Block 13:00-14:00hr

- Aerodynamic Features for the Complete Vehicle
- Automotive ethernet communication
- Trailer 2 Train
- Testing, validation and assessment of impact

The AEROFLEX project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 769658

Aerodynamic Features for the Complete Vehicle

Industry

Dr Per Elofsson, Scania CV, Senior Technical Manager

Roy Veldhuizen, ZF Group, Aerodynamic Expert

Research

Jaap van Muijden, NLR, Senior Scientist

Service and validation

Introduction

- Drive development of next generation of aerodynamic products to drastically reduce CO_2 emissions of long-haulage transport

Develop and quantify

- Model preparation
- Extended front design
- Design and simulations
- Post-processing
- Animations and renderings

Validate

- Scale model design
- Assembly
- Instrumentation
- Test

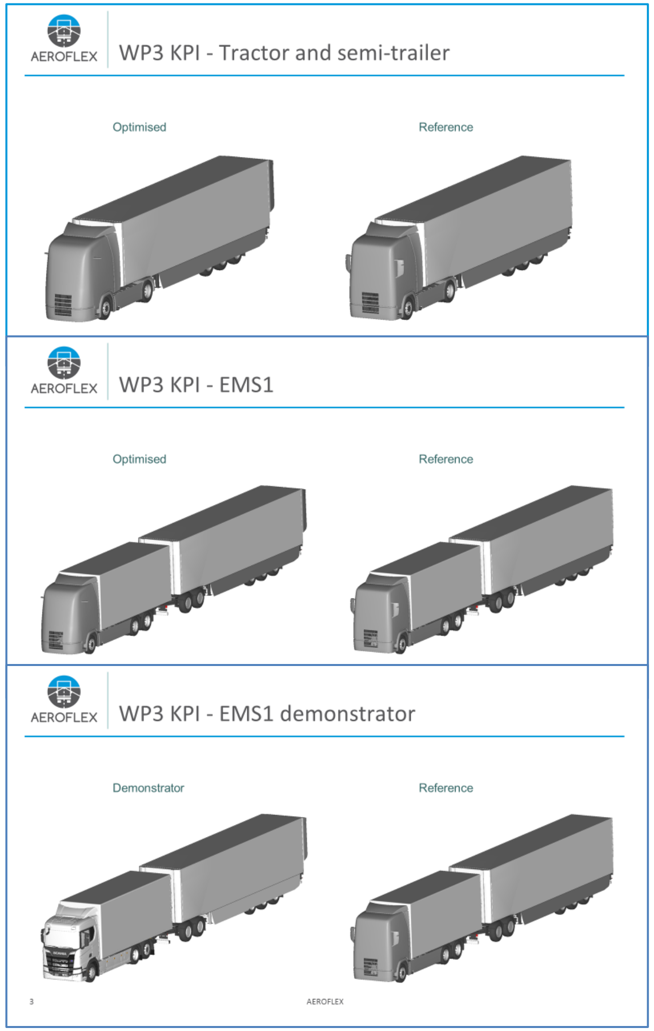
Demonstrate

- Definition
- Design of active and passive aero devices
- Installation and trouble shooting

KPI - Aerodynamic performance of innovations

- Targets on drag reduction have been met
  - Tractor and semitrailer ΔCdA=25%
  - EMS1 ΔCdA=17%
  - EMS1 demonstrator ΔCdA=15%

Drag reduction	**Tractor - ST**	**EMS1**
ΔCdA, *realistic*	2.09 m^2 (42%)	2.36 m^2 (40%)
ΔCdA, *maximum*	2.38 m^2 (48%)	2.62 m^2 (44%)



KPI - Demonstrator performance

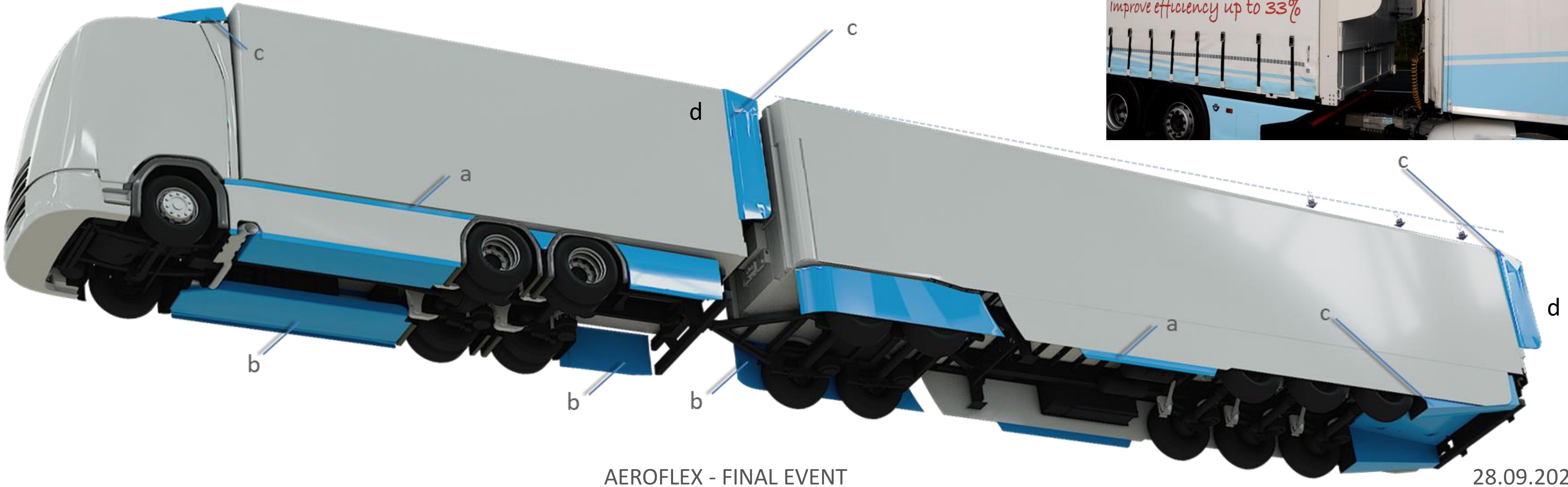
- KPI evaluation:

	High potential	Moderate	Final
ΔCdA reduction	2.07 m^2 (35%)	1.58 m^2 (27%)	1.69 m^2 (29%)

- The final configuration as designed for the demonstrator gave a 29% drag reduction compared to the EMS1 reference

Concept generation - principles

- (a) Seal the vehicle (extensions)
- (b) Cover (side skirts , panels)
- (c) Orient the flow (diffuser, gap reducer, boat-tail)
- (d) Flow control




AEROFLEX
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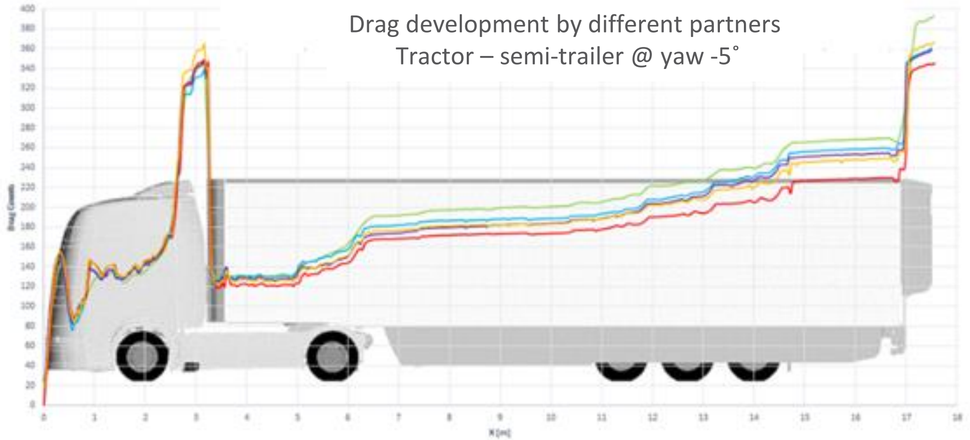
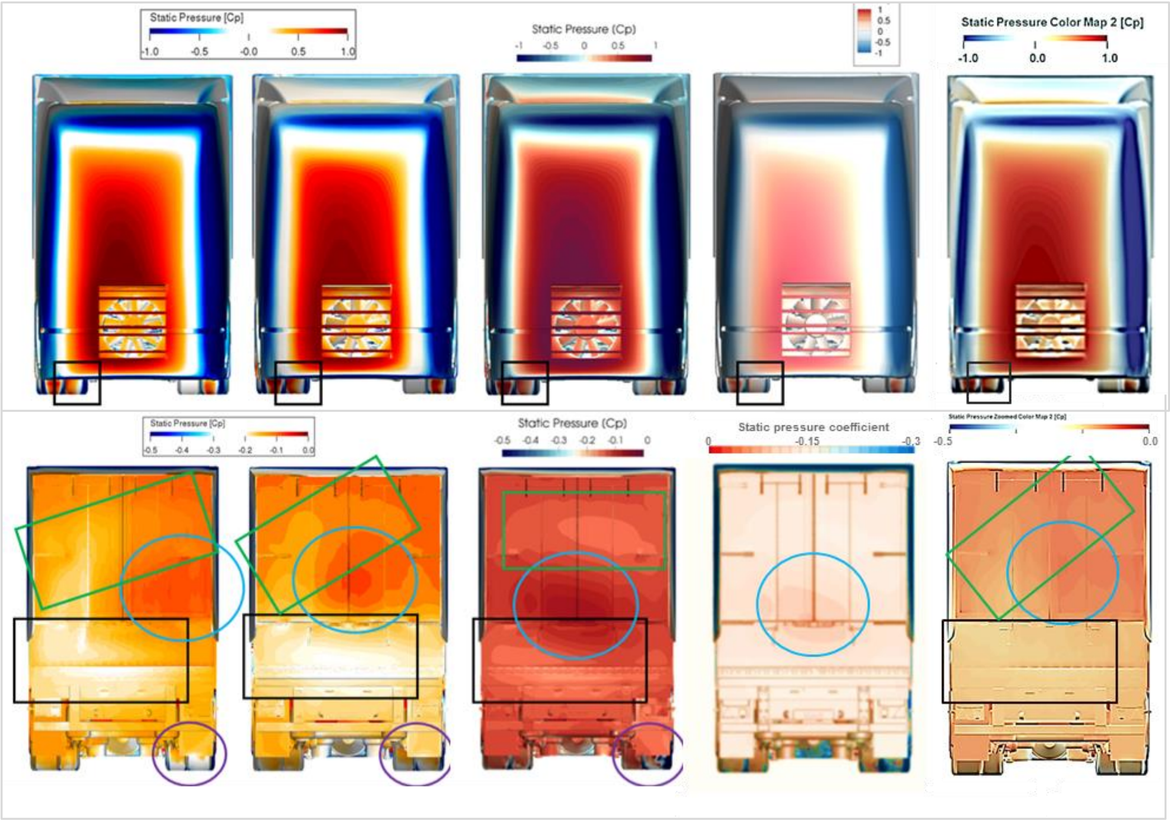
Initial CFD simulation of the Baseline models

- Initial simulation results for the Baseline models



Static pressure distribution, Tractor – semi-trailer @ yaw -5˚, according to different participants

