Innovative technical solutions for improved train
DYNAmics and operation of longer FREIGHt Trains

DYNAFREIGHT

Andrea Demadonna – UNIFE
Simon Iwnicki – Huddersfield University
Visakh V Krishna – KTH
Carlo Vaghi – FIT Consulting

Shift2Rail IP5 joint event
18 April 2018
Vienna

Grant Agreement
Number: 730811

DYNAFREIGHT | Innovative technical solutions for improved train DYNAmics and operation of longer FREIGHt Trains

DYNAFREIGHT in brief

- Budget: **1M EUR**
- Partners: **10**
- Duration: **20 months**
- Starting date: **Nov 16**
- End date: **Jun 18**

Shift2Rail

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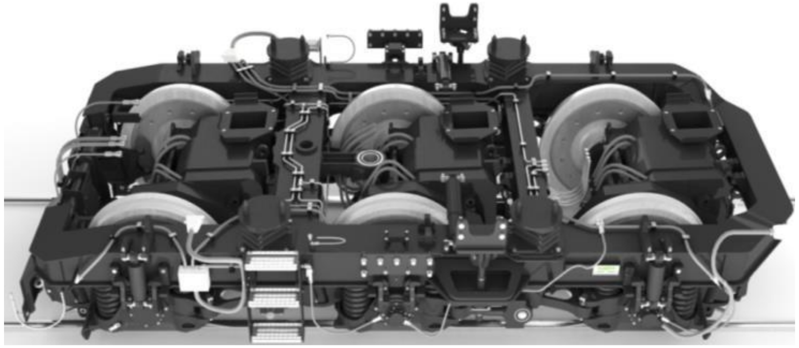
Main objectives

To provide the necessary inputs for the development of the next railway freight propulsion concepts within IP5 of Shift2Rrail

1) Next Generation of Freight Locomotive's Bogie: To specify, design and develop new concepts to be applied on future freight locomotive bogies

2) Increase of train length: to develop a technical solution for the regular operation of **long freight trains up to1,500m**



Structure

WP2
Next Generation Freight Locomotive's Bogie

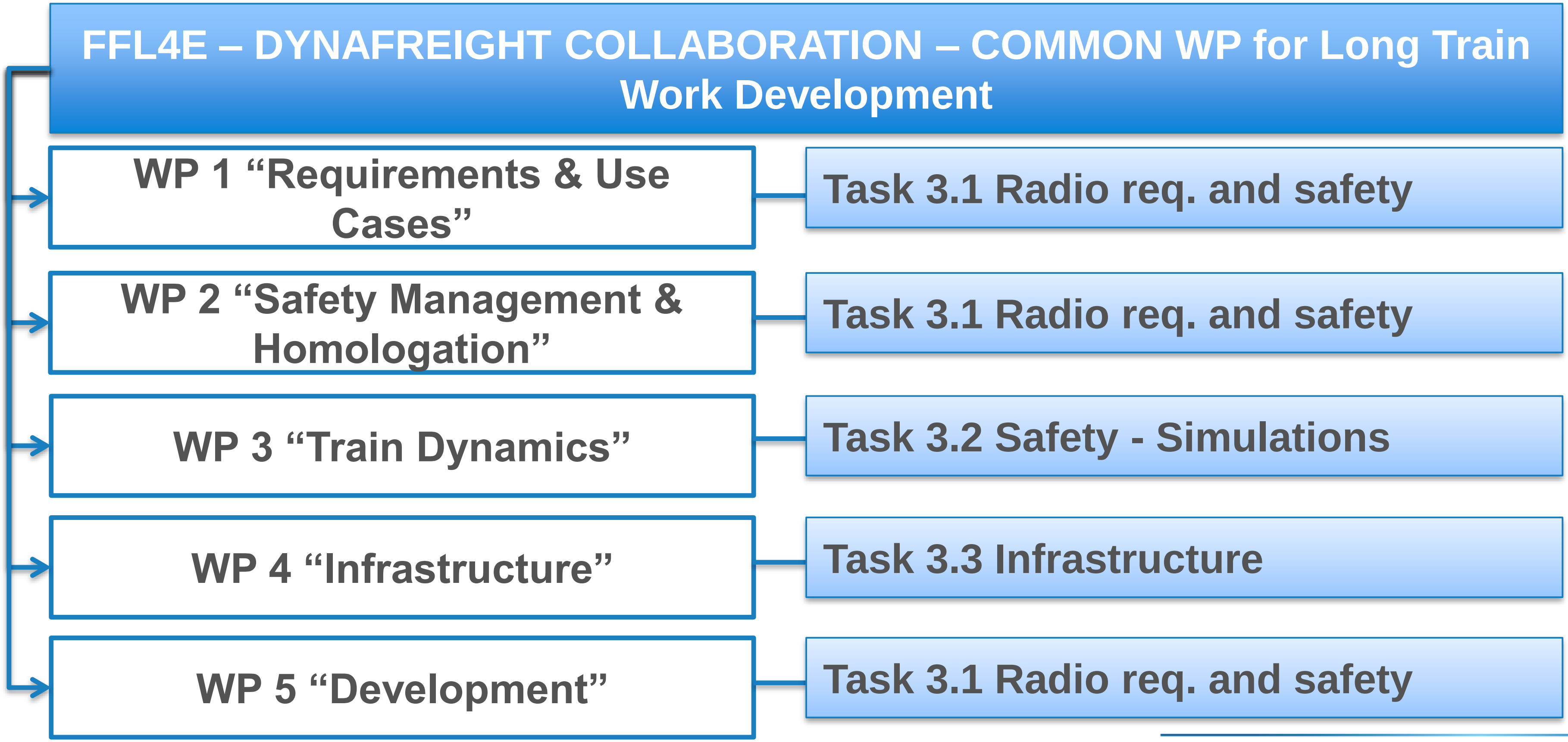
WP3
Technical Solution for regular Operation of 1,500mt long Freight Trains

T2.1 - Identification and evaluation of **lighter materials** to be used in a freight environment for bogie components
T2.2 - To study and develop **noise concepts** to reduce the overall noise level caused by freight running gear
T2.3 - To analyse **passive steering** and **active mechatronic systems** for improved curve negotiation
T2.4 - To **monitor the most maintenance-costly bogie elements**, in order to reduce LCC

T3.1 - Functional, technical and homologation requirements for a **radio remote controlled traction and braking system**
T3.2 - **Safety precautions** in train configuration and **brake application** by analysing and simulating the longitudinal forces and the derailment risk
T3.3 - Adaptions needed **in the infrastructure** for the operation of long freight trains up to 1,500m, which will be operated as double trains

Cooperation with FFL4E

Common WPs between both Collaborative Projects have been set in order to ensure proper alignment and cooperation for the Long Train work stream



FFL4E – DYNAFREIGHT COLLABORATION – COMMON WP for Long Train Work Development

WP 1 “Requirements & Use Cases”	**Task 3.1 Radio req. and safety**
WP 2 “Safety Management & Homologation”	**Task 3.1 Radio req. and safety**
WP 3 “Train Dynamics”	**Task 3.2 Safety - Simulations**
WP 4 “Infrastructure”	**Task 3.3 Infrastructure**
WP 5 “Development”	**Task 3.1 Radio req. and safety**

DYNAFREIGHT events

Advisory Group meeting

Presentation of mid-term results

When? **8-9 May**, Brussels

Registration still open
andrea.demadonna@unife.org

Final Conference

When? **27 June 2018**, Brussels

Registration and Programme will be available soon

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WP2: Next Generation of Freight Locomotive's Bogie

Simon Iwnicki
Huddersfield University

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Workpackage 2 Next Generation of Freight Locomotive Bogies

Task 2.1 Materials (Lightweighting)

Task 2.2 Noise Reduction

Task 2.3 Passive and Mechatronic Steering Systems

Task 2.4 Monitoring Systems

Task 2.1 Light Materials Assessment - OVERVIEW

Work has focused on the following areas:

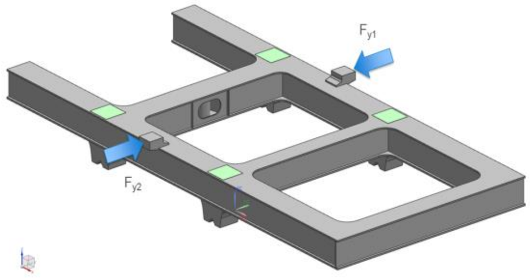
- Use of different steels but same basic design and construction method
- Different construction methods
  (manufactured sections, cast elements, different joining techniques, weld treatment…)
- More radical redesign including hydroforming, composite materials

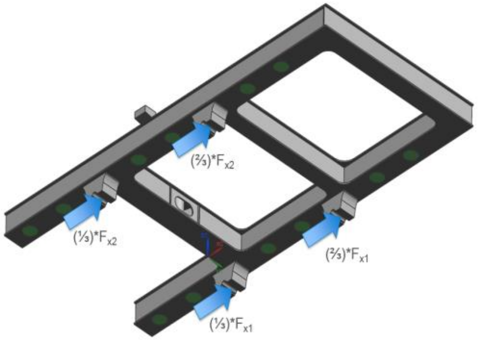
Models have been set up to allow:

