Newsletter

FOREWORD

AUGUST 2018

The development of a new generation of running gear is pivotal to the achievement of the ambitious goals set by Shift2Rail for future European trains, encompassing the substantial reduction of life cycle costs, improved reliability and energy efficiency, the reduction of noise emissions and of other externalities and the achievement of full interoperability of the rolling stock.

The challenge for Shift2Rail is therefore huge: to build a Running Gear Technology Demonstrator (TD1.4) that paves the way for the next generation of passenger rail vehicles. Once the demonstrator has been built, it will be extremely difficult to go back on decisions and re-iterate project work: it has to be right the first time. To be "right" means essentially that its benefits are such that manufacturers embrace the lightweight, mechatronic, quiet, reliable, easy-to-manufacture, low Life-Cycle-Cost, "attractive" concept and start producing it with the consequent envisaged positive economic, social and environmental impacts.

This is where the Open-Call RUN2Rail (Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles) project comes into the picture. The aim of the RUN2Rail project is to identify and develop the key methods and tools that are required to allow the design and manufacture of the next generation of running gear. The project is part of the Shift2Rail initiative and it has been granted EU funds under the Grant Agreement number 777564.

Marta Andreoni (UNIFE) and Stefano Bruni (Politecnico di Milano)

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No: 777564

PROJECT STRUCTURE

The RUN2RAIL project will explore an ensemble of technical developments for future running gear, looking into ways to design trains that are more reliable, lighter, less damaging to the track, more comfortable and less noisy. These innovations will be proposed in the form of case studies supported by the methods and tools elaborated in the project.

The project develops across four thematic Work Streams:

1. **Innovative sensors & condition monitoring;**
2. **Optimised materials & manufacturing technologies;**
3. **Active suspensions & mechatronics;**
4. **Noise & Vibration.**

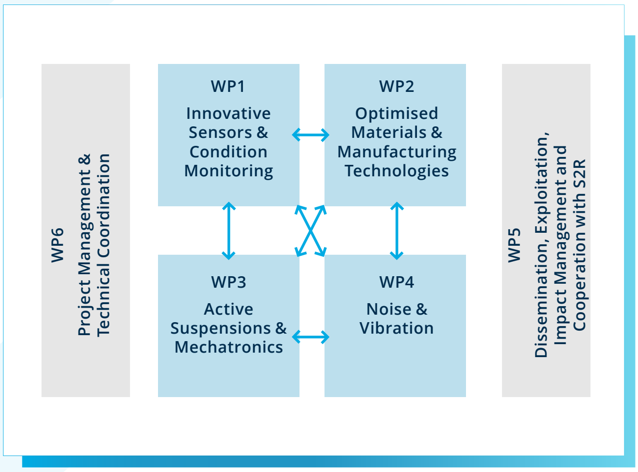

Fig. 1: RUN2Rail project structure

In these four areas, the project will provide a coordinated set of technical key contributions including (but not limited to):

- smart sensors and smart running gear components with self-diagnosing capability;
- use of novel materials and manufacturing methods in combination with intelligent / active suspensions to enable nonconventional running gear concepts;
- identification of efficient fabrication processes for the running gear (3D metal printing, automated tape layering of composite materials);
- assessment of existing off-the-shelf technology for active control coming from other sectors;
- development of a novel and comprehensive methodology for predicting the transmission of noise and vibration from the running gear to the carbody.

