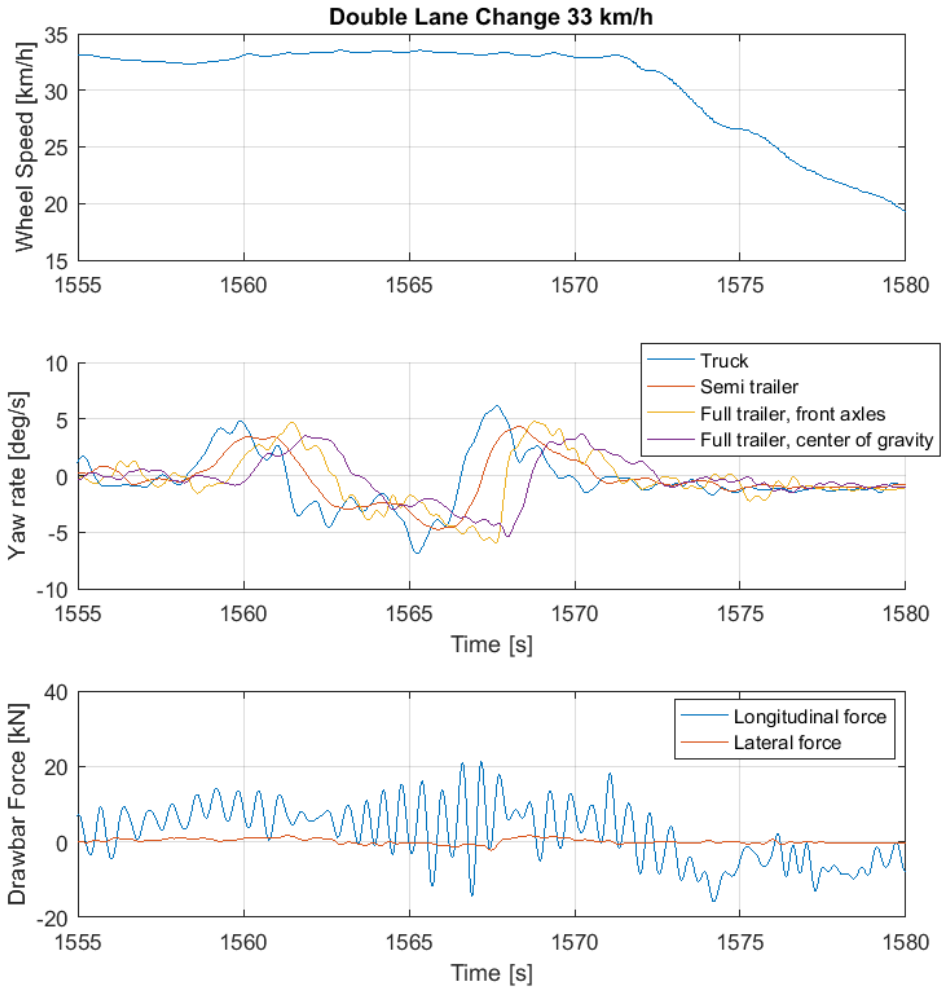
- 104 ton combination's braking distances ~ 10 % above normal 76 ton combination
- Drawbar force depends on deceleration
- Average drawbar force -22 kN



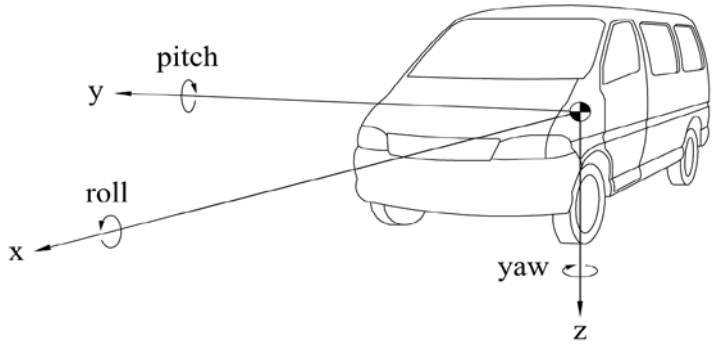
Results of Force Measurement– Double Lane Change

