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FR8RAIL: Development of functional requirements for sustainable and attractive European rail freight

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Abstract

The modal share of intra-EU rail freight transport is less than 20% of the freight transport sector. The current rail freight situation is not only due to the existence of legal barriers restricting competition (including the track access regime, taxation, etc.), but also due to limitations of operational and technical nature, which impact the overall capacity and performance of the sector.
In order to overcome these issues, Shift2Rail set a specific Innovation Programme 5 (IP5) focused on Technologies for Sustainable & Attractive European Rail Freight. In this context, the FR8RAIL project, is working on the "Development of Functional Requirements for Sustainable and Attractive European Rail".
To overcome these limitations, a holistic approach involving several technical areas, that form the backbone of the project approach. The outcomes of FR8RAIL will positively contribute to and support the Shift2Rail goals to strengthen the role of the freight rail transport.

Keywords: rail; freight; Shift2Rail; H2020

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Nomenclature

A. Cross-Cutting Areas and themes (CCA)
B. End of Train (EoT)
C. Innovation Programme 5 (IP5)
D. Research and Innovation (R&I)
E. Shift2Rail (S2R)
F. Technological Demonstrator (TD)
G. Technology Readiness Level (TRL)
H. Traffic Management System (TMS).
I. Wagon On-Board Unit (wOBU)
J. Work Package (WP)

1. Introduction

The modal share of intra-EU rail freight transport is less than 20% of the freight transport sector even though rail freight services in EU are not newcomers in the sector. The current rail freight situation is not only due to the existence of legal barriers restricting competition (including the track access regime, taxation, etc.), but also due to limitations of operational and technical nature, which impact the overall capacity and performance of the sector. In terms of developing rail freight the Transport White Paper sets ambitious objectives: almost doubling the use of rail freight compared to 2005, achieving a shift of 30 % of road freight over 300 km to modes such as rail or waterborne transport by 2030, and of more than 50 % by 2050. Therefore, with the aim of reaching these objectives, freight services need to be improved in terms of cost competitiveness and reliability. Then, rail freight will be in a position to offer a cost-effective, attractive service that will compete with the congested road network.
In order to overcome these issues, Shift2Rail set a specific Innovation Programme 5 (IP5) focused on Technologies for Sustainable & Attractive European Rail Freight. In this context, the FR8RAIL project, composed of eighteen European partners, is working on the "Development of Functional Requirements for Sustainable and Attractive European Rail" aiming at achieving:

- A 10 % reduction of cost of the freight transportation.
- A 10 % reduction in the time variations during dwelling.
- 100% availability of rail freight transportation information to logistic chain information system.

To achieve these objectives, the following limiting factors have to be tackled:

- High maintenance cost.
- Limitations due to standard coupler and missing electrification of freight wagons.
- Poor payload-deadweight ratios.
- Train integrity verification restrictions.
- Lack of integration of freight data.

To overcome these limitations, a holistic approach involving several technical areas is applied in FR8RAIL:

- Development of condition based and predictive maintenance technologies (WP2 Condition Based and Predictive Maintenance).
- Development of new telematics and electrification technologies (WP3 Telematics & Electrification).
- Development of technologies for a new concept of wagon and running gear (WP4 Running Gear, Core and Extended Market Wagon)
- Development of the technologies for a new automatic coupler (WP5 Automatic Coupling)

Additionally FR8RAIL deals with Business Analytics, KPIs, Top Level Requirements (WP1), High level System Architecture and Integration (WP6), as well as dissemination (WP7) and Management (WP8). The outcomes of FR8RAIL are expected to positively contribute to and support the Shift2Rail goals to strengthen the role of the freight rail transport.

This paper first introduces the topic of the rail freight and the introduction of the FR8RAIL project in the current section. Then, the context of Shift2Rail is explained, focusing on the Innovation Programme 5 (IP5) related to Technologies for Sustainable & Attractive European Rail Freight. After that, section 3 describes the FR8RAIL project including the description of the technical work packages. Finally, section 4 shows the conclusions of this work and section 5 the list of references employed.