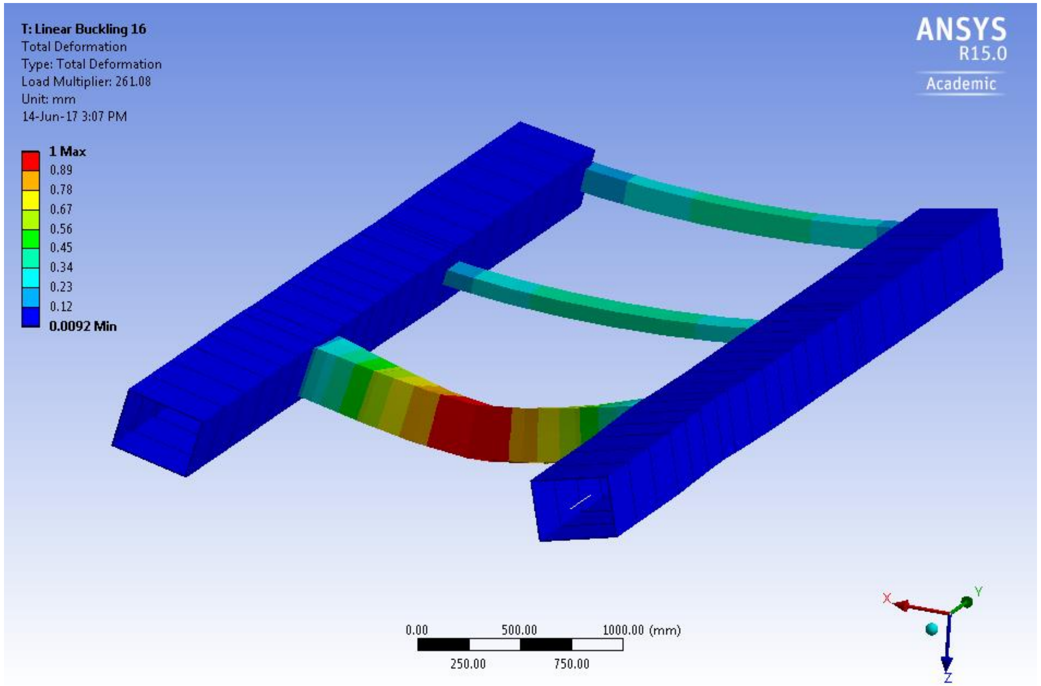
- Stress Analysis for the bogie frame [ANSYS]
- Assessment of the Vehicle Dynamics [VAMPIRE]

FE Analysis

21 load cases






T: Linear Buckling 16
Total Deformation
Type: Total Deformation
Load Multiplier: 261.08
Unit: mm
14-Jun-17 3:07 PM

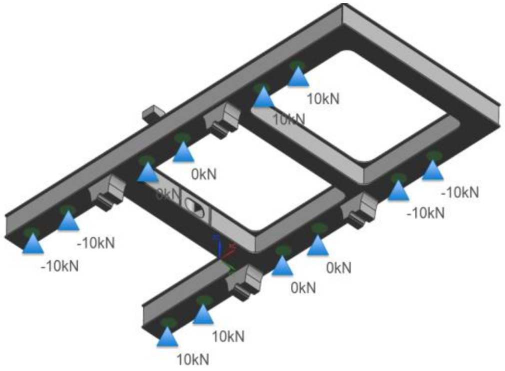


Figure 30 - Buckling mode, 261 factor on loads [load case 21 & 37% weight reduction]

Potential Improved Designs

Option A

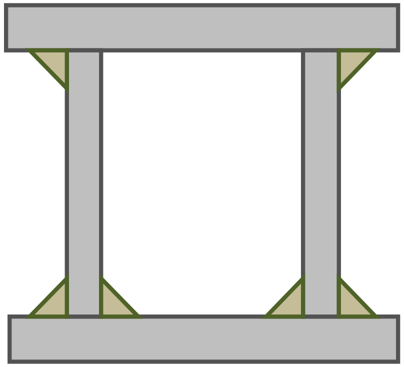
Current construction method with higher strength steel and improved weld techniques

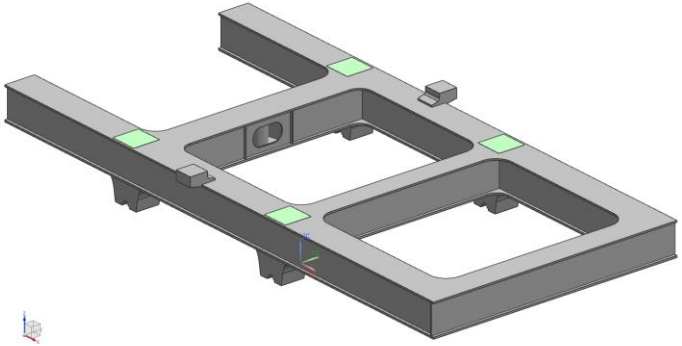
The current S355 steel is however replaced by high strength steel.

Improve weld performance by:

- Improve predicability of weld quality by maximizing use of automatic welding and non-destructive testing.
- Use of weld treatment technics such a ultrasonic impact treatment to improve weld properties

Potential for economical weight reduction is small.





Summary of FE parametric study

	End beam			Central beam			Traction beam			Side beam			Criteria			
mass saving	W	H	t	W	H	t	W	H	t	W	H	t	max deformation	lowest natural freq.	Euler buckling x load	**abs. normal stress**
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[Hz]		[MPa]
5%	100	200	5	100	100	5	500	250	5	500	500	10	1.0	44	322	80
16%	160	160	5	160	160	7.5	500	400	7.5	500	500	7.5	0.7	59	871	46
17%	160	160	7.5	300	300	7.5	500	400	7.5	500	400	7.5	0.6	66	842	46
19%	160	160	5	300	300	7.5	500	300	7.5	500	400	7.5	0.6	66	556	55
24%	160	160	7.5	150	150	7.5	500	500	7.5	300	500	7.5	1.4	49	676	46
24%	160	160	7.5	300	300	7.5	500	400	7.5	400	350	7.5	0.7	60	739	51
29%	160	160	5	300	300	7.5	300	500	7.5	300	400	7.5	1.4	48	712	75
30%	100	200	7.5	100	100	7.5	500	250	7.5	250	500	7.5	2.3	41	323	73
31%	100	100	7.5	100	100	7.5	500	250	7.5	250	500	7.5	2.4	40	315	73
32%	160	160	7.5	160	100	7.5	400	300	7.5	400	300	7.5	1.3	53	398	76
35%	150	150	7.1	160	100	7.1	400	300	7.1	400	300	7.1	1.4	53	378	80
35%	150	150	6.3	160	100	7.1	400	300	7.1	400	300	7.1	1.4	53	377	80
36%	150	150	6.3	150	100	7.1	400	300	7.1	400	300	7.1	1.4	52	377	80
36%	150	120	6.3	150	100	7.1	400	300	7.1	400	300	7.1	1.4	52	375	80
36%	120	120	6.3	150	100	7.1	400	300	7.1	400	300	7.1	1.5	51	375	80
36%	120	120	6.3	160	80	7.1	400	300	7.1	400	300	7.1	1.5	51	374	80
36%	120	120	6.3	120	100	7.1	400	300	7.1	400	300	7.1	1.6	50	374	80
37%	120	120	6.3	160	80	7.1	350	300	7.1	400	300	7.1	1.6	49	348	91
37%	120	120	6.3	160	80	7.1	350	250	7.1	400	300	7.1	1.7	48	261	102
39%	100	100	5	100	80	7.1	300	200	7.1	400	300	7.1	2.4	40	163	137
40%	160	160	7.1	160	100	7.1	300	250	7.1	300	300	7.5	2.2	43	211	129
41%	100	100	7.1	160	100	7.1	300	250	7.1	300	300	7.5	2.4	42	208	129
41%	100	100	7.1	160	100	7.1	250	250	7.1	300	300	7.5	2.7	39	185	155

Potential Improved Designs

Options B and C

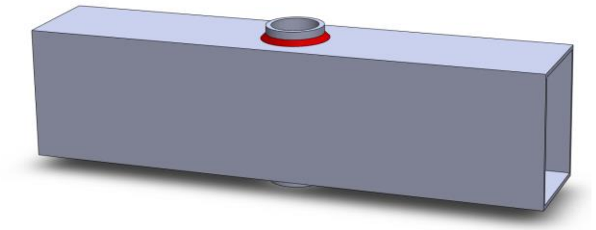
Replace the fabricated construction with commercial hollow sections

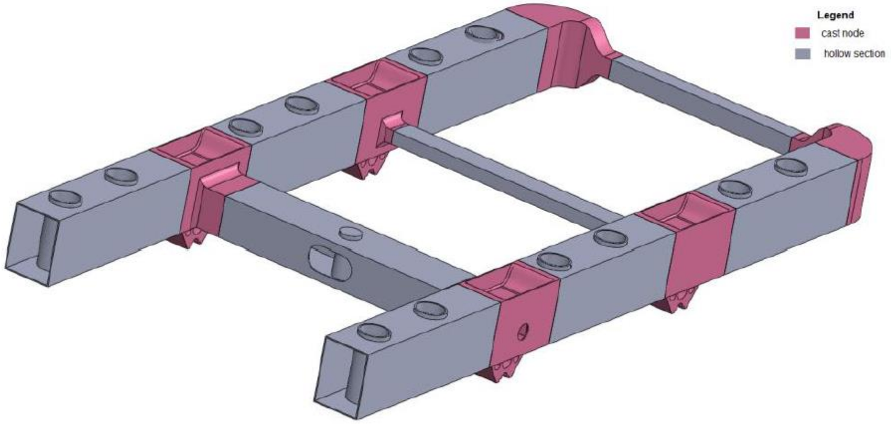
Good torsional stiffness using aligned rectangular or elliptical sections

Careful design reduces welding requirements (experience from offshore construction)

Possible inclusion of cast nodes and internal ribs

Potential for significant weight saving and cost savings





Potential Improved Designs

Option D

Use of cold-forming techniques such as hydroforming, electromagnetic forming and crimping.