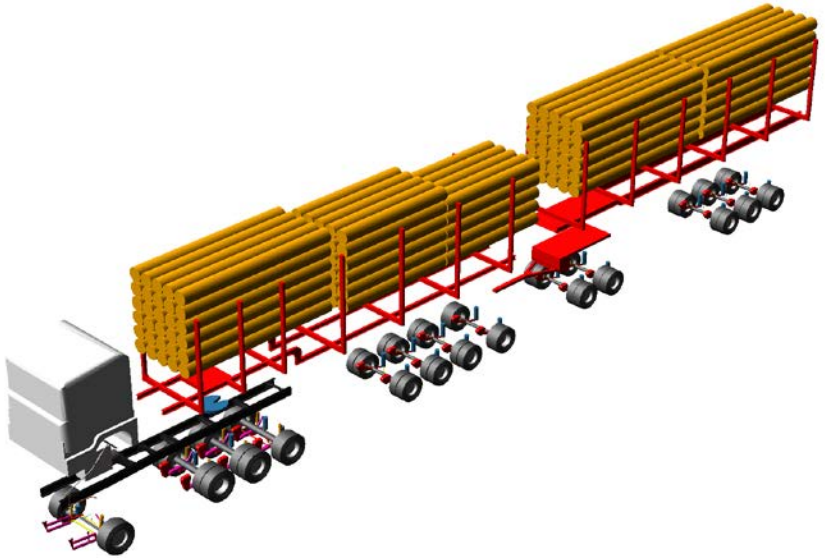
- **Lateral force small (-2,2 – 1,7 kN)**
- **Longitudinal force oscillates**
  - maximum amplitude: -14,4 – 21,4 kN (35,8 kN)





