DYNAFREIGHT in brief

Budget: 1M EUR

Partners: 10

Duration: 20 months

Starting date: Nov 16

End date: Jun 18
Main objectives

To provide the necessary inputs for the development of the next railway freight propulsion concepts within IP5 of Shift2Rail

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 to 1,500m
WP2
Next Generation Freight Locomotive’s Bogie

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

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

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
  - Task 3.2 Safety - Simulations

- **WP 3 “Train Dynamics”**
  - Task 3.3 Infrastructure

- **WP 4 “Infrastructure”**
  - Task 3.1 Radio req. and safety

- **WP 5 “Development”**
  - Task 3.1 Radio req. and safety
Advisory Group meeting

Presentation of mid-term results

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

Registration still open

[andrea.demadonna@unife.org](mailto:andrea.demadonna@unife.org)

---

Final Conference

When? **27 June 2018**, Brussels

Registration and Programme will be available soon
WP2: Next Generation of Freight Locomotive’s Bogie

Simon Iwnicki
Huddersfield University
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

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

<table>
<thead>
<tr>
<th>Mass saving (%)</th>
<th>End beam</th>
<th>Central beam</th>
<th>Traction beam</th>
<th>Side beam</th>
<th>Criteria</th>
<th>abs. normal stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass saving</td>
<td>W [mm]</td>
<td>H [mm]</td>
<td>t [mm]</td>
<td>W [mm]</td>
<td>H [mm]</td>
<td>t [mm]</td>
</tr>
<tr>
<td>5%</td>
<td>100</td>
<td>200</td>
<td>5</td>
<td>100</td>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>16%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
</tr>
<tr>
<td>17%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>300</td>
<td>7.5</td>
</tr>
<tr>
<td>19%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>300</td>
<td>7.5</td>
</tr>
<tr>
<td>24%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>150</td>
<td>7.5</td>
</tr>
<tr>
<td>24%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>300</td>
<td>7.5</td>
</tr>
<tr>
<td>29%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>300</td>
<td>7.5</td>
</tr>
<tr>
<td>30%</td>
<td>100</td>
<td>200</td>
<td>7.5</td>
<td>100</td>
<td>100</td>
<td>7.5</td>
</tr>
<tr>
<td>31%</td>
<td>100</td>
<td>100</td>
<td>7.5</td>
<td>100</td>
<td>100</td>
<td>7.5</td>
</tr>
<tr>
<td>32%</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
<td>160</td>
<td>160</td>
<td>7.5</td>
</tr>
<tr>
<td>35%</td>
<td>150</td>
<td>150</td>
<td>7.1</td>
<td>160</td>
<td>160</td>
<td>7.1</td>
</tr>
<tr>
<td>35%</td>
<td>150</td>
<td>150</td>
<td>6.3</td>
<td>160</td>
<td>160</td>
<td>7.1</td>
</tr>
<tr>
<td>36%</td>
<td>150</td>
<td>150</td>
<td>6.3</td>
<td>150</td>
<td>100</td>
<td>7.1</td>
</tr>
<tr>
<td>36%</td>
<td>150</td>
<td>150</td>
<td>6.3</td>
<td>150</td>
<td>150</td>
<td>7.1</td>
</tr>
<tr>
<td>36%</td>
<td>120</td>
<td>120</td>
<td>6.3</td>
<td>150</td>
<td>100</td>
<td>7.1</td>
</tr>
<tr>
<td>36%</td>
<td>120</td>
<td>120</td>
<td>6.3</td>
<td>120</td>
<td>100</td>
<td>7.1</td>
</tr>
<tr>
<td>37%</td>
<td>120</td>
<td>120</td>
<td>6.3</td>
<td>120</td>
<td>80</td>
<td>7.1</td>
</tr>
<tr>
<td>37%</td>
<td>120</td>
<td>120</td>
<td>6.3</td>
<td>160</td>
<td>80</td>
<td>7.1</td>
</tr>
<tr>
<td>39%</td>
<td>100</td>
<td>100</td>
<td>7.1</td>
<td>100</td>
<td>80</td>
<td>7.1</td>
</tr>
<tr>
<td>40%</td>
<td>160</td>
<td>160</td>
<td>7.1</td>
<td>160</td>
<td>100</td>
<td>7.1</td>
</tr>
<tr>
<td>41%</td>
<td>100</td>
<td>100</td>
<td>7.1</td>
<td>160</td>
<td>100</td>
<td>7.1</td>
</tr>
<tr>
<td>41%</td>
<td>100</td>
<td>100</td>
<td>7.1</td>
<td>160</td>
<td>100</td>
<td>7.1</td>
</tr>
</tbody>
</table>
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, appropriate mounting surfaces can provided for mounting suspension and other components via welding or crimping.
Option E

Use of composite materials

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

Kawasaki ‘efWING’ bogie

‘EUROBOGIE’ research project
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.
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 $T_y$ 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.
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
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.