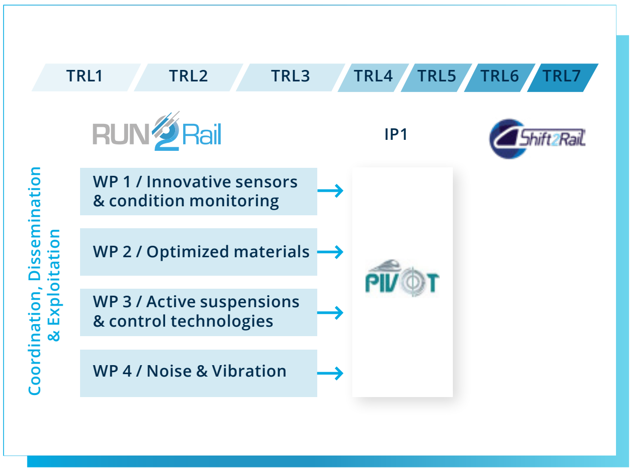

Fig. 2: RUN2Rail project structure within S2R frame

Within the four workstreams, the project will also perform a preliminary evaluation of the related regulatory and standardisation issues, together with a careful assessment of the impacts of the new solutions proposed.

The research conducted will be multidisciplinary, i.e. based on the integration of different branches of engineering such as mechanical, materials, electronic and electrical engineering, and will establish models and formal methods to explore a full set of technological developments, exploiting at best the matching mix of talent and diverse skills offered by the Consortium.

WP1 - INNOVATIVE SENSORS & CONDITION MONITORING

Recent years witnessed increasing interest for the use of condition monitoring (CM) systems in railway vehicles, with the aim of improving Reliability, Maintainability, Availability and Safety (RAMS) also through the implementation of predictive maintenance. However, the initial cost and complexity of monitoring hardware still represents a barrier to this process. RUN2Rail is exploring the potential for advanced applications of CM in the next generation of running gear, looking at solutions already available in other sectors but also aiming to formulate new solutions specifically targeted to the railway market. These general concepts are developed with reference to the following case studies:

- Use of embedded, self-powered sensors to monitor the in-service fatigue stress cycles of wheelset axles;
- Feasibility of a low-cost strain-gauge-based measuring system that can be used for monitoring wheel/rail contact forces;
- Monitoring of the powertrain system through the measure of the instantaneous angular velocity, allowing to diagnose the health of the gear chain using easy-to-access encoder signals;
- Monitoring of suspension components based on bogie-mounted acceleration sensors.

In a first stage of the research, a prioritisation of needs for CM from an operator's perspective was performed, based in particular on experience and historical data available at partner Metro De Madrid. A thorough analysis of existing solutions was also performed, not limited to the railway field, but also covering other fields of engineering, particularly automotive, energy and industrial engineering in general.

System requirements and architectures

A modular, flexible architecture was designed for the on-board CM system to enable the integration of state-of-the-art technology regarding sensing, processing, data storage, communication and power feeding. This work was led by partner EVOLEO Technologies. The concept for the global system architecture was defined having as final objectives a high flexibility, modularity and scalability of the on-board CM system.

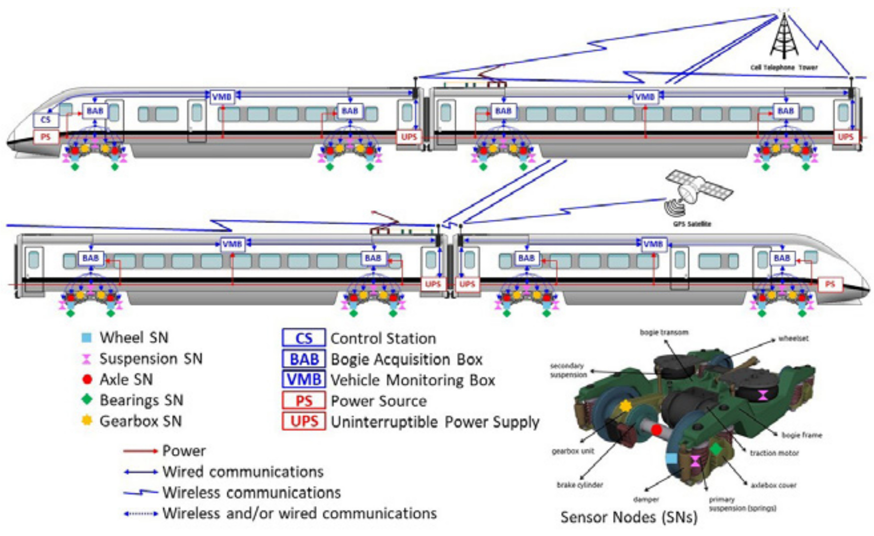

Fig. 3: Overview of the on-board CM system

Figure 1 provides an overview of the system architecture and of its hierarchy, which sees at the lower level the sensor nodes, at the intermediate level Bogie Acquisition Boxes (BAB) and at the higher level the Vehicle Monitoring Box. The processing of signals from the sensor nodes is performed locally at the BABs, to distribute the computing power needed and to minimise the amount of information transferred to the higher level of the CM system.