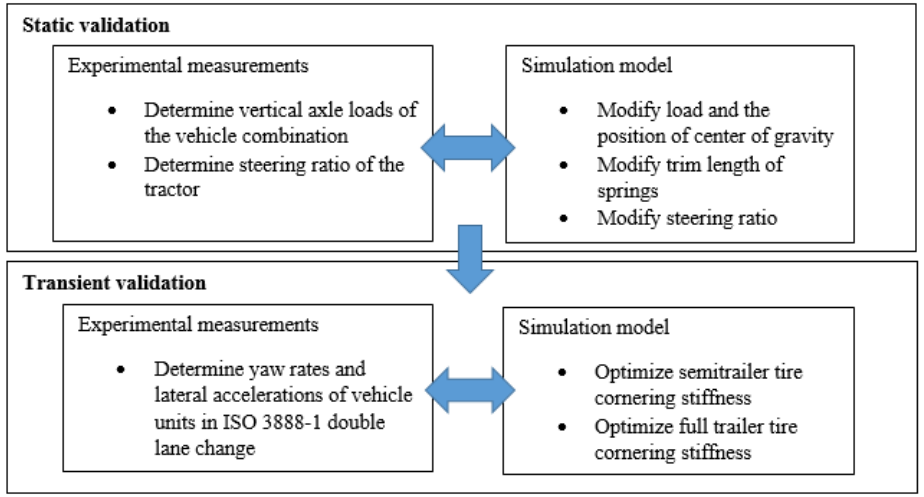
Simulation model

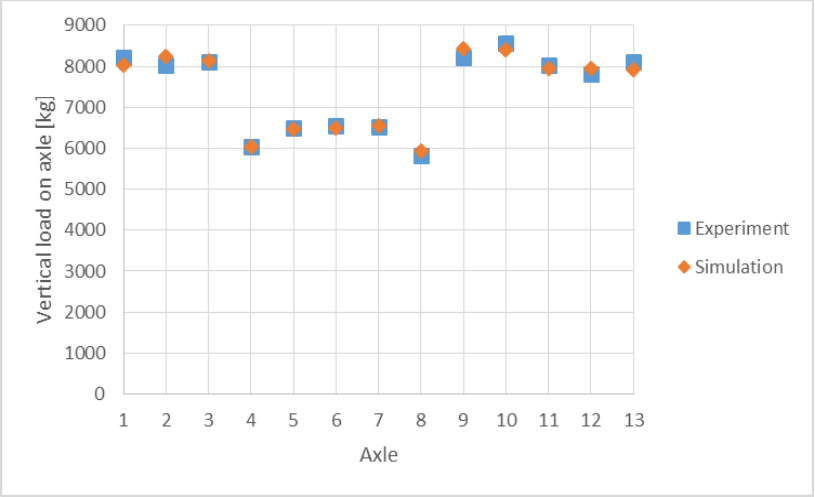




- Stability of the HCT vehicle combination is studied with ADAMS multibody dynamics software
- Models include suspension and main subsystems of the real life vehicle
- Parametrized subsystems can be used to define different types of vehicle combinations
- Springs modeled as ADAMS airsprings
- Lumped mass models with rigid frames, aerodynamic forces neglected
- The templates, subsystems and simulation models are built based on earlier studies and measurements off actual vehicles

