RAIL SWEDEN

Welcome to Rail Sweden webinar!

The meeting starts at 11.30 am

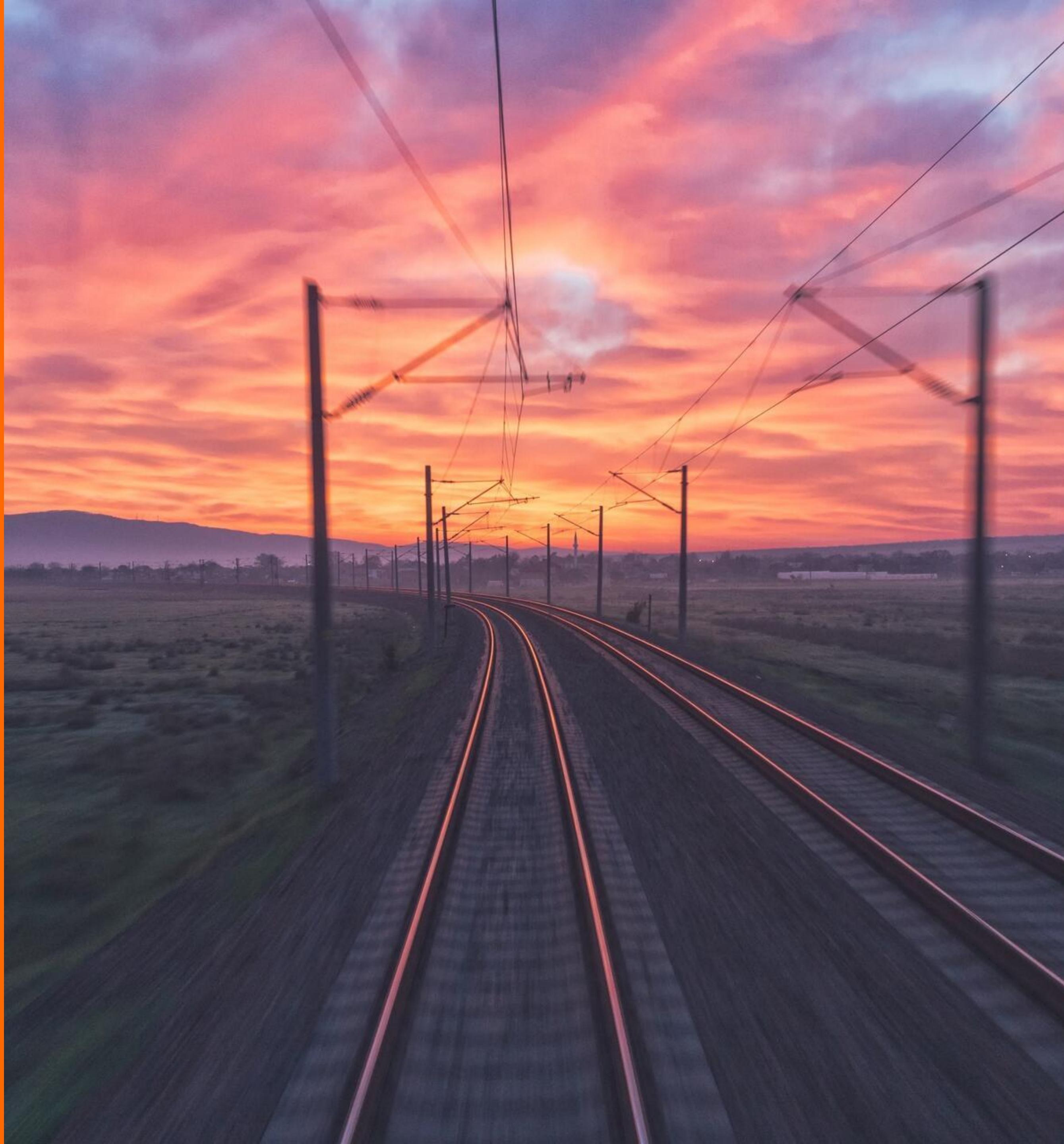
RAIL SWEDEN

Funded by the European Union and Trafikverket. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.

Rail Sweden

- Accelerating rail innovation and competitiveness through collaboration

- Automation & digitalization
- Demonstration and testing
- Knowledge hub for development



RAIL SWEDEN

Agenda – an update on ongoing activities

11.30 Welcome and introduction to Rail Sweden
Sneha Gosavi, Rail Sweden

11:40 Introduction to Innovative Assets
Iñigo Adin, CEIT - Asociación Centro Tecnológico

11:45 A. State-of-Art - Self Propelled Wagon (SPW)
Iñigo Adin, CEIT - Asociación Centro Tecnológico

B. Use cases and concepts of SPW
Behzad Kordnejad, KTH Royal Institute of Technology

12.20 Hydrogen Transport Container
Jürgen Klarner, VATUB - voestalpine Tubulars

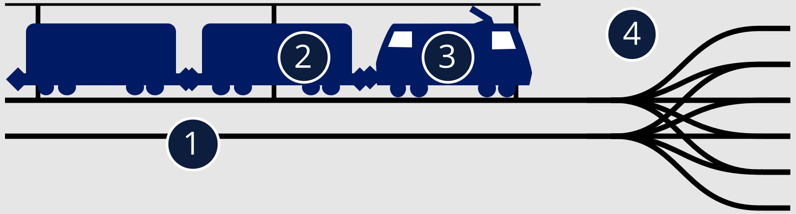
12.40 Freight Train Aerodynamics for Efficiency and Safety
James Bell, DLR - German Aerospace Center

12.59 Closing of the meeting
Sneha Gosavi, Rail Sweden

TRANS4M-R FP5

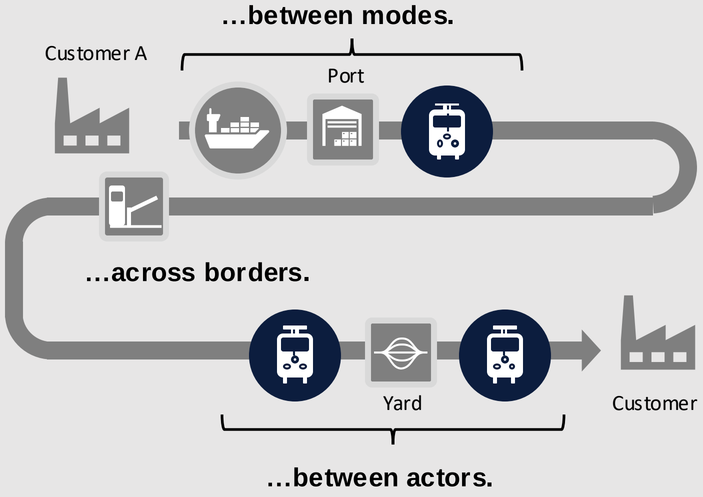
Three clusters enable „Transforming Europe‘s rail freight“

1 Full Digital Freight Train Operations (FDFTO)



1. Digital Automated Coupler (Typ 4+5+Hybrid)
2. Energy and Communication (400V + Train integrity)
3. Train functions (e.g. automated brake test)
4. Automated Yard Operations

2 Seamless Rail Freight…



- Seamless planning and dispatching
- Intermodal integration and prediction

3 Innovative Freight Assets

- Hydrogen transport container
- Self-Propelled Wagon
- Energy effciency strategy for freight

Innovative Freight Assets

Iñigo Adin | Asociación Centro Tecnológico CEIT

2024-09-12

Paving the way towards Innovative Freight Assets

Hydrogen Transport Container

- T22.1 Conceptual analysis on a small-scale multimodal container demonstrator.
- T22.2 Functional requirements and preliminary design of a multimodal container.
- T23.1 Multimodal container implementation and preliminary system validations.

- D22.1: System Specification Combined Container.
- D22.4: Functional requirements and conceptional design for multimodal hydrogen container

Self-Propelled Wagon

- T22.3 Needs analysis and preliminary concepts for self-propelled wagon.
- T22.4 System specification and validation strategies for self-propelled wagon concept
- T23.2 Traction system for self-propelled freight wagon validations under controlled environment

- D22.3: Use cases and conceptual system specification for Self-Propelled Wagon

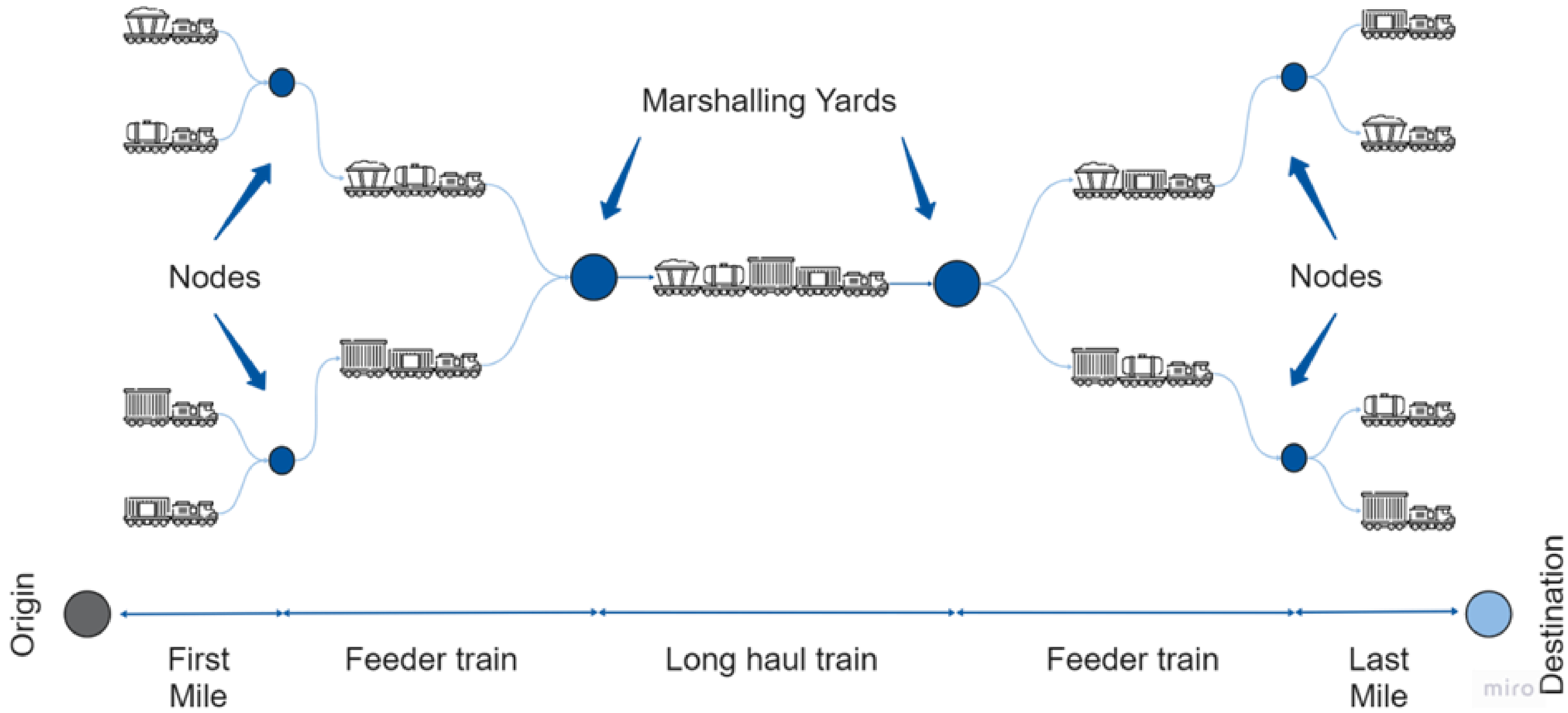
Energy Effciency Strategy for Freight

- T22.5 Analysis for energy efficiency
- T23.3 Energy efficiency strategies for freight.

- D22.2: Reports for aerodynamic characteristics and efficient driving specifications

Self Propelled Wagon

Production network in single-wagon load transport (example Germany)



Self Propelled Wagon State-of-the-art, use cases and concepts

Behzad Kordnejad, KTH
Ingrid Nordmark, KTH
Iñigo Adin, CEIT
David Krueger, DLR

RAIL SWEDEN

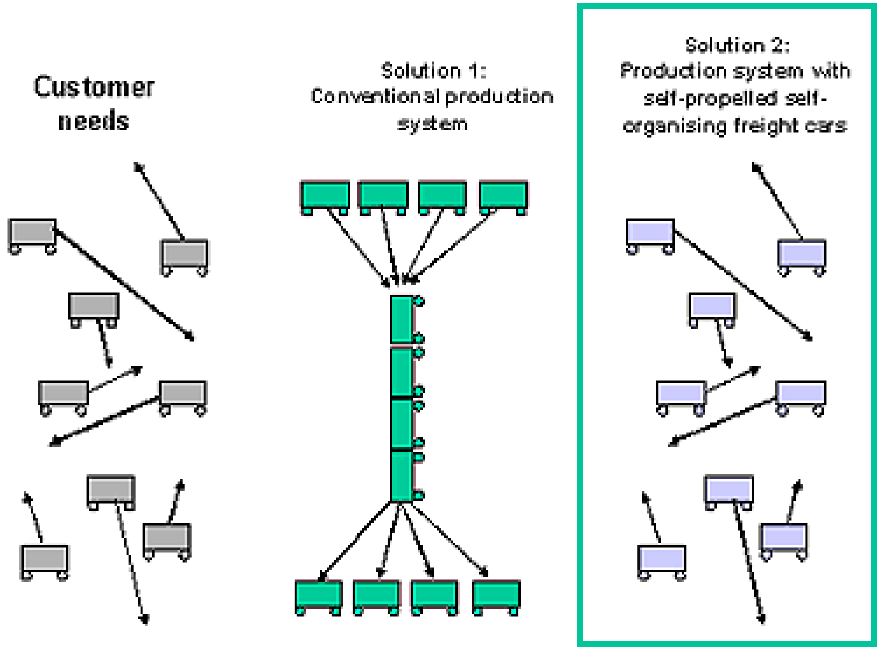
Why do we need a Self Propelled Wagon?

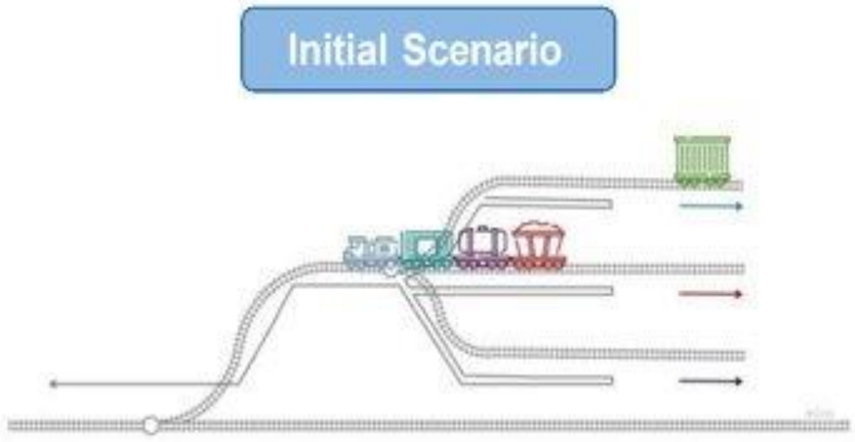
What has changed since 1996?

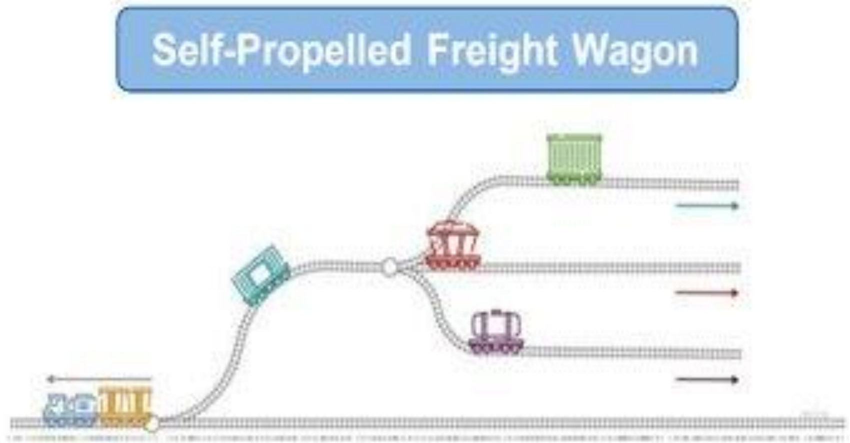
- Digitalization and monitoring
- Positioning technologies
- DAC
- Efficient motors and controls

Ref.- State of the art Frederich Lege 1996

UIC 2002







Self Propelled Wagon

Who has tried already?