A detailed set of requirements was defined in terms of the number and position of the sensor nodes required for each case study, performances expected from the sensor nodes, conditioning and acquisition of signals, data processing and storage, power supply. Operational requirements for the CM system were defined as well.

Task 1.2 Condition Monitoring Systems

This task deals with the identification of suitable hardware components for the different components of the CM system, in particular: sensors, data acquisition, data processing, data transmission, data storage, communications and interfaces, energy source. A focus is set on smart / innovative components, such as wireless self-powered sensor nodes. Once completed the selection of components, RAMS analyses will be performed to prove their suitability for operation in the railway environment.

Task 1.3 Methods for condition monitoring and fault detection

In parallel to the selection of hardware, data processing techniques are being defined to extract information on the running gear condition that can be used to implement predictive maintenance policies. Fault detection schemes are being developed for all case studies also with the help of numerical models such as Multi-Body Systems models of railway vehicles to define the effect of faults and their severity on the running dynamics of the vehicle and of Finite Element models to define optimal locations for strain gauge sensors to be used for the CM of wheelsets, see Figure 2.

The joint outcome of Tasks 1.2 and 1.3 will be technology concepts for each one of the CM case studies addressed.

Link with S2R:

The work being undertaken in Run2Rail WP1 is linked to PIVOT Task 1.3 "Health Monitoring Systems (HMS) for Condition Based Maintenance (CBM)". A joint workshop focussing on condition monitoring was held involving representatives from the two project and exchange of information and cooperation was agreed, particularly in the area of definition of specifications for sensors and monitoring system.

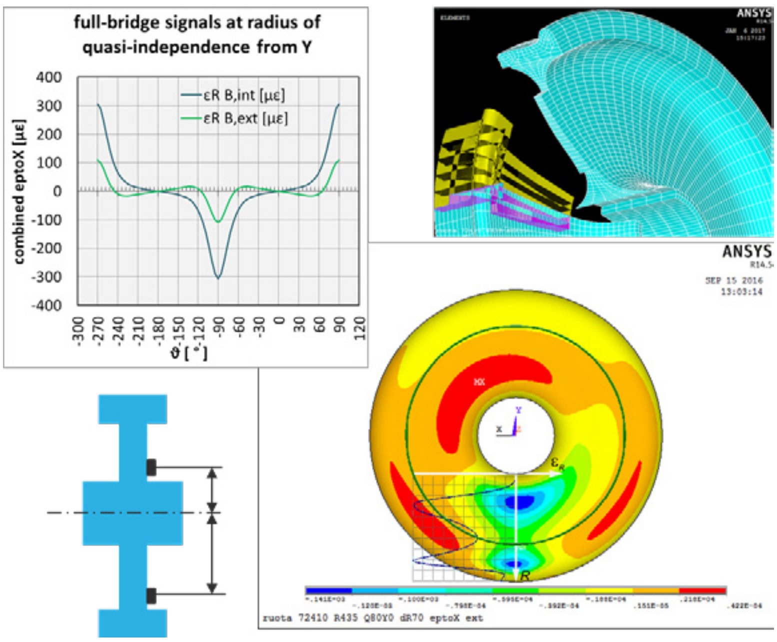

Fig. 4: FE analysis for the optimal location of stress measurements

WP2 - OPTIMISED MATERIALS & MANUFACTURING TECHNOLOGIES

Background

Novel materials bring enormous potential in the design of running gear for example in reducing mass and forces and in improving reliability but different techniques are required in both design and manufacturing to allow this potential to be realised. Materials solutions are being developed for both conventional bogie designs and novel two axle architectures to allow best advantage of active suspension elements to be taken. Up to now there has been very limited adoption of novel materials in the railways with one exception being the Kawasaki efWING bogie with composite suspension springs but conventional steel bogie frame. This WP is also assessing key areas where standards or culture need to be changed to allow the adoption of novel materials.