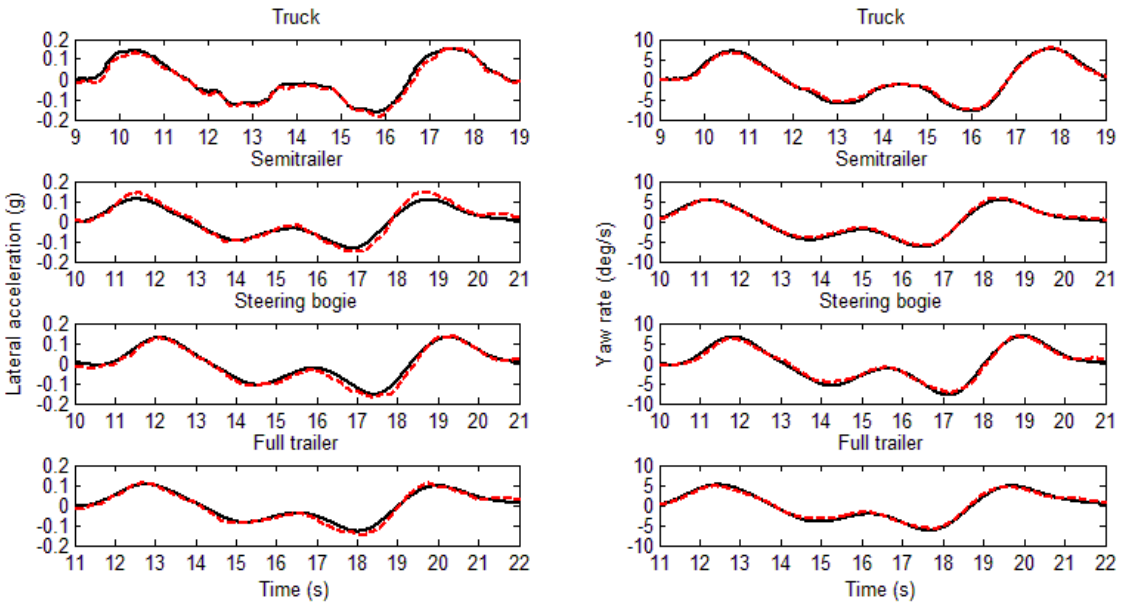
Simulation model validation





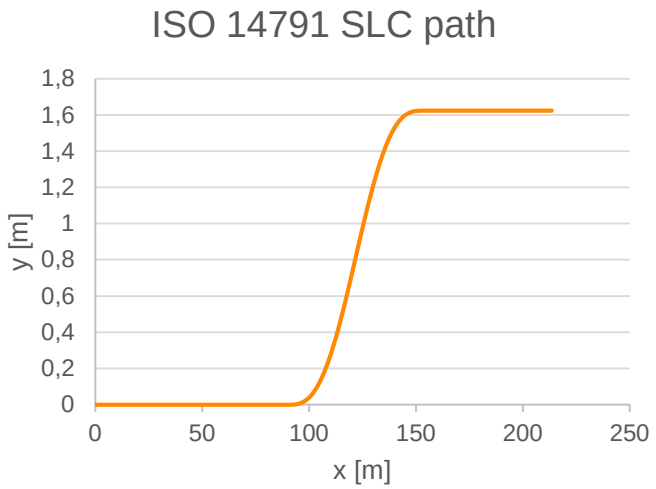
- **Simulation model is validated with the data from real life vehicle in full scale vehicle test**
- **ISO 3888-1 double lane change test used**
- **Static validation in bottom left (axle masses)**
- **Transient validation in bottom right (lateral accelarations and yaw rates of vehicle units)**

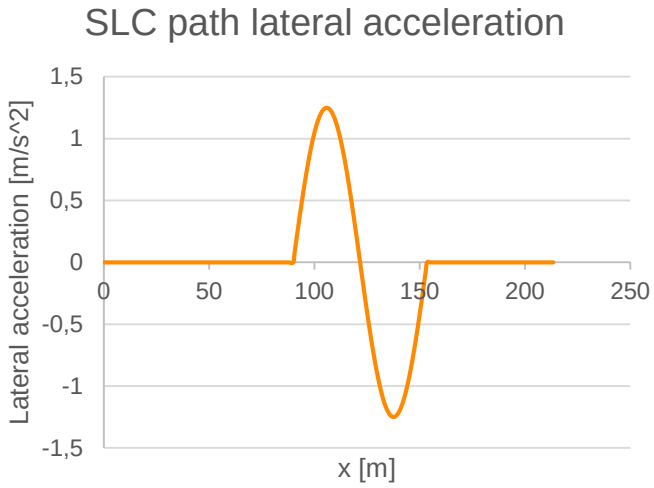
Measurements in red dashed line ----------
Simulation model output in black solid line ___