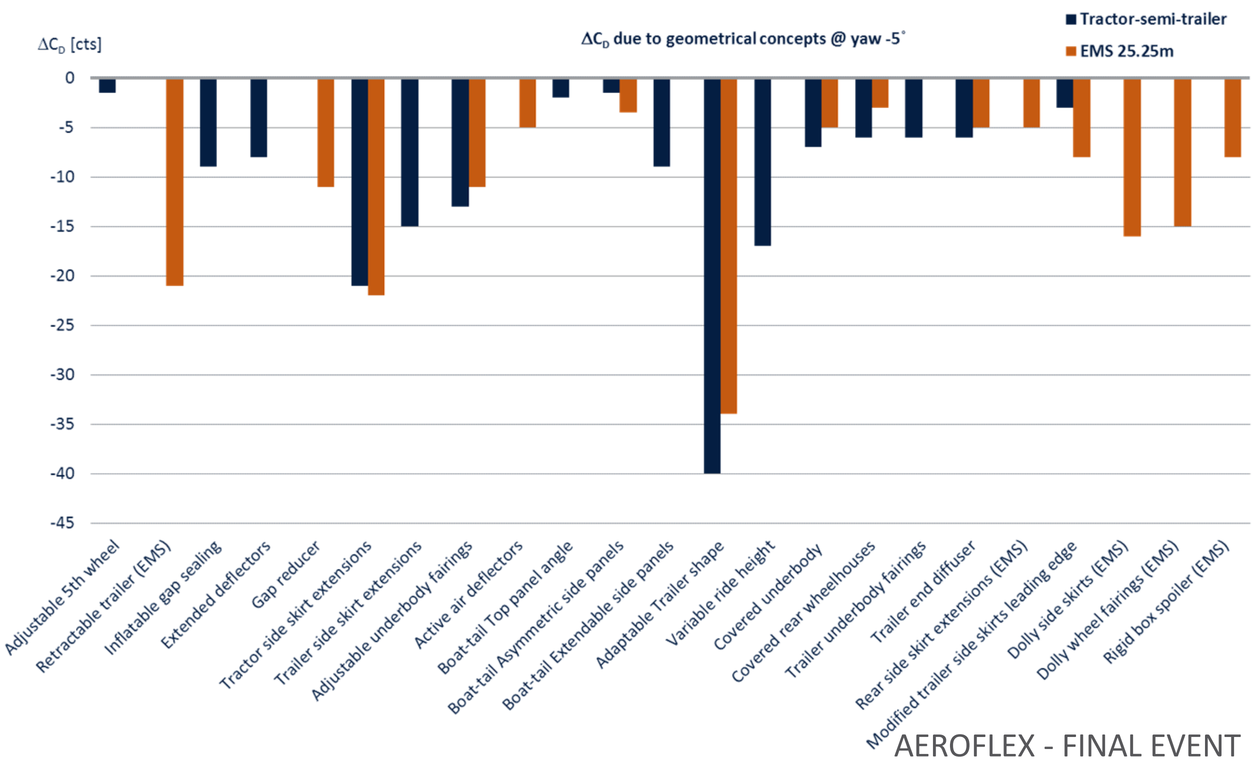


- ΔC_D of primary interest: Boat-tail on/off

ΔC_D (cts)
40
40
29
36
34

Concept simulations

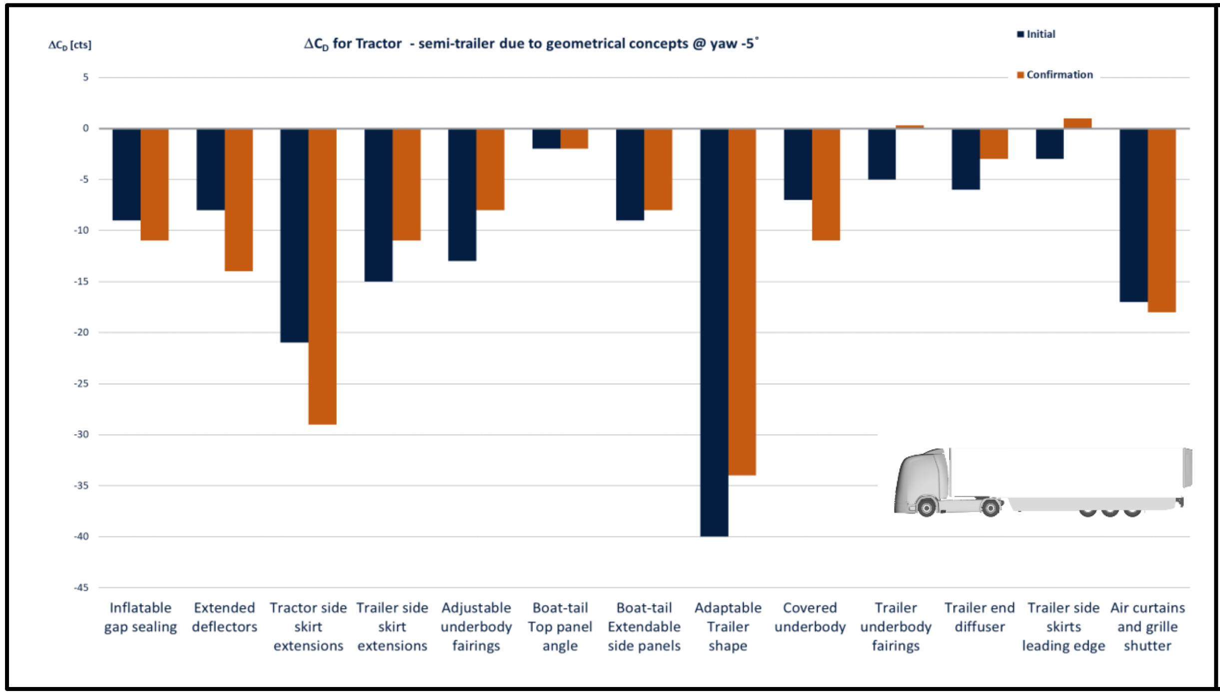
- Various concepts identified and listed as potentially interesting
- Concepts involved different parts and positions on the vehicles
- Geometrical measures as well as flow control methods included

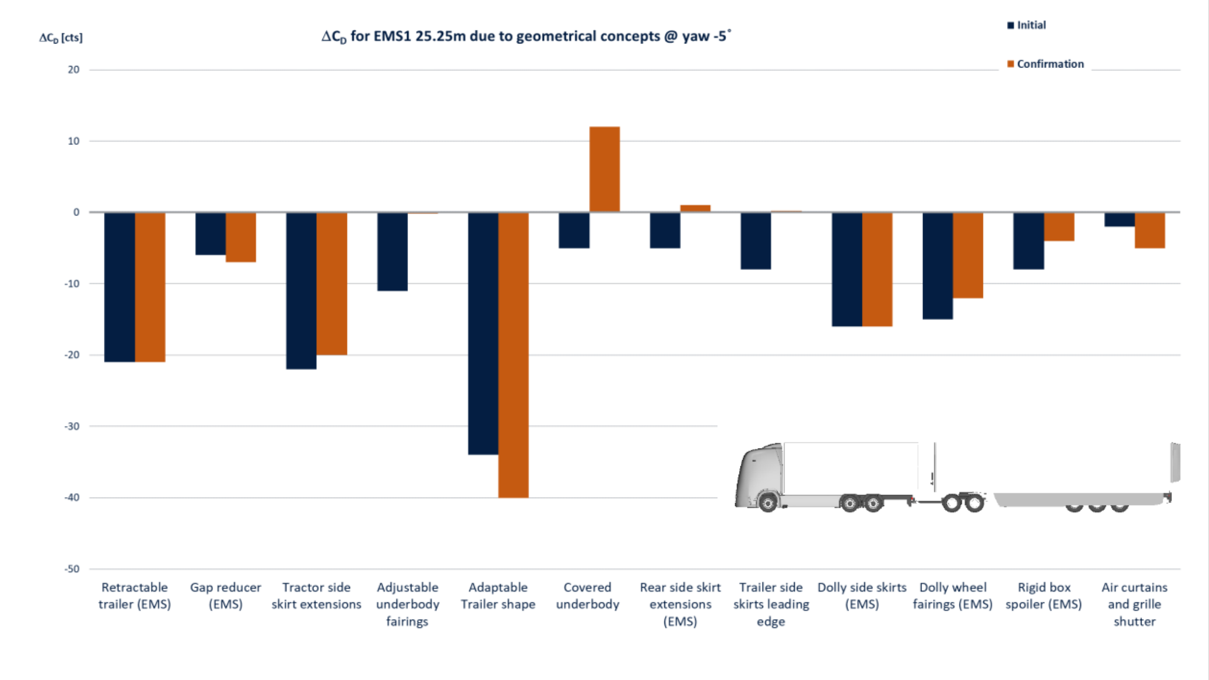


Group	Concept
Active geometries	Gap reduction 1. Adjustable 5th wheel 2. Retractable trailer
	Gap blockage 1. Inflatable gap sealing 2. Extended deflectors 3. Gap reducer
	Active side skirt extensions 1. Tractor 2. Trailer
	Adjustable underbody fairings
	Active air deflectors
	Adjustable boat-tail 1. Top panel angle 2. Asymmetric side panels 3. Extendable side panels
	Adaptable Trailer shape
	Variable ride height
Passive geometries	Covered underbody
	Covered rear wheelhouses
	Trailer underbody fairings
	Trailer end diffuser
	Rear side skirt extensions (EMS)
	Modified trailer side skirts leading edge
	Dolly side skirts (EMS)
	Dolly wheel fairings (EMS)
	Rigid box spoiler
Active flow control	Plasma actuators
	Synthetic jet
	Base bleeding
	Tangential blowing
Passive flow control	Vortex generators
	Air curtains and grille shutter

Confirmation simulations

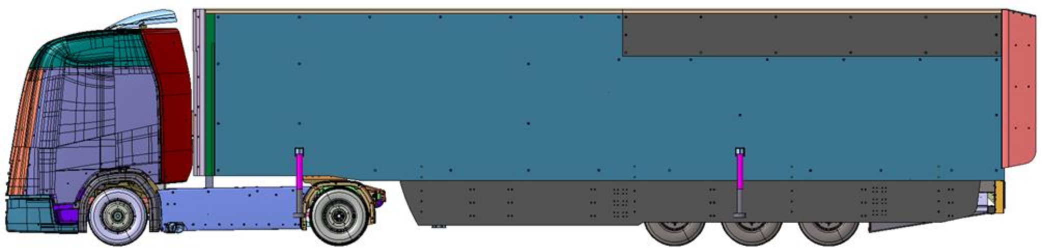
- Most promising and feasible concepts simulated in the confirmation simulation phase
- Some of the concepts also improved
- Generally, good agreement in trends and magnitudes of improvements





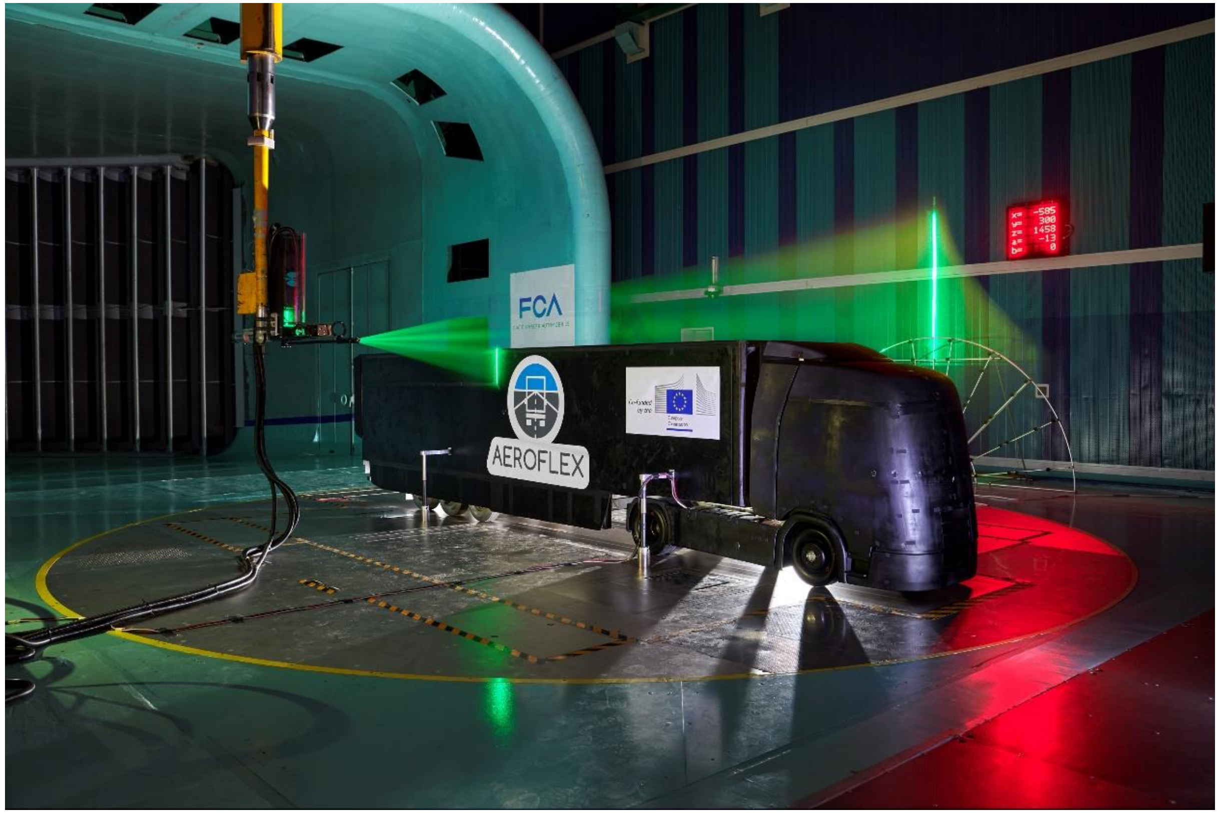
Wind tunnel investigations

- Validation of CFD and pre-selection of aero innovations
- Design of a 1:3 scale model
- Two test campaigns at the FCA wind tunnel