Structure

The workpackage is led by Huddersfield University and supported by Politecnico di Milano, KTH, DICEA, RINA-C, Lucchini Rail and Blue Engineering and supported by Metro Madrid. It has two initial tasks aimed at defining the performance requirements and setting specific load cases and a final task (common to all workpackages) which aims to assess and quantify the key impacts of the novel methods on the railway but the main activity is in task 3 which is looking at novel materials and manufacturing solutions.

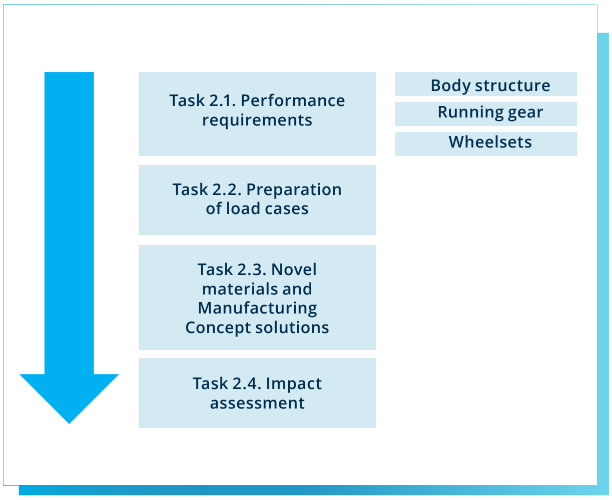

Fig. 5: Structure of WP2

The work will be based on non-motored passenger vehicles with two target applications:

- A conventional bogie vehicle (160 km/h 18T axle load)
- A novel bogieless two axle vehicle (120km/h 15T axle load)

Fig. 6: The two concept vehicles a) bogie b) two axle

The work will be focused around 3 case studies:

- Body structures
- Running gear
- Wheelsets

Novel manufacturing methods are being explored including:

- Metal Additive Manufacturing with Selective Laser Melting with:
- Different materials,
- Different heat treatments.
- Different powder morphologies and sizes
- Carbon fibre with robotic layup

Interim Outputs

Task 1 has been completed and Deliverable D2.1 has been completed. This includes a summary of assessment methods including those related to: Vehicle dynamic behaviour; Passenger comfort and Vehicle gauging. It also covers the requirements for specific components including: Body structures; Bogie frame; Running gear; Wheelsets. For all of these aspect the relevant EU standards are reviewed and suggestions made for areas where standards are not available. The relevance of previous projects including REFRESCO and WIDEM is also summarised.

Novel materials and Manufacturing methods

Components form the two concept vehicles are being assessed for their potential for the use of novel materials or manufacturing methods. Components such as the axle box, arm and fork. The selected components will have dimensions compliant with actual SLM facilities and with the facilities under development by main supplier. The focus is on smaller (non-structural) parts that may not have such a large impact on weight reduction, but would have significant impacts on maintenance costs, environmental compatibility, availability of spare parts and more

A deeper study on actual components and solutions where aluminium alloys is actually used will be done. Aluminum alloys should be more suitable for additive manufacturing solutions. New aluminium alloys will also be selected to ensure that load cases can be met.

Rapid prototyping of components made on new selected alloys. One chemical composition will be chosen among special steels, or nickel-based alloys or aluminium alloys.

Selection or development of a new metallic alloy with improved mechanical properties will be made for the final application. RINA-CSM will carry out powder manufacturing by gas atomization process, while the additive manufacturing process can be performed at POLIMI. Samples will be characterized also as a benchmark for new "AM Modeling software" used by BLUE Engineering for Additive Manufacturing process simulations.