Use of tubular sections formed via hydroforming to create beams with varying cross-section profiles to provide directional optimal beam stiffness and strength. Additionally, appropiate mounting surfaces can provided for mounting suspension and other components via welding or crimping.

Potential Improved Designs

Option E

Use of composite materials

Glass fibre and Carbon fibre have been considered and several experimental / prototype applications have

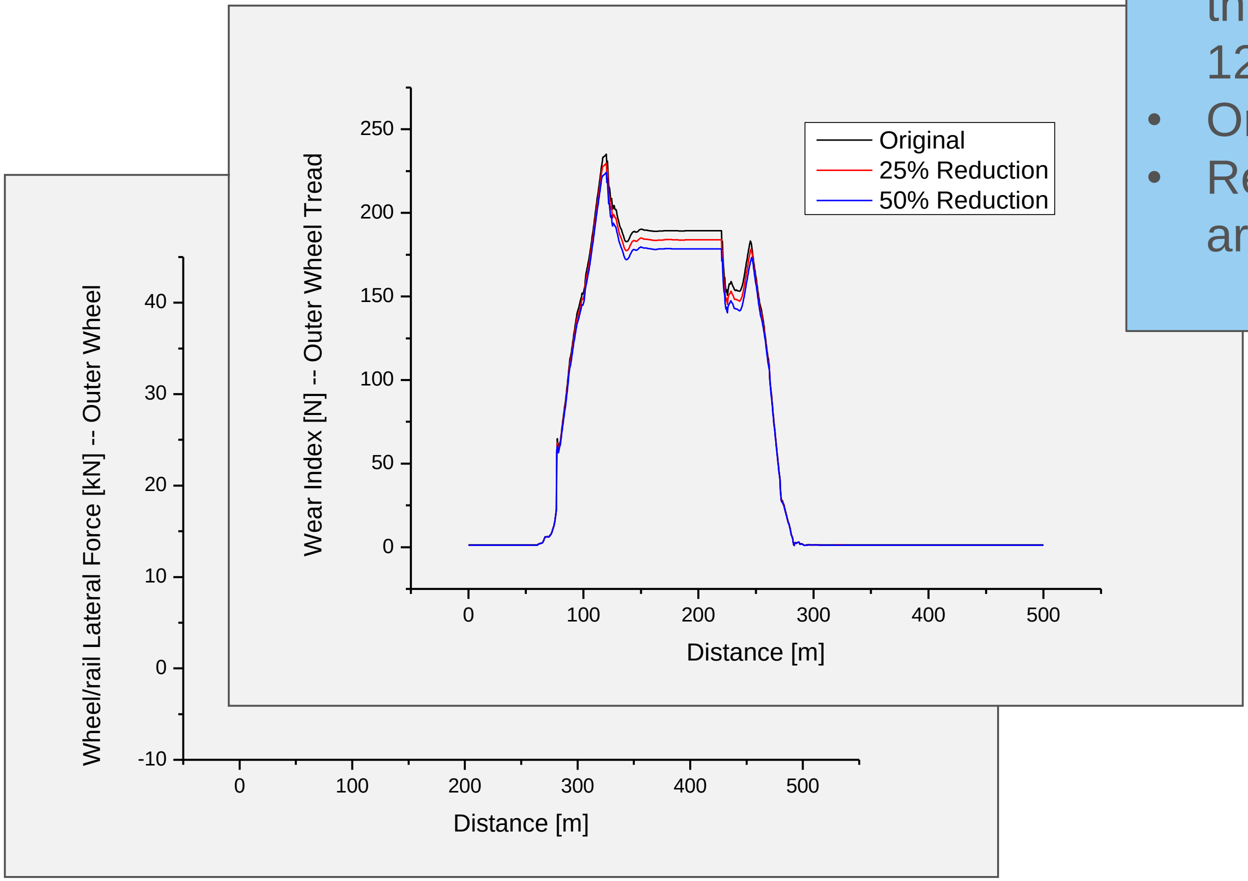
‘EUROBOGIE’ research project

Kawasaki ‘efWING’ bogie

Vehicle Dynamics Analysis

- Curve radius 600m; Speed 72km/h; Superelevation 90mm; Cant deficiency 60mm
- (60m transition - 100m constant radius - 60m transition)
- Bogie frame mass reduction of 25% and 50% considered

- Predicted wear reductions at the outer wheel tread of up to 12.5% achievable
- Only 7.5% reduction at flange
- Reductions at the inner wheels are not significant



Conclusions

- Finite Element analysis suggest that 37% bogie frame mass reduction is achievable using higher strength steel with conventional fabricated construction

- Further mass reductions and cost reductions are possible if tubular sections are used, possibly also with novel techniques such as hydroforming and cast nodes

- Weld performance improvement techniques such as ultrasonic impact treatment should be considered

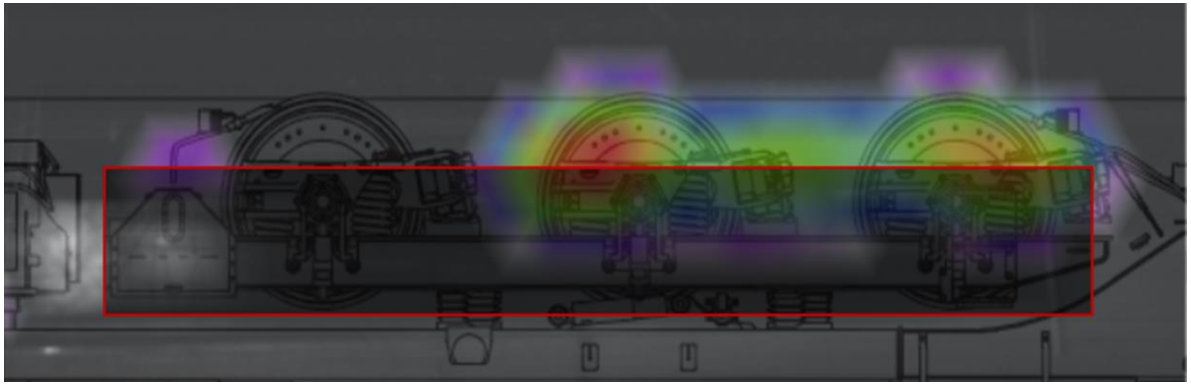
- Composite materials have very significant potential for mass reduction but failure modes are not well understood

- Vehicle Dynamics analysis shows that 12.5% reduction in wheel/rail wear is possible

T2.2 Noise Reduction

The noise mitigation potential of lateral skirts has been assessed by measurements on the EURODUAL locomotive. The analyses shows that the mitigation effect of the lateral skirts is highly frequency and train speed dependent. On average, the lateral skirt reduced the noise by 1 dB at 80km/h and by 4.2 dB at 120km/h over a frequency range of 100Hz-10kHz.

The EURODUAL locomotive with mounted lateral skirts

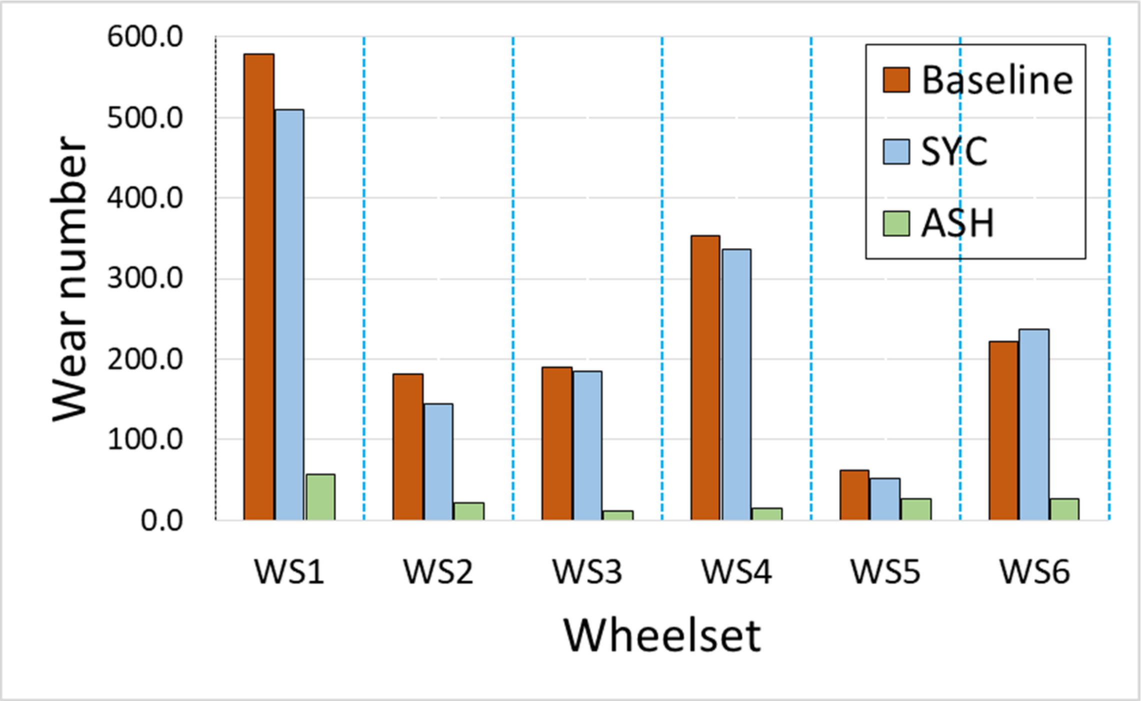


Results at 80kph
3rd Octave 1000Hz

T2.3 Passive and Mechatronic steering systems

A review of existing concepts for steering bogies was performed, outlining the advantages and disadvantages of the different concepts including:

- Active steering using secondary yaw control (SYC)
- Active steering using hydraulic actuation (ASH)



Comparison of the Tγ wear number for the baseline vehicle, SYC and ASH while the locomotive negotiates a curve of radius 300m at a non-compensated lateral acceleration of 0.6m/s^2. The values shown are the average of the wear number for the inner and outer wheel for the six wheelsets of the locomotive and the benefits of ASH are clearly visible.