<table>
<thead>
<tr>
<th>Partner</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAV</td>
<td>Traction and braking scenarios</td>
</tr>
<tr>
<td>POLIMI</td>
<td>Brake pneumatics simulations</td>
</tr>
<tr>
<td>TUB</td>
<td>One-dimensional simulations</td>
</tr>
<tr>
<td>KTH</td>
<td>Three-dimensional simulations</td>
</tr>
</tbody>
</table>
Safety precautions in train configuration and brake application

✓ Definition of traction and braking action at various scenarios

<table>
<thead>
<tr>
<th>No.</th>
<th>Config.</th>
<th>DPS party</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>VSC1</td>
<td>Slave</td>
<td>no action</td>
</tr>
<tr>
<td>102</td>
<td>VSC1</td>
<td>Master</td>
<td>Emergency brake. Running train in brake position P</td>
</tr>
<tr>
<td>103</td>
<td>VSC1</td>
<td>Slave</td>
<td>no action</td>
</tr>
<tr>
<td>104</td>
<td>VSC1</td>
<td>Master</td>
<td>Emergency brake. Running train in brake position P</td>
</tr>
<tr>
<td>105</td>
<td>VSC1</td>
<td>Slave</td>
<td>Emergency brake. Running train in brake position LL</td>
</tr>
<tr>
<td>106</td>
<td>VSC1</td>
<td>Master</td>
<td>Emergency brake. Running train in brake position LL</td>
</tr>
</tbody>
</table>

- 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

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.

Pressure time history for the brake cylinder for emergency braking of a 1200 m long train
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.*
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.
Safety precautions in train configuration and brake application

✓ Consolidated tool

Starting with scenario

Train configuration

Braking pneumatic calc. tool

Operation scenario

1D simulation tool

LCF max_1D

Infrastructure bottleneck

3D look-up table

LCF limit_3D

Changing the critical parameter

Identification of a possible critical parameter to change, that limits LCF limit

Is limit_3D > max_1D

NO

YES

Approval of the scenario for operation

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

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

<table>
<thead>
<tr>
<th>Concept</th>
<th>B-6108</th>
<th>B-6103</th>
<th>B-6104</th>
<th>B-6105</th>
<th>B-6106</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lenght</td>
<td>68,806 km</td>
<td>120,782 km</td>
<td>106,392 km</td>
<td>78,708 km</td>
<td>70,181 km</td>
</tr>
<tr>
<td>Sidings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>8</td>
<td>14</td>
<td>10</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Maximum length</td>
<td>630 m</td>
<td>1200 m</td>
<td>681 m</td>
<td>693 m</td>
<td>404 m</td>
</tr>
<tr>
<td>Traffic incidences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Track</td>
<td>65,306 km</td>
<td>120,782 km</td>
<td>106,392 km</td>
<td>78,708 km</td>
<td>70,181 km</td>
</tr>
<tr>
<td>Single Track</td>
<td>3.5 km</td>
<td>0 km</td>
<td>0 km</td>
<td>0 km</td>
<td>0 km</td>
</tr>
<tr>
<td>Traffic density</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Characteristic ramp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>→</td>
<td>11 %</td>
<td>15 %</td>
<td>15 %</td>
<td>9 %</td>
<td>13 %</td>
</tr>
<tr>
<td>←</td>
<td>9 %</td>
<td>2 %</td>
<td>12 %</td>
<td>10 %</td>
<td>18 %</td>
</tr>
<tr>
<td>ATP</td>
<td>A.S.F.A</td>
<td>A.S.F.A</td>
<td>A.S.F.A</td>
<td>A.S.F.A</td>
<td>A.S.F.A</td>
</tr>
<tr>
<td>Block system</td>
<td>B.A.B</td>
<td>B.A.B</td>
<td>B.A.B</td>
<td>B.A.B</td>
<td>B.A.B</td>
</tr>
<tr>
<td>Radio</td>
<td>Tren/Tierra</td>
<td>Tren/Tierra</td>
<td>Tren/Tierra</td>
<td>Tren/Tierra</td>
<td>Tren/Tierra</td>
</tr>
<tr>
<td>Fixed installation of electric traction (power supply)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>4 (2 x 2 Mw)</td>
<td>5 (1 x 3 Mw)</td>
<td>6 (1 x 3 Mw)</td>
<td>5 (2 x 3 Mw)</td>
<td>4 (2 x 3 Mw)</td>
</tr>
<tr>
<td>Catenary Line</td>
<td>3000 V (DC)</td>
<td>3000 V (DC)</td>
<td>3000 V (DC)</td>
<td>3000 V (DC)</td>
<td>3000 V (DC)</td>
</tr>
<tr>
<td>Trans. Line</td>
<td>45 kV</td>
<td>45 kV</td>
<td>45-30 kV</td>
<td>30 kV</td>
<td>30 kV</td>
</tr>
<tr>
<td>Power density</td>
<td>0.3 Mw/km</td>
<td>0.2 Mw/km</td>
<td>0.3 Mw/km</td>
<td>0.4 Mw/km</td>
<td>0.3 Mw/km</td>
</tr>
<tr>
<td>Hotbox detection and treatment</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Level crossings</td>
<td>6</td>
<td>0</td>
<td>13</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Weight on bridges</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Block sections and axle counters</td>
<td>Track Circuit</td>
<td>Track Circuit</td>
<td>Track Circuit</td>
<td>Track Circuit</td>
<td>Track Circuit</td>
</tr>
</tbody>
</table>

✓ Track characteristics of DYNAFREIGHT long train corridor in Spain

![Shift2Rail](https://example.com/shift2rail.png)
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**
  - 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).
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)
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.
Thank you for the attention!

www.dynafreight-rail.eu