Fig. 7: Meetings of the Run2Rail WP2 team

WP3 - ACTIVE SUSPENSION & CONTROL TECHNOLOGY

Research on active dynamic suspension in rail vehicles has been carried out for several decades. Very few studies, however, reached implementation in commercial vehicles. Reasons for that are increased first cost of the vehicle and a fear for reduced reliability due to more complexity in the vehicles. It has also become obvious that a reduction of vibration levels in the carbody to improve ride comfort is generally not economically interesting enough to achieve a breakthrough of active technology. A ride comfort improvement has to go along with other features like increased passenger capacity, reduced maintenance cost or lower vehicle cost by simplified vehicle layout.

Task 3.1 State of the art of actuator technology

Several active and semi-active actuators technologies are existing in railway and non-railway applications. Task 3.1 describes the technologies which were realized in different sectors and that might be applicable to railways. The actuator technologies were examined from different perspectives. The first one was the technology itself. The second one focused on the application, where the technology is used in the industry. I a third step we went deeper into the use in railway applications and the needs for primary and secondary suspension in lateral, vertical and yaw direction. For each single suspension type on a railway vehicle it the intention of the application and their requirements was defined.

This is the technical basis for the Task 3.2 and other project (e.g. PIVOT) which has the target to improve the technical performance of the chassis control in railway application.

Finally, the technologies were validated by using a matrix, which gives a compact view on the technology and its possible use on railway vehicles.

Actuator technology											
Type				Full active					Semi-active		
				1	2	3	4	5	6	7	8
Description				hydraulic central power pack	hydraulic compact actuator	electro-mechanical	pneumatic use of existing supply	electro-magnetic	hydraulic	magneto rheological	electro rheological
Level of maturity of technology			slow acting	5	5	5	5	2			
			fast acting	5	5	4	2	4	5	5	1
Active suspension application	vehicle with 2 suspension stages	Secondary	lateral (centering)	3,33	4,17	3,50	4,00	2,17	2,00	1,67	1,17
			lateral (dynamic)	3,33	4,33	3,00	2,17	4,00	4,50	3,00	1,83
			vertical (levelling)	3,17	4,00	3,33	4,83	2,17	2,00	1,67	1,17
			vertical (dynamic)	3,17	4,00	2,83	2,00	3,50	4,50	3,50	2,17
			yaw (stability)	3,33	3,83	3,17	1,33	2,33	3,17	2,33	1,67
			yaw (steering)	3,00	3,67	4,00	2,00	2,33	2,00	2,00	1,50
		Primary	lateral (dynamic)	1,33	1,50	1,17	1,00	1,17	1,83	1,17	1,00
			vertical (dynamic)	1,83	2,17	2,00	1,83	2,00	3,17	2,33	1,33
			yaw (stability)	2,50	3,00	3,50	1,50	1,83	2,00	1,00	1,00
			yaw (steering)	3,00	3,83	4,83	2,33	1,67	1,00	0,83	0,83
	Innovative vehicle with one suspension stage		lateral (centring)	2,50	3,17	2,50	3,33	2,00	1,83	1,50	1,00
			lateral (dynamic)	2,83	3,33	2,50	1,83	3,67	3,83	2,83	1,83
			vertical (levelling)	2,67	3,50	2,50	3,83	2,17	2,00	1,67	1,17
			vertical (dynamic)	2,83	3,50	2,33	2,33	3,33	4,17	3,50	2,33
			yaw stability	3,00	3,33	3,33	1,50	1,67	2,50	1,67	1,33
			yaw (steering)	3,17	3,67	4,67	2,00	1,83	1,00	0,83	0,83

Fig. 8: Actuator technology matrix

Legend / Ease of use at railway - +

Task 3.2 Implementation of active technology on conventional bogievehicles respectively a two-axle vehicle

New concepts for actuations on existing vehicles that shall optimize the cost benefit ratio shall be investigated. This includes both actuation and control strategies. Bogies with solid wheelsets and running gear with independently rotating wheels will be looked at. A type of vehicle on which active suspension can be very effective is the two-axle rail vehicle. This type of vehicle is simple and cheaper compared to bogie vehicles but has many dynamic limitations. Therefore, in the second part of this task it will be investigated whether active technology can make single axle running gear vehicles a competitive alternative to today's bogie vehicles. Benefits would be reduced weight and energy consumption.