→ Commercial initiatives end to end (e.g. Intramotev, Parallel)

→ Commercial references for enclosed areas (e.g. HIAROM)

Intramotev "ReVolt"

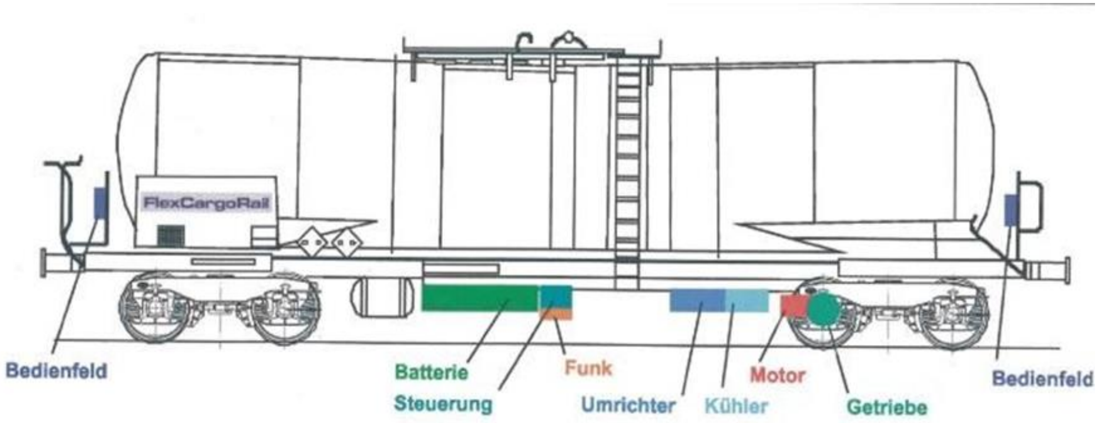
Parallel Systems

HIAROM

Self Propelled Wagon

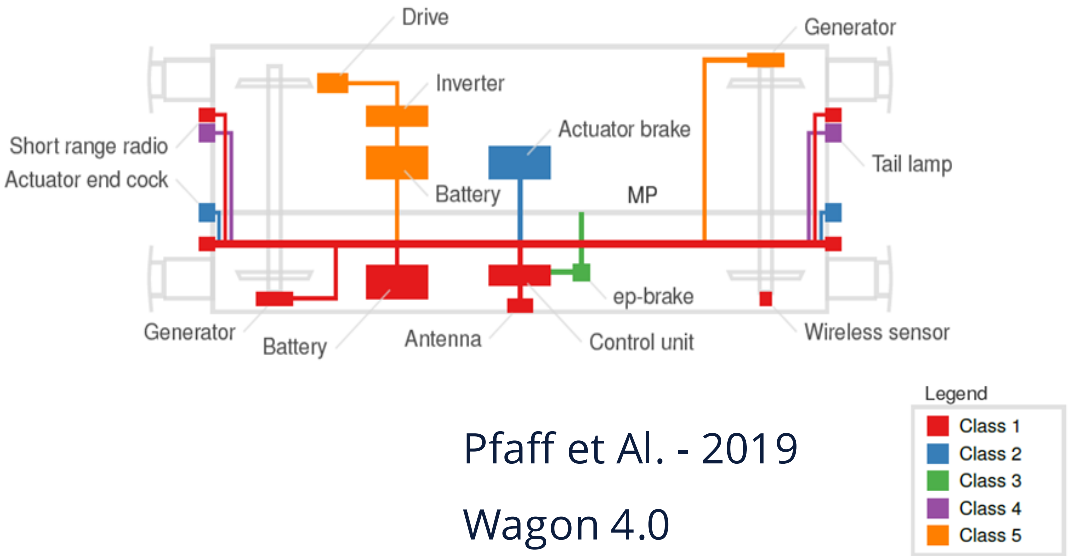
Who has studied and published on that topic?

→ Varied scientific approach on full system approach, subsystems and types of use cases



Baier et Al. - 2009

FlexcargoRail



Pfaff et Al. - 2019

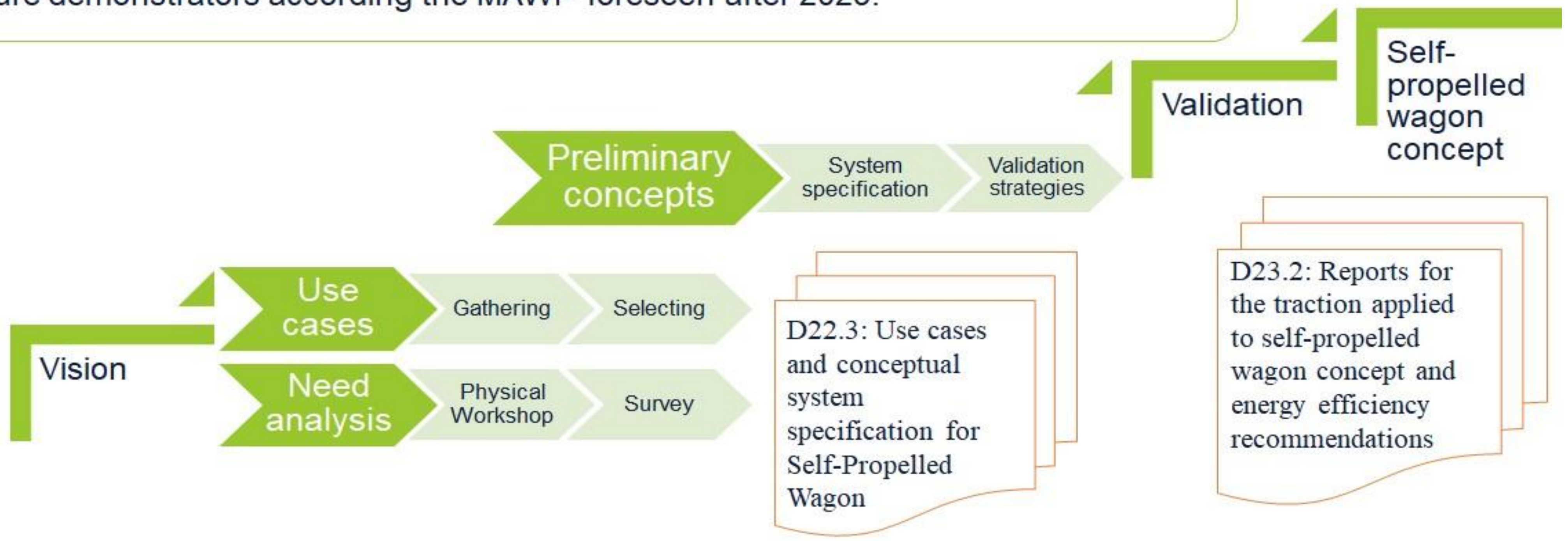
Wagon 4.0

Overview of the work process of the Self-Propelled freight wagon

(Task 22.3 and Task 22.4)

Vision: Future freight train is able to run between different end-costumers with wagons that disconnect and connect autonomously at nearby sidings to the costumers

Project aim: Elaborate the concept of innovative freight assets providing answer concerning autonomous propulsion. FP5-TRANS4M-R will do preparatory work for future demonstrators according the MAWP foreseen after 2025.



Self Propelled Wagon

Europe's Rail

FP5 TRANS4M-R Transforming Europe's Rail Freight

Workshop and survey to understand stakeholder needs

Potential for self-propelled freight wagon to revolutionize freight operations through increased efficiency, flexibility and sustainability

- Better understanding of the use cases prioritized and stakeholders' expectations
- Valuable ranges for the operations

Stakeholder Expectations

1. Last mile service from the mainline to the industrial area.
2. Self-loading and unloading.
3. Reduce the train time.
4. Reduce the need of feeder locomotives.
5. Reduce the need for shunting locomotives
6. Infrastructure way of thinking: Trains occupy tracks and they should move as much as possible.
7. Needs to be safe and reliable
8. Knowledge of the tracks (lack of energy), speed that you have to have going up a hill with a certain load
9. Cheap
10. Battery for the part of the track that don't have electricity

Question	Minimum	Maximum	Number of answers
Range Speed	15 km/h	120 km/h	7
Range gradient	4 ‰	25 ‰	4
Range distance with self-propulsion	1 km	More than 20 km	13
Distance track in the train formation between shunting operations	50 km	400 km	12
Time in which the wagons are uncoupled from the train set	1 h	168 h	8
Stationary time of the wagon at the destination	6 h	168 h	10
Number of start-up operations	3	12	11
Range curve radius	80 m	90 m	2
Permanently coupled wagon units	1	More than 5	11

Self Propelled Wagon – Use Cases

FP5TRANS4M-R
Transforming Europe's Rail Freight

1. Private yard load automation (last mile)

2. Challenging tractive power and braking scenarios

3. Coordinating groups of Self Propelled freight wagons

4. Autonomous loading and unloading

Self Propelled Wagon – Use Cases

FP5TRANS4M-R
Transforming Europe's Rail Freight

1. Private yard load automation (last mile)

1. **Efficiency and cost reduction**: Self-propelled wagons streamline operations, reducing the need for shunting locomotives and manual labour
2. **Technical Feasibility**: Integrating traction motors, converters, batteries, and modified braking systems requires further analysis.
3. **Energy Optimization**: Analyzing torque, power, and speed profiles to design efficient systems, including regenerative braking

Figure 1 Aerial view of the private yard (Google Maps, 2023)

Use case	
Use case name	Private yard load automation
Use case number	1
System	Self-propelled freight wagon
Stakeholders/actors	1. Train operator
	2. Yard operator
Use case goal	**1. Integrate traction motor, converter and batteries in an existing freight wagon**
	2. Modify the braking system to allow braking decoupled wagons
Preconditions - Functions and Requirements	1. Traction system to propel the wagon (motor, converter and batteries)
	2. The braking system needs to be prepared to work with uncoupled wagons (need of compressor and additional valves)
	3. Communication systems need to be designed to command the self-propelled freight wagon (speed control and braking)
Current basic process flow	1. Train arrives in the yard
	2. Wagons are towed using a crane or a locomotive to the loading dock
	3. The wagon is towed back to the train
Envisioned alternate process flow	1. The train arrives in the yard
	2. The self-propelled freight wagon decouples (manual or automatic)
	3. The self-propelled freight wagon travels to the loading dock
	4. The self-propelled freight wagon returns back to the train and is coupled again

Self Propelled Wagon - Use Cases

1. Private yard load automation (last mile)

1. **Efficiency and cost reduction**: Self-propelled wagons streamline operations, reducing the need for shunting locomotives and manual labour

2. **Technical Feasibility**: Integrating traction motors, converters, batteries, and modified braking systems requires further analysis.

3. **Energy Optimization**: Analyzing torque, power, and speed profiles to design efficient systems, including regenerative braking

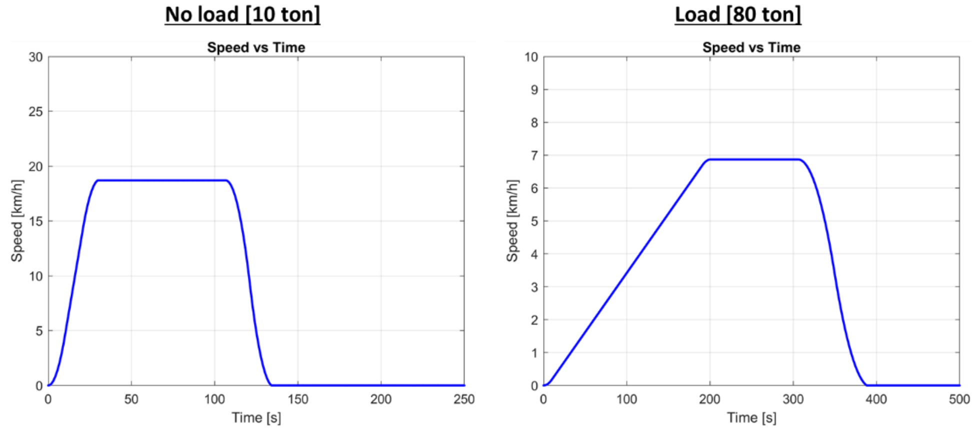


Figure 1. Speed profiles for the self-propelled freight wagon

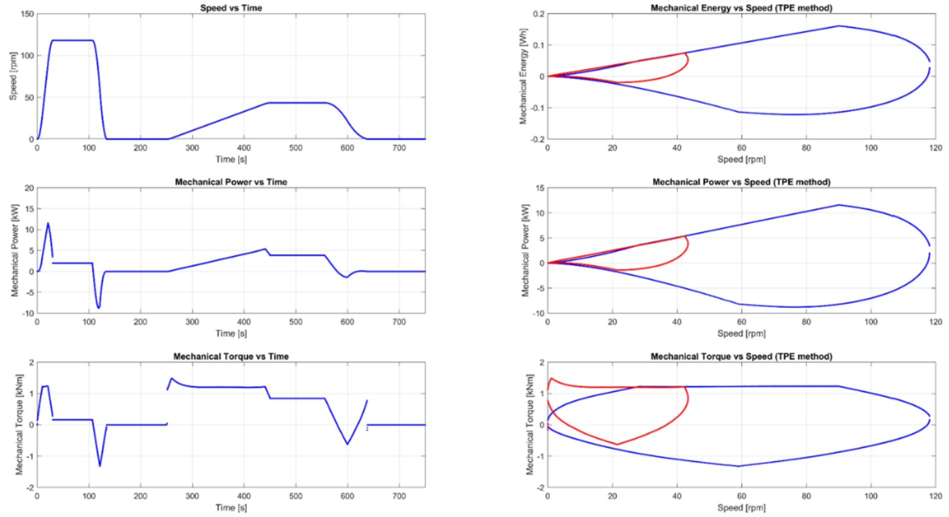


Figure 1. Torque, power and energy requirements for the traction system [loaded in red / unloaded in blue]

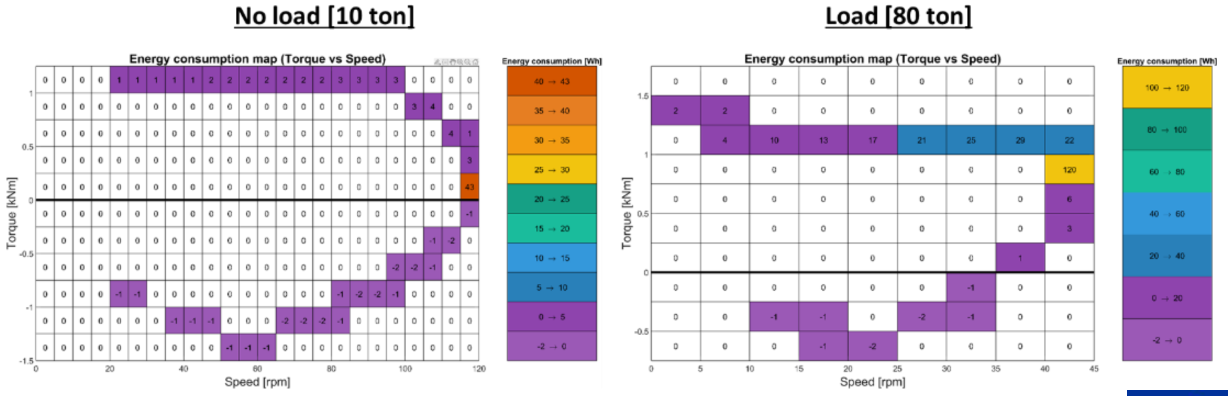


Figure 1. Energy consumption map for the traction system

Self Propelled Wagon - Use Cases

Europe's Rail

FP5 TRANS4M-R Transforming Europe's Rail Freight

2. Challenging tractive power and braking scenarios

1. **Parametric Study:** High-level analysis of battery-powered electric powertrains for self-propelled freight wagons, focusing on low-speed and high-power scenarios.
2. **Powertrain Conflict:** Identified conflict between last-mile delivery and traction support needs, suggesting a two-stage gearbox and mid-range powertrain as a solution.
3. **Case Study and Simulations**: Initial simulations in Sweden show potential benefits, with further analysis needed to explore operational benefits using existing motor and battery sizes.