Wind tunnel investigations

- Validation data include forces, surface pressures and flow field data
- Scale model and validation data can be provided to other research projects

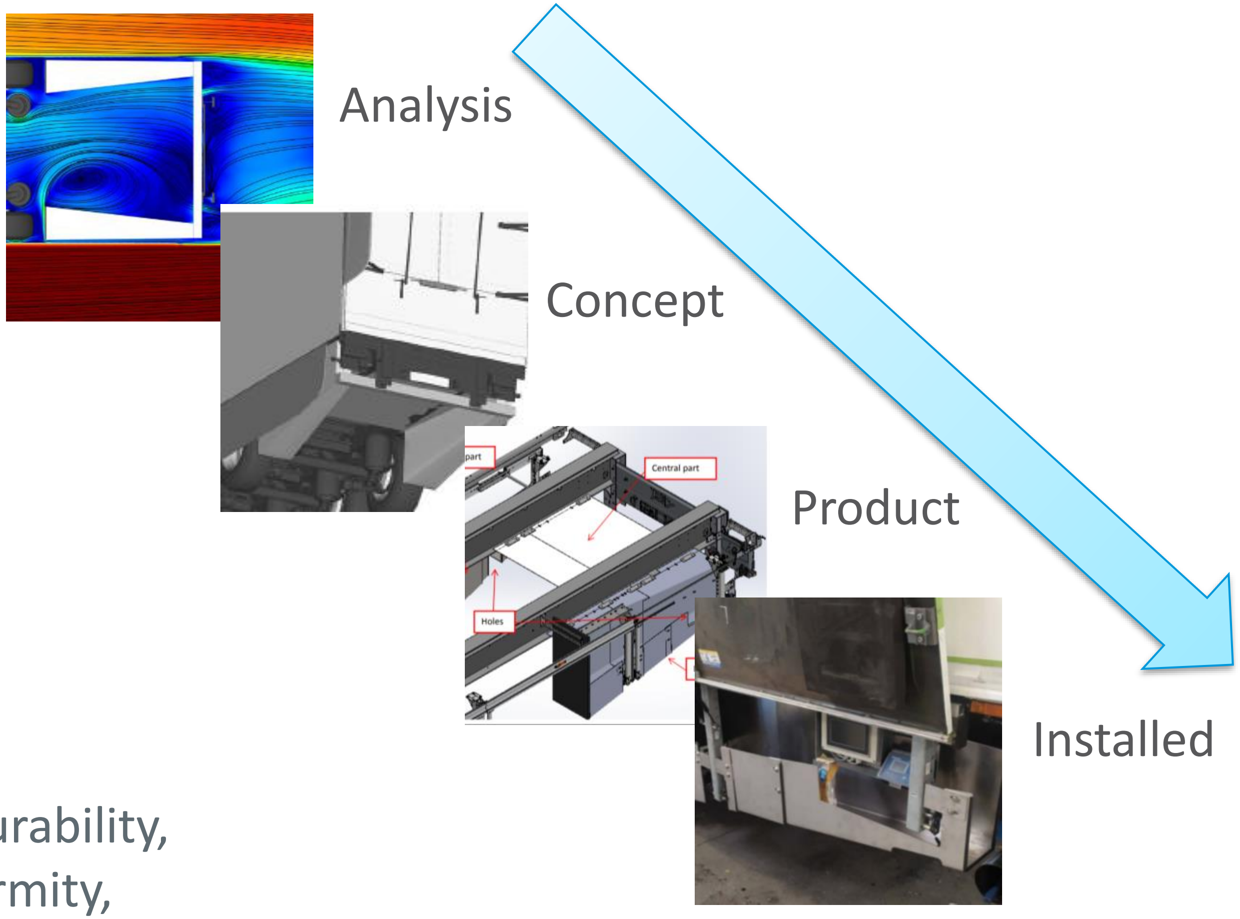


CFD to Wind Tunnel comparison

	Cd_0	Cd_5
Wind Tunnel 1:3 scale	0.396	0.423
CFD Open road 1:1	0.336	0.393
CFD as WT 1:3 scale	0.392	0.418

AeroLoad demonstrator construction

- Demonstrate that promising aerodynamic concepts can be developed into real-life prototypes
- Demonstrate
  - Move from concepts to pre-products:
    1st step towards industrialization
- Promising aerodynamic concepts
  - 14 best innovations were selected based on:
    - Aerodynamic performance
    - Applicability, feasibility & TRL
- Developed into real-life prototypes
  - Theoretical designs were adapted for manufacturability, installation & integration and operational conformity,
    to **show that aerodynamic devices can deliver short-term real-world savings**



Demonstrator

Adaptable box and trailer shape (40 cts)

Adjustable air deflector (10-30 cts)

Gap reducer(7 cts)

Boat-tail (35 cts)

Underbody panel (5 cts)

Rear side skirt extension(4 cts)

Dolly side skirts (12 cts)

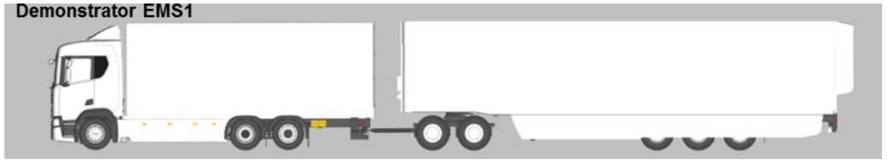
Trailer active side skirt extensions(15 cts)

Diffuser (5 cts)

Truck side skirt extensions (25 cts)

Active ride height (3-10 cts)

- Total drag reduction of 21% from aero innovations compared to a state-of-the-art vehicle combination



Summary

- Passive and active aero concepts developed using CFD and Wind tunnel
- A selection of the concepts were designed and implemented on a demonstrator
- Significant drag reductions achieved contributing to reduced energy consumption and CO_2 emissions:
  - ΔCdA > 40% Tractor-semitrailer (KPI)
  - ΔCdA = 40% EMS1 (KPI)
  - ΔCdA = 29% EMS1 Demonstrator (KPI)
  - ΔCdA = 21% EMS1 Demonstrator vs. Advanced reference

Automotive ethernet communication

Industry

Andelko Glavinic, ZF CVS, development engineer, vehicle communication AEROFLEX

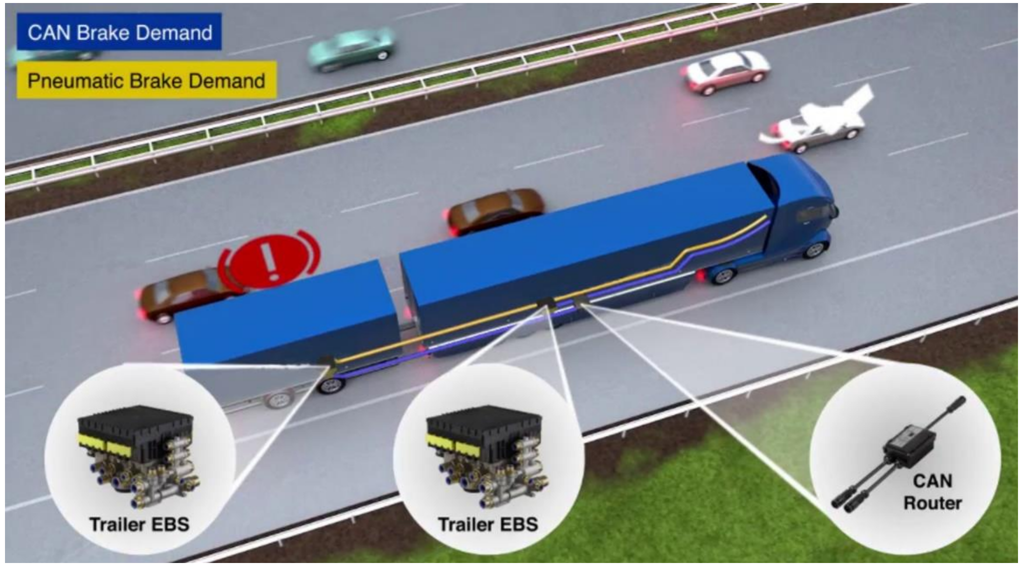
Research

Service and validation

Automotive ethernet communication

- **Objectives**
  - Within AeroFlex the development of **new interface solutions for a safe communication between truck and trailers with high bandwidth and flexibility** for Advanced Energy Power-Train (AEMPT) and Aerodynamic control functions was requested

- **State of the Art**
  - Since 1998 the **ISO 11992** CAN based protocol family is commonly used in Europe. It combines trucks and max. up to 5 Trailers to build road trains.
  - ISO-CAN is over the years exploited and not promising to fulfill future application requirements where fast and time sensitive communication with high bandwidths are needed.

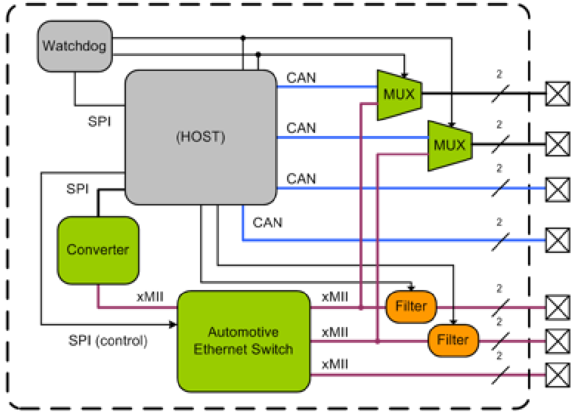


Source: ZF CVCS

Automotive ethernet communication

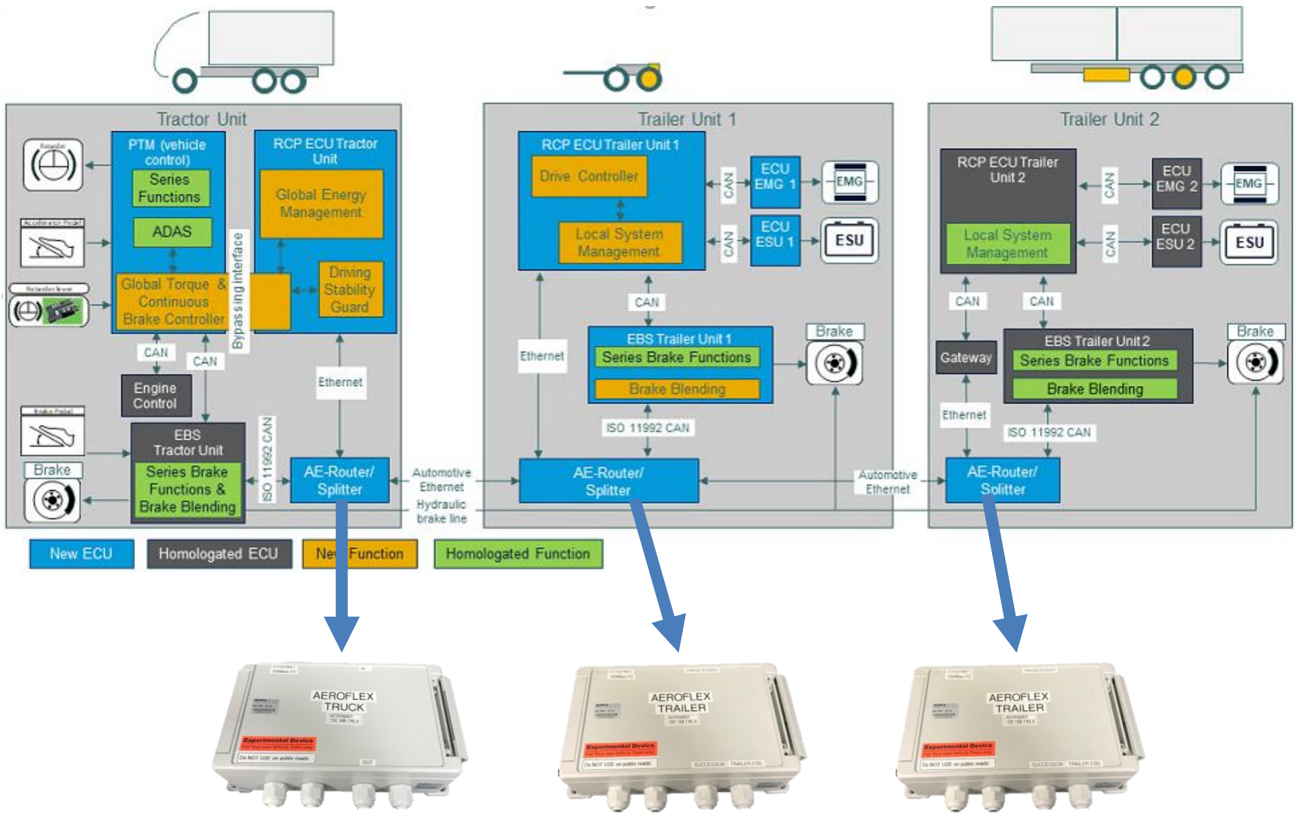
- **Challenges**
  - The selected communication technology has to **be fast, flexible, reliable and extendable**
  - The **control and monitoring of generic electric engines architectures** shall be possible
  - **No additional plugs** shall be installed but reuse of existing ISO plugs and cables is preferred.
  - **Legacy Support** for classic truck trailer combinations shall be given, no adapters wanted

- **Approach**
  - Usage of **Automotive Ethernet technology (100 Mbit/s, OA BroadR Reach) on existing ISO CAN** plugs and cables
  - **Prototype** is based on existing serial ISO CAN Router Repeater + AE module
  - To support legacy CAN based vehicles, an **automated detection procedure** is implemented to switch to Automotive Ethernet only when both vehicles supports this technology.
  - **New communication protocol draft** for control and monitoring of electrified engines were developed



Automotive ethernet communication

- **Results**
  - **Stable communication** with cable lengths < 20 m (15 m specified)
  - **Auto switching** between CAN and Automotive Ethernet mode **successful**.
  - Automotive Ethernet on ISO Cables does not fulfill EMC Requirements (Source: VDA FAT project)



- **Next steps**
  - **Creation of international standardisation proposal** (SAE/ISO) for Automotive Ethernet communication **using 1Gbit/s on 40m** (shielded twisted pair cables on additional connector) with suitable protocol.