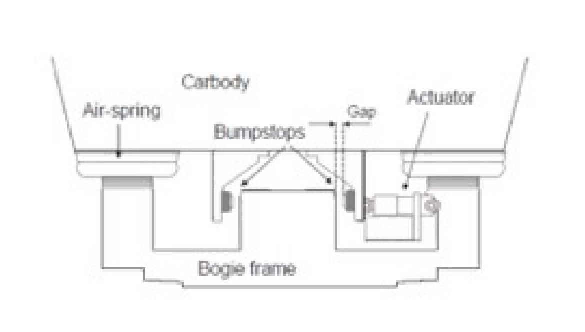

Fig. 9: Active lateral suspension

Task 3.3 Authorisation strategy for active suspension

Task 3.3 is aimed at providing the basis for an Authorisation Strategy for active suspension systems. Although some active concepts (tilting, etc.) have already been accepted for full operation, there is potential for more advanced systems where authorisation using current standards and approaches will be more difficult. The plan is to produce a framework based upon CENELEC standards for incorporating electronics and control into railways. Work is in progress to prepare a set of Safety Case guidelines for:

1. Generalised Products (i.e. sets of active technologies),
2. Generalised Applications (e.g. Active secondary, active primary, etc.) and
3. Specific Applications (i.e. combinations of (1) and (2))."

There is significant commonality with the Shift2Rail PIVOT project, and Run2Rail's ideas have been presented to members of this project in order to identify collaboration possibilities.

Link with S2R:

The state-of-the-art study on available actuator technologies and their readiness for usage in railway applications is a valuable input to S2R and especially the Pivot project. The Run2Rail active suspension and control strategies proposed in Task 3.2 can be used by Pivot project partners in their solutions developed. Also, the strategies for an authorisation process of vehicles with active suspension are essential for future implementation of the technology and are requested from us by S2R (cf. above).

WP4 - NOISE & VIBRATION

The acoustic environment inside rail vehicles is an important aspect of the comfort of passengers and staff. The main source of noise in many situations is generated at the wheel/rail interface and this is transmitted from the running gear to the carbody through structural vibration as well as through airborne paths. These paths are complex and current prediction methodologies are not sufficiently reliable. The project therefore aims to develop validated tools and methodologies for predicting the transmission of noise and vibration from the running gear into the carbody. The work is focussed on developing simulation models that can be used as 'virtual test methods' and validating them using field experiments.

Fig. 10: Acoustic source inside the vehicle used to measure transmission through the carbody

Field tests

An extensive test campaign was carried out in March 2018 at the facilities of Metro de Madrid's Cuatro Vientos Depot. The test rolling stock was the Series 8000-2 metro train. The purpose of the tests was to quantify experimentally the various airborne and structure-borne paths by which sound is transmitted into a vehicle from the running gear. Static tests were performed to measure the vibration behaviour of the bogie using impact hammer excitation. These measurements are used to fine-tune numerical models of the bogie frame. The airborne sound transmission was also measured from a known sound source through the walls, doors, gangway etc.

Running tests were also carried out on a test track to determine the vibration and noise behaviour of the bogie under running conditions. By combining static and running tests the forces acting at the connection points on the carbody can be determined using an inverse method. Moreover, the characteristics of the test track, such as rail roughness and track decay rates, were also measured. These results will be used for validation of the completed models.