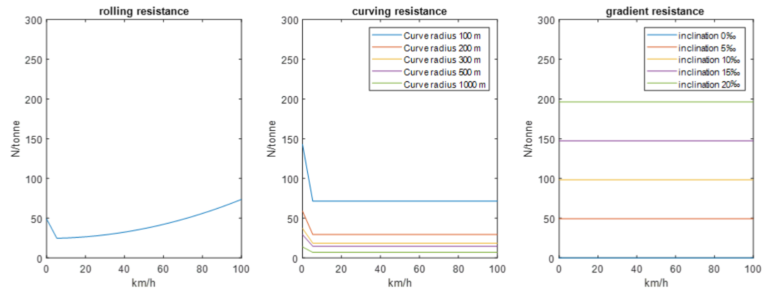


Figure 1. Rolling resistance, curving resistance and gradient resistance in Newtons per tonne vehicle as a function of speed for different running conditions.

Table 1. Example self-propelled freight wagons with powertrain characteristics

	Mass for vehicle or consist	Maximum tractive force	Maximum power	Base speed
Single self-propelled freight wagon low speed	80 tonnes	16kN	50kW	11.25 km/h
Self-propelled freight wagon with towed wagons at line speed	200 tonnes	40 kN	500kW	45 km/h

Use case	
Use case name	Challenging tractive power and braking scenarios: Power booster - Incline Pusher
Use case number	2a
System	Self-propelled freight wagon
Stakeholders/actors	1. Train operator 2. Infrastructure manager
Use case goal	**1. Test an Incline Pusher functionality where the propelled bogies give extra power in uphill gradients** **2. Analyse the number of necessary powered wagons in the train for a certain level of performance** **3. Analyse the battery reloading capabilities in regular operation**
Preconditions - Functions and Requirements	The next functions are needed if the wagon is to be used as power booster for conventional freight trains: Boosting capability at high speed Supporting distributed power (DPS) Ability to climb at least 1,25% grade Energy self-sufficiency (no external charging required) Regenerative braking from high speed Braking capability The next functions are needed if the wagons are to be independent while integrated in the operation: Regenerative braking Advanced braking Thermal management: Battery heating (case dependent) Emissions-free (Battery electric propulsion) Battery Support train run functions and Train operation modes (TOM)
Current basic process flow	1. Fully loaded freight vehicle reaches an uphill gradient 2. The train drag force, due to the increased gradient resistance, becomes higher than the possible traction force from the locomotive 3. The train gradually decelerates, reducing its speed and limiting line capacity
Envisioned alternate process flow	1. Fully loaded freight vehicle reaches an uphill gradient 2. The train drag force, due to the increased gradient resistance, becomes higher than the possible traction force from the locomotive 3. The self-propelled freight wagons introduce traction force to supplement the locomotive, enabling constant speed and maintaining maximum line capacity

Self Propelled Wagon - Use Cases

2. Challenging tractive power and braking scenarios

1. **Parametric Study:** High-level analysis of battery-powered electric powertrains for self-propelled freight wagons, focusing on low-speed and high-power scenarios.
2. **Powertrain Conflict:** Identified conflict between last-mile delivery and traction support needs, suggesting a two-stage gearbox and mid-range powertrain as a solution.
3. **Case Study and Simulations**: Initial simulations in Sweden show potential benefits, with further analysis needed to explore operational benefits using existing motor and battery sizes.

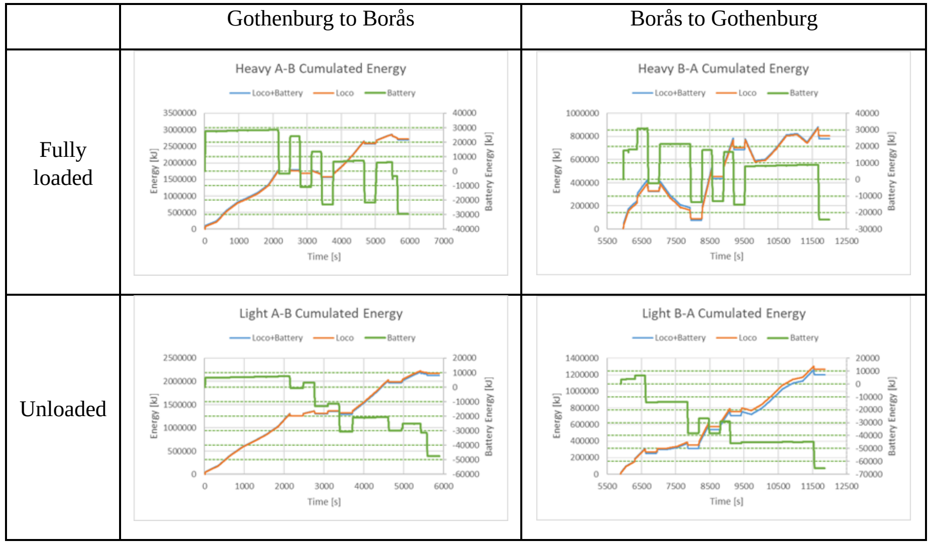


Figure 25. Cumulated energy consumption; contribution of the locomotive (orange), additional energy from distributed power (green), and total energy (blue)

Use case	
Use case name	Challenging tractive power and braking scenarios: Power Peak Shaving which includes the regenerative braking analysis.
Use case number	2b
System	Self-propelled freight wagon
Stakeholders/actors	1. Train operator 2. Infrastructure manager (electrical substations)
Use case goal	**1. Test a Power Peak Shaving functionality where the propelled bogies reduce the power needs from the locomotive in a case with overloaded electric substations** **2. Analyse the number of necessary powered wagons in the train for a certain level of performance** **3. Analyse the battery reloading capabilities in regular operation**
Preconditions - Functions and Requirements	The next functions are needed if the wagon is to be used as power booster for conventional freight trains: Supporting distributed power (DPS) Ability to climb at least 1,25% grade – likely to consume more power and thus be part of a Power Peak event Energy self-sufficiency (no external charging required) Regenerative braking from high speed Braking capability The next functions are needed if the wagons are to be independent while integrated in the operation: Regenerative braking Thermal management: Battery heating (case dependent) Emissions-free (Battery electric propulsion) Battery Support train run functions and Train operation modes (TOM) It would also need to be able to communicate the status of the electrical grid to the powered bogies in order to be able to act upon the power peaks
Current basic process flow	1. Fully loaded freight vehicle requires power at a track section with overloaded power system 2. The electric substation cannot provide the required power to all the trains in the network.
Envisioned alternate process flow	1. Fully loaded freight vehicle requires power at a track section with overloaded power substation 2. The communications system receives the Power Peak signal 3. The locomotive reduces its traction output, while the battery-powered bogies increase their traction output by the same amount, in order to not affect the trains traction needs. Commands to be transferred to every SPFW control unit 4. The reduced power intake from the locomotive alleviates the Power Peak in the electric network.

Self Propelled Wagon – Use Cases

FP5TRANS4M-R Transforming Europe's Rail Freight

3. Coordinating groups of self propelled freight wagons

1. **Efficiency Gains:** Concurrent shunting with self-propelled wagons reduced shunting time by 43% compared to sequential methods.
2. **Optimization and Limitations:** Centralized planning and evolutionary optimization minimized shunting duration, but scalability and real-world constraints need further research.
3. **Future Work:** Evaluate with larger fleets, develop alternative optimization methods, and integrate real-world constraints for practical deployment.

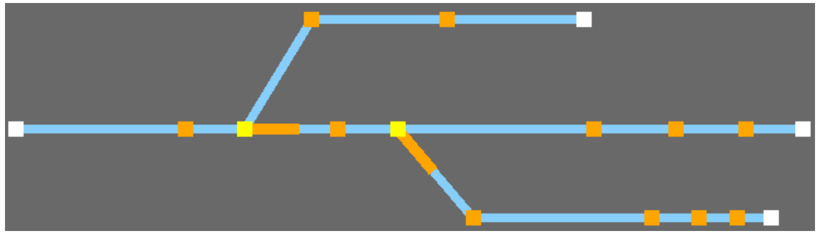


Figure 1. A simple topological map, defining a shunting yard with 4 siding tracks, 2 junction nodes (switches), and 11 transit nodes.

Use case	
Use case name	Coordinating groups of self-propelled wagons: Automated shunting operation
Use case number	3
System	Set of self-propelled freight wagons in yard (simulated)
Stakeholders/ actors	1 Shunting locomotive operator
	2 Yard operator
Use case goal	**1 To demonstrate automated switching functionality for self-propelled rail wagons.**
	2 Compare time consumption with traditional process, demonstrate efficiency gains.
Preconditions - Functions and Requirements	1. In order to drive within the yard, the wagon needs to be self-propelled (F)
	2. In order to navigate within the yard, the wagon needs to be autonomous (F)
	3. The wagon needs to be able to couple/decouple through DAC (F) Not implemented in simulation.
Current basic process flow	1 A set of rail wagons are parked at a yard, at different siding tracks.
	2 A shunting locomotive picks up wagons one by one to form a train.
	3 Wagons are parked on one track to form a train, to be picked-up by outgoing train operator.
Envisioned alternate process flow	1 A set of self-propelled freight wagons are parked at a yard, on different siding tracks.
	2 A plan is generated off line for assembly of the train, wagons placed on a single track.
	3 Plan is executed: Wagons move by themselves simultaneously to form a train on a single track, ready to be picked-up by outgoing train operator.

Self Propelled Wagon - Use Cases

3. Coordinating groups of self propelled freight wagons

1. **Efficiency Gains:** Concurrent shunting with self-propelled wagons reduced shunting time by 43% compared to sequential methods.
2. **Optimization and Limitations:** Centralized planning and evolutionary optimization minimized shunting duration, but scalability and real-world constraints need further research.
3. **Future Work:** Evaluate with larger fleets, develop alternative optimization methods, and integrate real-world constraints for practical deployment.

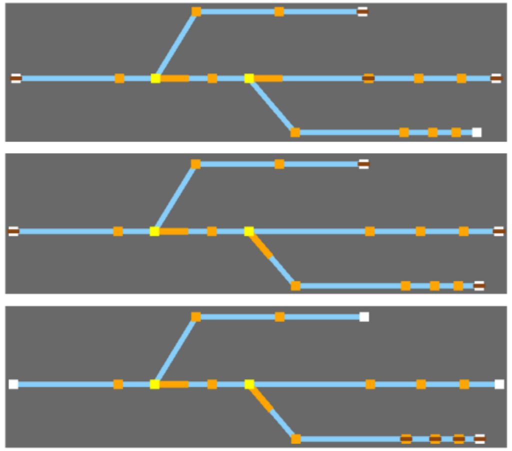


Figure 28. Sequential shunting.

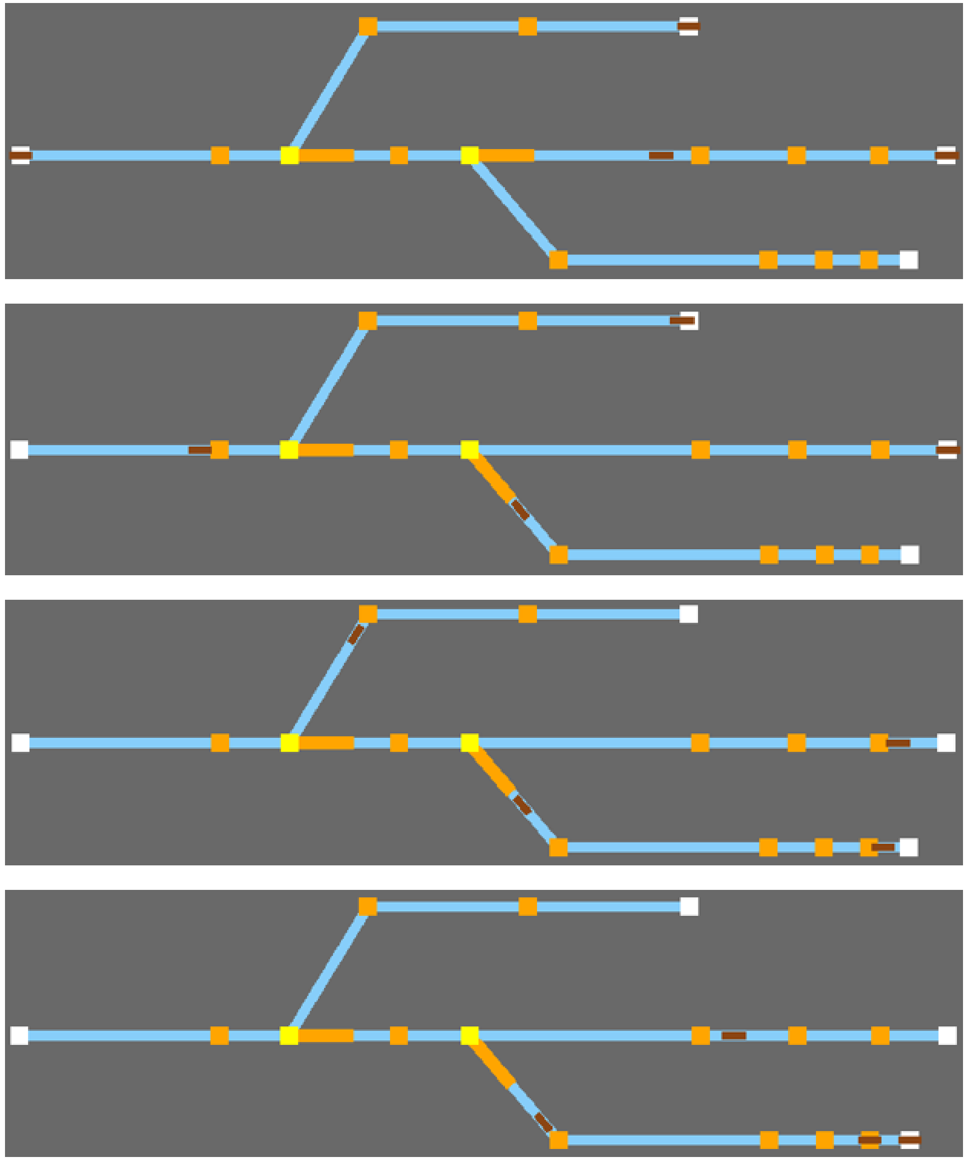


Figure 29. Concurrent shunting, over the same scenario shown in Figure 28.

Self Propelled Wagon - Use Cases

4. Autonomous loading and unloading

1. **Autonomous Yard Operations:** Investigated conditions for self-propelled wagons to autonomously enter, load/unload, and exit yards/terminals.
2. **Intermodal Focus:** Proposed constructing self-propelled wagons as intermodal due to feasibility of autonomous transshipment technology over non-containerized freight.
3. **Technology Survey:** Identified suitable technologies (AMCCT and SUM automatic loader) for autonomous loading/unloading, noting limitations of conventional gantry cranes.