2. Shift2Rail context

Shift2Rail programme aims at promoting the modal shift and the competitiveness of the European railway industry by meeting the challenges set in the EU's new programme for research and innovation (R&I), Horizon 2020 (H2020). The programme will run from 2014 to 2020 with an estimated total budget of EUR 77 billion, of which around EUR 6.339 million are assigned to the "Smart, green and integrated transport" challenge. Within the "Smart, green and integrated transport" challenge, a budget of EUR 450 million are employed for research and innovation activities in the rail sector in the frame of the Shift2Rail (S2R) programme. Rail's advantages in terms of environmental performance, land use, energy consumption and safety, are aligned with the challenge objectives. The rail sector can and must further enhance its performance in these areas through innovation, which will help to address short/medium term problems in the railway sector while also initiating a new paradigm for a more ambitious future for the rail sector.
The Shift2Rail programme, as indicated in the Shift2Rail Master Plan, has a structure of five asset-specific Innovation Programmes (IPs), that will be supported by work in five cross-cutting areas and themes (CCA). This overall programme structure is schematised in Figure 1 below. Shift2Rail will address the above-mentioned IPs and CCA by funding Research and Innovation activities that will range from applied research activities (TRL 1 to 3) to demonstration activities (TRL 4 to 7), i.e. from technology developments in laboratory to system prototype demonstrations in operational environments.

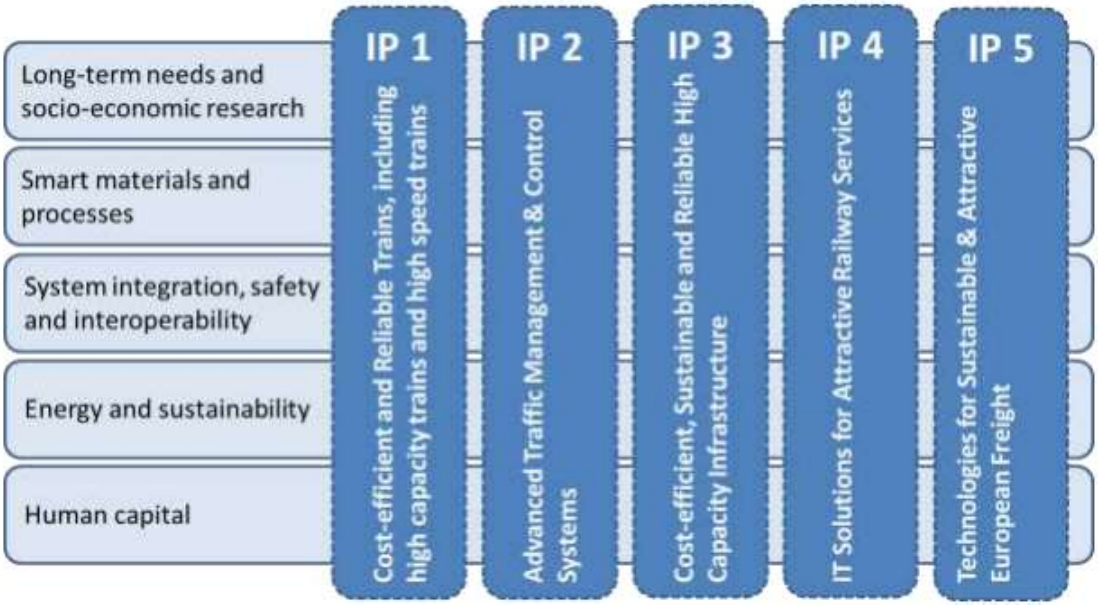

Fig. 1 Overall structure of the S2R JU programme

2.1. IP5 Context

The present work lies on the IP5 related to Technologies for Sustainable & Attractive European Rail Freight. Rail freight markets within the EU have been open for a some years, however, the modal share of intra-EU rail freight transport has slightly declined in the past decade. Therefore, the sector has the risk of not fulfilling the objectives related to develop the rail freight set in the Transport White Paper: double the use of rail freight compared to 2005 and to achieve a shift of 30% of road freight over 300 km to modes such as rail transport by 2030. The sector's situation can be partly explained by the existence of legal barriers restricting competition (including the infrastructure access regime, taxation, etc.), but also by problems of operational and technical nature, referred to the overall capacity and performance of the sector. Today's main limiting factors are:

- problems with handling freight trains on mixed traffic lines during peak passenger trains hours.
- long- and unreliable lead-time in terminals, hubs and marshalling yards accompanied with high operational costs.
- low reliability and high operational cost due to manual handling processes.
- limited train weight, length and speed due to limits in couplers strength and propulsion concepts of locos.
- low performance and flexibility in serving the last mile in single wagon load.
- reduced acceptance as an environmental friendly transport mode due to noise/vibration of freight trains/wagon.
- missing electrification of freight wagons to benefit from intelligent sensors and communication systems.

For European rail freight to become more attractive, the rail freight sector must provide customer tailored services to its clients and be more effectively integrated in the logistics value chain. Reliability, lead times, deliveries on-time and in full, frequencies and cost must meet customer requirements for different goods segments. Action in the rail freight sector is urgent as it risks losing its position as the most environmentally friendly transport mode due to innovations in other transport modes.

2.2. IP5 challenges and structure

In Innovation Programme 5 (IP5), Technologies for Sustainable & Attractive European Rail Freight, two challenges have been addressed:

- To acquire a new service-oriented profile for rail freight services based on excellence in on time delivery at competitive prices, interweaving its operations with other transport modes, addressing the needs of the clientele among others by incorporating innovative value-added services.
- To increase productivity, by addressing current operational and system weaknesses and limitations, including interoperability issues, and finding cost-effective solutions to these problems, including optimisation of existing infrastructure and fostering technology transfer from other sectors into rail freight.

In order to achieve the two challenges above IP5 have worked out a vision for future freight and a connected storyline that is based on digitalization enabling a higher degree of automation on line as well as in the nodes.

IP5 follows a holistic system approach to ensure value creation for customers, the rail operating community and society. The innovations and enabling technologies defined in IP5 aims at achieving a long term vision of the rail freight. It focuses on a number of specific work areas arranged in TDs (See Table 2) to improve the performance of rail freight. The main areas are listed as follows:

- The huge potential offered by digitalisation, built on the TAF TSI, will boost rail freight productivity and punctuality, creating competitive cost structures and stimulating growth in Europe by providing more efficient, reliable and high-quality rail freight services.
- The development of technologies that enable a higher degree of automation and autonomous operations will raise productivity, reliability and reduce cost dramatically.
- Automation in train composition and operation will raise the quality of rail freight services, improve staff productivity and resource utilisation and increase infrastructure capacity.
- Customers and lifecycle-costs will benefit from predictive maintenance and smart, self-monitoring freight assets. The fusion of sensor data with pattern recognition methods will ensure cost-efficient asset management in both operations and maintenance.
- Driver assistance, component optimisation and advanced propulsion technologies will significantly reduce energy consumption and emissions, strengthening competitiveness while lowering the carbon footprint.

All TDs have to consider the TAF/TSI: current and future (2020) standards, the Strategic European Deployment Plan and the corresponding current processes. The next table provides an overview of the TDs of IP5.

Table 1. IP5 TD list.

Research and Innovation Area	Technology Demonstrator	Focus Area
Implementation Strategies and Business Analytics	T.D. 5.0	Analytics Identification of market segments Development of KPI's Migration Plan
Freight Electrification, Brake and Telematics	T.D. 5.1	Condition-based maintenance Automatic Coupling Telematics and electrification
Access and Operation	T.D. 5.2	Improved methods for time table planning Real-time yard management Real-time network management Increasing speed for freight trains
Wagon design	T.D. 5.3	Low-noise, lightweight, high Speed & track friendly running gear Core market wagon 2020 New market wagon 2020

Novel Terminal, Hubs, Marshalling yards, Sidings	T.D. 5.4	Intelligent video gate terminal with new design Hybridisation of legacy shunting fleet
New Freight Propulsion Concepts	T.D. 5.5	Freight Loco of the future Last mile propulsion system Long Trains up to 1500 m Driver Advisory System

3. FR8RAIL

One of the projects of Shift2Rail IP5 that started in 2016 is the FR8RAIL "Development of functional requirements for sustainable and attractive European rail freight". The main aim of the FR8RAIL project is the development of functional requirements for sustainable and attractive European rail freight related to:

- Reduction in the cost of freight transport measured by tonnes per km.
- Reduction in the time variations during dwelling.
- Increase attractiveness of logistic chains by making available the rail freight transport information.