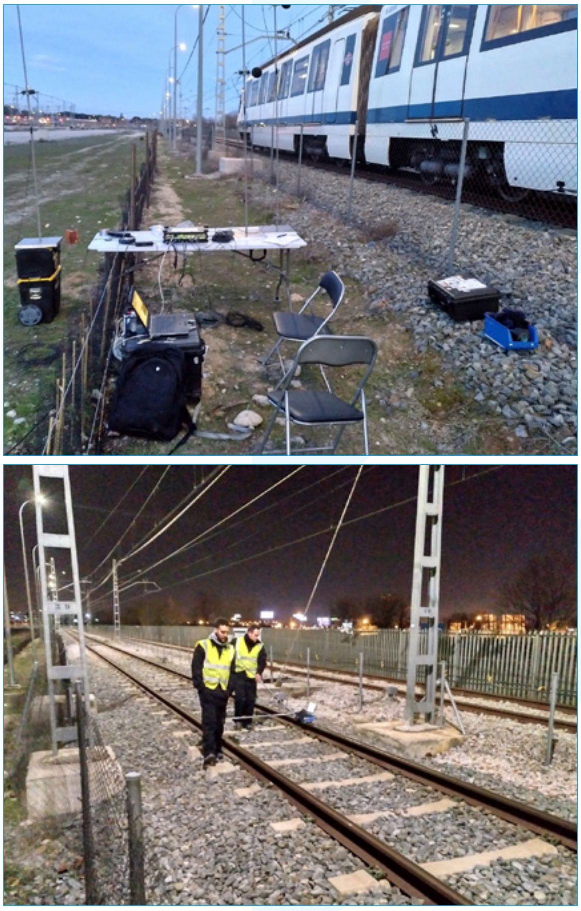

Fig. 11: Measurements of rail roughness (left) and Running tests on Metro de Madrid test track (right)

Virtual test methods for airborne and structure-borne noise transmission

Models are being developed for both airborne and structure-borne transmission. A target vehicle has been selected based on Metro de Madrid's Series 8000-2 train, as used in the field tests, and a finite element model of the wheelset and the bogie frame has been produced. This will be verified against the static field tests.

The airborne noise is modelled using the TWINS approach. Although this is well-known and widely used, particular attention must be paid to the way in which the sound propagates beneath the vehicle and around the outside of the carbody. Again the field measurements will be used to verify the approach taken.

Characterising suspension elements

The suspension elements, such as springs and dampers, and other connections such as traction bars, form an important part of the structural transmission path. However, their behaviour is complex due to internal resonances and non-linear material behaviour. Consequently it is necessary to determine their properties using laboratory tests. Measurements are being carried out on a rubber primary suspension spring, a lateral damper and a traction bar. In the latter cases the rubber bushings are critical components and so these are being studied separately. From these measurements, suitable reduced-order models will be developed that can be combined with the model of the bogie frame to form the overall structure-borne noise model.

Noise reduction technologies including new materials

Work in the second year of the project will focus on using the newly developed and validated models to study a variety of both new and existing techniques for reducing noise and vibration transmission from running gear in order to improve passenger comfort. The implications for noise of introducing new materials and active control solutions developed in other parts of the project will also be assessed.

Link with S2R:

Discussions are held with the PIVOT project about common work areas, especially the evaluation of noise reduction technologies for running gear. The FINE1 project is also studying vehicle interior noise; a presentation was given to the FINE1 project mid-term meeting in May 2018 to ensure good understanding of the work carried out in RUN2Rail.

IMPACT ASSESSMENT

RUN2Rail includes a cross-cutting Work Stream (WS) 'Impact Management Support and Assessment' that addresses the evaluation of impacts for the new technologies explored in the thematic WS and is looking into aspects related with the authorisation of vehicles with innovative components.

The direct impacts aimed for in RUN2Rail's thematic WS involve getting its outputs to affect positively the right stakeholders.