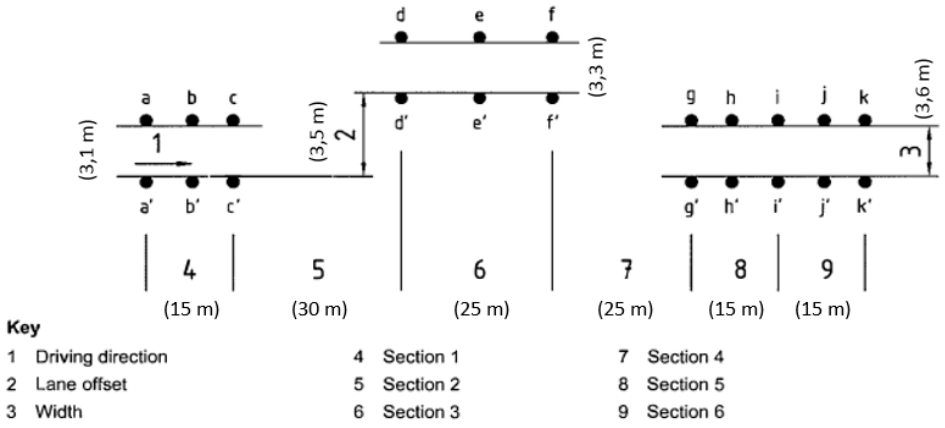


Tests Used in Simulations

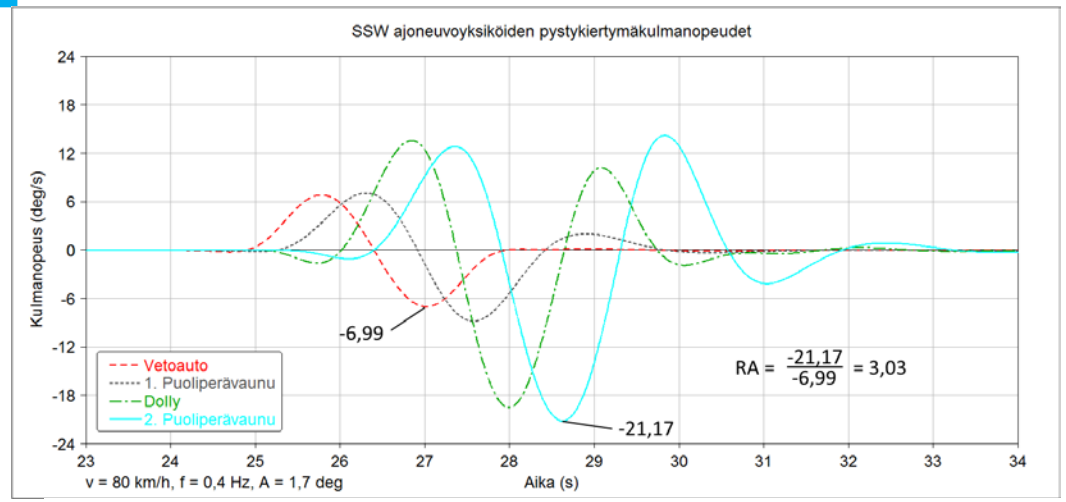
- Double lane change according to ISO 3888-1 (closed loop)
- Single lane change and single sine wave steer input tests according to ISO 14791 (open loop and closed loop)
- Pulse steer input test according to ISO 14791 (open loop)

