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INNOWAG

__INNO__vative monitoring and predictive maintenance solutions on lightweight __WAG__on

Horizon 2020
European Union Funding
for Research & Innovation

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INNOWAG Project in a nutshell

Project coordinator: University of Newcastle upon Tyne
Total Budget:1.5ML
Duration: 01/11/2016 – 30/06/2019
Call addressed: *S2R-OC-IP5-03-2015*
Complementary CFM project: *S2R-CFM-IP5-01-2015 - FR8RAIL*

The Challenge

The **rail freight challenge** is to increase its competitiveness and attractiveness through a higher ***productivity*** and ***efficienc*y** as well as by adding ***novel features*** that would respond to new demands from customers and end-users.

Innovation in rail freight is, therefore, driven by both external drivers of change (such as demographics, globalisation, technology, sustainability, economic competitiveness, regulation) and internal drivers of change that are specific to the rail freight market (e.g., time and space, demand of new logistic services, complexity and sophistication of supply chains). Such requirements have to be fulfilled through development of hardware and software technologies to be implemented in new equipment design and management of information.

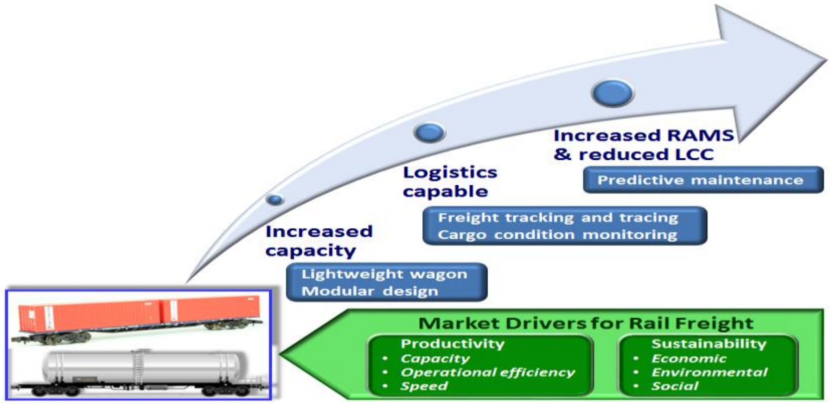


Figure 1: The INNOWAG Challenge

INNOWAG tackles the internal drivers of change, with the overall goal to increase the rail market share in accessible segments, and thus support the shift of freight transport to rail. INNOWAG develops innovations in **three macro-areas** "cargo condition monitoring, wagon design, and predictive maintenance", from concept to laboratory and real environment testing, for further integration and implementation.

The project objectives and approach

The concept underpinning the INNOWAG project, aims to address the actual needs of rail freight for increasing its competitiveness and attractiveness. The project, therefore, contributes to the development of rail freight services that fits the needs of modern manufacturing and supply chains.

The objective of the INNOWAG project is to develop intelligent ***cargo monitoring*** and ***predictive maintenance*** solutions integrated on a ***novel concept of lightweight wagon***, which would respond to major challenges in rail freight competitiveness, in relation to: increase of transport capacity, logistic capability and an improved RAMS together with lower LCC.

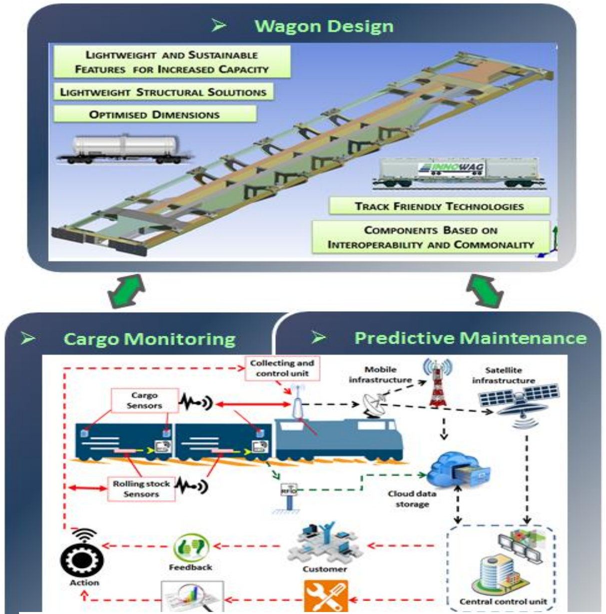


Figure 2:The INNOWAG Structure

The development of novel technology concepts, predictive maintenance models and procedures have been separately addressed by the INNOWAG work streams, which tackle the specific challenges in their essential areas:

- ***Cargo condition monitoring***: Development of an autonomous self-powered sensor system for cargo tracing and condition monitoring of key parameters for critical types of freight;
- ***Wagon design***: Development of a novel concept of modular and lightweight wagon;
- ***Predictive maintenance***: Development of an integrated predictive maintenance approach to enable efficient use of both remote condition monitoring and historical data, to further support the implementation of predictive models and tools in rolling stock maintenance programmes.