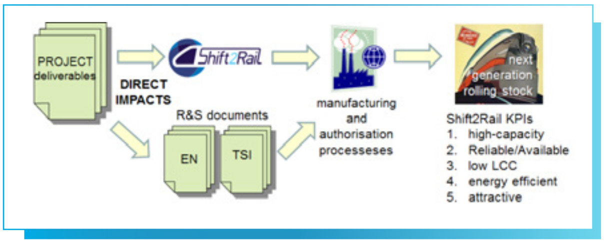

Fig. 12: RUN2Rail impacts to S2R

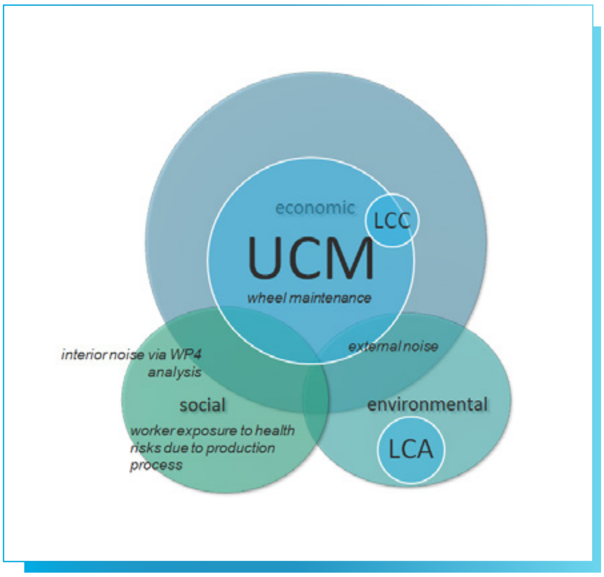

Fig. 13: RUN2Rail cross-cutting impacts

The cross-cutting Impact WS not only addresses the direct impacts, by creating an "impact-conscious" project, but also:

- a broad scope of economic, social and environmental impacts on stakeholders both within and outside the railway sector;
- the whole impact pathway, from the end of the project to its exploitation for SHIFT2RAIL Technological Demonstrator TD1.4, to the envisaged entry into service of running gear based on RUN2Rail concepts;
- the whole life-cycle of running gear.

Key questions that are being approached are:

- how can condition monitoring improve maintenance?
- what are the environmental impacts of novel materials and manufacturing processes?
- what needs to be done to make authorisation of vehicles with active components inexpensive, easy and safe?
- how do novel materials and suspensions affect noise emission?

RUN2Rail is drawing input mainly from previous projects (e.g. IMPACT-1 for the its approach and Roll2Rail for its Universal Cost Model UCM), through on-going collaboration with CFM project PIVOT, and through interaction with the key stakeholders in the RUN2Rail Advisory Group.

Initial work has led to the issue of a first deliverable on targeted impacts, and work is now proceeding on approach refinement, in order to have a framework ready for thematic WS input at the end of 2018.

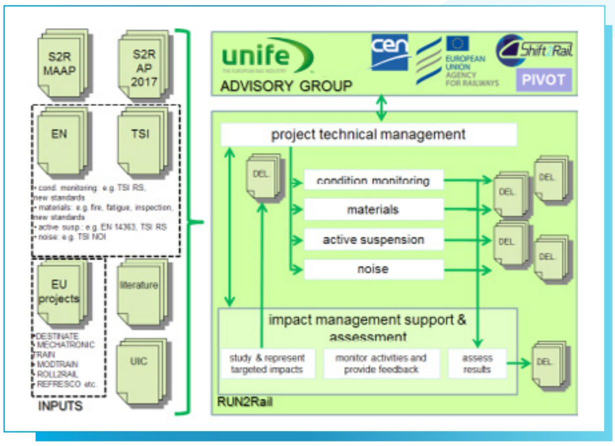

Fig. 14: RUN2Rail Advisory Group and relations with Standardisation and Regulation process

PARTNERS

Projectcoordinator

Technical leader

Beneficiaries

FACT & FIGURES

2.7 M
Total Project Value

15
partners

24
MONTHS

CONTACT US

Marta Andreoni (UNIFE)
Project Coordinator
Marta.andreoni@unife.org
www.run2rail.eu