Use Case	
Use case name	Autonomous loading/unloading
Use case number	4
System	Self-propelled freight wagon
Stakeholders/actors	1. Train operator
	2. Terminal / Yard operator
	3. Infrastructure manager of the node
	4. Infrastructure manager of the line
Use case goal	**1. Conditions for autonomously entering and exiting the yard/terminal**
	2. Survey concepts that enable autonomous loading/unloading and transshipment
	3. Investigate a common solution for autonomous entering/exiting yards/terminals and loading/unloading and transshipment of ILUs
Preconditions - Functions and Requirements	1. In order to autonomously entering and exiting the yard/terminal, the wagon needs to be self-propelled (F)
	2. The wagon needs to be able to couple/decouple through DAC (F)
	3. Autonomous transshipment technology of ILU's (F)
	4. Autonomous unloading and loading of non-containerized freight (F)
Current basic process flow	1a. For intermodal terminals, typically the train, once entering the terminal from the rail network, is divided in section lengths accommodated by the transshipment tracks of the terminal
	2a. For intermodal terminals, the ILUs are transhipped with cranes or reach-stackers
	1b. For yards, typically the shunting engine pushes the wagons over a hump into the classification yard where outgoing trains are built
	2b. For yards, the wagons (multi-purpose or specialized) are either unloaded and loaded on site or further transported to the end destination and then unloaded and loaded
	3. Loaded wagon is coupled to outgoing train
	4. Outgoing train returns to rail network
Envisioned alternate process flow	1a. The self-propelled freight wagon will autonomously disconnect from the train at a siding and enter the terminal/yard autonomously
	2a. For intermodal terminals, the ILUs are autonomously transhipped from and to the wagon
	2b. For yards, the wagons (multi-purpose or specialized) are autonomously unloaded and loaded (on site or at final destination)
	3. The self-propelled freight wagon will autonomously connect to the outgoing train at a siding
	4. Outgoing train returns to rail network

Self Propelled Wagon - Use Cases

Europe's Rail

FP5 TRANS4M-R Transforming Europe's Rail Freight

4. Autonomous loading and unloading

1. **Autonomous Yard Operations:** Investigated conditions for self-propelled wagons to autonomously enter, load/unload, and exit yards/terminals.

2. **Intermodal Focus:** Proposed constructing self-propelled wagons as intermodal due to feasibility of autonomous transshipment technology over non-containerized freight.

3. **Technology Survey:** Identified suitable technologies (AMCCT and SUM automatic loader) for autonomous loading/unloading, noting limitations of conventional gantry cranes.

Table 15. Survey on intermodal transhipment technologies

	Transshipment Technology	Low TRL (<9) - Not proven in operational environment	Intended for rail operations	Unaccompanied loading	Automation and digitalisation easy to implement	Horizontal	Type of loading: ISO Container	Type of loading: Inland container	Type of loading: Swap body	Type of loading: Semi-trailer "cranable"	Type of loading: Semi-trailer "Uncranable"	Type of loading: Complete road vehicle
1	Gantry Crane		x	x	x		x	x	x	x		
2	Reach Stacker		x				x	x	x	x		
3	Hydraulic Material Handling Crane			x			x	x	x	x		
4	Mobile Harbour Crane						x	x	x	x		
5	Crane Ship	x		x								
6	Furmia RTS 500*	x		x								
7	RoRo Ramp to/from Ship						x	x	x	x	x	x
8	RoRo double stacking cassettes						x	x	x	x	x	x
9	Metrocargo	x	x	x		x	x	x	x			
10	N.E.H.T.S. (Neuweiler)	x	x	x		x	x	x	x			
11	IUT (ÖBB Rail Cargo Austria)*	x	x	x	x							
12	CarConTrain	x	x	x	x	x	x	x	x			
13	Sidelifter		x	x	x	x	x	x	x			
14	BOXMover		x		x	x	x	x	x			
15	Mobiler (Rail Cargo Austria)		x	x		x	x**	x**				
16	Container Mover 3020 (Innovatrain)		x	x		x	x***	x***	x***			
17	Cargo Beamer 1st generation (Cargobeamer AG)	x	x	x	x					x	x	
18	Cargo Beamer next generation (Cargobeamer AG)		x	x	x					x	x	
19	Modalohr 1st generation (AFA)	x	x	x						x	x	
20	Modalohr 2nd generation « N/A » (Lohr Industrie)	x	x	x						x	x	
21	Modalohr UIC (Lohr Industrie, VIA)		x	x						x	x	
22	Helrom		x	x						x	x	
23	Nikrasa		x	x	x					x	x	
24	ISU (ÖBB Rail Cargo Austria)		x	x		x	x	x	x			
25	Megaswing		x	x						x	x	
26	Cargospeed	x	x	x						x	x	
27	Rail Runner (Europe)*	x	x	x		x	x	x	x			
28	RoLa Ramp		x									x
29	Eurotunnel Le Shuttle freight	x	x									x
30	Flexiwaggon		x									x
31	r2l 2.0 road rail link (VEGA)									x	x	

Source: (KombiConsult analysis, 2022)

Self Propelled Wagon - Use Cases

FP5 TRANS4M-R
Transforming Europe's Rail Freight

4. Autonomous loading and unloading

1. **Autonomous Yard Operations:** Investigated conditions for self-propelled wagons to autonomously enter, load/unload, and exit yards/terminals.
2. **Intermodal Focus:** Proposed constructing self-propelled wagons as intermodal due to feasibility of autonomous transshipment technology over non-containerized freight.
3. **Technology Survey:** Identified suitable technologies (AMCCT and SUM automatic loader) for autonomous loading/unloading, noting limitations of conventional gantry cranes.

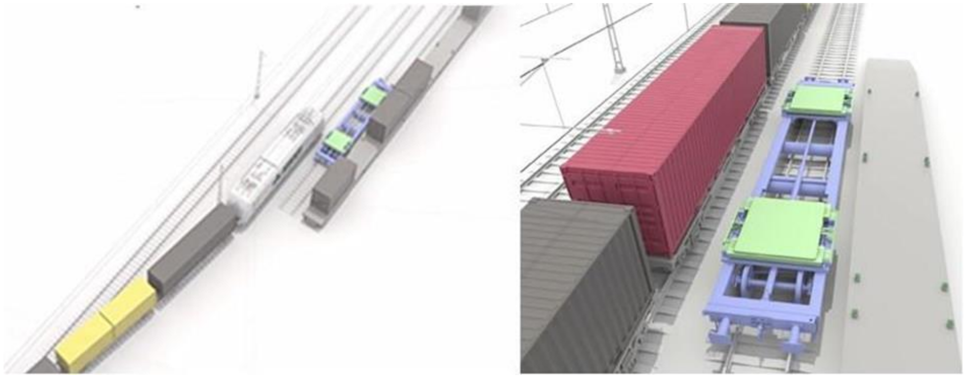


Figure 30. Fully automated terminals at a siding. Source: AMCCT.

Figure 31. Loading and unloading of containers with the SUM

Self Propelled Wagon - Use Cases

Preliminary architecture

Conceptual analysis on the impact of self propelled objective on the digitalization of the freight trains (efficiency of the processes, calculation of the adequate traction units, IoT and traction integration with their interfaces, Infrastructure needs)

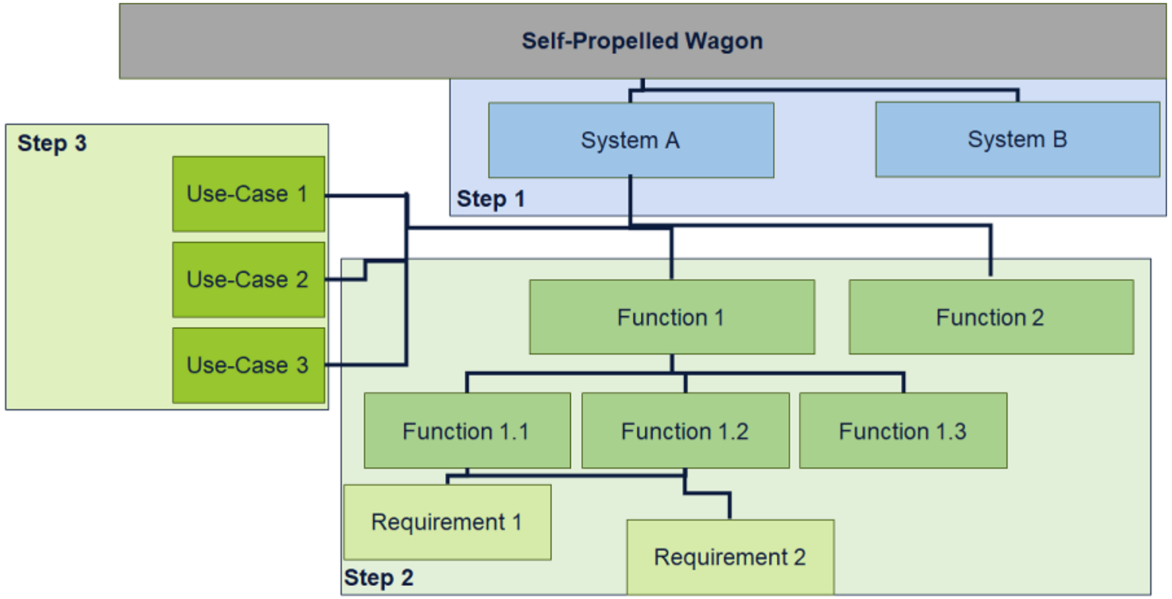
Conceptual system specification and preliminary high level functional requirements (appendix)

Step1:
A workshop was carried out to identify and prioritize features of the SPW, according to MoSCoW method

- M - Must have
- S - Should have
- C - Could have
- W - Won't have

Step 2:
Divide the features into functions and requirements

Step 3:
Link functions, requirements and use cases to sub-systems

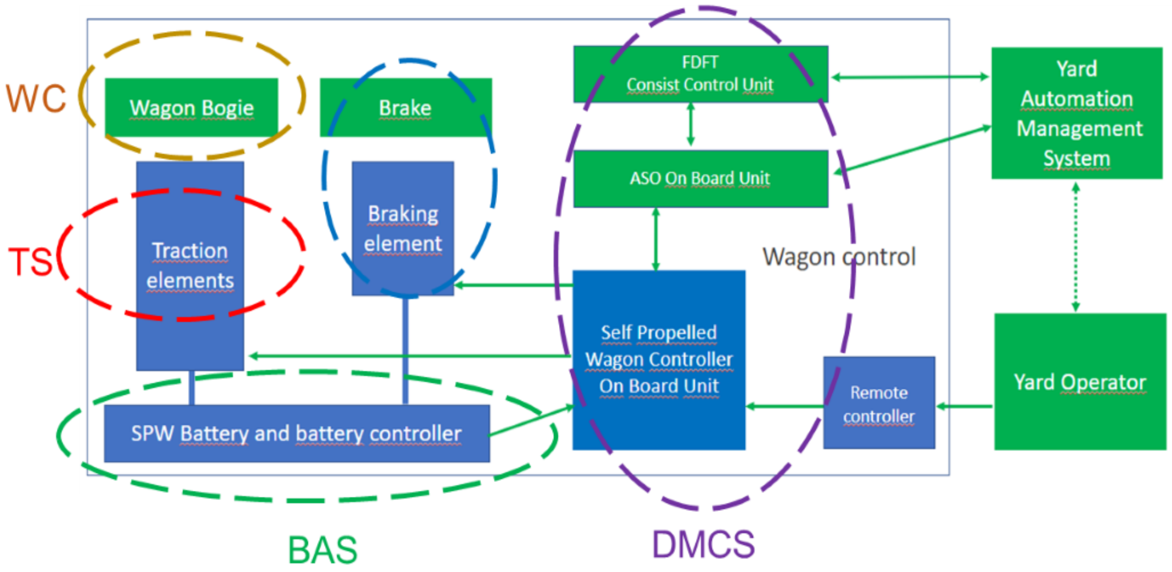


Self Propelled Wagon- Use Cases

Preliminary architecture

Conceptual analysis on the impact of self propelled objective on the digitalization of the freight trains (efficiency of the processes, calculation of the adequate traction units, IoT and traction integration with their interfaces, Infrastructure needs)

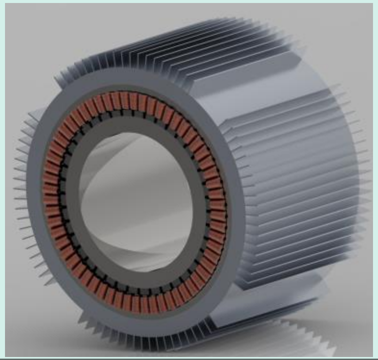
Conceptual system specification and preliminary high level functional requirements (appendix)



Sub-systems of SPW	
Wagon construction + other sub-systems	WC
Traction system	TS
Braking system	BS
Battery system	BAS
Data management and control system	DMCS

Future work

Theoretical calculations, implementation of first prototype for direct drive motor and Laboratory testing (WP23)



Hydrogen Transport container

Juergen Klarner, voestalpine Tubulars (VAT)

Manuel Zangl, voestalpine Tubulars (VAT)

Holger Schnideritsch, voestalpine Tubulars (VAT)

Daniel Bertuzzi, Innofreight Solutions GmbH (INNO)

RAIL SWEDEN

Project structure

H2RailTube
Austrian FFG funded project in the program „Mobility of the future 2021“
This project is placed as IKAA in the TRANS4M-R project.

Duration: Sept. 2021 – Aug. 2024

Concept phase

IKAA

TRANS4M-R Multimodal Hydrogen Transport Container
EU-Rail FA5 – Innovative Freight Assets

Duration: Jul. 2022 – Dec. 2026 (Manufacturing of the prototype / 1. call EU-Rail)
Duration: Jan. 2027 – Dec. 2028 (Field testing of prototype / 2. call EU-Rail)

Prototyping phase

Project partner

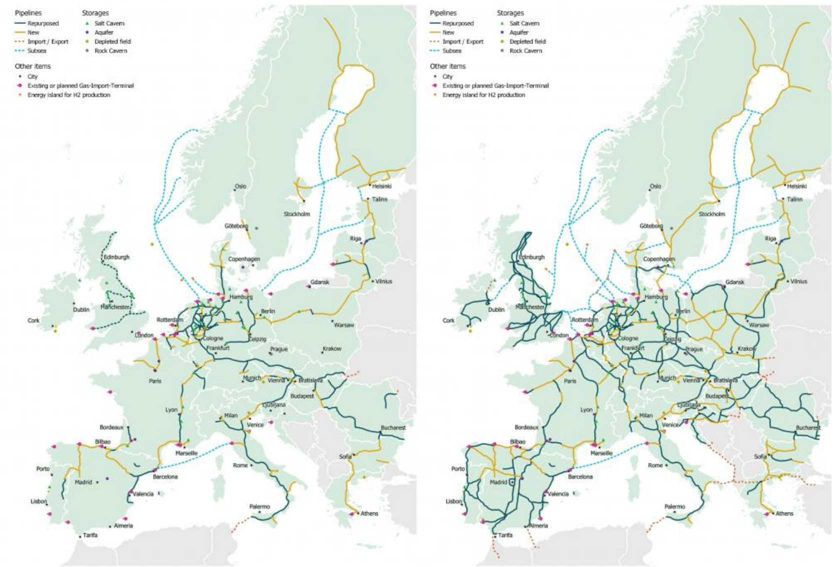
voestalpine ONE STEP AHEAD. · innofreight · Rail Cargo Group Member of ÖBB

Project backgroun

European Hydrogen Backbone

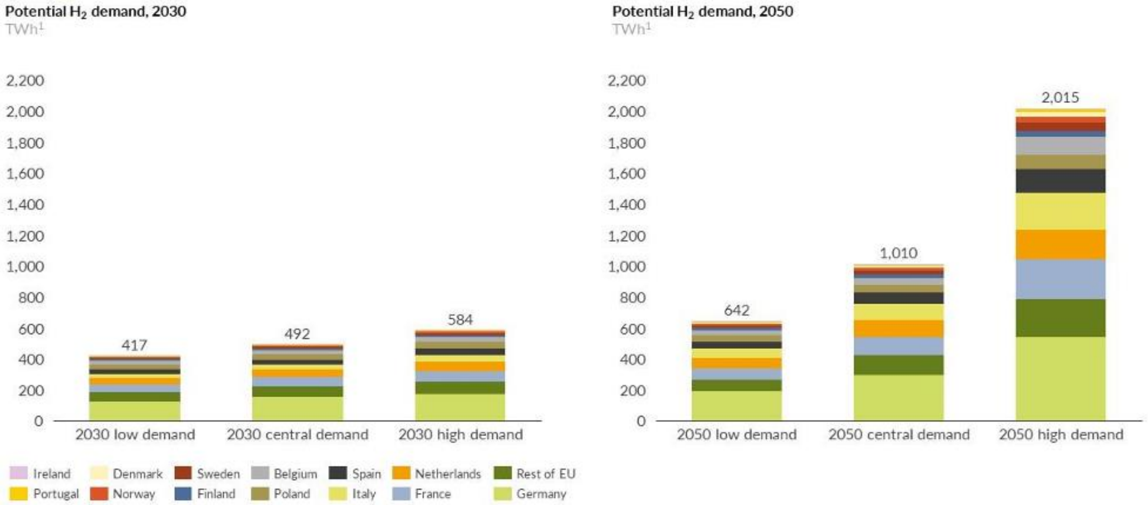
= hydrogen pipeline network

- According the decarbonisation goals for 2030
- 30,000 km of new hydrogen pipelines until 2030
  → Are they realistic in this time? (construction, authorization, commissioning, …)
- Containers ate the supply for consumers without pipeline connection