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Summary

For a high performance freight locomotive with 3 axle ‘Co-Co’ bogies the use of advanced materials and manufacturing processes; the adoption of passive and mechatronic systems for radial steering of bogies; the use of noise optimized wheelsets and noise absorbing structure and condition monitoring of key components have been evaluated.

Optimisation of the material specifications for the existing design including variations in material thickness and the use of higher strength steel can potentially result in a reduction by 43% of the bogie frame mass. Vehicle dynamics studies show that this would translate into a 12.5% reduction in track damage and a 5% reduction in energy consumption.

Several steering concepts are being considered for Co-Co freight locomotives which will allow improved running performances compared to conventional bogies. The main benefits are significant reduction of wheel wear and damage, improved traction in curves and reduced resistance to motion in sharp curves.

Task 3.2: Safety precautions in train configuration and brake application

Visakh V Krishna

KTH Royal Institute of Technology

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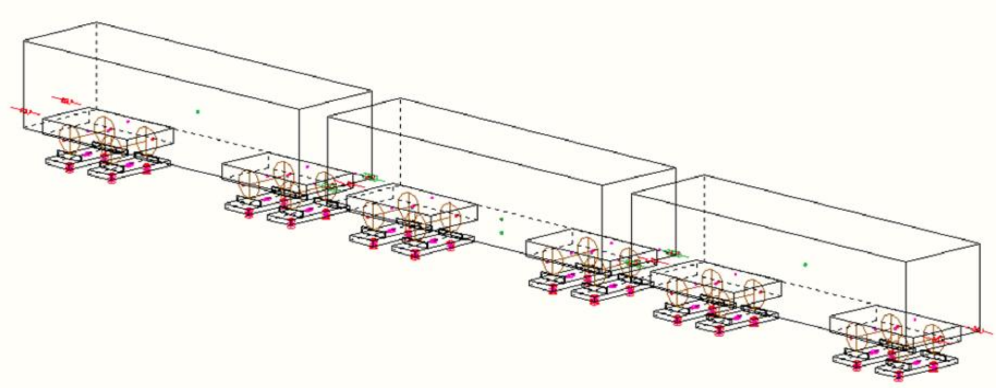
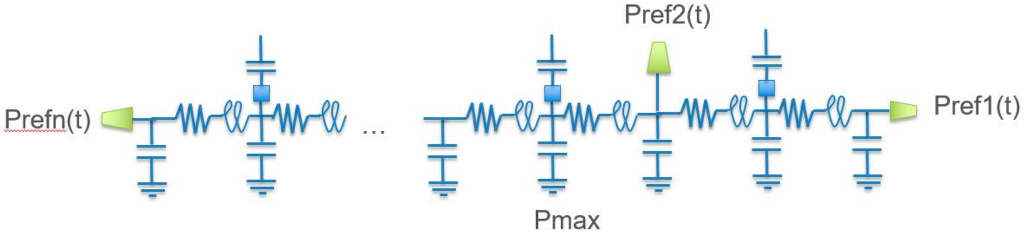
WP 3.2: Safety precautions in train configuration and brake application

✓ *Consolidation of overall strategy*

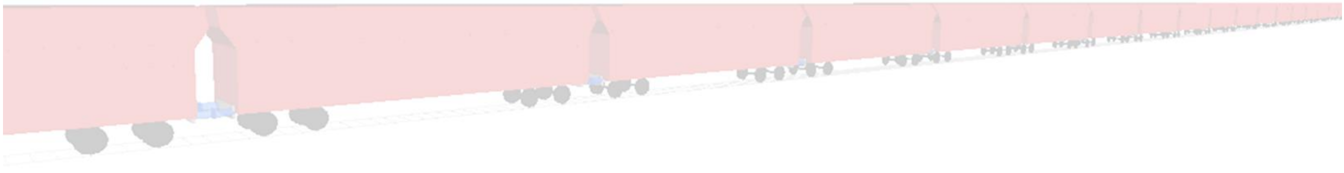
- **Longitudinal Train Dynamics (LTD)** becomes a major issue for longer trains in the running safety considerations in tight *S-curves* especially when *traditional pneumatic (P) braking system* and *distributed power* are used.

- Collaboration with FFL4E in the task for operational scenarios.





Partner	Task
STAV	Traction and braking scenarios
POLIMI	Brake pneumatics simulations
TUB	One-dimensional simulations
KTH	Three-dimensional simulations



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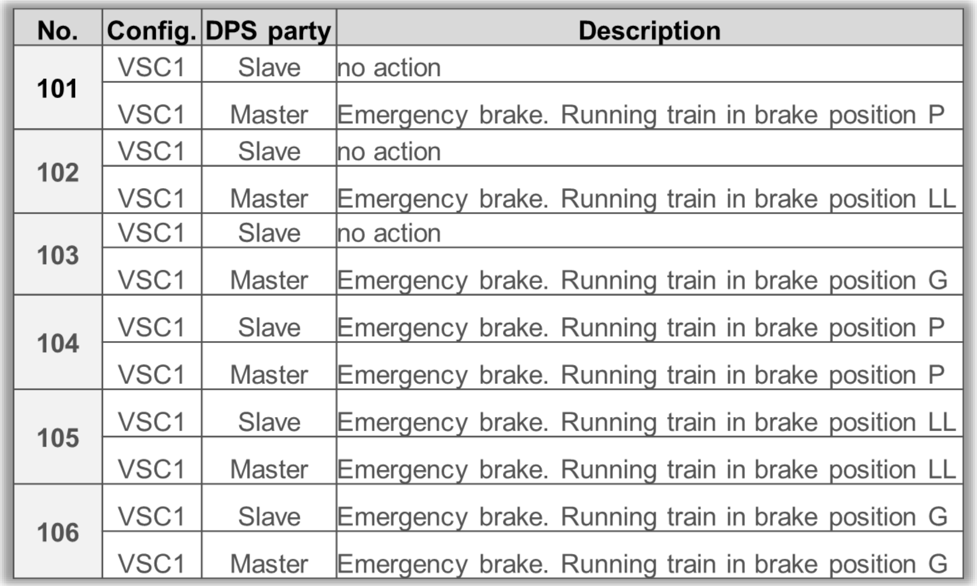
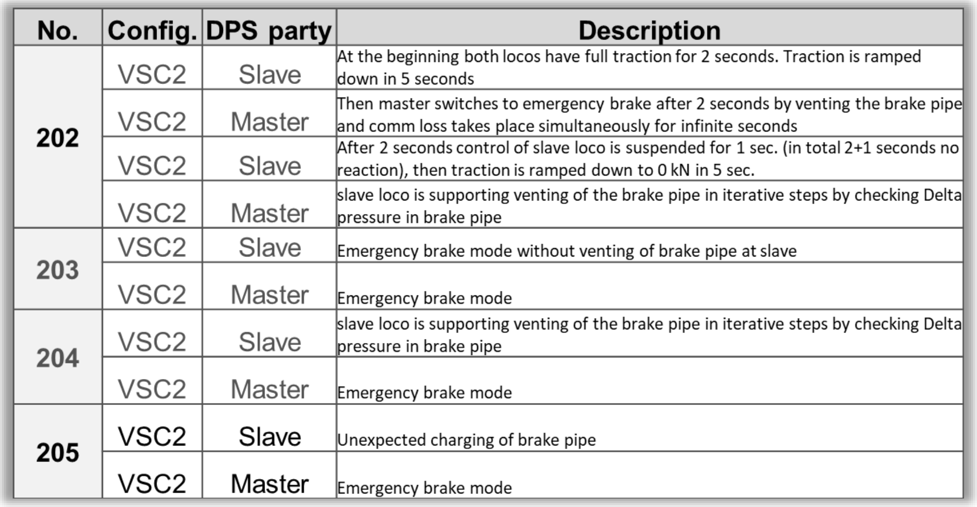
Safety precautions in train configuration and brake application