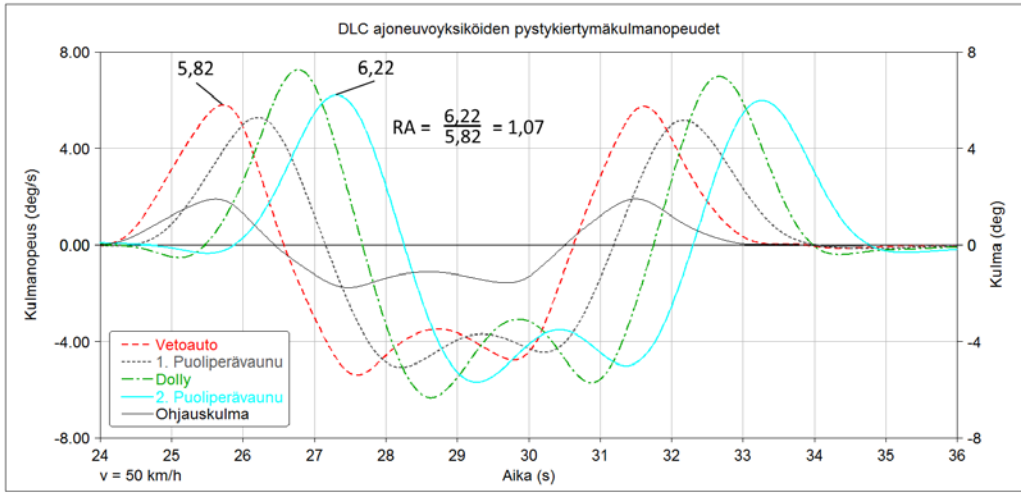




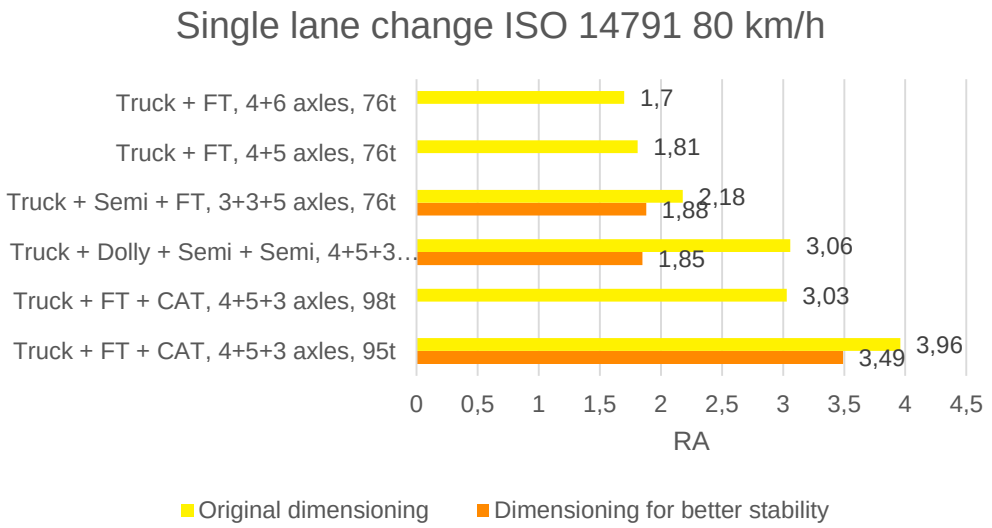


Impact of Vehicle Dimensioning



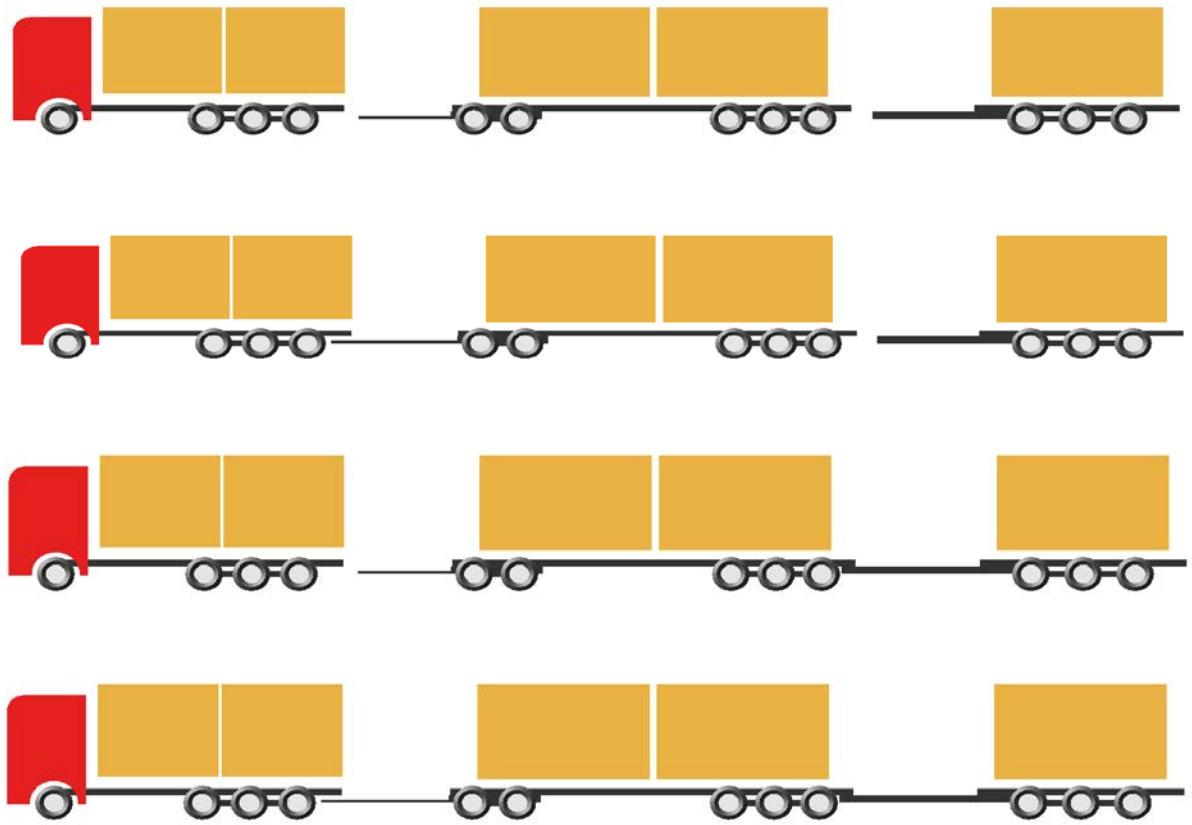


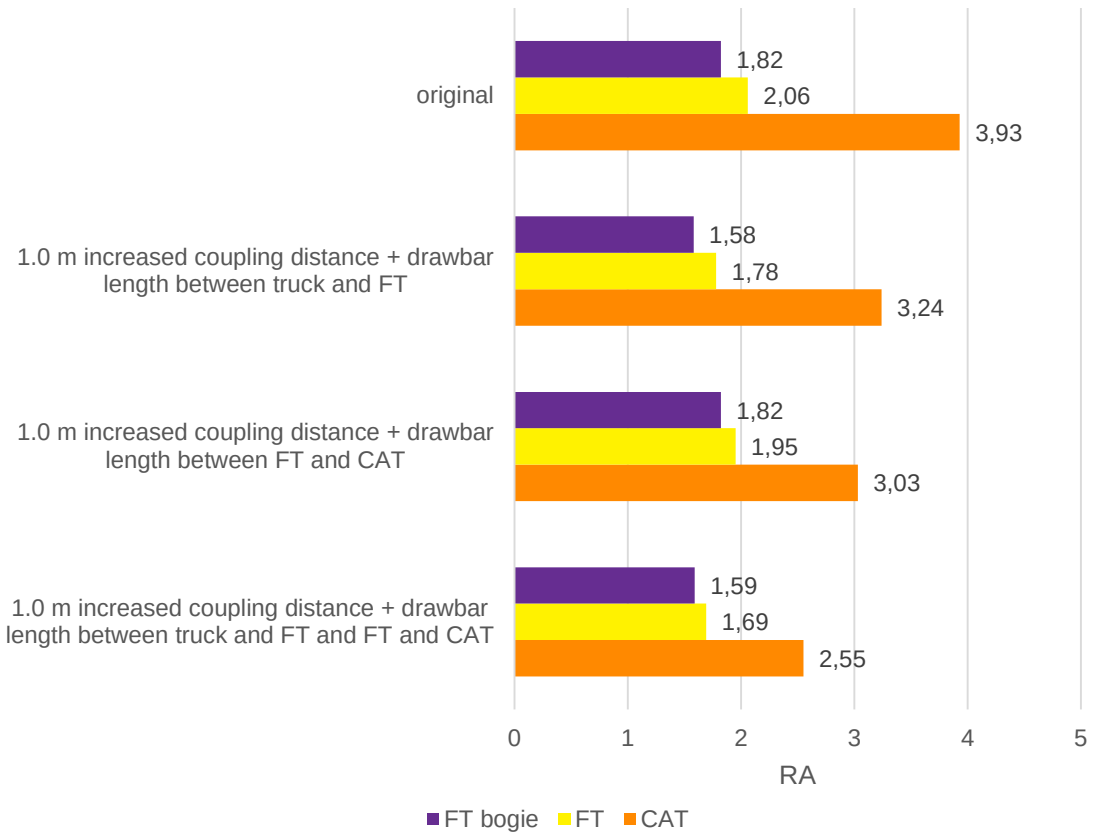
- To study how different coupling lengths, drawbar lengths and other dimensioning parameters affect the lateral stability of a HCT vehicle
- To find a good compromise for coupling parameters between turning and lateral stability for a specific vehicle
- To evaluate lateral stability of a HCT vehicle