Source: European Hydrogen Backbone 2023, https://www.gasconnect.at/en/recent/news/detail/ehb-infrastrukturkarten-update-februar-2023-einschliesslich-neuester-machbarkeitsschaetzungen-und-pci-einreichungen

Hydrogen demand in EU per country



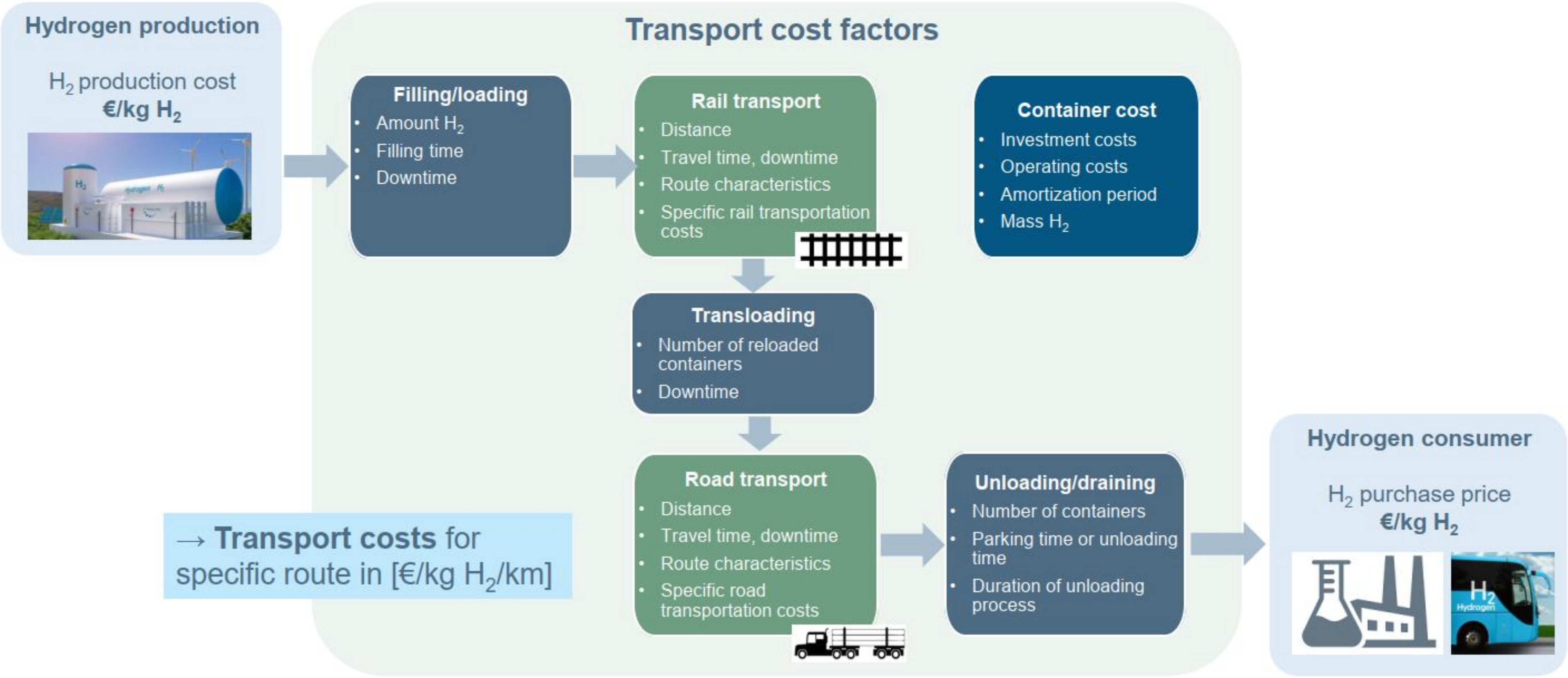
Source: Enabling the European hydrogen economy, report by Aurora Energy Research, 2021. https://auroraer.com/wp-content/uploads/2021/06/Aurora-MCS-Enabling-the-European-hydrogen-economy-Report-20210611.pdf

Avg. values of gathered forecasts by European Commission‘s European Hydrogen Observatory

Year	Hydrogen demand forecast	
2030	10 Mt	412 TWh
2040	16 Mt	913TWh
2050	25 Mt	1520 TWh

Source: European Commission‘s European Hydrogen Observatory, https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/end-use/hydrogen-demand

Logistics model for multimodal hydrogen transport



Project objectives

FP5TRANS4M-R
Transforming Europe's Rail Freight

Conventional carbon fiber (CF) H2 trailer

- Light weight
- High pressure possible
- Expensive production of CF
- Energy-intensive production of CF
- Thermal sensitivity (filling process)
- Lack of recyclability
- Road transpo

H2RailTube steel container

- High pressure storage system with steel tubes
- Maximum operating pressure 500 bar
- Approx. 0,5 t H2 per container, approx. 2 t H2 per double rail wagon
- Container dimensions 40ft half-height container
- Cost-effective
- Multimodal transport (road & rail)
- Sustainable recyclable high-strength steel

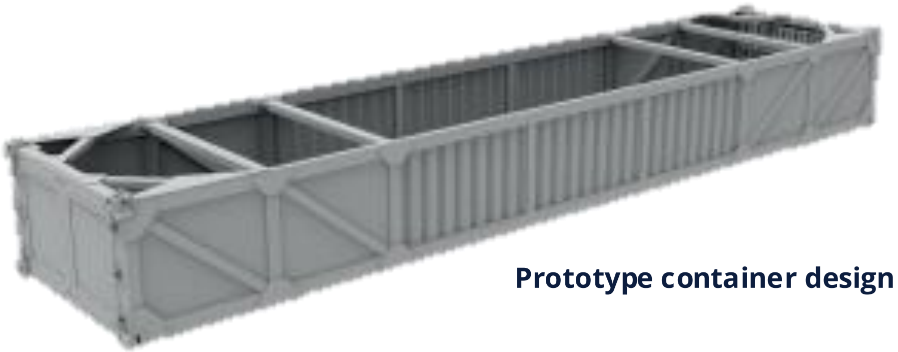
Application

- Single container for stationary storage
- Multiple containers/full train for mass transport, filling of local storage tanks

Container design phase

Design

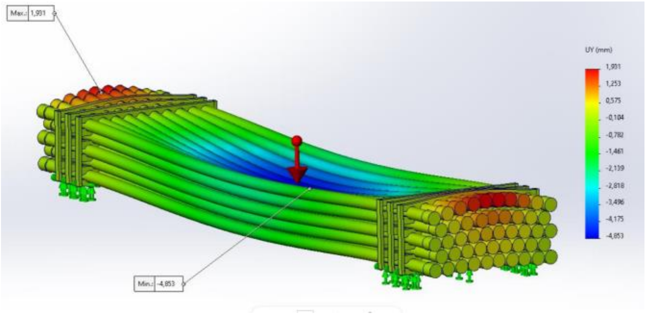
- Definition of functional requirements
- Basic functions and design
- Pressure cascades
- Instrumentation and piping system
- Sensors and monitoring system



Prototype container design

Simulation and testing

- Finite Element Analysis simulations of mechanical structure under different loads
- Material testing under hydrogen to ensure resistivity against brittle rupture
- Pressure tests and pressure cycling
- Instrumented filling tests with hydrogen



FEA simulation tube storage unit under load

Single-tube-prototype in cyclic pressure test

Container prototype phase

Manufacturing of the container demonstrator

- Manufacturing of the container casing
- Manufacturing of components for the hydrogen storage system
- Assembly of the container and the hydrogen storage unit
- Structural testing

Authority approval

- Approval in compliance with norms and standards like
  - ADR (International Carriage of Dangerous Goods by Road)
  - RID (International Carriage by Rail)
  - Several ISO/EN standards

Double-wagon with container

Conclusion

1. **Cost-efficient transport of large hydrogen amounts**
2. **Multimodal** hydrogen transport on road and **rail**
3. **Flexibility for producers and consumers**
   - For producers: Collection of containers or filling on site
   - For consumer: Unloading of filled container (use as local storage) or discharging of containers into stationary tanks
4. **Sustainable** steel **solution with** low carbon footprint, **recyclability.**
5. **Possible** customization of container, equipment and instrumentation according to customer needs.

Freight Train Aerodynamics for efficiency and safety

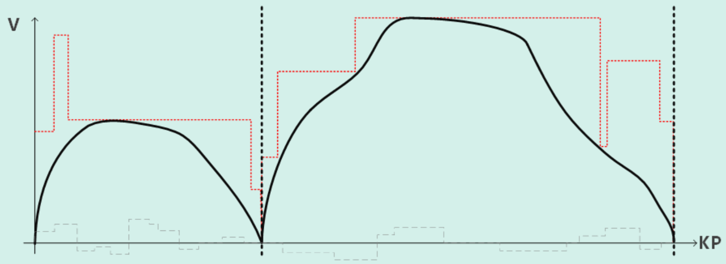
James R. Bell, German Aerospace Center DLR

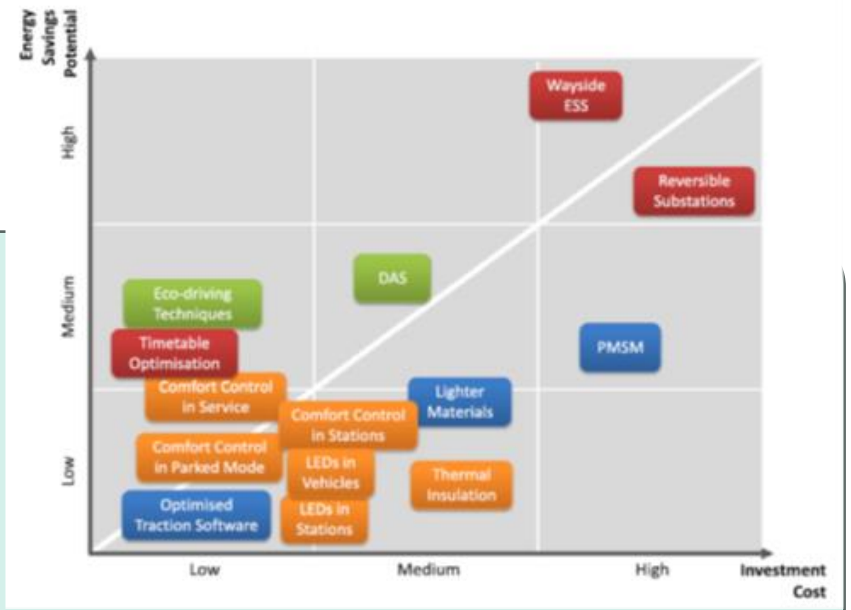
12.09.2024

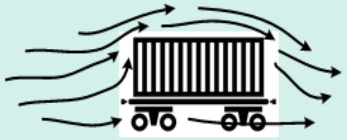
Efficient Concepts

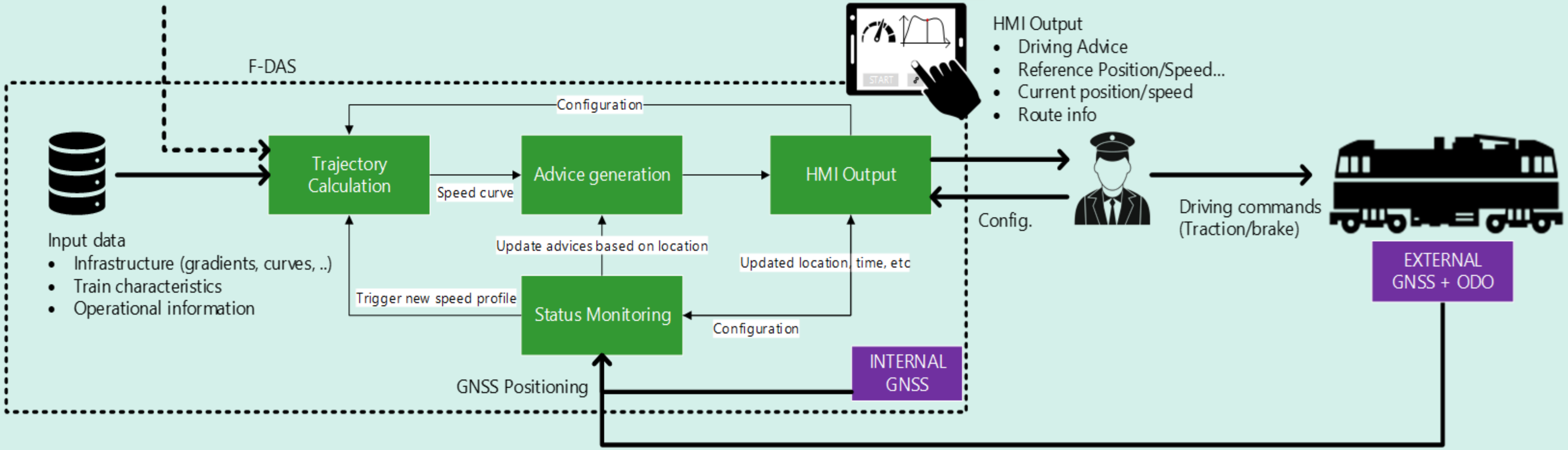
Efficient Driving strategies

- Introduction and ecodriving
- Methodology of calculations
- Specifications for Efficiency









Freight Train Aerodynamics for

Introduction

Full-scale data acquisition experiment, logistic support by RENFE

FR8-LAB:

- self-contained 'swap-body' container that can be transported on normal operating freight-trains/trucks
- on-board data acquisition, power supply and communication systems

Characterization of generic, average 'real-world' conditions

- Surface pressure, forces & moments + probability/statistics

Correlation with Environmental Conditions Location (GNSS), topography (LIDAR, thermal cameras)

Identification of important specific operating scenarios for energy efficiency, safety

Freight Train Aerodynamics

Approach

Full-scale operational measurements
general characteristics, specific scenarios

Aerodynamic Optimization Hypotheses
loading configuration
wagon design
infrastructure design

Improved understanding
of underlying causal physics

Real-world Conditions
Turbulence, pressure distribution, fluctuations, force magnitudes,
specfic transient & non-stationary events

Validation
of scaled experiments

Reduced-scale wind-tunnel experiments
forces/moments, pressure & flow field

Freight Train Aerodynamics

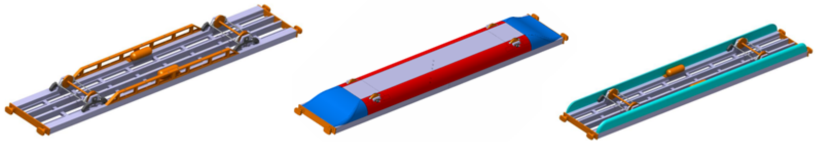
FP5 TRANS4M-R
Transforming Europe's Rail Freight

Europe's Rail

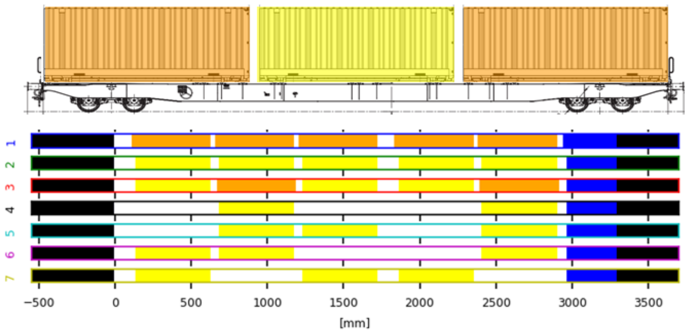
Approach

Aerodynamic Optimization Hypotheses
loading configuration
wagon design
infrastructure design