Work Stream 1: Cargo Condition Monitoring

The concept behind cargo condition monitoring is to develop an **autonomous self-powered wireless sensor** system for cargo tracing and condition monitoring of key parameters for critical types of freight, such as perishable goods, high value sensitive goods and dangerous goods. Energy harvesting technologies are employed for power generation; wireless sensor networks are established for data communication. This concept overcomes the main obstacles of wiring for power supply within the context of rail freight vehicles.

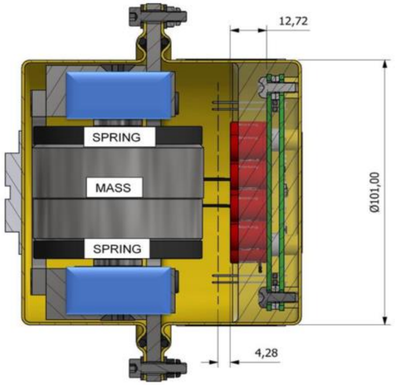


Figure 3: Sensor structure

Three system architectures have been designed, implemented and tested at different TRL within INNOWAG project:

1. The first, is **based on Bluetooth** for local communication between the sensors and the gateway, **GPRS** for remote communication between the gateway and the cloud serve and the solar power supply. The prototypes were validated in normal freight operation of a tank wagon in Romania (i.e. TRL 6).
2. The second, uses **RFID** technology for local communication between sensor and gateway. In this case, the passive RFID sensor node does not require external power supply. The communication distance is much shorter than Bluetooth. This architecture has been validated on a shunting locomotive in normal shunting operation (TRL 5).
3. The third, is based on **trackside RFID** solution, where the sensor data is obtained by the trackside RFID during the pass-by time, instead of GPRS. This architecture has been tested in a shunting yard for max. shunting speed (25 km/h) and different distances between trackside reader and onboard tag.

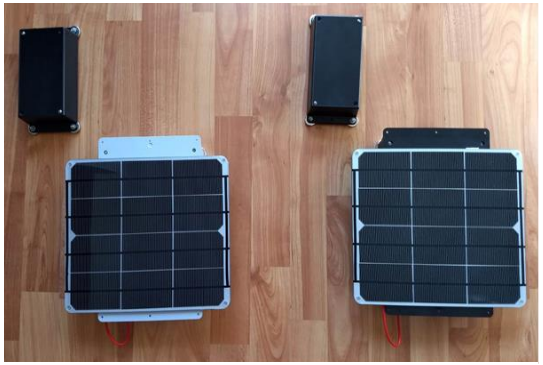


Figure 4: Bletooth based sensor prototypes

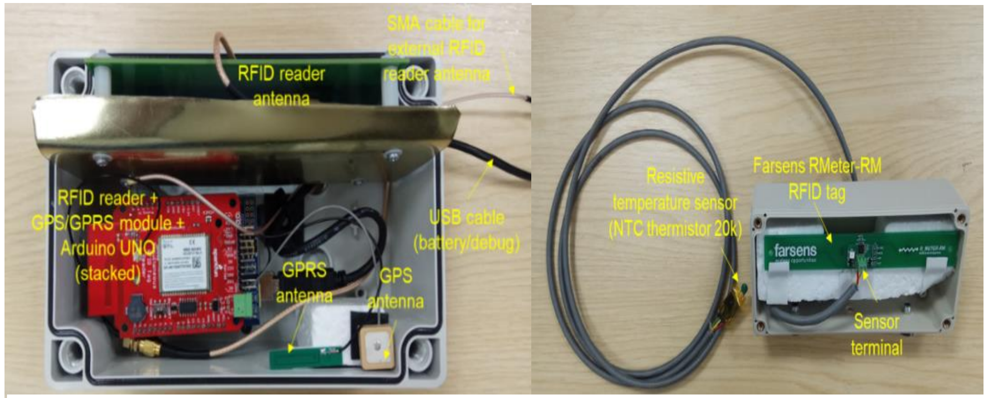


Figure 5: RFID based sensor prototypes

Vibration energy harvesting (VEH) at carbody level has been investigated, where the vibration level is significantly lower than axle bearings. Based on the existing Perpetuum's VEH (original designed for axle bearing installation), a prototype of VEH was developed and validated on a hoper good wagon in normal freight operations.