✓ *Definition of traction and braking action at various scenarios*



No.	Config.	DPS party	Description
101	VSC1	Slave	no action
	VSC1	Master	Emergency brake. Running train in brake position P
102	VSC1	Slave	no action
	VSC1	Master	Emergency brake. Running train in brake position LL
103	VSC1	Slave	no action
	VSC1	Master	Emergency brake. Running train in brake position G
104	VSC1	Slave	Emergency brake. Running train in brake position P
	VSC1	Master	Emergency brake. Running train in brake position P
105	VSC1	Slave	Emergency brake. Running train in brake position LL
	VSC1	Master	Emergency brake. Running train in brake position LL
106	VSC1	Slave	Emergency brake. Running train in brake position G
	VSC1	Master	Emergency brake. Running train in brake position G

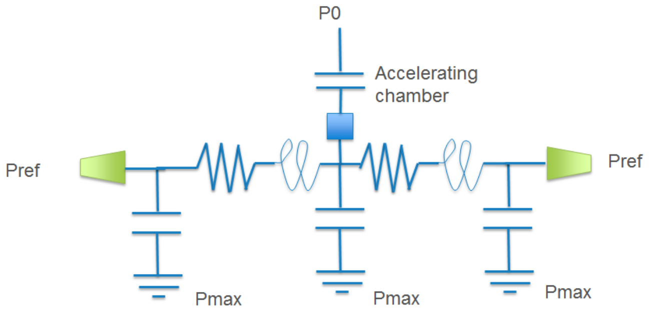


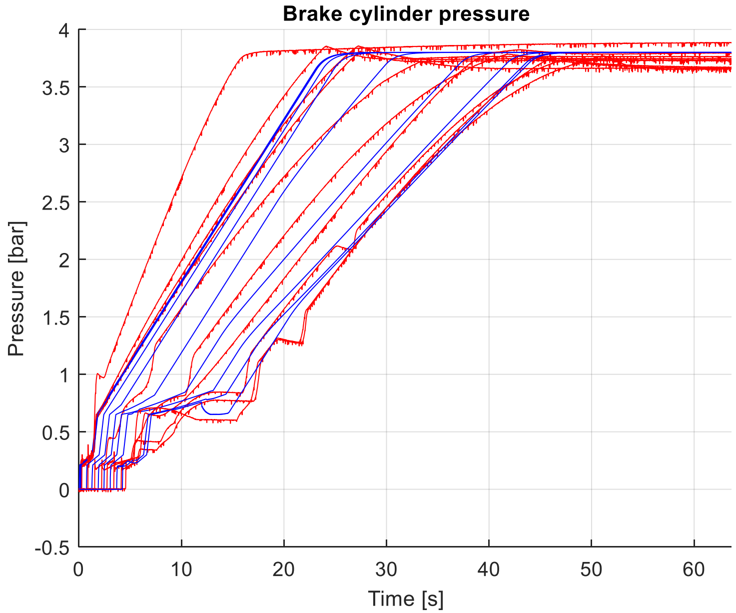
No.	Config.	DPS party	Description
202	VSC2	Slave	At the beginning both locos have full traction for 2 seconds. Traction is ramped down in 5 seconds
	VSC2	Master	Then master switches to emergency brake after 2 seconds by venting the brake pipe and comm loss takes place simultaneously for infinite seconds
	VSC2	Slave	After 2 seconds control of slave loco is suspended for 1 sec. (in total 2+1 seconds no reaction), then traction is ramped down to 0 kN in 5 sec.
	VSC2	Master	slave loco is supporting venting of the brake pipe in iterative steps by checking Delta pressure in brake pipe
203	VSC2	Slave	Emergency brake mode without venting of brake pipe at slave
	VSC2	Master	Emergency brake mode
204	VSC2	Slave	slave loco is supporting venting of the brake pipe in iterative steps by checking Delta pressure in brake pipe
	VSC2	Master	Emergency brake mode
205	VSC2	Slave	Unexpected charging of brake pipe
	VSC2	Master	Emergency brake mode

- Traction and braking scenarios were defined for various operating scenarios under the nominal and the degraded working modes.
- These scenarios were further used to determine the brake pressures along the train, necessary to determine the generated in-train forces.

Safety precautions in train configuration and brake application

✓ *Simulation of brake pressure propagation and wheel braking forces*





Pressure time history for the brake cylinder for emergency braking of a 1200 m long train

TSDYN (TrainSet Dynamics) is a software for the simulation of 1D trainset dynamics developed by POLIMI.

Main braking pipe (MBP) is schematised with a lumped parameter model reproducing fluid elasticity (C), inertia (L) and internal friction (R).

Effect of accelerating chamber is included.

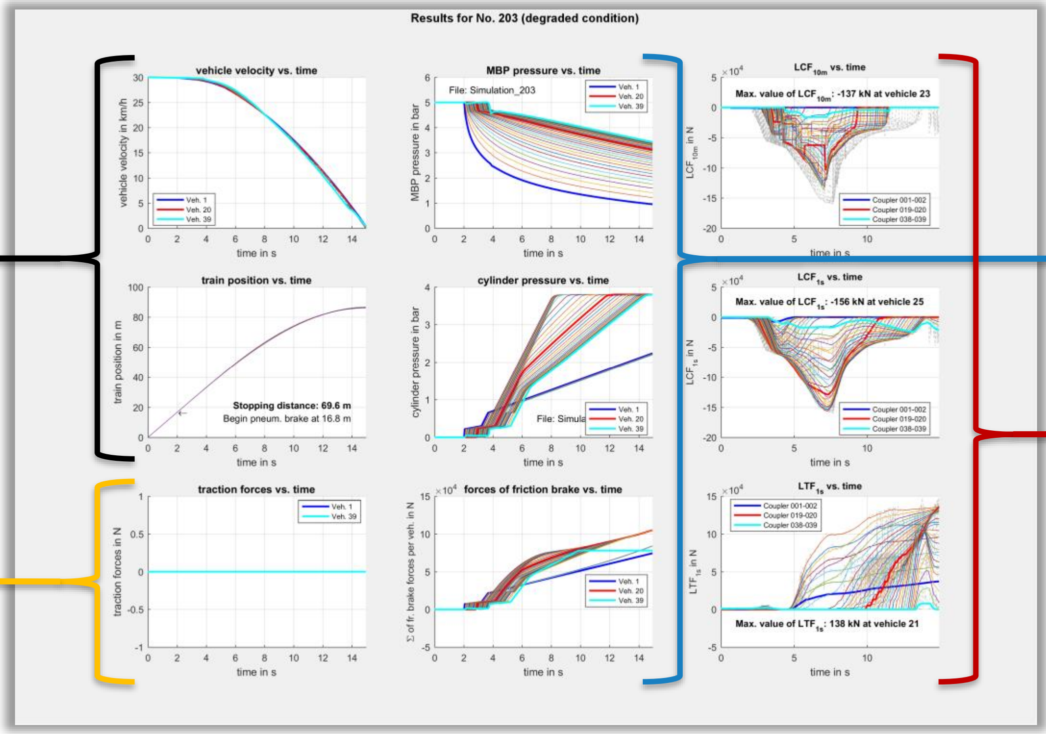
MBP can be vented from a generic position along the train.

Brake distributors are modelled as a series of valves of suitable section whose opening is regulated by pressure drop in MBP.

Safety precautions in train configuration and brake application

✓ *Simulation of braking torques and longitudinal buffer forces*

- Creation of a *numerical tool* to calculate in-train forces from the input received from brake pneumatic simulations for each scenario for braking/traction.
- The effect of the parameters evaluated: *Brake blocks, load devices, total mass of wagon, rigging efficiency, buffers, draw gear, coupler play.*