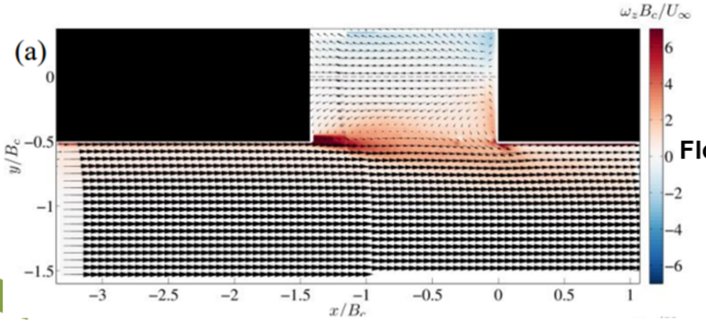
Improved understanding
of underlying causal physics



Wagon Geometry



Loading Configuration



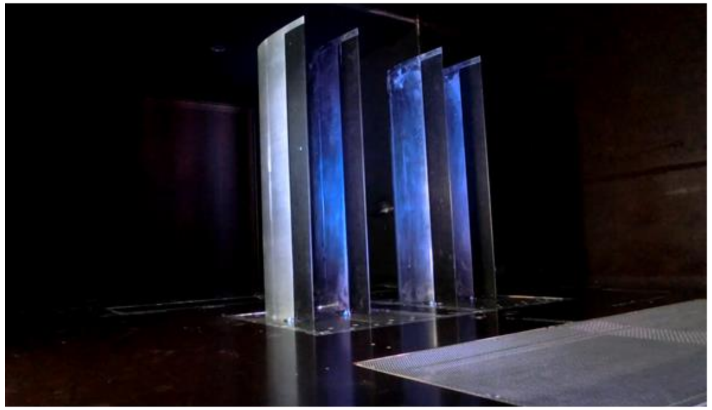
Flow Physics

Freight Train Aerodynamics

FP5TRANS4M-R
Transforming Europe's Rail Freight

Approach

Representative oncoming flow



Specific Transient Events: e.g. tunnel entry, crosswind gust

Representative vehicle-ground interaction

Representative Train Length/Boundary Layer

Real-world Conditions
Turbulence, pressure distribution, fluctuations, force magnitudes, specfic transient/non-stationary events

Validation
of scaled experiments

Freight Train Aerodynamics

FP5 TRANS4M-R
Transforming Europe's Rail Freight

Approach

Aerodynamic Optimization Hypotheses
loading configuration
wagon design
infrastructure design

Improved understanding
of underlying causal physics

Full-scale operational measurements

Reduced-scale experiments

Real-world Conditions
Turbulence, pressure distribution, fluctuations, force magnitudes,
specfic transient &
non-stationary events

Validation
of scaled experiments

Freight Train Aerodynamics

DLR FR8-LAB

‘middle’ of freight-train is representative of ~90%of a freight-train consist
beyond local head and tail effects.

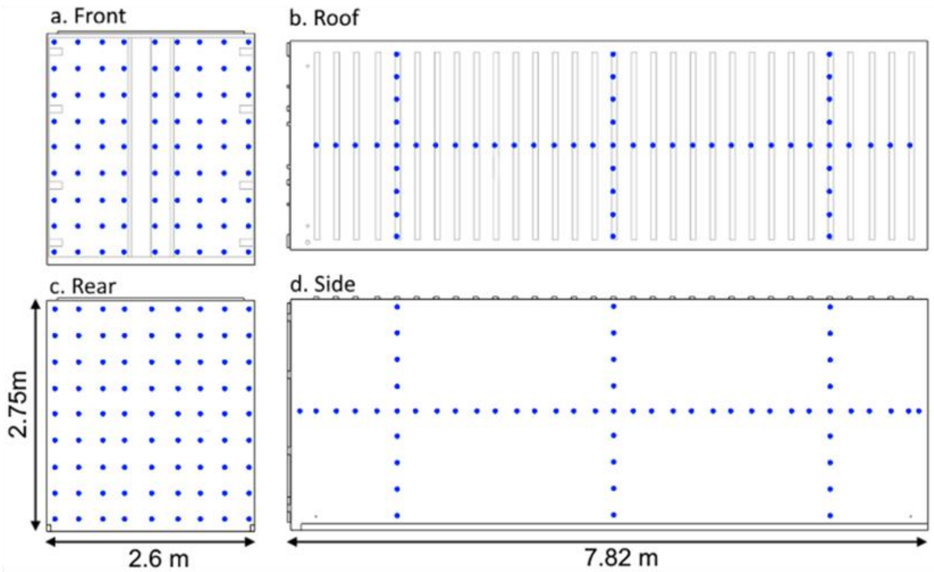
Freight Train Aerodynamics

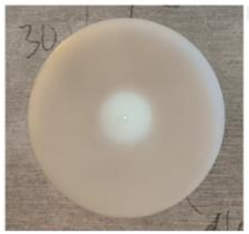
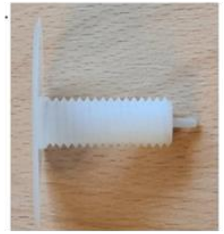
FP5 TRANS4M-R
Transforming Europe's Rail Freight

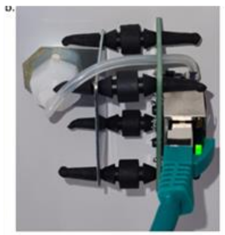
DLR FR8-LAB

Positions:

- 320 pressure taps:
- 9 x 9 grid: front & rear: pressure drag
- 3 x ‘belts’: 3 x 9 LHS, roof, RHS: rolling moment & side force
- 3 x 31 longitudinal roof and sides: variation/pressure gradients



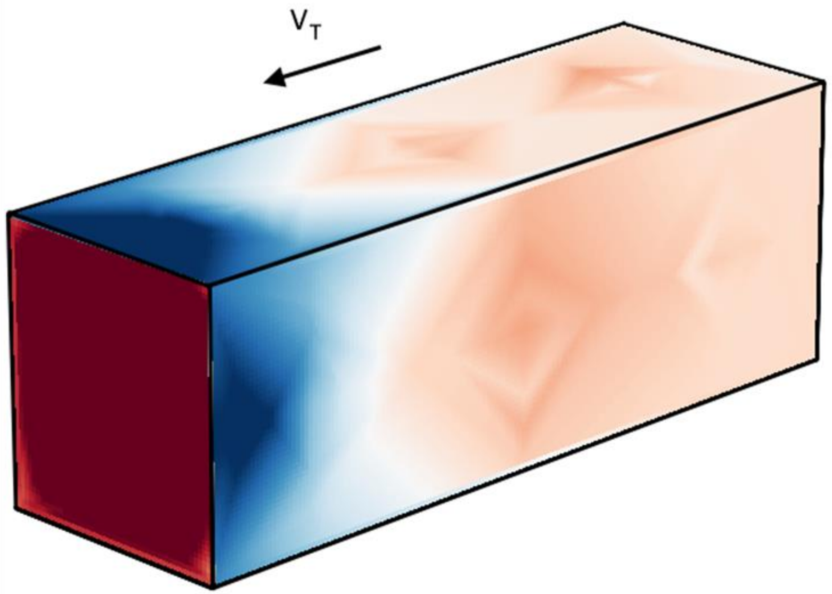



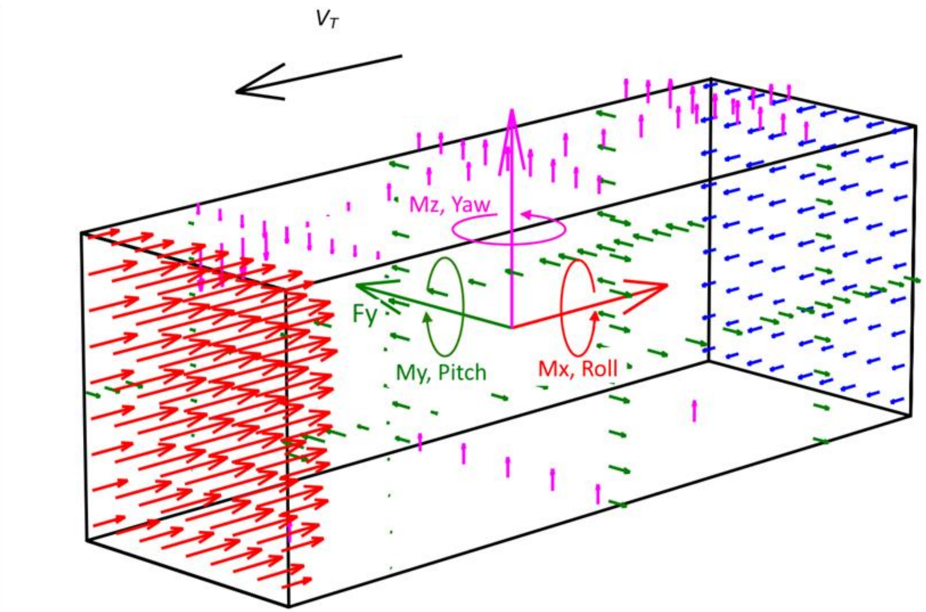
Freight Train Aerodynamics

FP5TRANS4M-R Transforming Europe's Rail Freight

DLR FR8-LAB

- **Integration of Surface Pressure:**
  - Aerodynamic Drag (Energy Efficiency)
  - Side Force, Lift, & Rolling Moment (Safety)



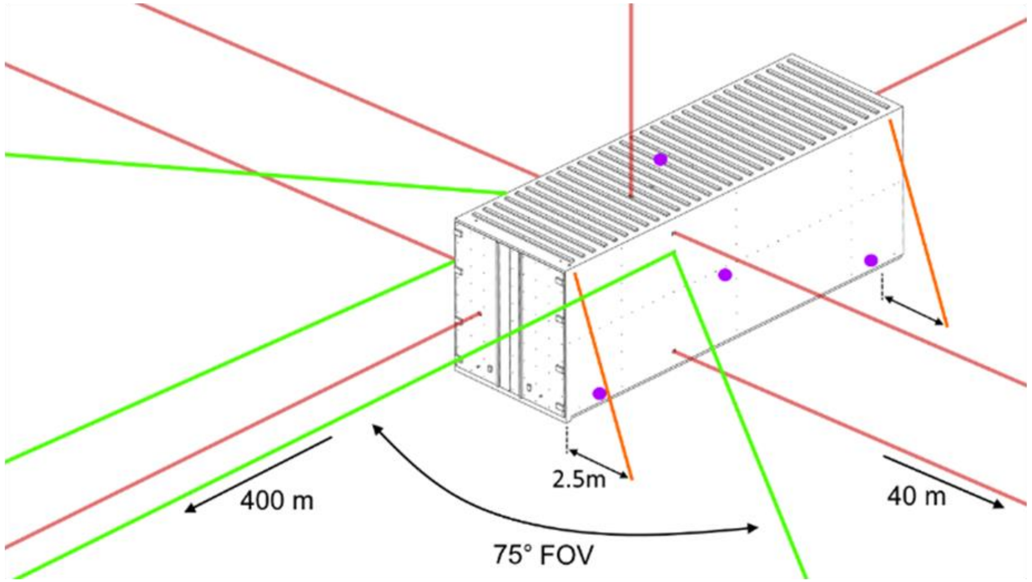


Freight Train Aerodynamics

FP5 TRANS4M-R
Transforming Europe's Rail Freight

DLR FR8-LAB

- Global navigational satellite system (**GNSS**):
  vehicle velocity, position, altitude
- 7 x **LiDAR** sensors:
  quantitative topography
- 2 x **VoG LiDAR** Velocity over Ground sensors pointed diagonally at ground,
- 2 x **Thermal cameras**:
  qualitative topography
  (e.g. identify a passing train)
- **Accelerometers**, temperature, barometric pressure: vibrations & operating conditions



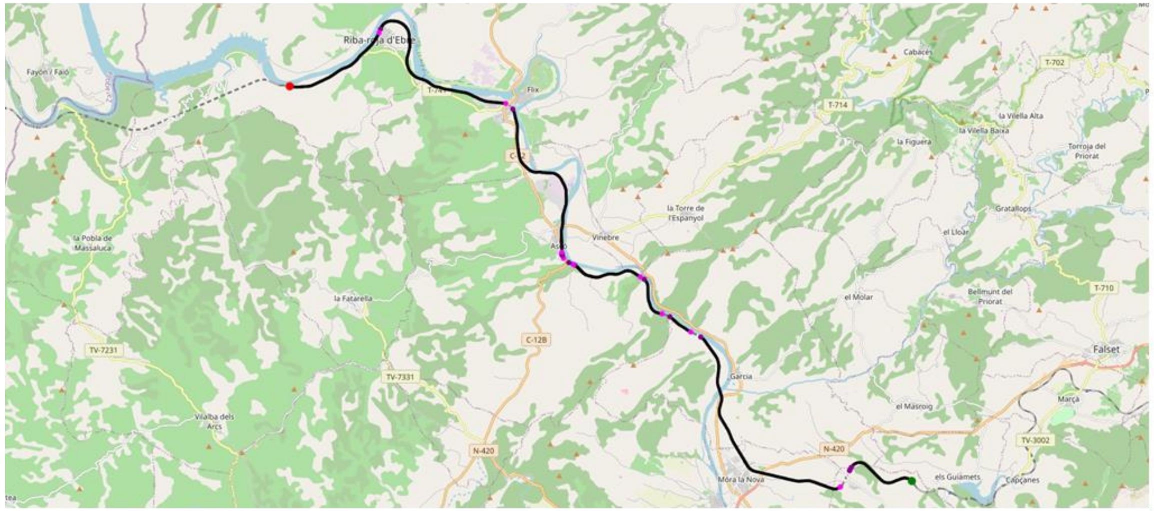
Freight Train Aerodynamics

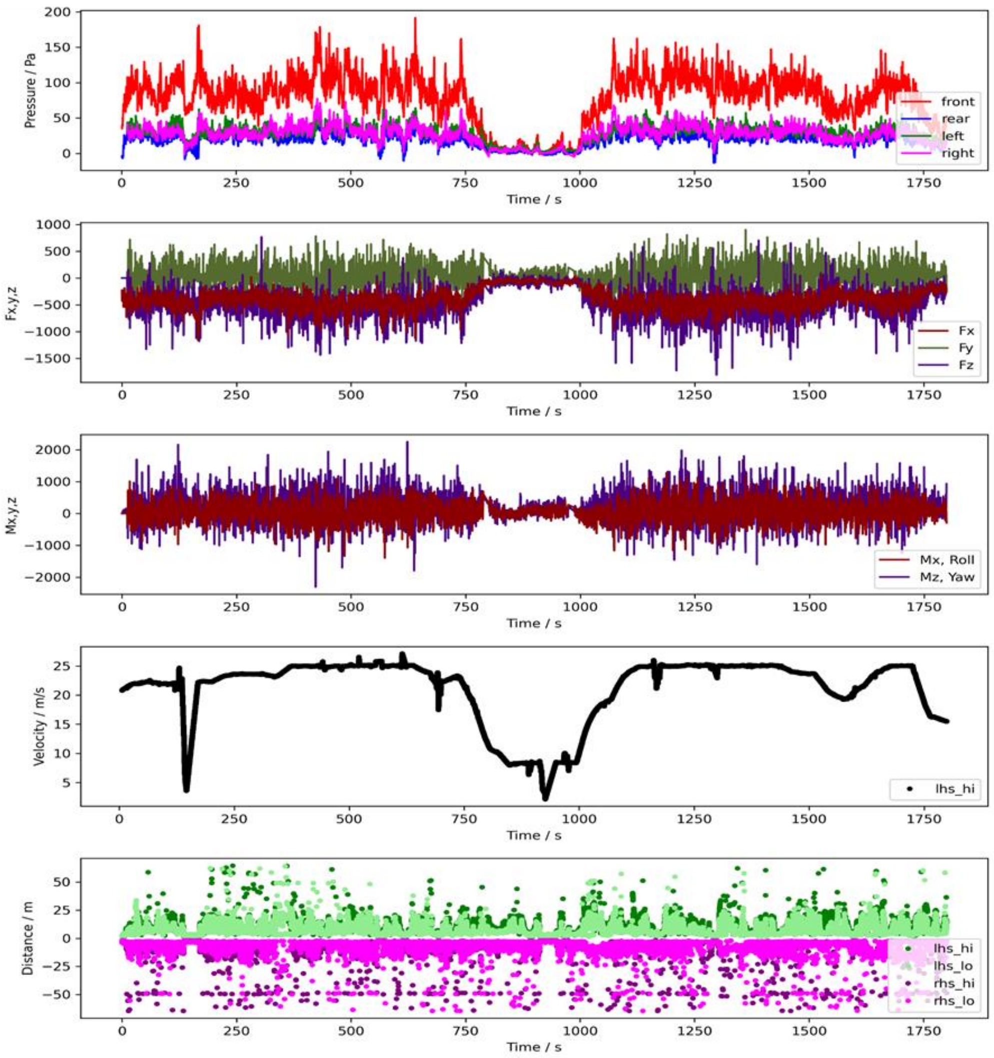
Results

30min example measurement: Absolute

- Transient-pressure (@front, rear, left, right)
- Force (drag, side-force, lift): Fx,y,z
- Moments: Mx,y,z
- Train-speed
- Lidar (distance left, right)