The ambitious progress beyond the state of the art proposed by the project will improve the logistic chain as described in the following points:

- **Condition based maintenance** will change completely the organizational model of maintenance services. Currently, maintenance units traditionally work like a production chain reducing the number of human resources at expenses of the availability of the asset. Condition based maintenance will provoke a change of paradigm in maintenance process and will evolve to a situation where the information about the asset is the driving force and all the operations are focused on reducing asset unavailability.
- **Telematics** in the wagon will enable new integrated services for logistic operations. This will increase the attractiveness of rail mode for special goods which will bring more margin to freight trains operating companies.
- **Running gear, core and extended wagon design** concept will contribute to following strategic areas: better transportation conditions, increased flexibility, longer trains and increased payloads, life cycle cost reduction and increased reliability.
- **Automated couplers** will enable safer and more efficient terminal handling along with longer trains.

3.1. Research and Innovation Activities Linked to the Project

The FR8RAIL consortium will take into consideration results achieved in various research activities undertaken by the rail community in the last years. Further projects are still ongoing or just started recently and could have a potential impact for the FR8RAIL activities. However, the information flow is ensured, having members being involved in one or several of these projects. Table 3: Relevant projects

Table 2. National or International Research and Innovation Activities Linked to the Project.

Research / Innovation activity	Valuable output for FR8RAIL
SMARTRAIL	Market analysis and stakeholder needs
Capacity4Rail	Wagon design
Roll2Rail WP4	Universal Cost Model, developing a clear method of quantifying the life-cycle cost impact of existing and new technological solutions in the field of railway running gear in order to unblock innovation in railway vehicles.
SPECTRUM	New concept trains for new markets
Vel-Wagon	Versatile, Efficient and Longer Wagon for European Transportation. Light weight and logistic capable principles in wagon design
Wear and RCF Phenomena in Metro Operation	Modelling and assessment of Wear and RCF Phenomena on Wheel and Rail in the Viennese Metro network serves as solid basis for developing track friendly freight running gear (national)
EURAXLES (FP7)	Calculation method for the design of axles. LCC analysis of axles
HERMES	New concept trains for new markets

EATS	Positioning techniques for the railway sector based on multi-constellation information and multiple receivers
SUSTRAIL	Condition based maintenance in the railway sector

Throughout the research and innovation activities of the FR8RAIL, interdisciplinary considerations will also play a major role as solutions and insights from other sectors (e.g. the telematic industry) will be closely monitored and considered for adaptation.

3.2. Objectives

The objective of FR8RAIL project cover some of the challenges addressed by S2R IP5 as highlighted in Figure 3:

- Autonomous freight train operation, **intelligent freight wagons**, **automated coupled** up to a 1500 m long train from automated nodes along the European freight corridors will be the future transportbackbone for the European economy.
- Diagnosis and monitoring systems will provide real-time information for shippers, forwarders and train operators concerning goods status.
- **Energy-supplied freight wagons** with **advanced monitoring**, localization and braking performance will enable increased availability, reliability and significantly reduced the costs for a new service-oriented profile for rail freight services.
- **Condition based and predictive maintenance** will achieve a paradigm shift from costly predetermined to cost efficient condition based and predictive maintenance due to monitoring the component status.
- Hybridization of propulsion systems, **low noise and vibration boogies with less wheel-track wear**, improved train aero dynamic and less energy consumption due to automated train operation will ensure the number one position of railway as the most eco-friendly transport system.
- The real-time yard management and the intelligent video gate in terminals will reduce the lead time and increase the cost-effectiveness in the nodes and connect the traffic management system with a real-time network management. The new freight locomotive, with dual power and driver-assistance system will ensure competitiveness for the rail freight.