Trailer 2 Train

Industry

Eric Lambert
Société nationale des chemins de fer luxembourgeois (CFL)

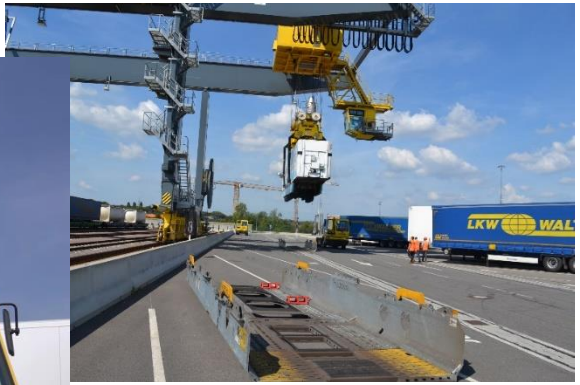
Ton Bertens
Van Eck Trailers

Research

Service and validation

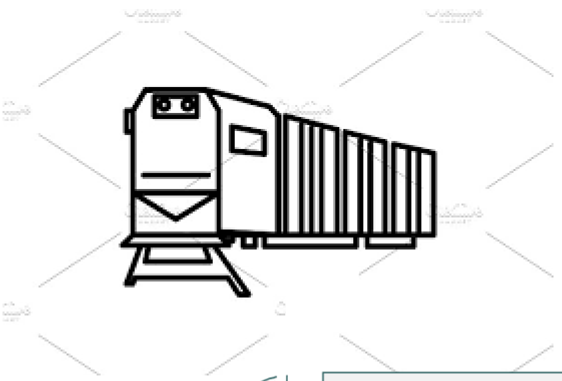
Eric Feyen
Union Internationale pour le transport combine Rail Route

Trailer 2 Train, impression of the tests



Trailer to Train and EMS2

- **Concept:** Multimodal - Market segment: long distance transports
- Aerodynamic optimized trailer must fit for 6 most relevant multimodal techniques in EU: Crane (>97% rail market share), NiKraSa, Modalohr, CargoBeamer, RoLa & ferry
- Proof aerodynamic devices (boat tail and side skirts) do not cause problems for multi-modality



- **Highlights:**
- EMS2, opportunity to bring high amount of cargo to rail and potentially **reduce emissions by >20% and cost by >30%**
- Craneablity of trailer realised by VanEck
- Demonstration in Q1/2021 in real life at CFL, Bettembourg Luxembourg, lifting via crane and train transport via Modalohr to le Boulou France – Spanish border

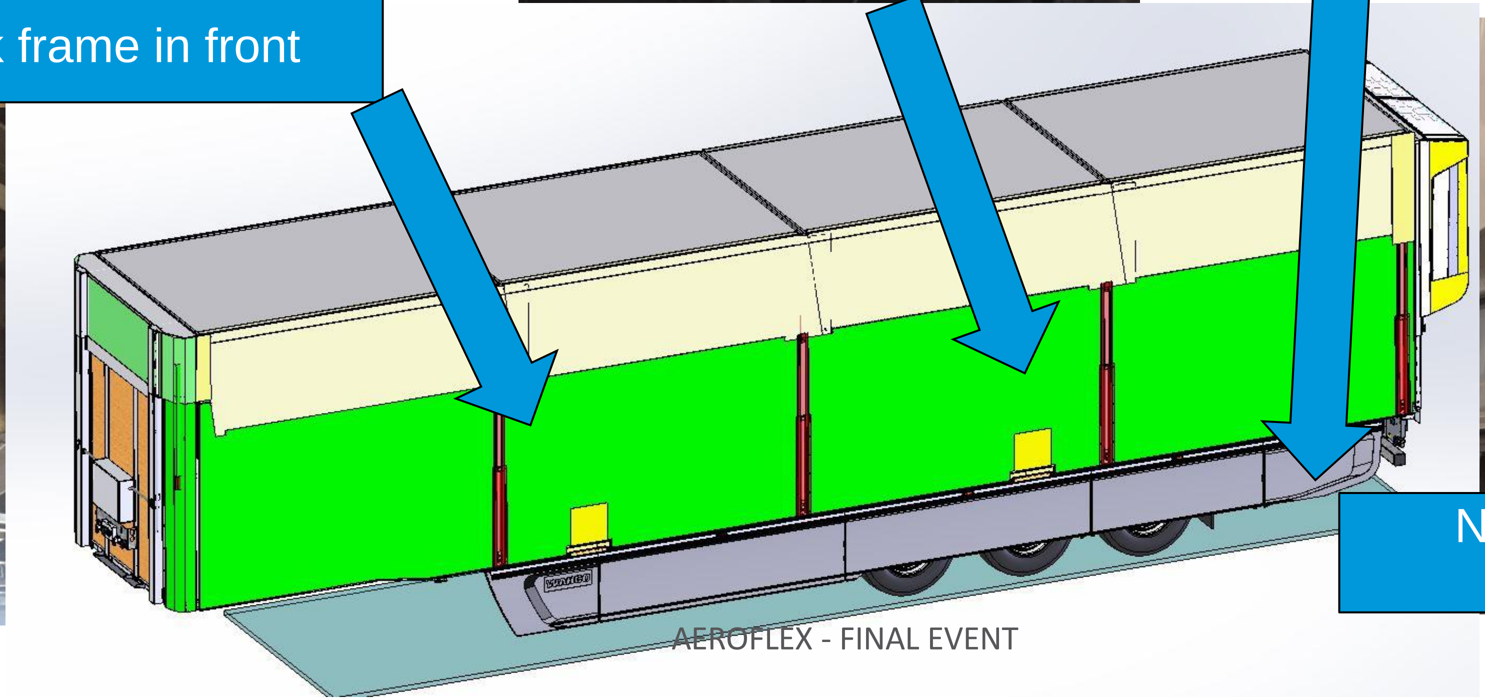
AEROFLEX

Transform the Transformer trailer

Huckepack frame in front

Huckepack frame axles

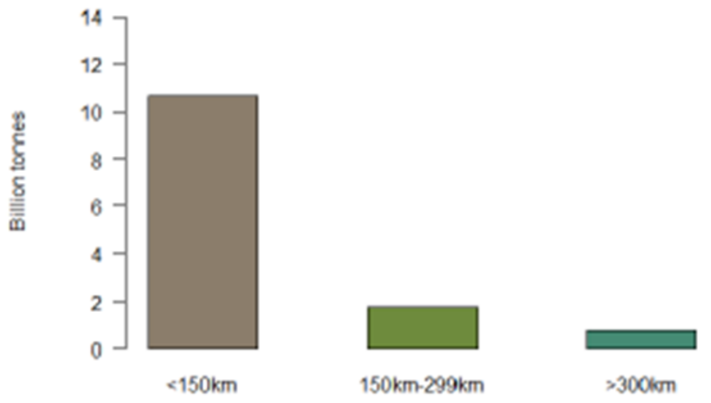
EMS 2 coupling frame

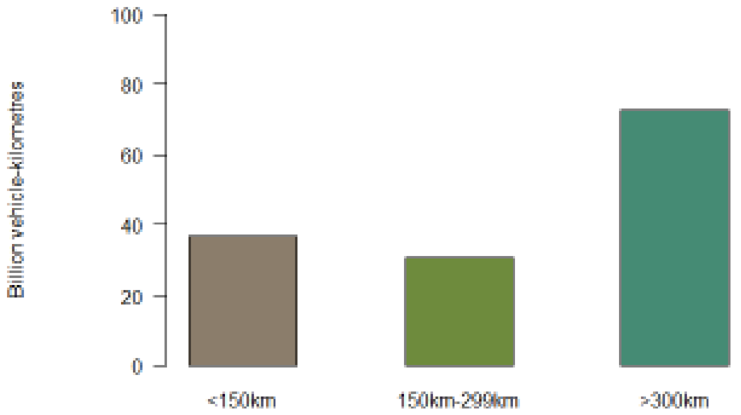


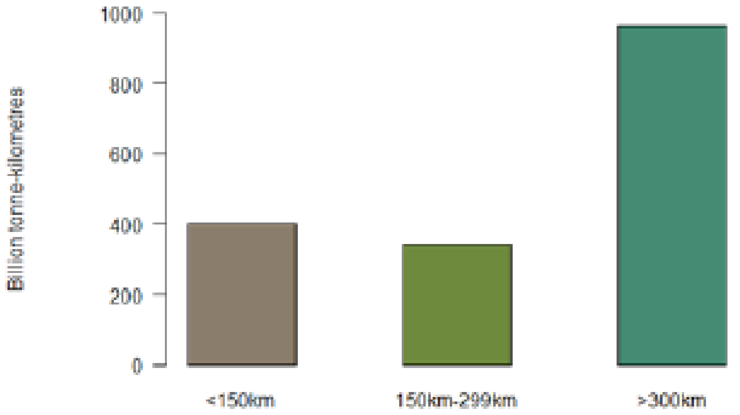
New closing system and actuators on boattail

Transport market, cargo and distance

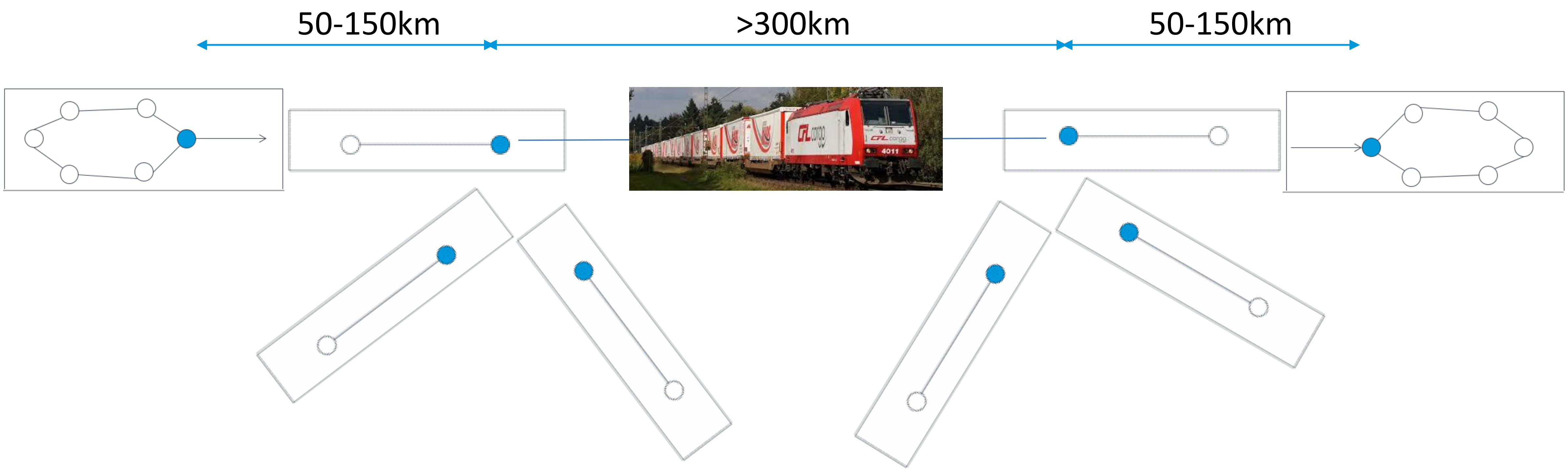
- 3 categories in EU 29 road freight transport - tonnes, vkm, and tkm
  - 80% of t is in the transport distance class below 150 km
  - 75% of tkm are in the group above 150 km transport distances
- The concept of rail-road should focus on transport distances above 300km
- Challenges
  - Minimize transshipment's
  - Minimize vehicle kilometers above 300km
  - Optimize availability, reliability and cost