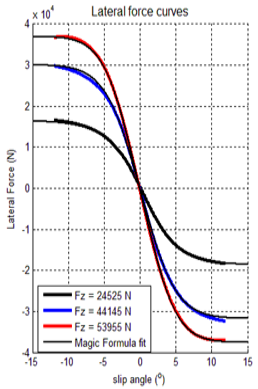
Results – Example of Vehicle Model

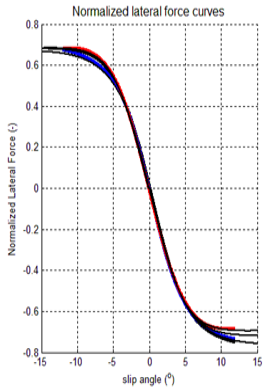
- Exaggerated coupling dimension changes for demonstration purposes
- YAW rate RA values from ISO 14791 single lane change test

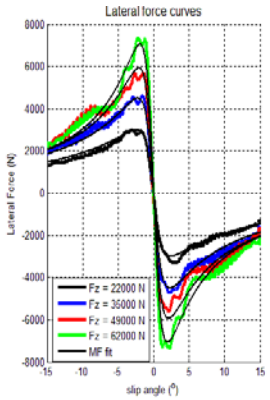


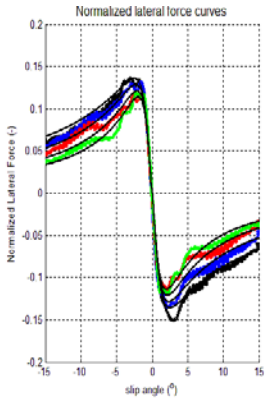


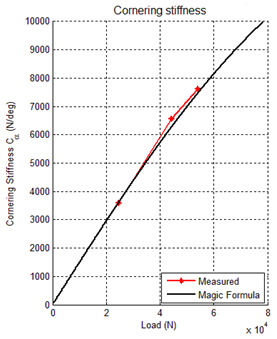
Tyre Research -Tyre models

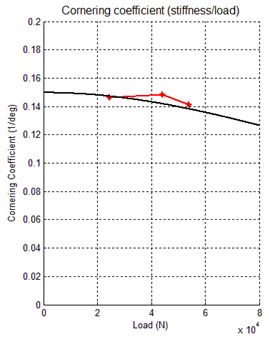


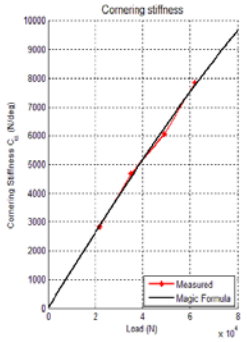


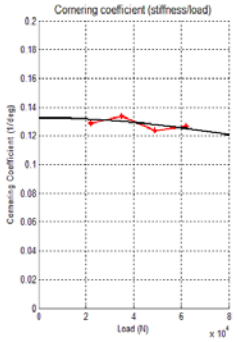












- Pac2002 tyre models, which are based on Pacejkas Magic Formula
- Parameters for the tire models are defined based on measured force output of the tires (for 385/55 R22.5 and 315/70 R22.5 tires)
- Tire models for dry and wet asphalt and for ice
- Smaller tire models (trailer tires) are modified from 385/55 R22.5 tire models with scaling factors based on the data from full scale vehicle tests

Conclusions

- **Vehicle combinations are complicated kinematic systems and their behavior should be examined carefully with experimental and computational methods before use**
- **There is no considerable difference between ordinary vehicle combinations and some of the HCT-combinations**
- **Simulation model output and measurements have correlation**
- **Simulation models can be used to effectively study and improve dimensioning and the traffic safety of a HCT vehicle combination**
- **Further studies:**

- Use of optimization methods to define recommendations for dimensioning of different types of vehicle combinations
- More detailed analysis of measurement results (report in the beginning of the year 2018)

Thank you for your attention !

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