→ Clear transient effects, peaks, fluctuations and influence of infrastructure (tunnel)





Freight Train Aerodynamics

FP5TRANS4M-R Transforming Europe's Rail Freight

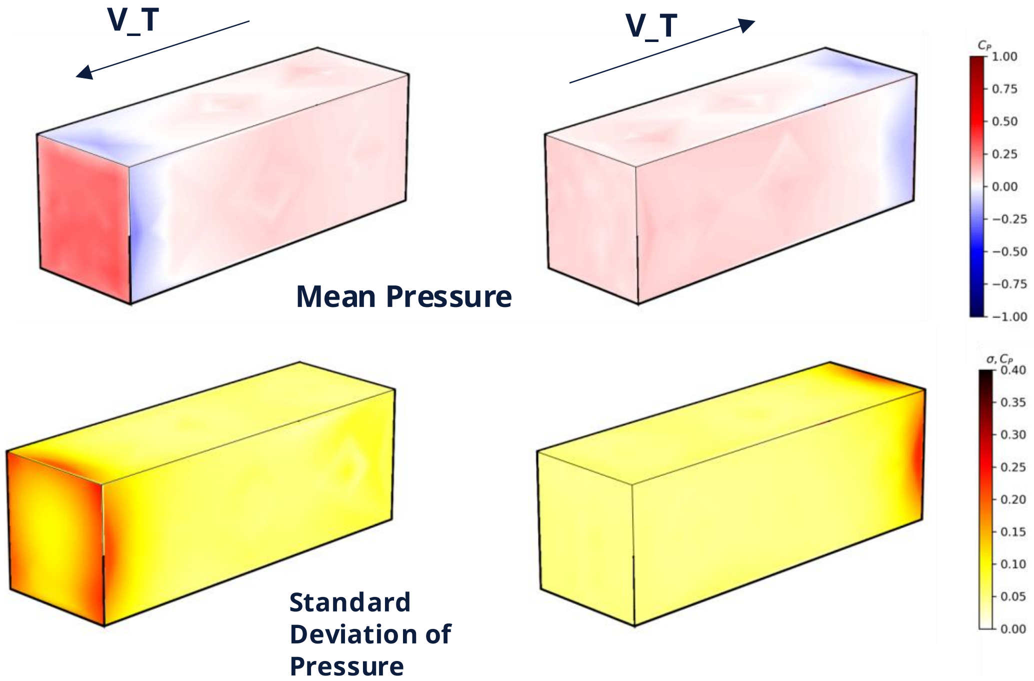
Results

Aerodynamic characteristics of a freight-container:

- **Very High pressure (red)** on front-surface
- **Very Low pressure (blue)** at front of sides and roof: flow separates from surface
- minimal pressure on sides and rear-surface

- **High fluctuations** (standard deviation) at front corners
  - ➢ Peak pressures

(**V_T i**s train travelling direction)



Freight Train Aerodynamics

FP5TRANS4M-R
Transforming Europe's Rail Freight

Results

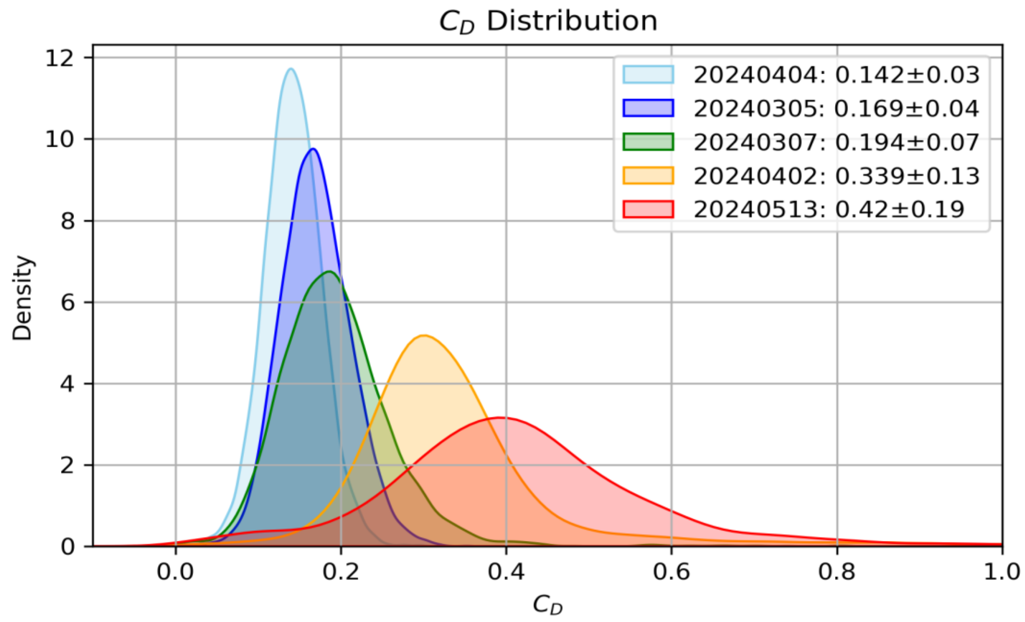
Characterization of generic, average 'real-world'

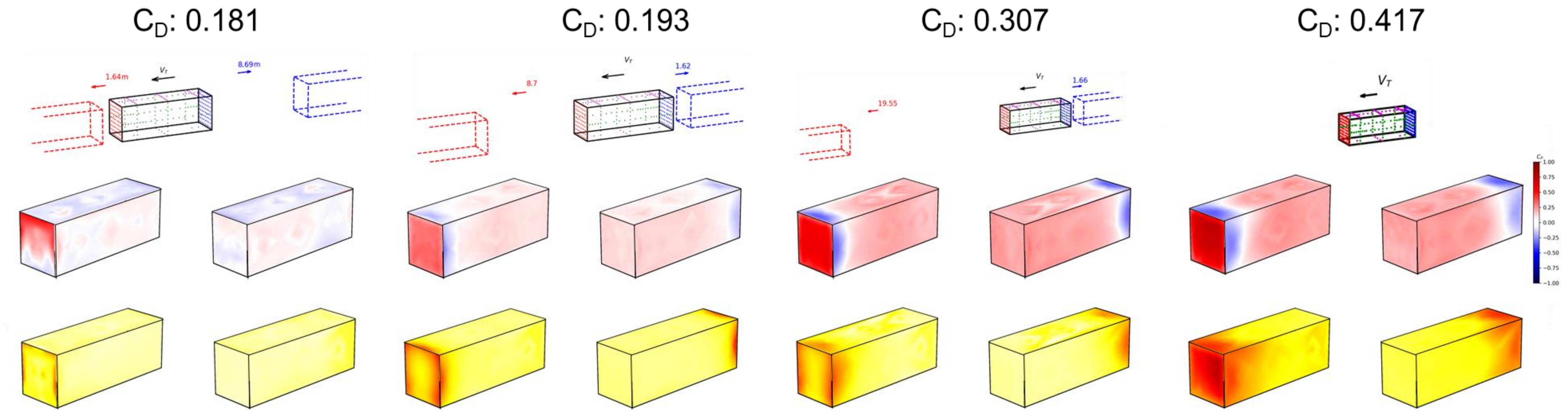
- Surface pressure, forces & moments + probability/statistics
- Validation of Laboratory investigations
- ➢ Greater confidence in aerodynamic optimizations recommendations
- ➢ Improvement of 'quality' of laboratory investigations – more representative of real-world operation

E.g. Loading configuration optimization

Significant difference in **aerodynamic drag (C_D)** for different gaps

- Predicted in wind-tunnel experiments
- ➢ confirmed by FR8-LAB measurements





Freight Train Aerodynamics

Europe's Rail

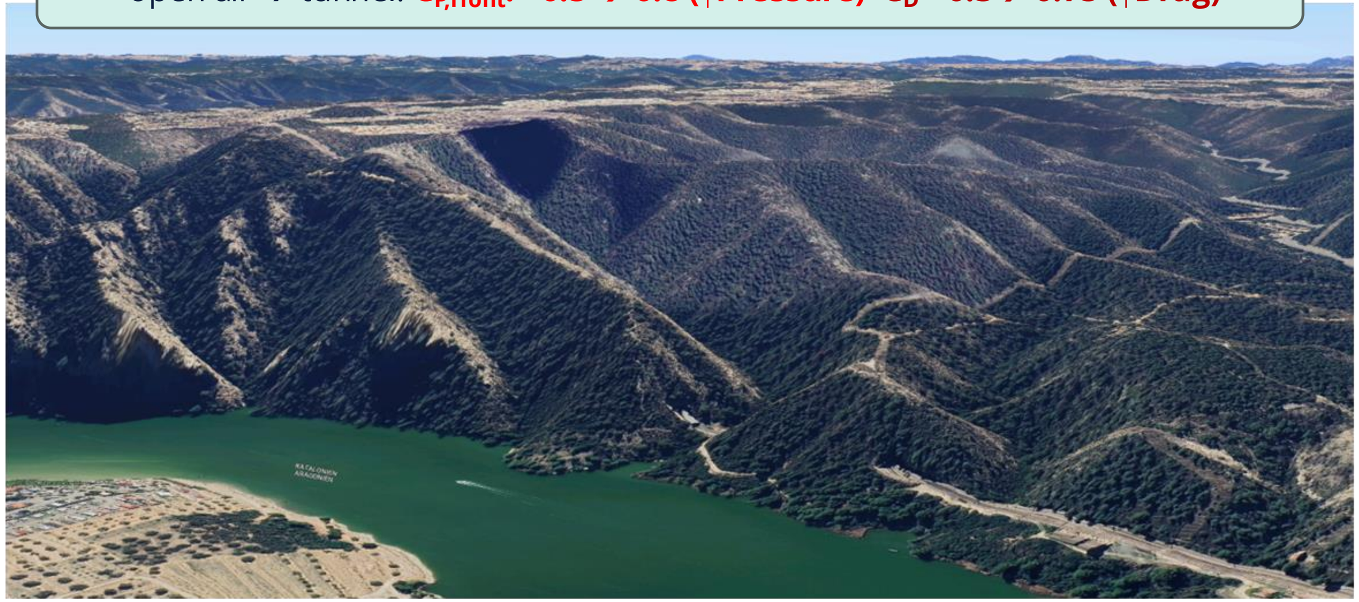
FP5 TRANS4M-R
Transforming Europe's Rail Freight

Results

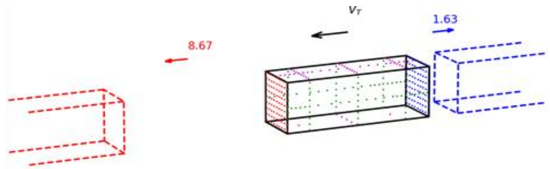
Characterization of specific operating scenarios
> where aerodynamics is important, e.g. Tunnel

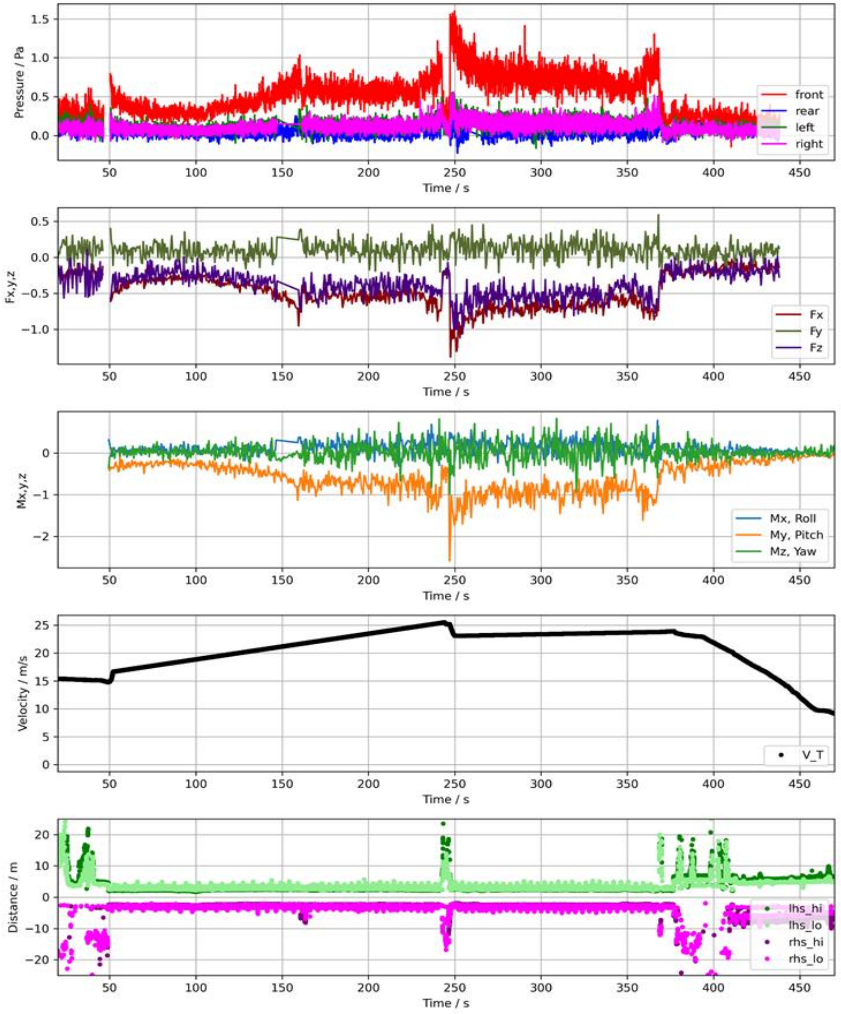
- High average aerodynamic drag (lower operating efficiency)
- Peaks in local pressure and global forces (safety)

  open air → tunnel: **$C_{P,front}$: ~0.5 → 0.8 (↑Pressure) C_D=-0.3→-0.75 (↑Drag)**



Bilder © 2024 Airbus,Google,Data SIO, NOAA, U.S. Navy, NGA, GEBCO,TerraMetricus,Landsat / Copernicus,Bilder © 2024 Airbus,Maxar Technologies,Kartendaten © 2024 Google,Inst. Geogr. Nacional