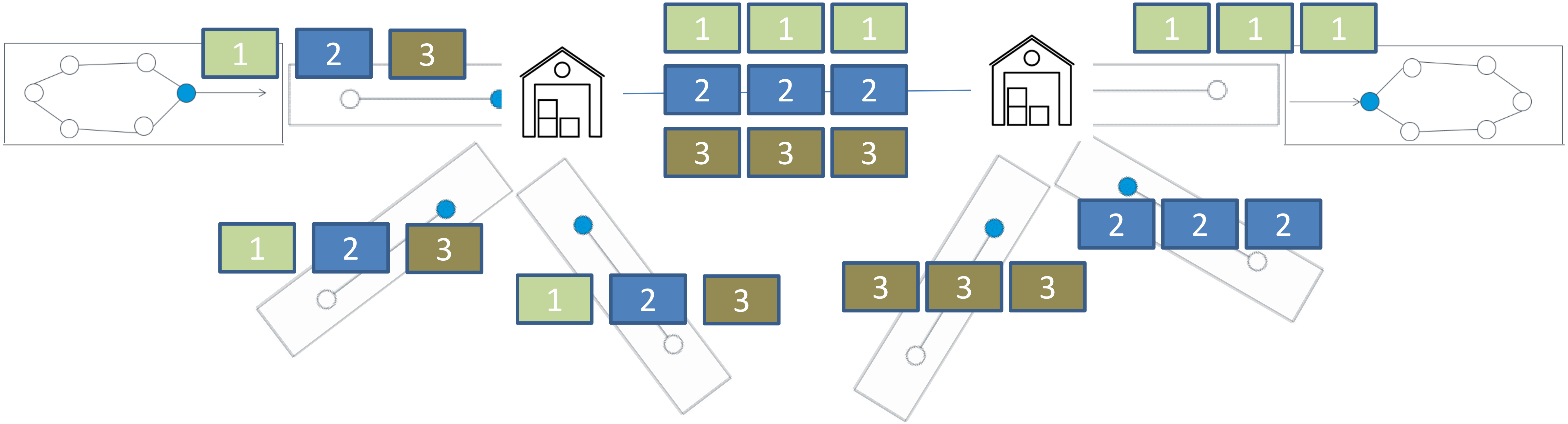




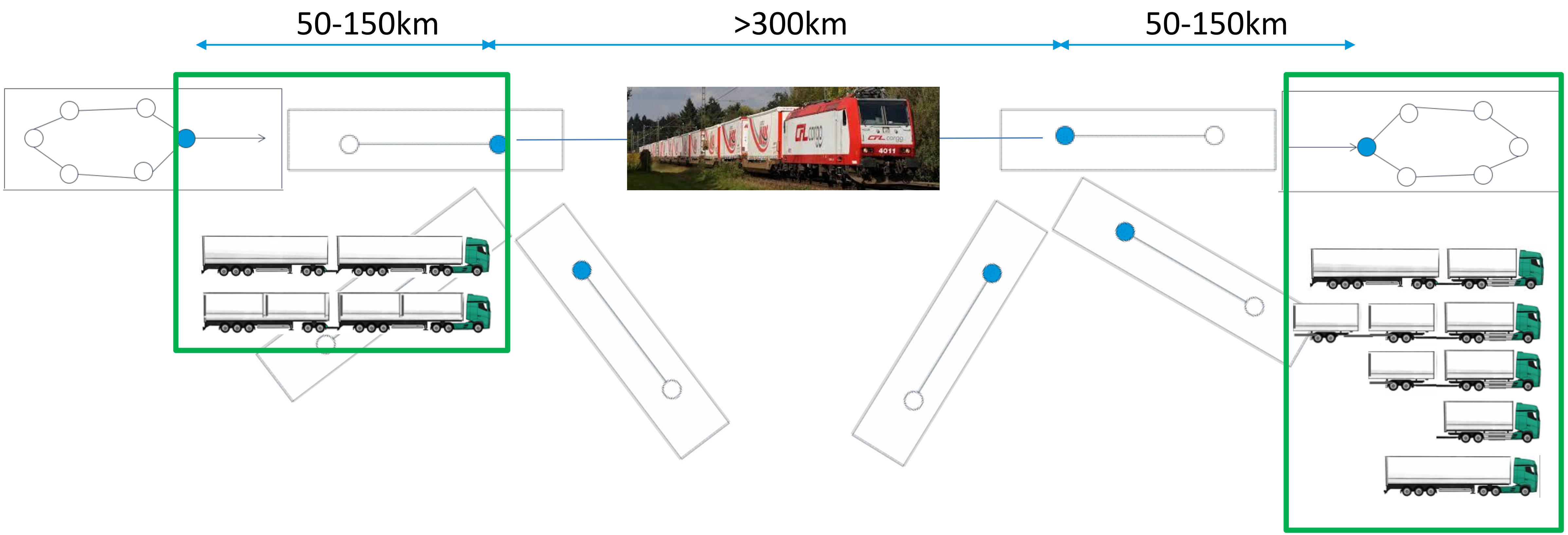
Concept bringing cargo to rail



Warehouse, cargo consolidation and sorting



Optimal use of EMS vehicle configuratiuons



Sustainability of Combined Transport
What makes the difference to road transport

ECONOMIC
- Cost advantage through mass
- Low risk of damages for the goods
- High goods security
- Best usage of transport modes
- Better plannability due to fixed journeys

ENVIRONMENTAL
- 6x less energy consumption (energy efficiency)
- 9x less greenhouse gas emissions
- 12x Less external costs
- Less land usage

SOCIAL
- Less road congestions
- Fewer casualties
- Less dependency on energy reserves
- Less noise
- Focus on first/last mile instead of long haul

Source: UIRR

CFL multimodal

One-stop shop offering multimodal services

Key figures (2020)

- Staff: ca. 1140 FTE
- Turnover: ca. 260 Mio. EUR

Core activities

Logistics

Rail

Infrastructure in Luxembourg

Certifications

Concept of EMS2 bringing cargo to rail

- Test results
  - Crane application
  - r2L platform
  - Nikrasa
  - Modalohr

Concept of EMS2 bringing cargo to rail

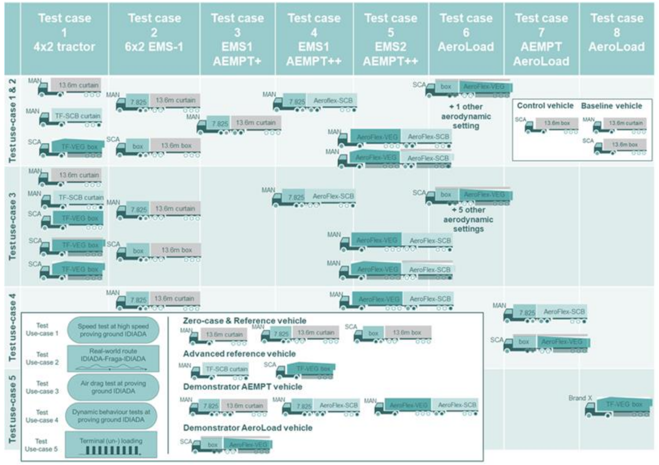
- Aeroflex innovations, specifically the aerodynamic features have proven combined transport is possible to improve, when considering from the beginning

- Next steps
  - Regulation for street application need to be fit for rail/ water as well (weight & dimensions)
    - Tuning from GCW and loading units for CT (2 -> 1)
    - Merge the advantages from both modes

Testing, validation and assessment of impact

Industry		
Research	TNO innovation for life	Paul Mentink, senior scientist integrator powertrains Emiel van Eijk, research scientist sustainable transport
Service and validation	Applus IDIADA	Alex Freixas, powertrain engineer

Demonstration, validation and feasibility



TEST MATRIX DEFINITION

FUEL CONSUMPTION TEST TRACK & REAL ROUTE

VALIDATION TEST PROTOCOL

AIRDRAG MEASUREMENTS ACCORDING EU 2017/2400

DYNAMIC VEHICLE BEHAVIOUR

Fuel consumption and airdrag results

- **Fuel consumption tests**
  - **On test track:** Constant speed test of 85 km/h at high-speed test track
  - **On real route:** Distance: 242,5 km / Average speed:74,5 km/h
- **Airdrag tests**
  - According annex VIII of Commission Regulation (EU) 2017/2400




	FUEL CONSUMPTION (l/100km)				AIRDRAG (CdxA)	
	CONSTANT SPEED		REAL ROUTE			
	50% load weight				Empty conditions	
	Result	Confidence interval	Result	Confidence interval	Result	Confidence interval
EMS1 AEMPT++ Demonstrator vs EMS1 AEMPT Baseline	--	--	**-3.5%**	1.2%	--	--
EMS1 AEROLOAD Demonstrator vs EMS1 AEROLOAD Baseline	**-8.0%**	1.4%	**-4.1%**	1.5%	**-9.0%**	2.1%
EMS2 AEROLOAD Demonstrator vs EMS2 AEROLOAD Baseline	**-2.1%**	--	--	--	--	--

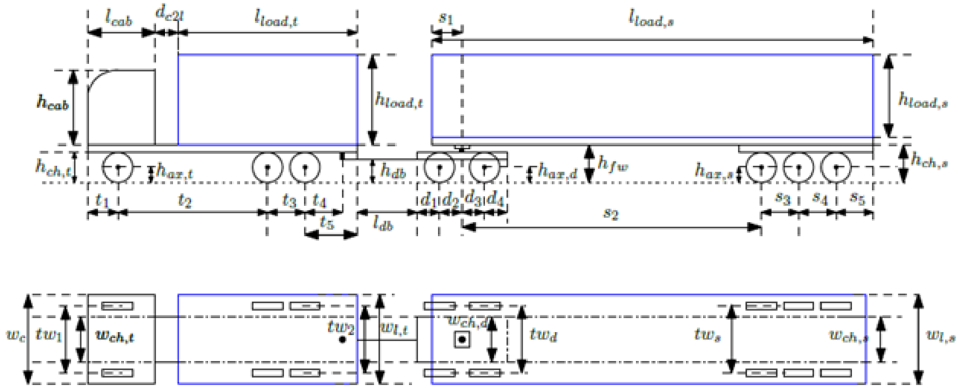




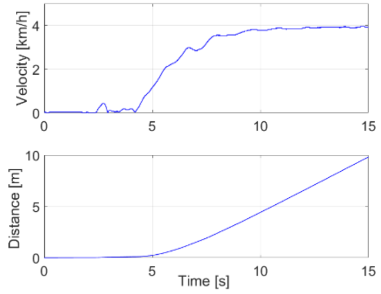
Dynamic vehicle behavior

- **Protocol:** Performance Based Standards and Vehicle Assessment Rules of the NTC of Australia (PBS)

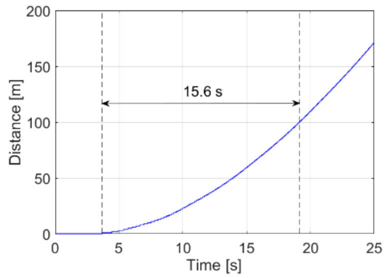
Key Performance Indicators
1. Startability, [% grade]
2. Gradeability-A, [% grade]
3. Gradeability-B, [km/h]
4. Acceleration capability, [s]
5. Directional stability under braking: (c) Average deceleration, [g] (d) Maximum lane-width, [m]
6. Frontal swing: (b) Maximum frontal swing (FS_{max}), [m]
7. Tail swing at entry (TS_{entry}), [m]:
8. Low-speed swept path width (SPW): (c) 90 degree, [m] (d) 360 degree, [m]
9. Rearward amplification (RA), [-]
10. High-speed transient off-tracking ($HSTO$): (c) Overshoot, [m] (d) Undershoot, [m]
11. Yaw damping coefficient (YD), [-]
12. Static rollover threshold (SRT), [g]