Velocity and stopping distance

Traction Forces

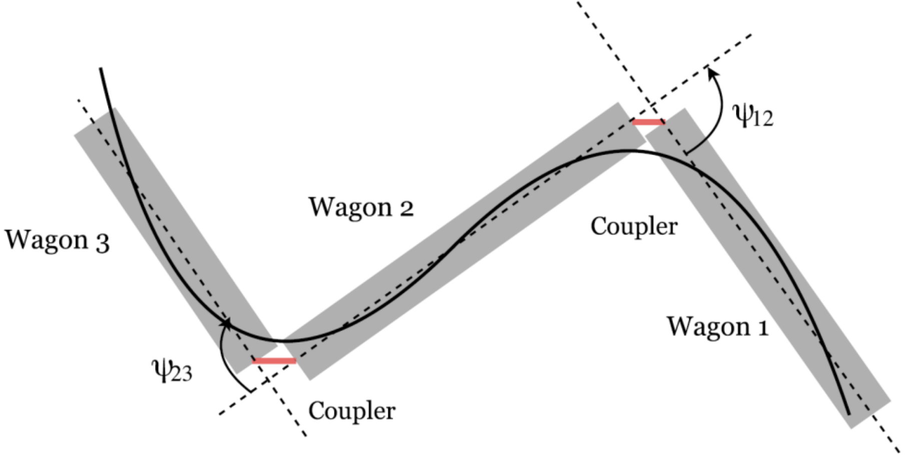
MBP and BC pressure, Brake forces

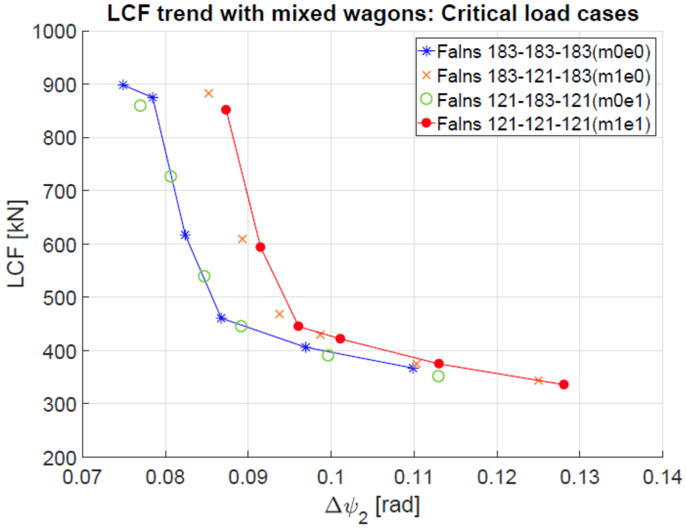
LCF and LTF, unfiltered + filtered

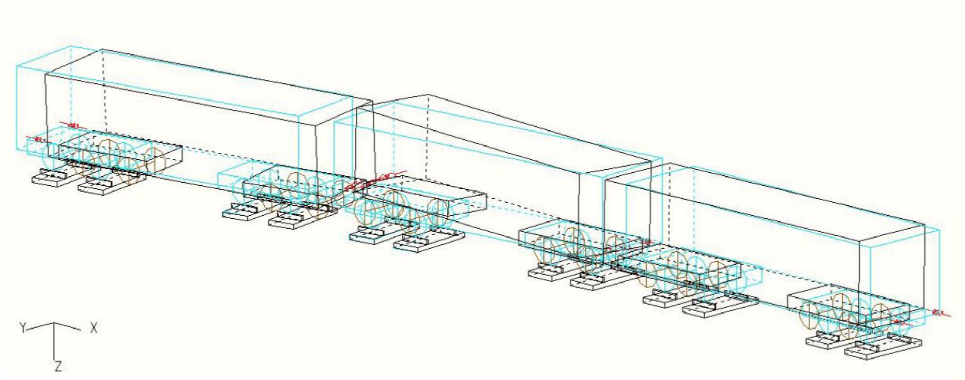
Safety precautions in train configuration and brake application

✓ *3D simulations of derailment risk at various track layouts*

- Calculation of Tolerable Longitudinal Compressive Forces (LCF) using three-dimensional simulations.
- Methodology for simulations adopted from UIC 530-2 leaflet.
- The effect of the parameters evaluated: *Carbody torsional stiffness, buffer characteristics, payload and the horizontal track curvature, wagon geometry, wagon arrangement, gradients.*







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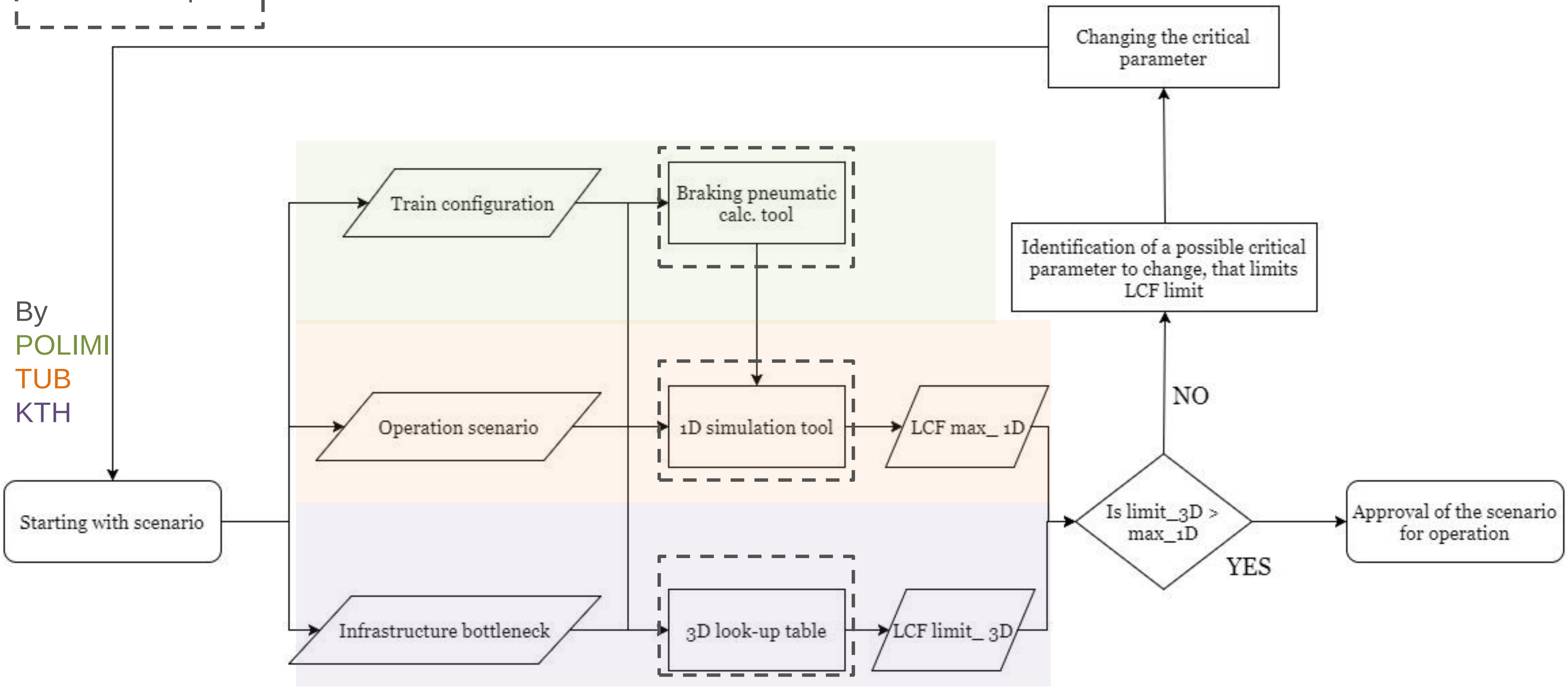
Safety precautions in train configuration and brake application

✓ *Consolidated tool*

Tool developed

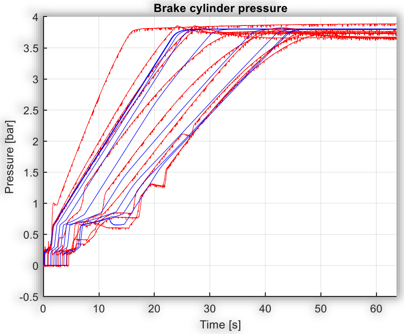


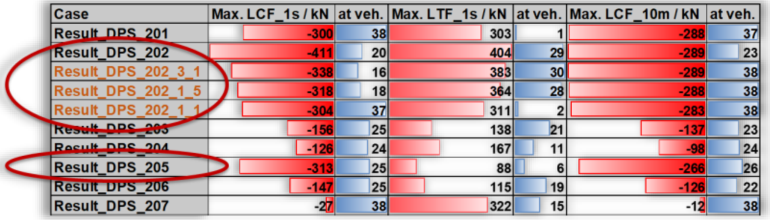
By
POLIMI
TUB
KTH

Intended output for DYNAFREIGHT 3.2: "Methodology for the approval of operation-specific freight trains using numerical simulations"

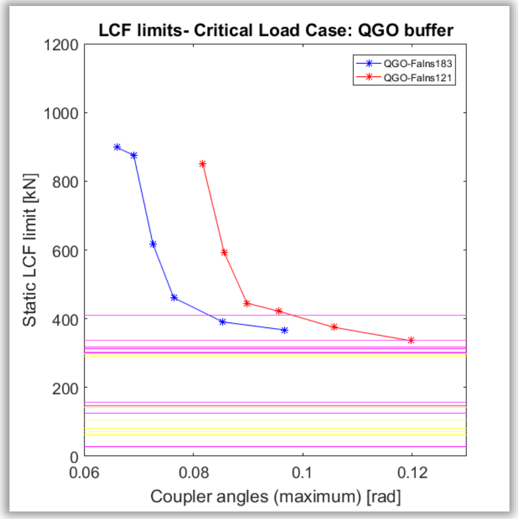
Safety precautions in train configuration and brake application

✓ *Conclusions and guidelines on derailment risk reduction*





Case	Max. LCF_1s / kN	at veh.	Max. LTF_1s / kN	at veh.	Max. LCF_10m / kN	at veh.
Result_DPS_201	-300	38	303	1	-288	37
Result_DPS_202	-411	20	404	29	-289	23
Result_DPS_202_3_1	-338	16	383	30	-289	38
Result_DPS_202_1_5	-318	18	364	28	-288	38
Result_DPS_202_1_1	-304	37	311	2	-283	38
Result_DPS_203	-156	25	138	21	-137	23
Result_DPS_204	-126	24	167	11	-98	24
Result_DPS_205	-313	25	88	6	-266	26
Result_DPS_206	-147	25	115	19	-126	22
Result_DPS_207	-27	38	322	15	-12	38



Guidelines for safe operation

- Based on the methodology, guidelines were prepared for the safe operation of the demonstrator train case by examining the effect of:
    - Braking scenarios
    - Brake blocks
    - Buffers/Draw gears
    - Gradients
    - Payload
    - Wagon characteristics and arrangements
    - Slave locomotive position, etc.
- The developed methodology is being used to examine longer train cases (up to 1500 m)

Task 3.3: Adaptions in the rail infrastructure for long-train operation

Carlo Vaghi
FIT Consulting

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The Spanish case of longer trains