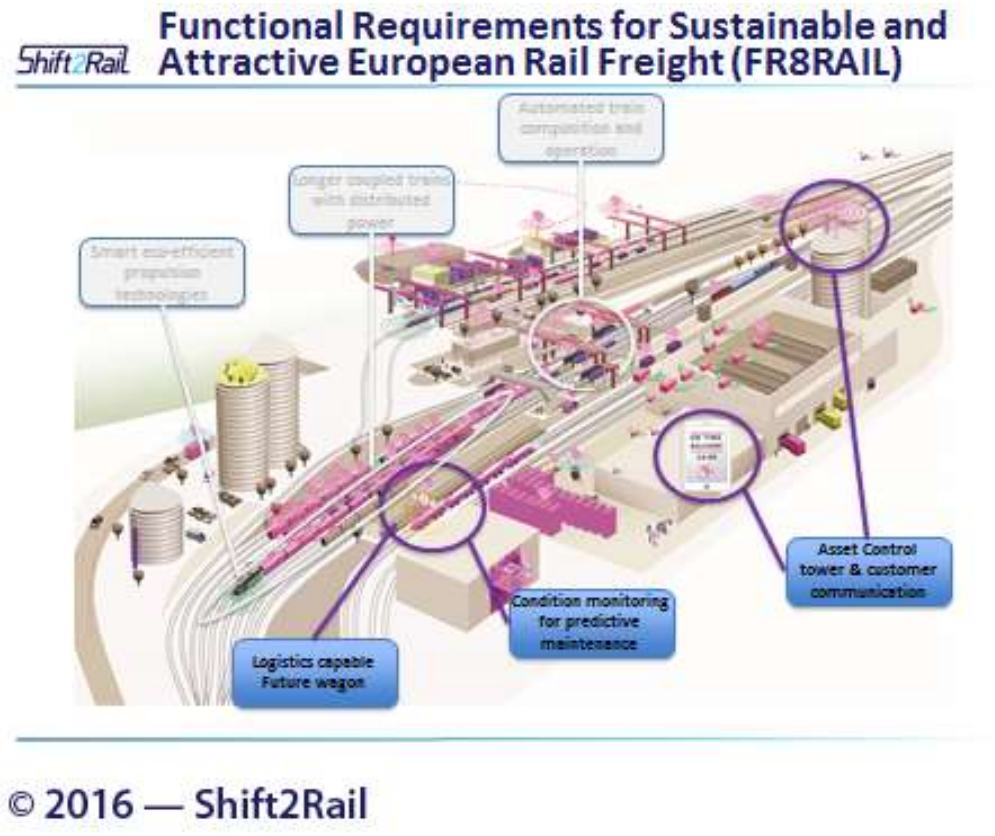

Figure 3 FR8RAIL concept

3.3. Consortium

Under the coordination of Trafikverket, the partnership for the FR8RAIL proposal contains members of the SHIFT2RAIL Joint Undertaking. To achieve the FR8RAIL objectives the consortium is composed of 18 partners from 7 EU Member states (Sweden, Italy, Spain, Germany, Austria, Slovakia, Belgium – see figure below). This gives a broad Member-state coverage to FR8RAIL consortium. The scope of activities of each partner within FR8RAIL is aligned according to their individual capabilities to contribute to the FR8RAIL objectives. This will ensure that all partners can effectively contribute to the successful delivery of the project.
FR8RAIL brings together the several of the main European railway freight stakeholders like Deutsche Bahn and EUROC consortium covering the most important Rail Freight Undertakings. Trafikverket as an Infrastructure Manager will significantly contribute with its expertise on the infrastructure needs, requirements and impact of the requirements to be developed when implementing this proposal. With Knorr Bremse, Bombardier, Ansaldo STS, CAF, Indra, and PJM, highly relevant suppliers to the rail freight sector are contributing with expertise and technologies in order to meet the objectives of this proposal. European Freight Wagon Manufacturers Tatravagonka together with Wagonbau Niesky will work jointly in order to bringing forward the 5L freight wagon idea to first concepts, which will then in later calls be developed further to protoype demonstrators. The consortium will be supported by highly-skilled research centres such as CEIT-IK4, DLR (the German Aerospace Centre), Virtual Vehicle, MCL, and AC2T. It can therefore be seen that FR8RAIL covers the entire value chain and includes a majority of the main actors within the European rail freight sector.