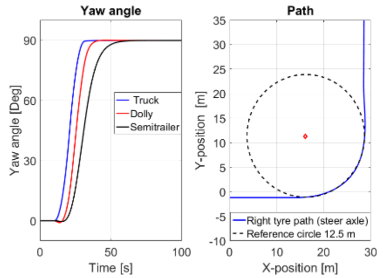
Startability



Acceleration



Frontal swing



Dynamic vehicle behavior

Key Performance Indicators	EMS1 Baseline		EMS1 Demo AEROLOAD		EMS1 Demo AEMPT++	
	Average Performance achieved	PBS level achieved	Average Performance achieved	PBS level achieved	Average Performance achieved	PBS level achieved
1. Startability, [% grade]	15	1	15	1	> 12	2
2. Gradeability-A, [% grade]	18	2	18	2	> 12	3
3. Gradeability-B, [km/h]	> 70	2	> 70	2	> 80	1
4. Acceleration capability, [s]	15.6	1	15.6	1	20.3	2
5. Directional stability under braking: (e) Average deceleration, [g] (f) Maximum lane-width, [m]	 0.47 2.9	 1 1	 0.47 2.9	 1 1	 0.58 2.76	 1 1
6. Frontal swing: (c) Maximum frontal swing (FS_{max}), [m]	0.47	Acceptable	0.47	Acceptable	0.57	Acceptable
7. Tail swing at entry (TS_{entry}), [m]:	0.20	1	0.21	1	0.26	1
8. Low-speed swept path width (SPW): (e) 90 degree, [m] (f) 360 degree, [m]	 6.67 7.78	 1 Acceptable	 6.64 7.85	 1 Acceptable	 6.88 7.91	 1 Acceptable
9. Rearward amplification (RA), [-]	1.54	Acceptable	1.58	Acceptable	1.67	Acceptable
10. High-speed transient off-tracking ($HSTO$): (e) Overshoot, [m] (f) Undershoot, [m]	 0.09 -0.01	1	 0.08 -0.03	1	 0.07 -0.01	1
11. Yaw damping coefficient (YD), [-]	0.37	Acceptable	0.34	Acceptable	0.39	Acceptable
12. Static rollover threshold (SRT), [g]	> 0.48	Acceptable	> 0.47	Acceptable	> 0.39	Acceptable

Conclusions

- **Fuel consumption, airdrag and dynamic protocols** used during all the testing campaign (reference, advanced reference and demonstrators) provide **a robustly methodology** to evaluate the KPI's and compare the results obtained within different type of vehicles (reference, advanced reference, EMS1 and EMS2).

- The implementation of the **Hybrid-on-Demand technologies** provides a significant improvement in fuel consumption results, basically on real routes with cumulative slopes. The technology does not provide a fuel consumption improvement during constant speed testing.

- Although the improvement of fuel consumption and aerodynamic results are quite important at constant speed and real route tests, the implementation of the **Aeroload technologies** provides more significant fuel consumption improvement at test track (it could be considered as best case) compared to real route. The same behavior is appreciated on the airdrag tests.

- No noticeable differences in the vehicle dynamic behavior have been identified after implement the Aeroload developments on the demonstrator vehicle. **The dynamic KPI's measured** for the EMS1 Baseline and EMS1 Demonstrator vehicles are **inside the safety levels** indicated on NTC Performance Based Standards.

Key takeaways

The impact of AEROFLEX innovations ...

improve fuel efficiency

Advanced aerodynamics, distributed powertrains and smart loading units reduce the energy use of EMS vehicles significantly

show a positive cost-benefit

Innovations immediately pay off and have additional benefits in enabling EMS vehicles on the road

are dependent on cargo type

The impact of the innovations is seen for various cargo densities, but is highest for high volume, low mass goods

can be achieved and scaled-up

The flexible and modular micromodel used in the AEROFLEX project supports speeding up deployment

The main vehicle combinations

Tractor semi-trailer

- **TST**, 40t, 16.5m

Truck-dolly-semi-trailer

- **EMS1**, 60t, 25m

Tractor semitrailer-dolly-semitrailer

- **EMS2**, 74t, 32m

Overview of the results and impact to the customer use-cases

THE IMPACT ON FUEL CONSUMPTION AND EFFICIENCY

Assessment framework

A flexible and modular micromodel is used to assess the impact of the AEROFLEX innovations on real-world logistics usecases

REAL LOGISTICS USECASES

INPUTS

Legs
- Origin
- Destination

Vehicle type

Cargo information

TEST RESULTS

FIT AND VALIDATION

High speed test track
- Constant speed

Real-world route
- Fraga-IDIADA

MICROMODEL MODULES

Route profile generator

Mission profile generator

Vehicle model

Powertrain model

Energy carrier

OUTPUTS

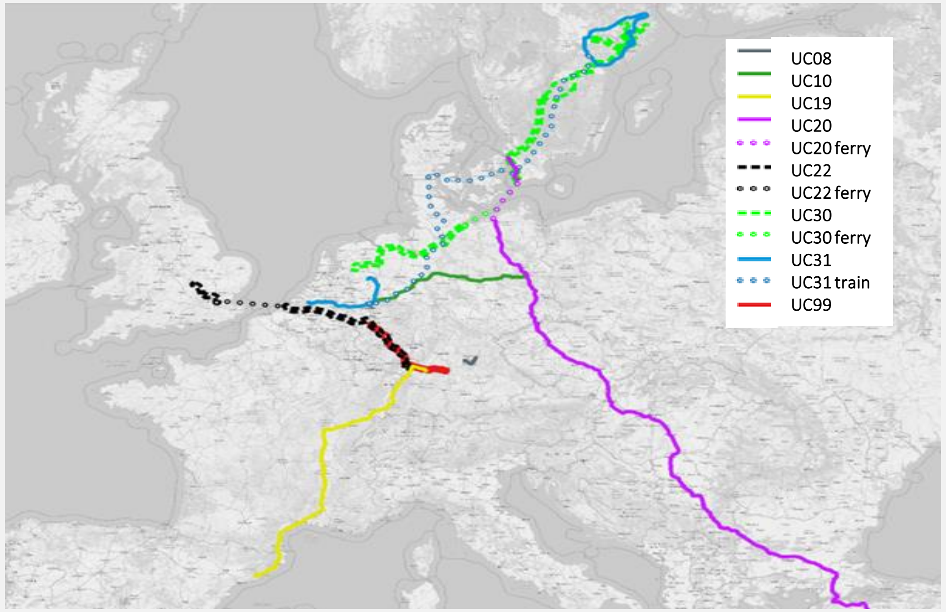
Different cross-sections: [l/km], [l/t-km], etc.

Comparisons of use-cases, payload, route, innovations, prime candidates

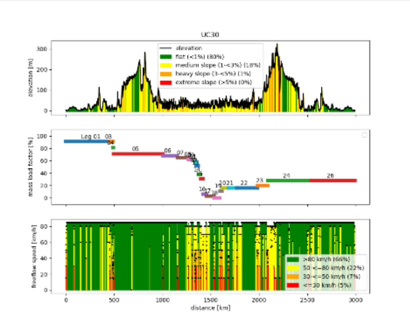
AEROFLEX

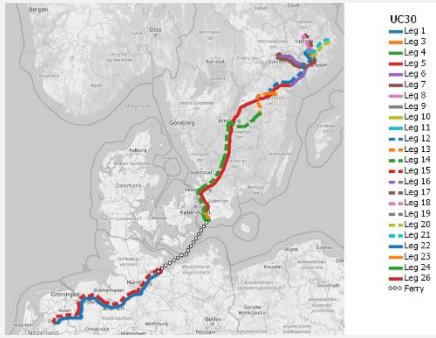
Customer use-cases across Europe are analyzed

With variations in types of cargo, intermodal links, routes, logistics operations and prime candidates

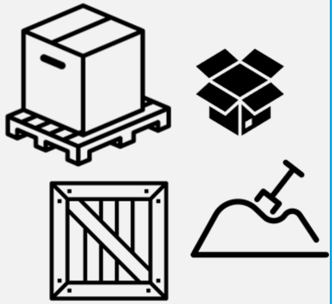


Route & legs

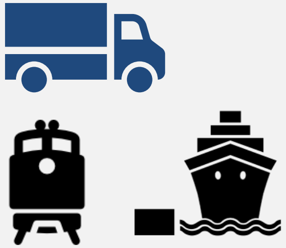




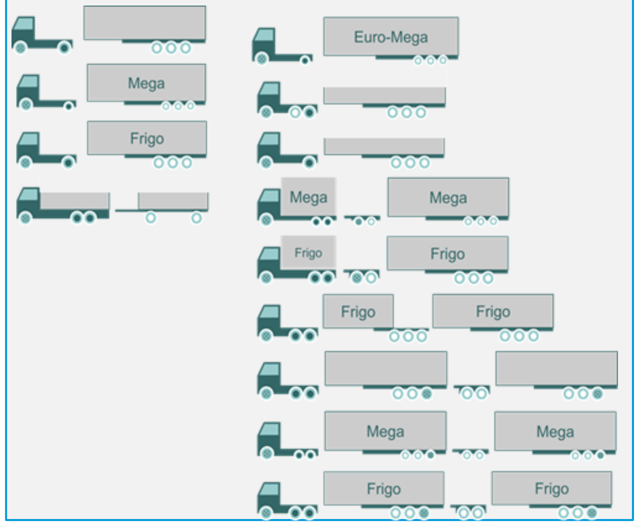
Cargo



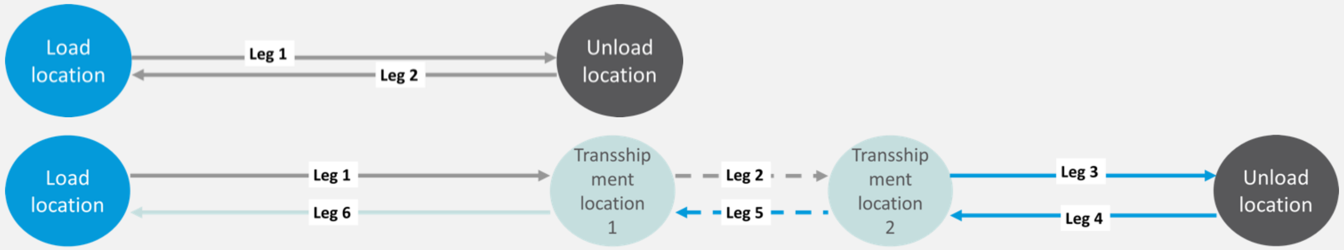
Intermodal



Prime candidates

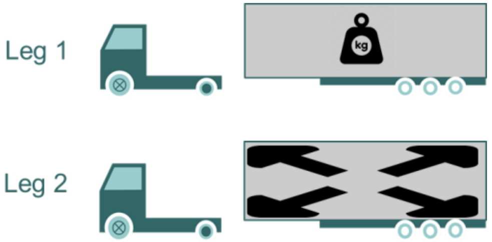


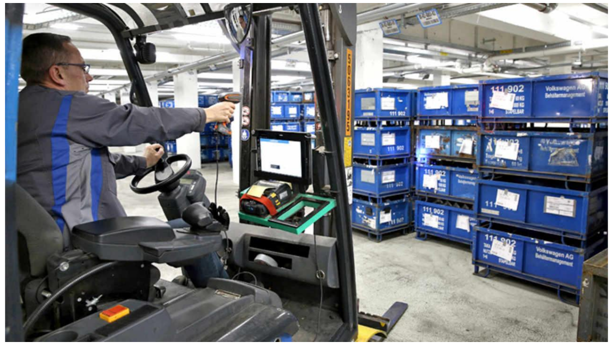
Logistics operation

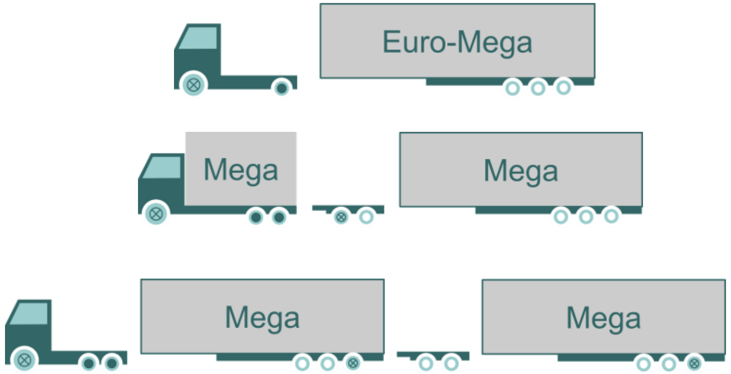


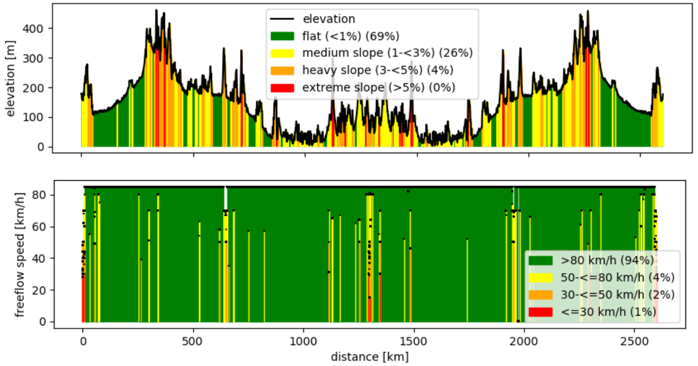
Micro-modelling the complete end-to-end line-hauls