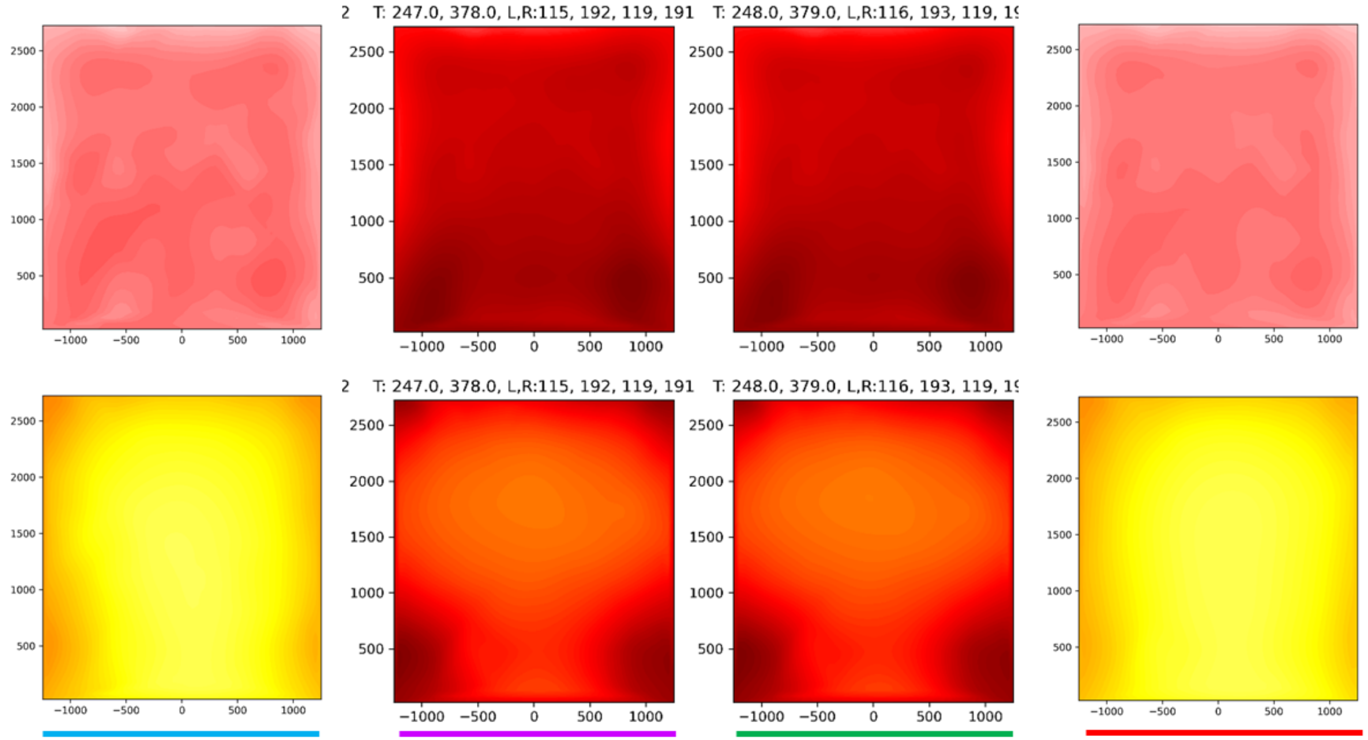
Freight Train Aerodynamics

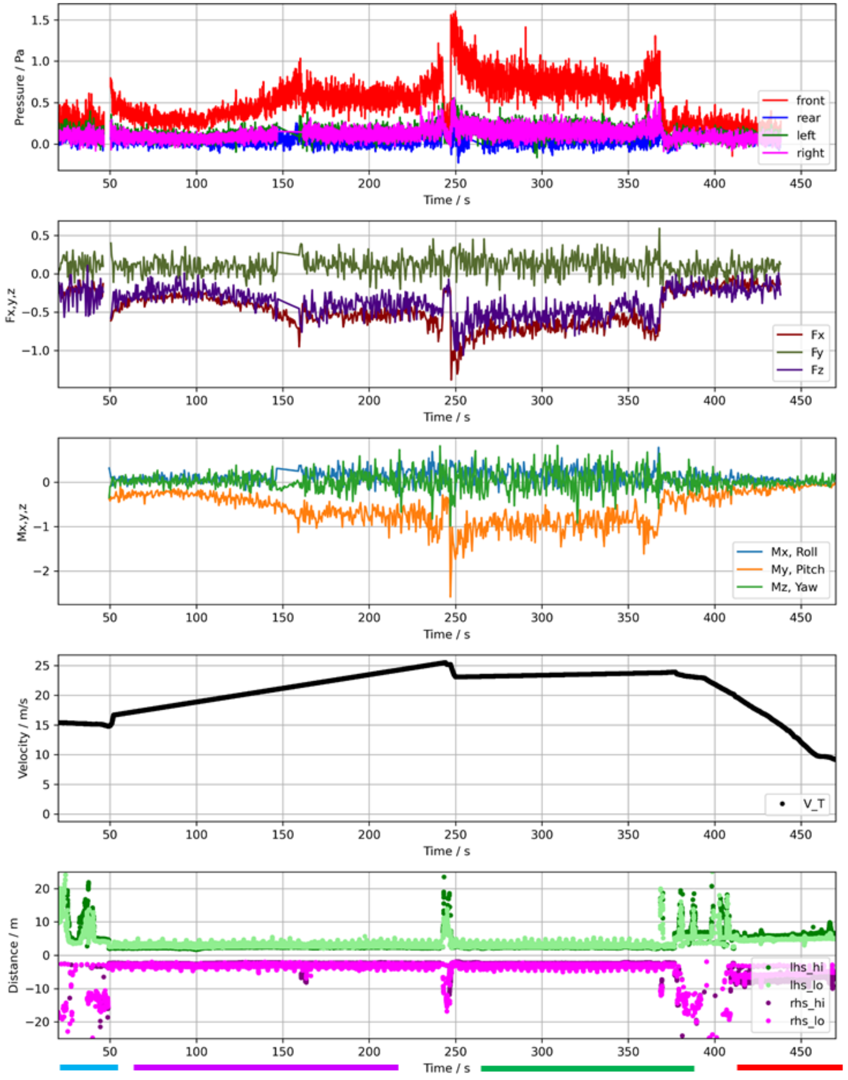
FP5 TRANS4M-R
Transforming Europe's Rail Freight

Results

Characterization of specific operating scenarios
> where aerodynamics is important, e.g. Tunnel

- High average aerodynamic drag (lower operating efficiency)
- Peaks in local pressure and global forces (safety)
- **Different pressure distributions**, different flow field
  improve current understanding -> scope for new aerodynamic optimization





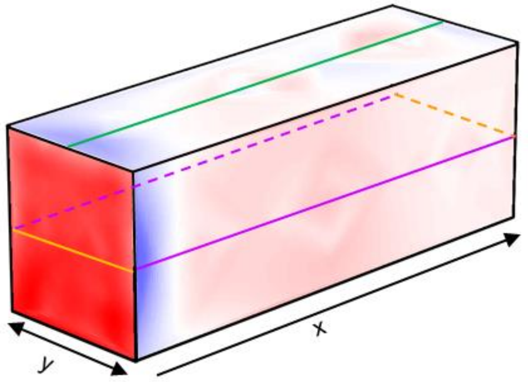
Freight Train Aerodynamics

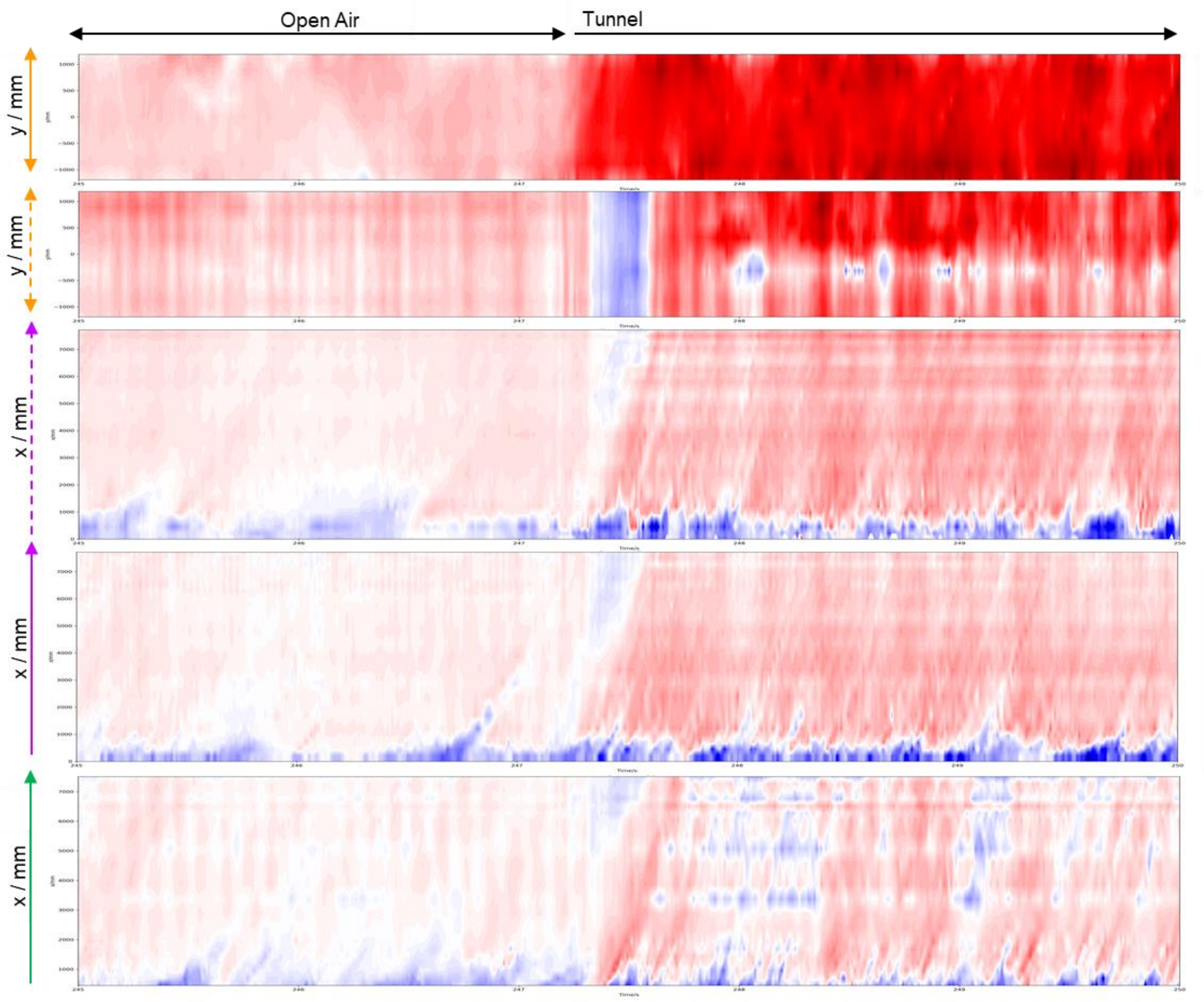
FP5 TRANS4M-R Transforming Europe's Rail Freight

Results

Characterization of specific operating scenarios
> where aerodynamics is important, e.g. Tunnel

- High average aerodynamic drag (lower operating efficiency)
- Peaks in local pressure and global forces (safety)
- Even insight into transient pressure over surfaces
- **improve current understanding -> scope for new aerodynamic optimization**





Freight Train Aerodynamics

Results

Characterization of specific operating scenarios
> where aerodynamics is important, e.g. Crosswind
(weather data to confirm)

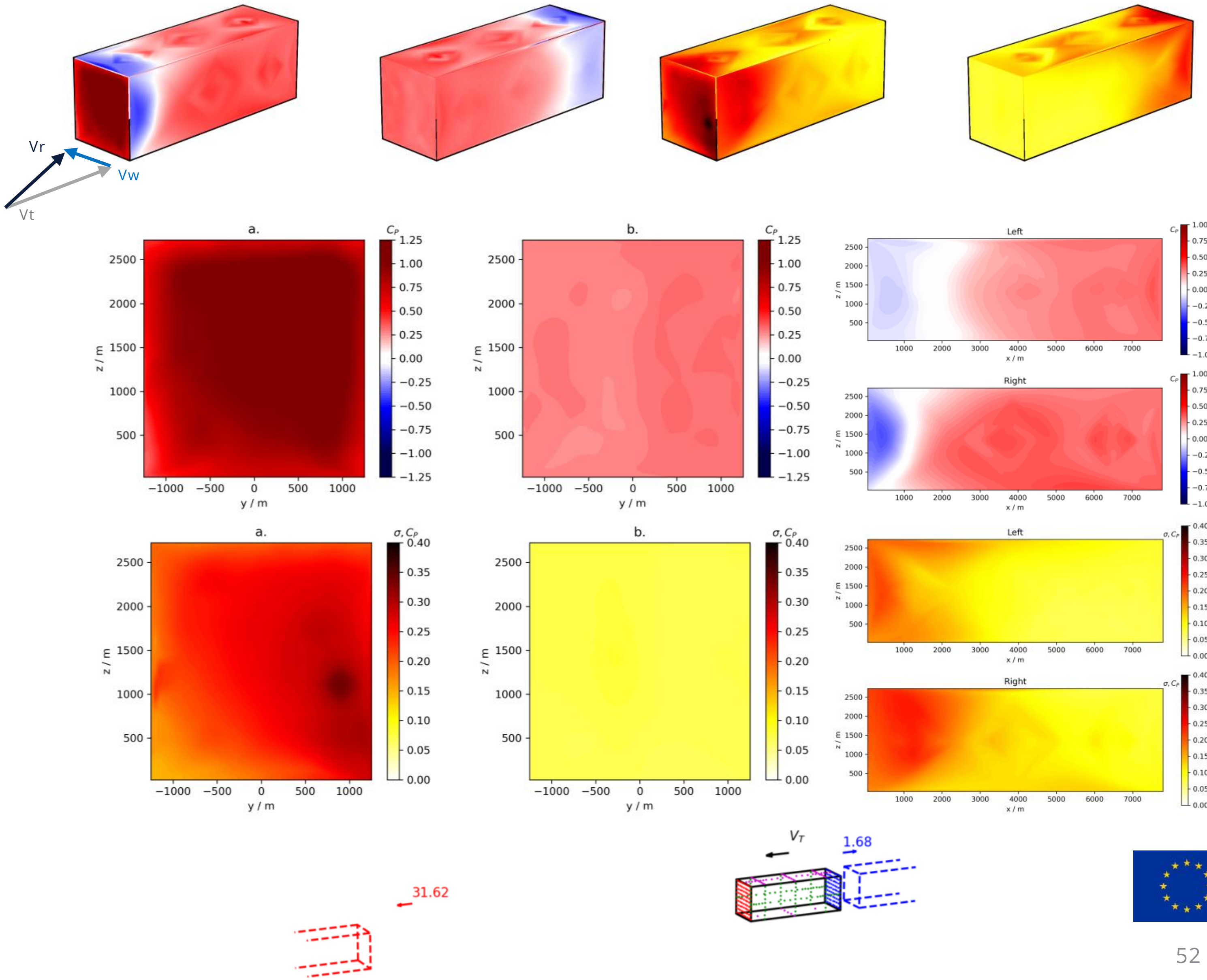
Clear asymmetry in pressure distribution: average and fluctuating

@Windward corner:
smaller separation region,
lower pressure
higher magnitude fluctuations

@Leeward corner:
larger separation region,
moderate low pressure

C_D=0.604 ± 0.159(σ): Aerodynamic Drag
➢ **Efficiency**

C_S=0.172 ± 0.232(σ): Side-Force
➢ **Safety**



Freight Train Aerodynamics

FP5TRANS4M-R
Transforming Europe's Rail Freight

Europe's Rail

Summary

General Characteristics:

- defined for real-world operation
- interesting aerodynamic phenomena <u>exist</u>

➢ scope for aerodynamic optimization

Validation:

- parallel scaled wind-tunnel experiments

➢ confidence in aerodynamic optimizations

Specific Scenarios:

- Mutiple scenarios with different aerodynamic characteristics: tunnels, train passing, bridges

➢ scope for <u>specific</u> aerodynamic optimization

FP5 Partners

FP5 Associated Partners

Thanks for your attention!

Follow Rail Sweden on LinkedIn and Rail Sweden web

Funded by the European Union and Trafikverket. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Europe's Rail Joint Undertaking. Neither the European Union nor the granting authority can be held responsible for them.

RAIL SWEDEN