3.4. Project structure

The objectives of the FR8RAIL project will be achieved by developing a number of vital areas within freight rail distributed in WPs as shown in Figure 4. There are six main areas of work that form the backbone of this project's approach:

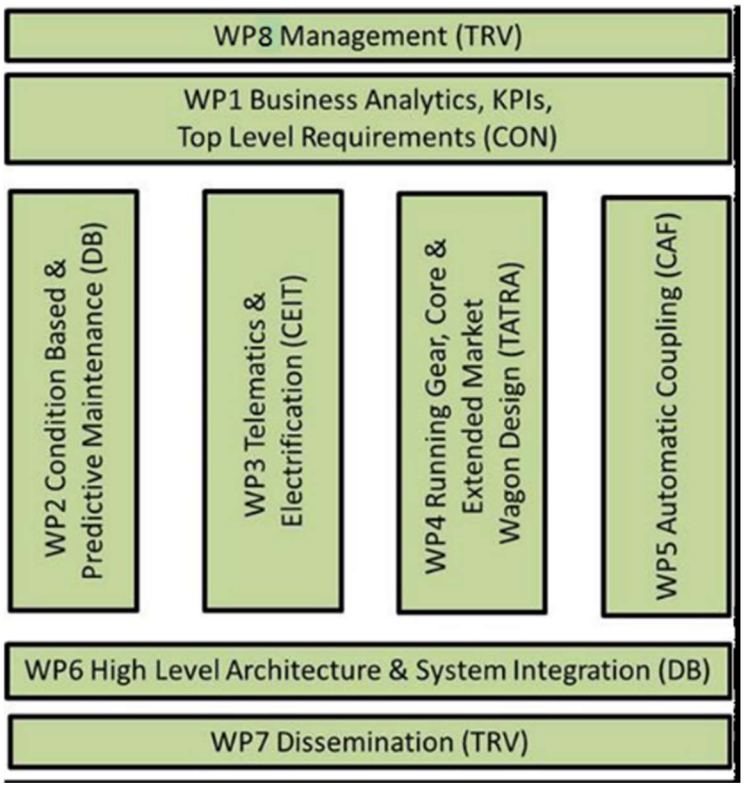

Figure 4 FR8RAIL WP structure

- WP1 Business Analytics, KPIs, Top Level Requirements
  The objectives are as follows:
  - Identification of Market Segments and its requirements in the transport market to defend and expand the market share of freight rail business.