Real-world AEROFLEX usecase 19 – transport of automotive parts from Germany to Spain

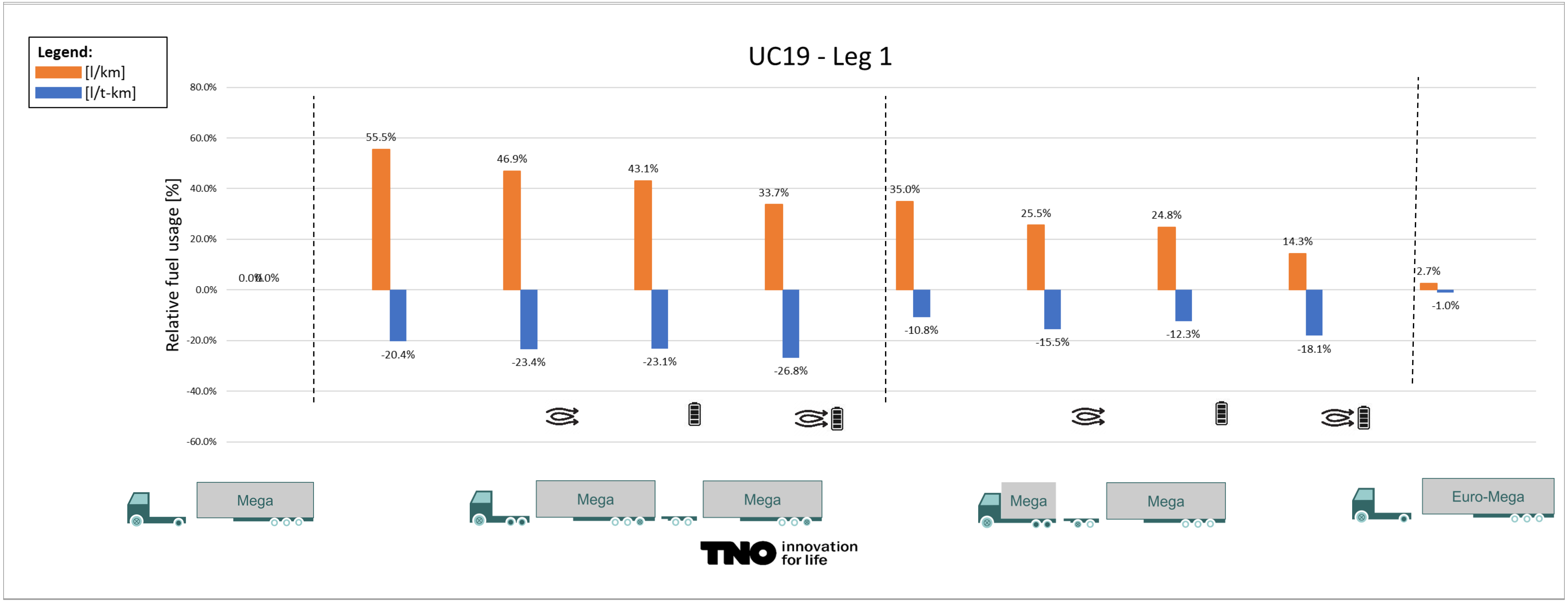




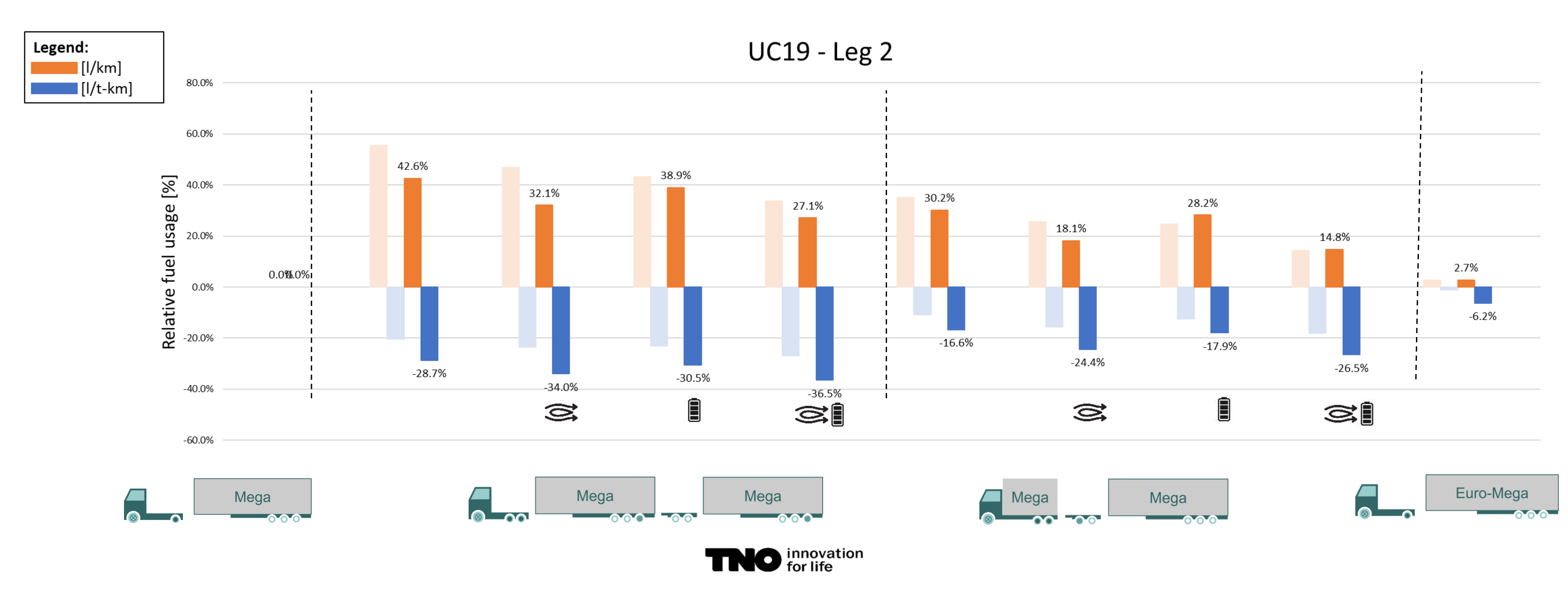




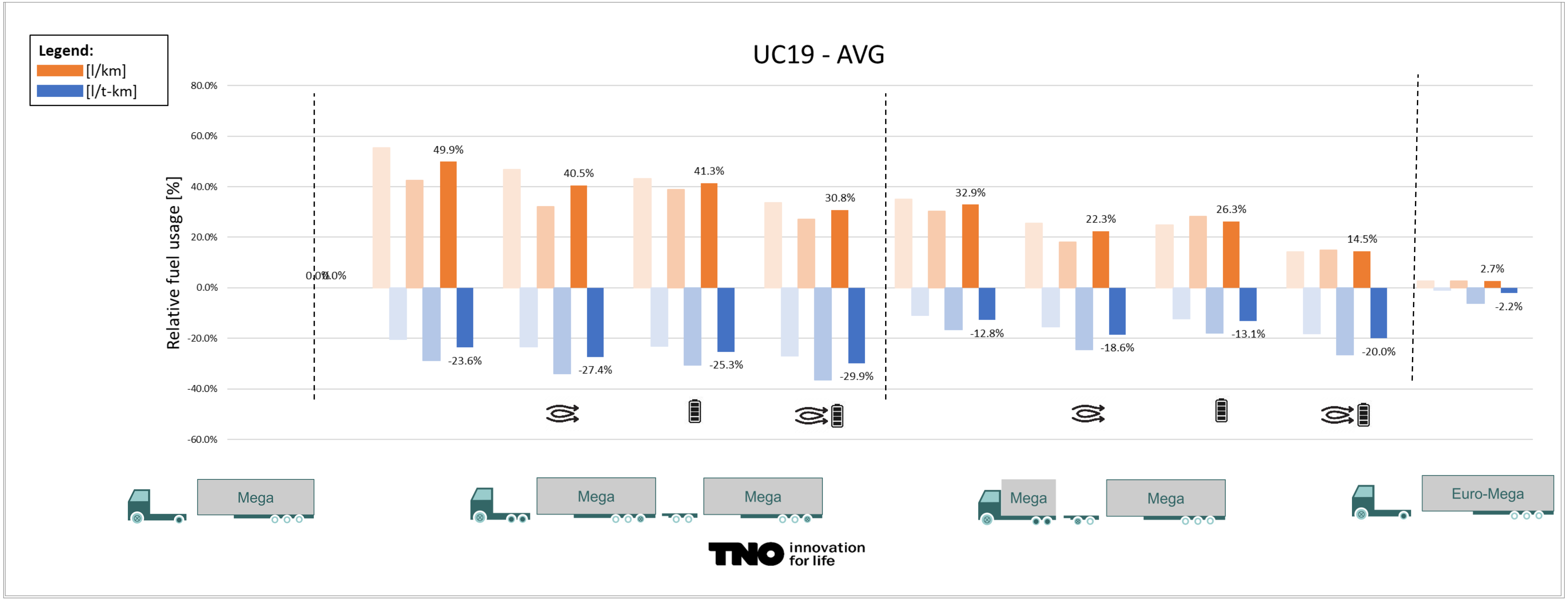
AEROFLEX innovations increase fuel efficiency gains of larger vehicle



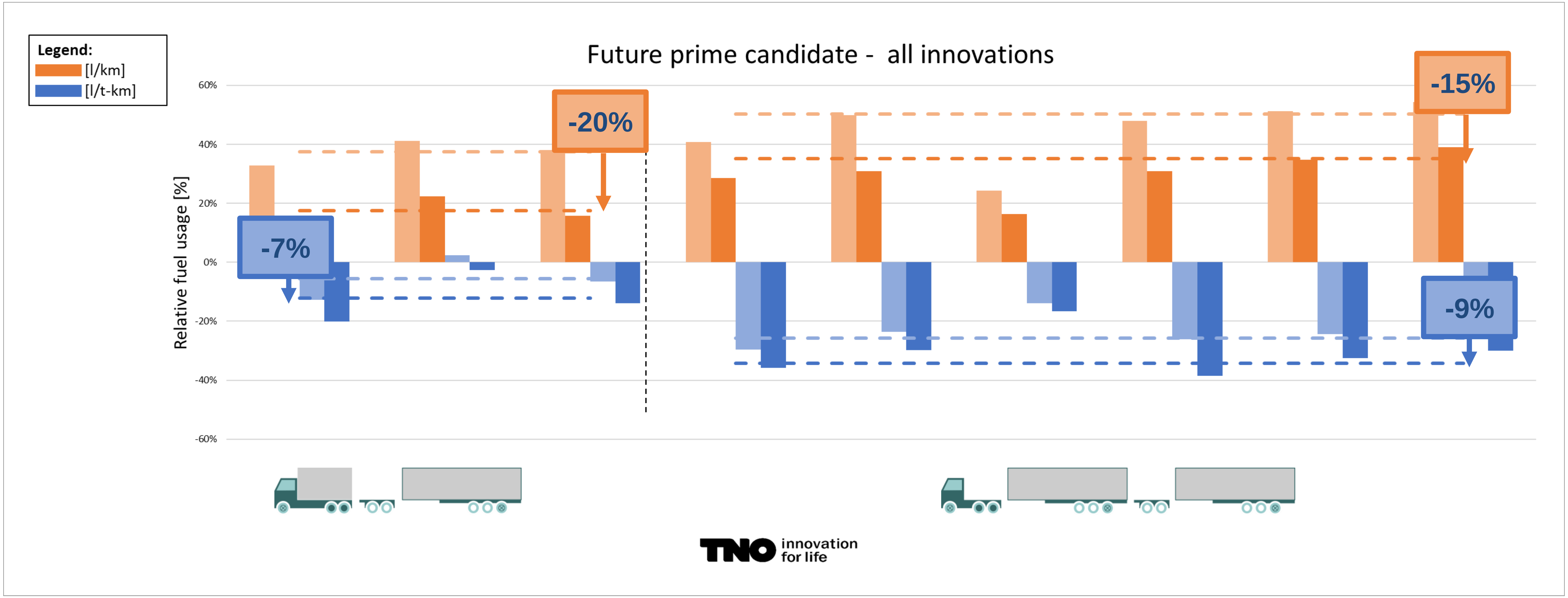
Higher gains on (volume limited) return leg