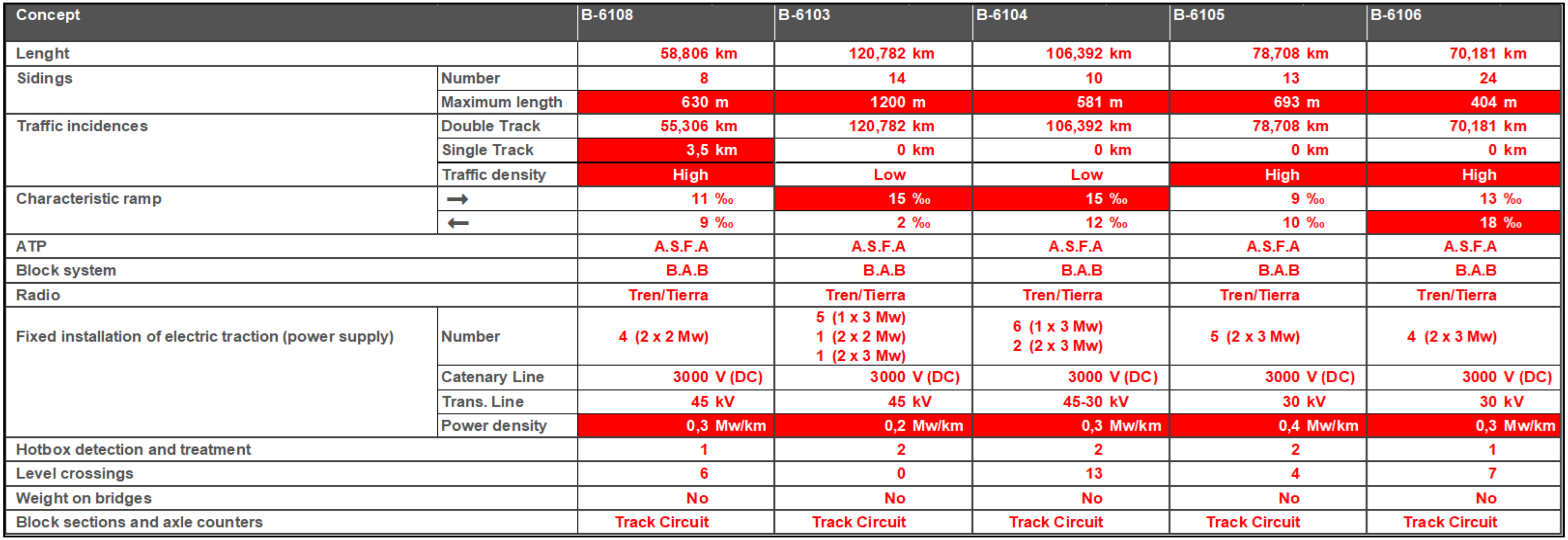
ADIF (IM of the Spanish network) is providing data to perform the analysis of the network to verify opportunities to run longer freight trains:

1. General analysis
2. Operational aspects along the railway lines
3. Design aspects along the railway lines
4. Operational aspects in terminals (in progress)
5. Track deterioration (in progress).

✓ *Geographical location of DYNAFREIGHT long train corridor in Spain, within TEN-T Atlantic Corridor*

The general analysis

The analysis of different tracks suitable for longer trains show very heterogeneous characteristics of the network, some of which may constitute barriers.

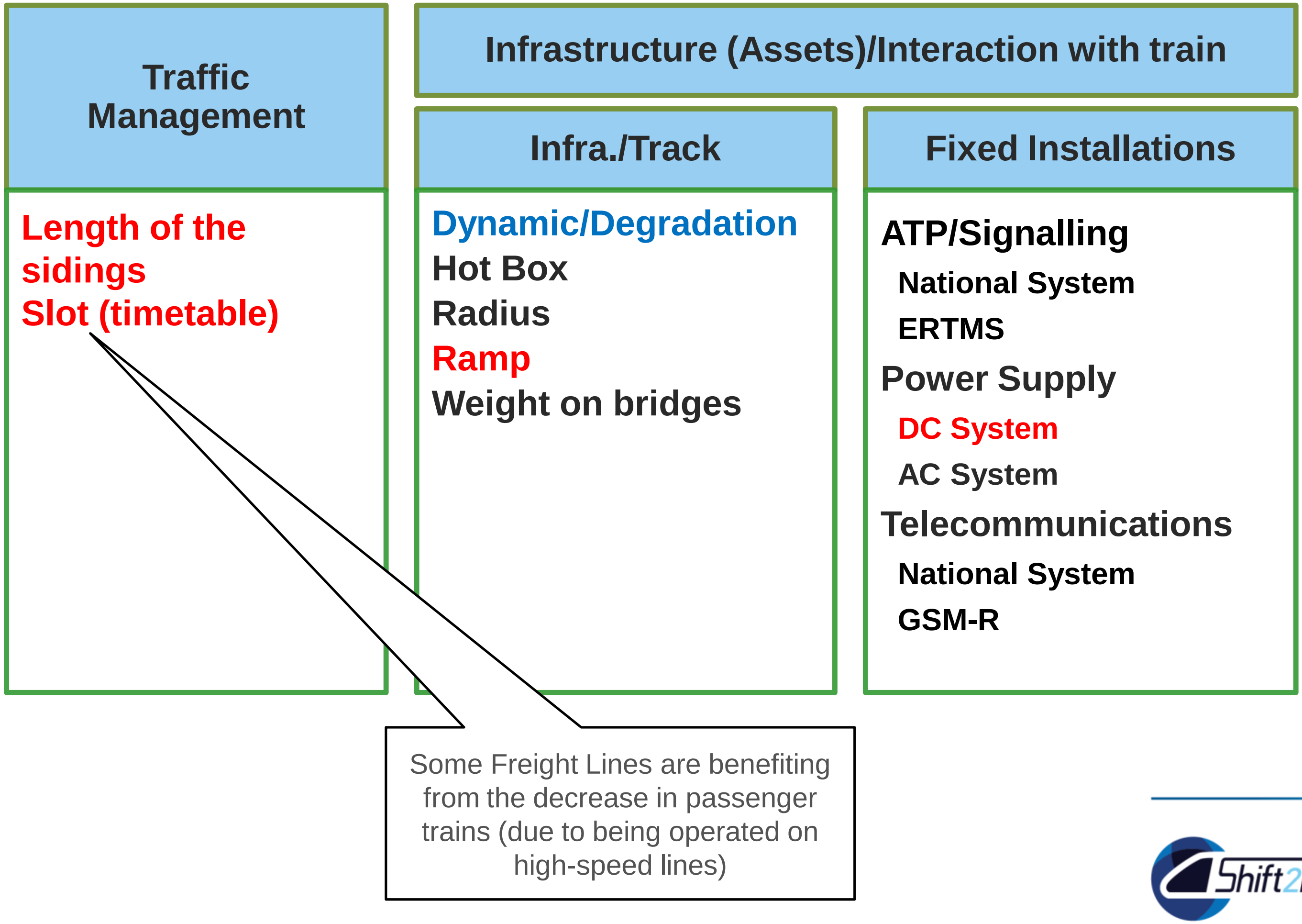


Concept		B-6108	B-6103	B-6104	B-6105	B-6106
Lenght		58,806 km	120,782 km	106,392 km	78,708 km	70,181 km
Sidings	Number	8	14	10	13	24
	Maximum length	🟥 630 m	🟥 1200 m	🟥 581 m	🟥 693 m	🟥 404 m
Traffic incidences	Double Track	55,306 km	120,782 km	106,392 km	78,708 km	70,181 km
	Single Track	🟥 3,5 km	0 km	0 km	0 km	0 km
	Traffic density	🟥 High	Low	Low	🟥 High	🟥 High
Characteristic ramp	→	11 ‰	🟥 15 ‰	🟥 15 ‰	9 ‰	13 ‰
	←	9 ‰	2 ‰	12 ‰	10 ‰	🟥 18 ‰
ATP		A.S.F.A	A.S.F.A	A.S.F.A	A.S.F.A	A.S.F.A
Block system		B.A.B	B.A.B	B.A.B	B.A.B	B.A.B
Radio		Tren/Tierra	Tren/Tierra	Tren/Tierra	Tren/Tierra	Tren/Tierra
Fixed installation of electric traction (power supply)	Number	4 (2 x 2 Mw)	5 (1 x 3 Mw) 1 (2 x 2 Mw) 1 (2 x 3 Mw)	6 (1 x 3 Mw) 2 (2 x 3 Mw)	5 (2 x 3 Mw)	4 (2 x 3 Mw)
	Catenary Line	3000 V (DC)	3000 V (DC)	3000 V (DC)	3000 V (DC)	3000 V (DC)
	Trans. Line	45 kV	45 kV	45-30 kV	30 kV	30 kV
	Power density	🟥 0,3 Mw/km	🟥 0,2 Mw/km	🟥 0,3 Mw/km	🟥 0,4 Mw/km	🟥 0,3 Mw/km
Hotbox detection and treatment		1	2	2	2	1
Level crossings		6	0	13	4	7
Weight on bridges		No	No	No	No	No
Block sections and axle counters		Track Circuit	Track Circuit	Track Circuit	Track Circuit	Track Circuit