  - Development of high level technical specifications
  - Development of Key Performance Indicators for the whole IP 5 Programme
- WP2 Condition Based and Predictive Maintenance
  The objective of this work package is to:
  - Develop an overall condition based and predictive maintenance strategy for rail freight rolling stock (locomotives and wagons) in alignment with all overall Shift2Rail targets.
  - Define new roles (e.g. reliability engineering) and responsibilities (e.g. technical support) in the interaction of the area asset, fleet and maintenance management.
  - Develop a condition based and predictive maintenance program based on specific locomotives and based on a number of components.
- WP3 Telematics & Electrification
  The objective of this work package is the development of telematics technologies (including hardware, software and algorithms), which will provide essential input information for different applications such as condition based and predictive maintenance, logistic services, traffic management, real time network management and intelligent gate terminals. The development comprises a wagon On-Board Unit (wOBU), different modules of a wagon and cargo monitoring system for maintenance and logistic purposes, systems for on board and wayside communication.
  The wOBU and referenced components focused at this stage will be the basis for being able to implement applications, such as automatic train set-up functionalities as well as a technical solution to provide information about the train (train integrity and end of train (EoT)) to the Traffic Management System (TMS).
- WP4 Running Gear, Core and Extended Market Wagon
  This work package will create the framework and functional requirements for the development of a track friendly, low weight, low noise high speed Running Gear capable to run under standard wagon bodies and the freight wagons 2020 State of the art technologies and relevant research activities regarding all relevant aspects of freight transport will be compiled.
  Initial investigations on vehicle-track interaction (vehicle dynamics, wheel-rail wear and damage, etc.) and strength will be carried out. Next, life cycle costs (LCC) will be assessed according to the KPIs developed in WP1 (interaction with Universal Cost Model from Roll2Rail) resulting in a prioritised concept.
  In the final stage of the project this prioritized concept will be further developed as basis for the development of a technical demonstrator of the next generation Running Gear and Core Market Wagon.
  A further focus of the project will be set on optimizing the acoustic and aerodynamic characteristics of the wagon design.
  Acoustic and aero acoustic noise sources will be identified and evaluated for potential reduction.
- WP5 Automatic Coupling
  Automatic coupling is one of the key technologies needed to meet the expectations of a sustainable and attractive European rail freight in the future by providing higher load capacity and intelligence in the operation.
  - The objectives of this WP areto define the technical requirements of the automatic coupler integrating all the requested functionalities in order to achieve a common basis for the development of an European-wise solution.
  - To define a migration strategy to introduce the automatic couplers in the freight market based on a cost benefit analysis.
- WP6 High level System Architecture and Integration.
  This work package is focused in two areas:
  - The information system (which combines telematics applications and condition based and predictive maintenance), and
  - The technical and process systems (which includes running gear, core and new market wagons, and automatic couplings).

  The objective for this WP is the alignment and synchronization of the high level system architectures (information systems and technical and process systems) between each WP to ensure an overall picture and enable the future integration of the developed subsystems among them and with other systems in other projects within the Shift2Rail.

4. Conclusions

Rail freight needs an evolution to increase its attractiveness and competitiveness. Therefore, Shift2Rail, included in its activities the Innovation Programme 5 (IP5) “Technologies for Sustainable & Attractive European Rail

Freight" of Shift2Rail. Thanks to the objectives defined in IP5, it is expected the required evolution of the rail freight sector.
In this context, the H2020 project FR8RAIL "Development of functional requirements for sustainable and attractive European rail freight" will offer the first stone to the evolution of the rail freight defined in the IP5 programme. The FR8RAIL project composed by 18 partners deals with a number of topics, such as Condition Based Maintenance, Telematics, Running Gear, Core and Extended Wagon Design Concept and Automated couplers, that will be the corner stones of the future rail freight evolution.

Acknowledgements

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5. References

Shift2Rail Master Plan, https://ec.europa.eu/transport/sites/transport/files/modes/rail/doc/2015-03-31-decisionn4-2015-adoption-s2r-masterplan.pdf 2015

Transport White Paper https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en, 2011

SMARTRAIL "Smart Supply Chain Oriented Rail Freight Services", http://smartrail-project.eu/, 2015-2018

Capacity4Rail "Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations", http://www.capacity4rail.eu/, 2013-2017

Roll2Rail, "NEW DEPENDABLE ROLLING STOCK FOR A MORE SUSTAINABLE, INTELLIGENT AND COMFORTABLE RAIL TRANSPORT IN EUROPE", http://www.roll2rail.eu/, 2015-2017

SPECTRUM, Solutions and Processes to Enhance the Competitiveness of Transport by Rail in Unexploited Markets, http://www.spectrumrail.info, 2011-2015

Vel-Wagon Versatile, "Efficient and Longer Wagon for European Transportation", 2010-2012

Wear and RCF Phenomena in Metro Operation, 2009

EURAXLES "Minimizing the risk of fatigue failure of railway axles", 2010-2014

HERMES "DEVELOPMENT OF SMART AND FLEXIBLE FREIGHT WAGONS AND FACILITIES FOR IMPROVED TRANSPORT OF GRANULAR MULTIMATERIALS", http://www.hermes-h2020.eu/, 2015-2018

EATS "ETCS Advanced Testing and Smart Train Positioning System" http://eats-eu.org/ 2012-2016

SUSTRAIL "The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost", http://www.sustrail.eu/, 2011-2015