On the total use-case 30% can be saved by EMS2 and 20% by EMS1



Results all customer use-cases



Overview of the results at TEN-T corridors

IMPACT ON MAIN EUROPEAN ROAD TRANSPORT CORRIDORS

28.09.2021

Innovations at TEN-T corridors

Unique application of assessment framework

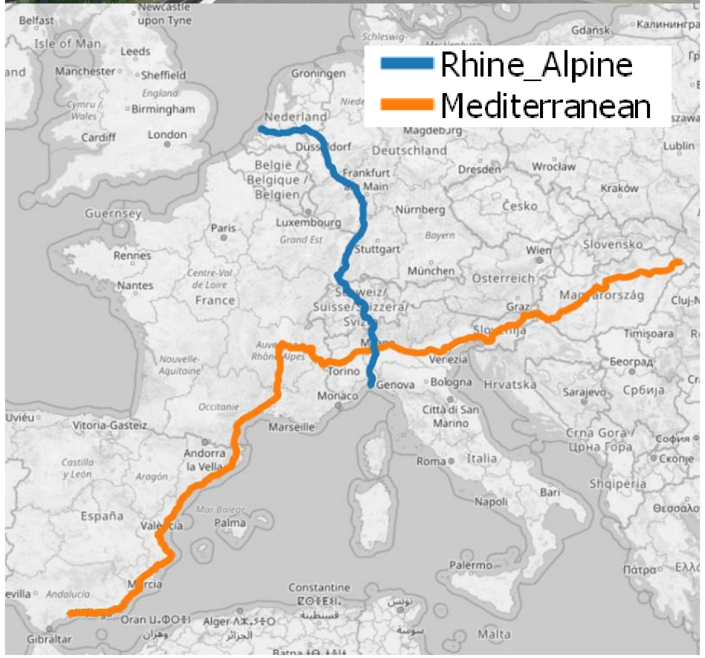
Trans-European Transport Network (TEN-T)

> “The Core Network includes the most important connections, linking the most important nodes, and is to be completed by 2030”
>
> “The Comprehensive Network covers all European regions and is to be completed by 2050”

9 Core Network Corridors

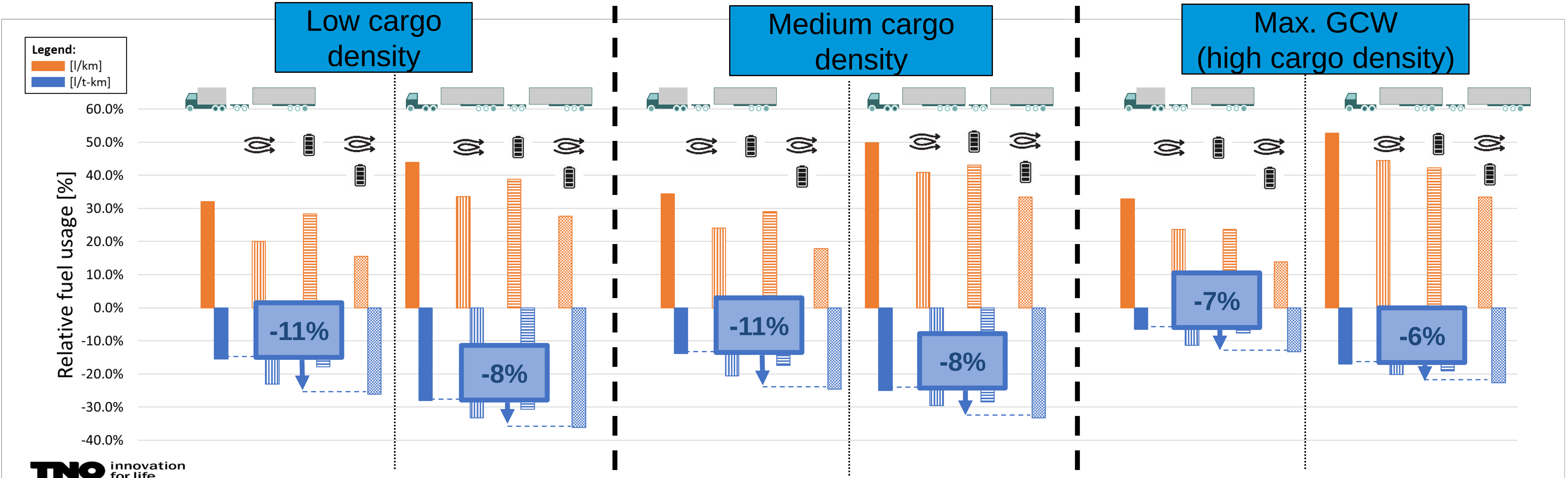
Subset of 2 road corridors is taken:

- Mediterranean
- **Rhine Alpine**
- Both show similar results



Fuel efficiency gains at Rhine-Alpine TEN-T corridor
Reference: typical tractor semi-trailer

Variations in vehicle configuration, (combination of) innovations (excl. doubleload floor) and cargo density
Consequent reductions in fuel consumption and transport efficiency for Aeroload and AEMPT
AEMPT and Aeroload reinforce eachother when combined
Impact of vehicle configuration and innovation is larger at low cargo densities as observed before
AEROFLEX innovations increase fuel effiency gains from: up to 28% → up to 35%



Overview of the Total-Cost-of-Ownership

COST BENEFIT ANALYSIS RESULTS

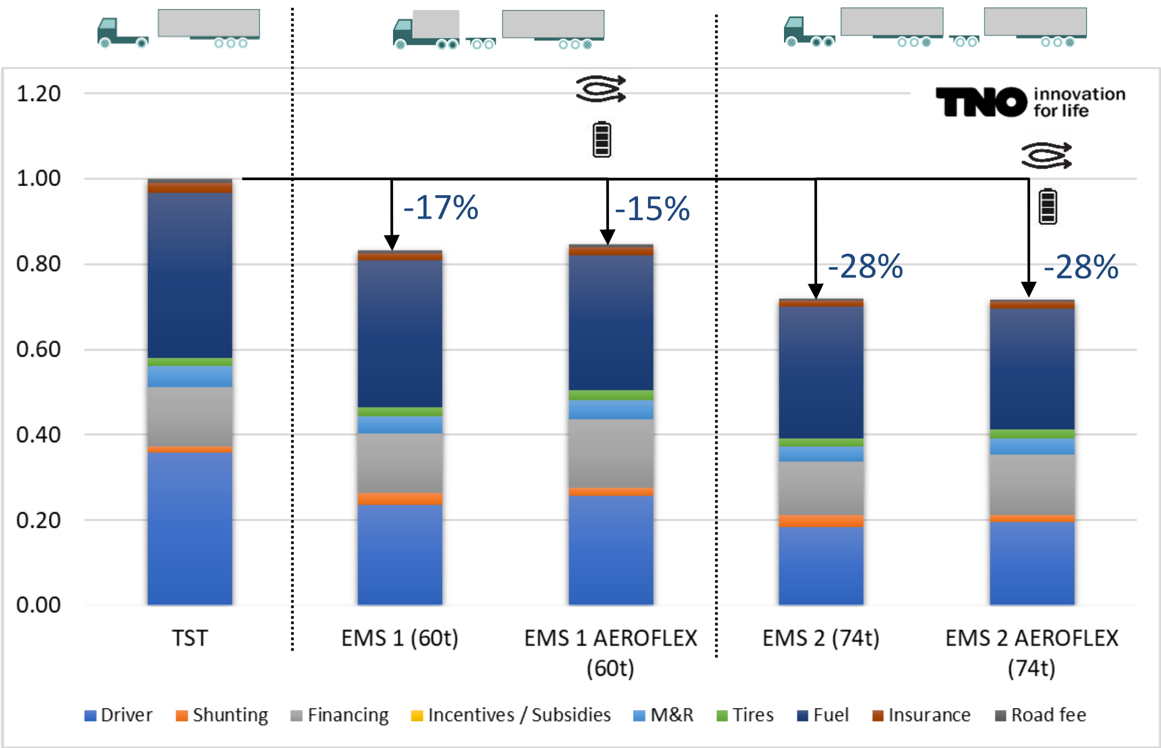
Cost aspects CBA applied to Automotive parts use-case

- Fuel
- Maintenance & repair
- Insurance
- Driver
- Tires
- Shunting
- Financing
- Road fee
- Incentives/ subsidies

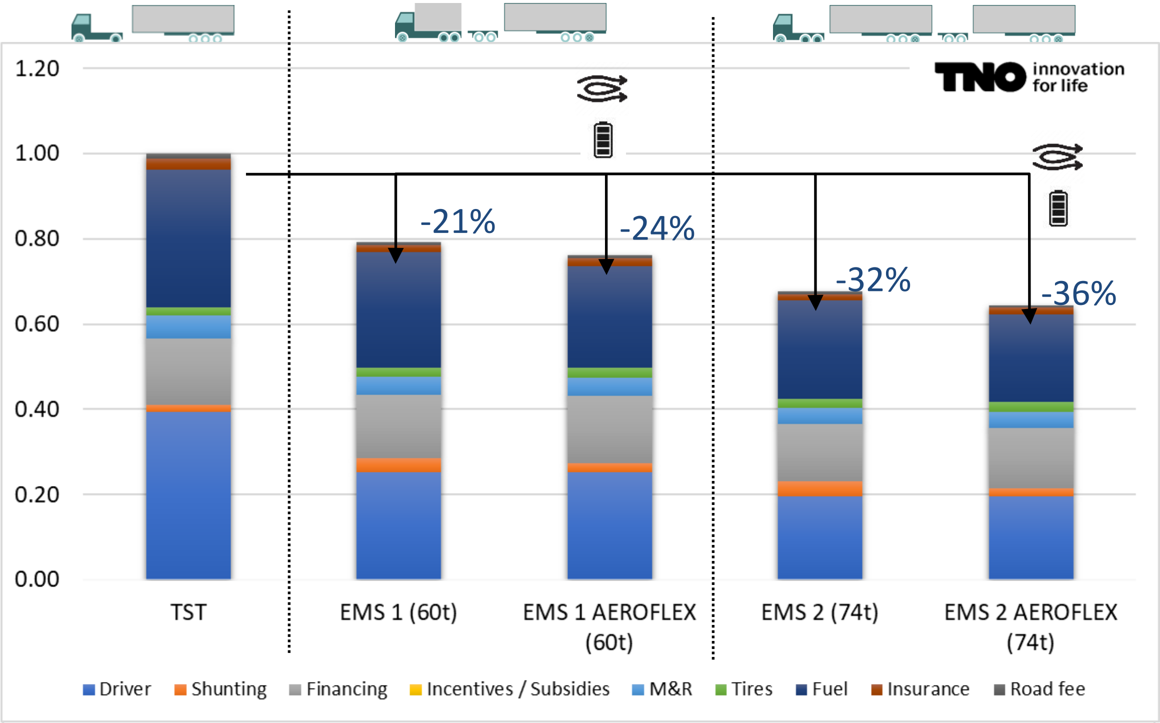
Results Cost – Benefit at tonne-km basis: Automotive parts use-case

A default EMS1 vehicle saves cost between 17-21% and EMS2 reduces cost from 28-32%
Cost reductions are larger for volume limited transport due to max GCW in case of mass limited transport
Fuel cost term becomes even more dominant in total cost for EMS vehicles
Cost neutral in case of AEROFLEX innovations on mass limited transport
Additional cost reductions in case of volume limited transport by the AEROFLEX innovations

Mass limited



Volume limited



Key takeaways

The impact of AEROFLEX innovations …

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improve fuel efficiency

Advanced aerodynamics, distributed powertrains and smart loading units reduce the energy use of EMS vehicles significantly

show a positive cost-benefit

Innovations immediately pay off and have additional benefits in enabling EMS vehicles on the road

are dependent on cargo type

The impact of the innovations is seen for various cargo densities, but is highest for high volume, low mass goods

can be achieved and scaled-up

The flexible and modular micromodel used in the AEROFLEX project supports speeding up deployment

AEROFLEX

Thank you

The research leading to these results has received funding from the European Union