✓ *Track characteristics of DYNAFREIGHT long train corridor in Spain*

Operational aspects

The following main characteristics of the line have been analysed to identify barriers to longer train operations



Traffic Management

- **Length of the sidings**
- **Slot (timetable)**

Infrastructure (Assets)/Interaction with train

Infra./Track

- **Dynamic/Degradation**
- **Hot Box**
- **Radius**
- **Ramp**
- **Weight on bridges**

Fixed Installations

- **ATP/Signalling**
  - **National System**
  - **ERTMS**
- **Power Supply**
  - **DC System**
  - **AC System**
- **Telecommunications**
  - **National System**
  - **GSM-R**

Some Freight Lines are benefiting from the decrease in passenger trains (due to being operated on high-speed lines)

🟥 *Restriction*
⬛ *Non restriction*
🟦 *Not analyzed specifically*

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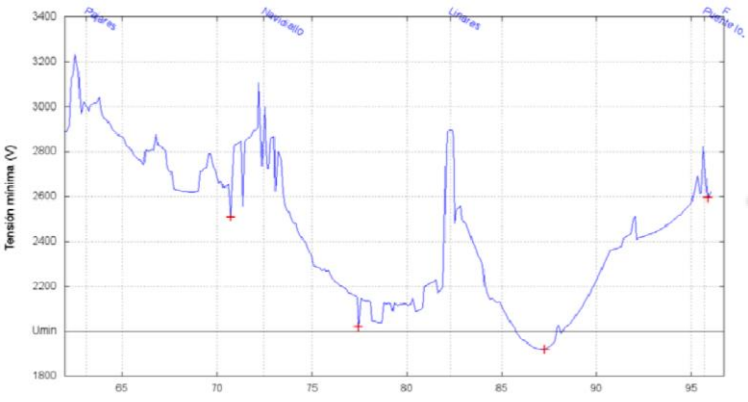
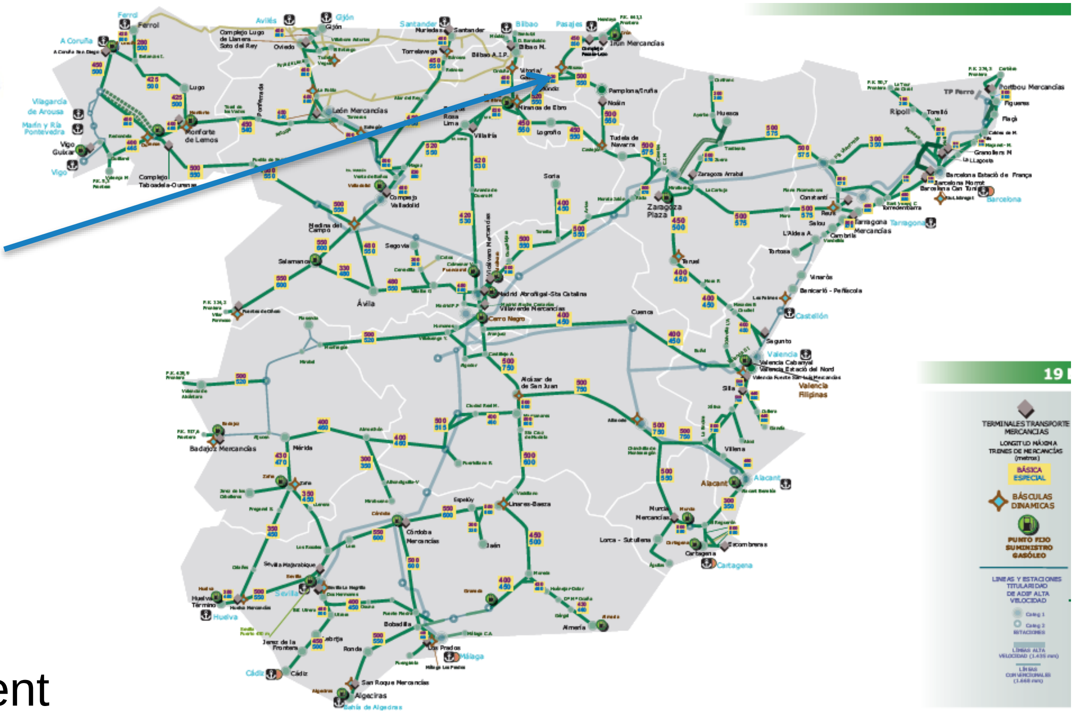
Operational aspects





A significant barrier is the DC system: standard locomotives may be insufficient for high-tonnage trains in certain points of the network (15-23‰)

Simulation made with standard train: 2 TRAXX with coil wagons (variable length)

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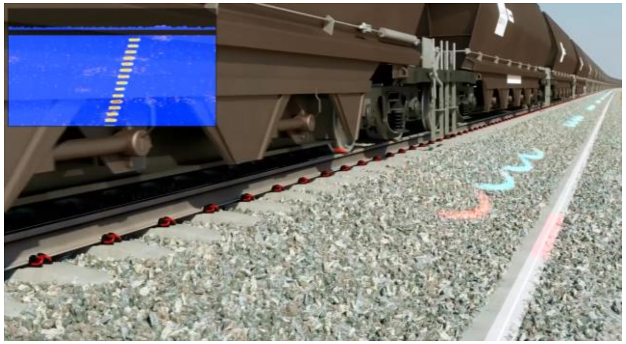
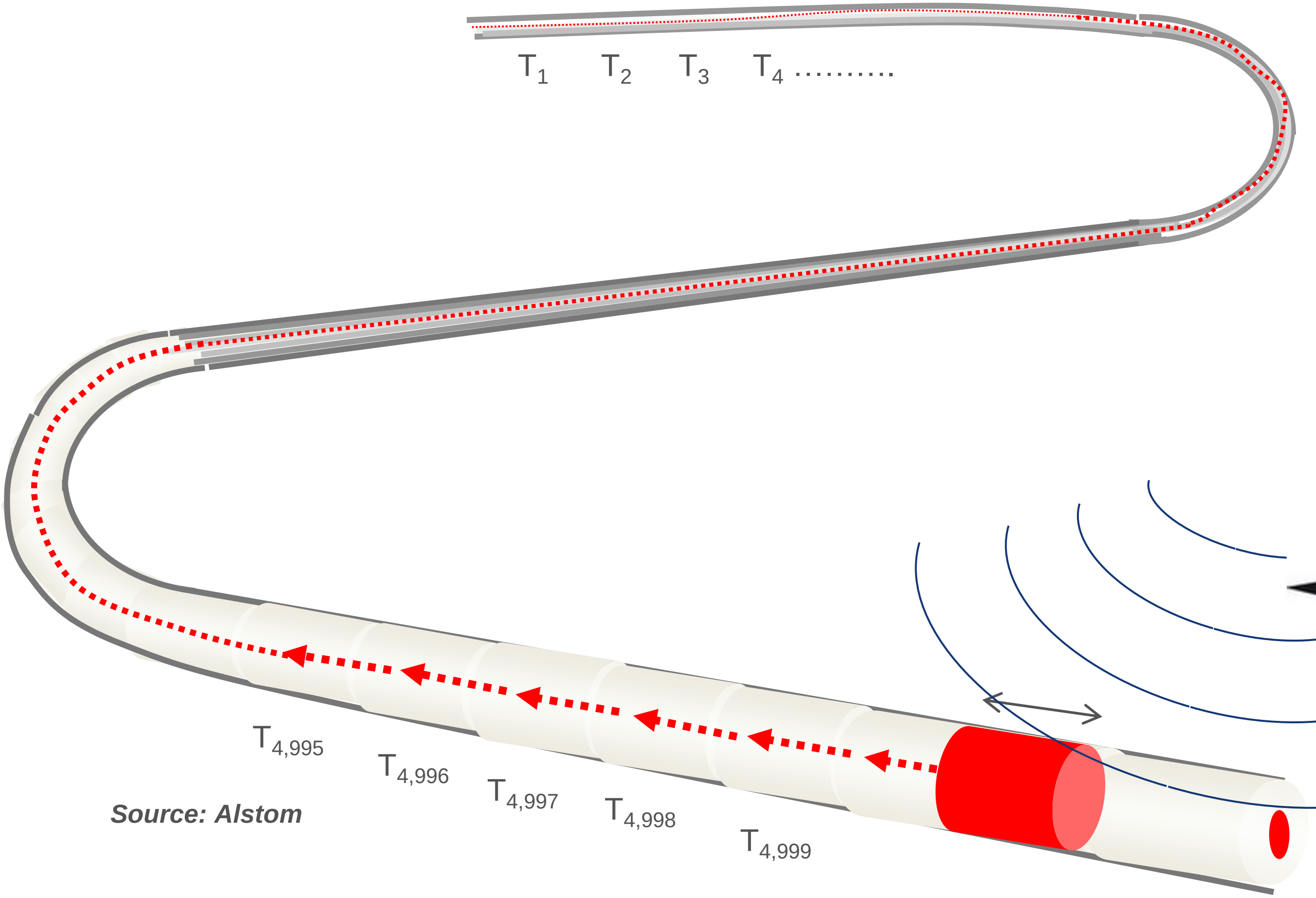
Design aspects

Adif has evaluated (and is going to test) a system based on Fiber Optics (DAS system) to control, among others, the possible failures in the rolling of the trains. In the case of long trains, this system could provide other advantages



Source: Frauscher



Source: Alstom

Thank you for the attention!

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