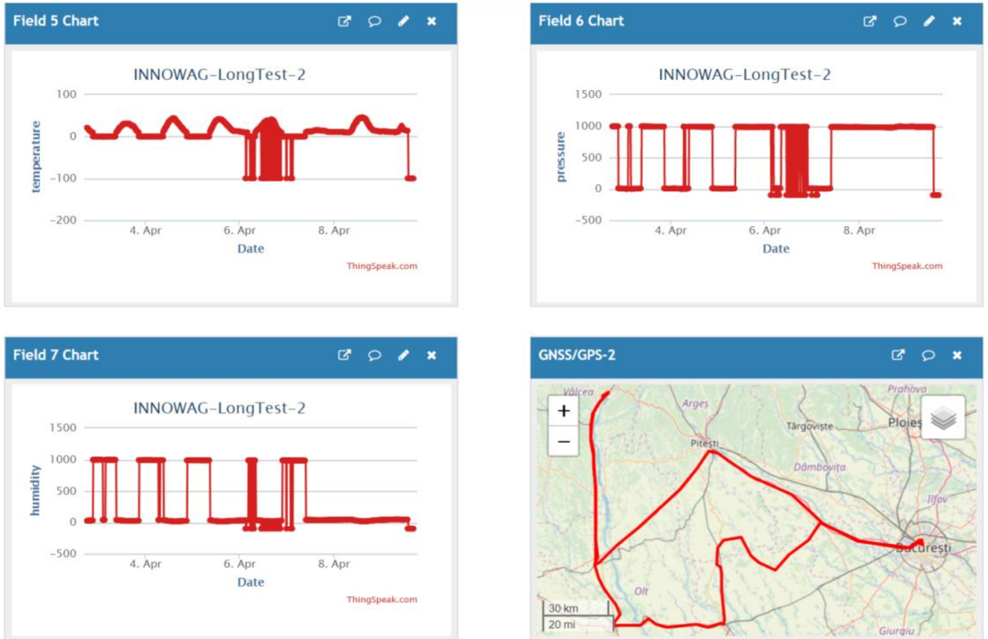


Figure 6: Monitoring results

Figure 7: Practical applications of the INNOWAG sensors

Work Stream 2: Wagon Design

The **specific objectives** of the INNOWAG Work Stream dedicated to wagon design and lightwear material are hereby listed:

- To develop a novel concept of modular and lightweight wagon through:
    - *Analysis and selection of lightweight materials;*
    - *Optimised structural design;*
    - *Modular components and/or sub-assemblies;*
- Structural strength and fatigue analysis of critical sub-assemblies;
- Validation of design concepts through specific laboratory tests.

Three different **lightweight solutions** have been investigated and developed within INNOWAG project lifetime. The most important are**:**

1. Lightweight bogie of the Y25 family (17% mass reduction)

The main characteristics of this innovative lightweight bogie are:

- *HSS bogie frame*
- *lightweight wheelsets and brake assembly*

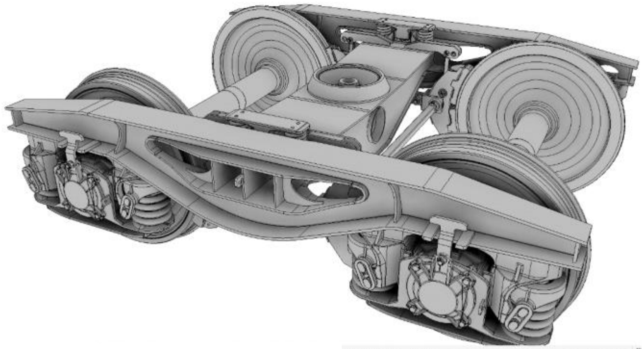


Figure 8: Lightweight Y25 bogie

2. **Lightweight 60‘ container wagon** (22% mass reduction)

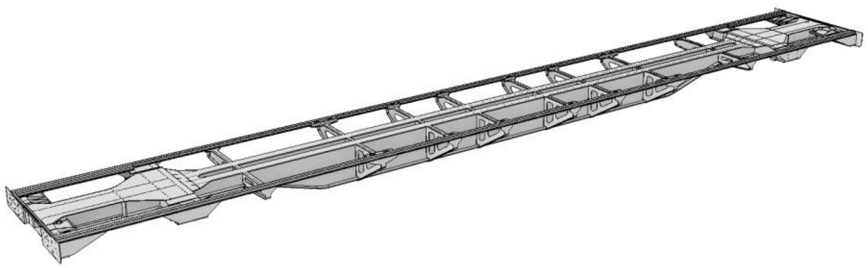


Figure 9: Lightweight 60' container wagon

3. **Lightweight cereal hopper wagon** (21–27% mass reduction)

The main characteristics of this innovative lightweight wagon are:

- *HSS underframe and bottom*
- *composite (GFRP) side wall panels*
- *lightweight bogies*

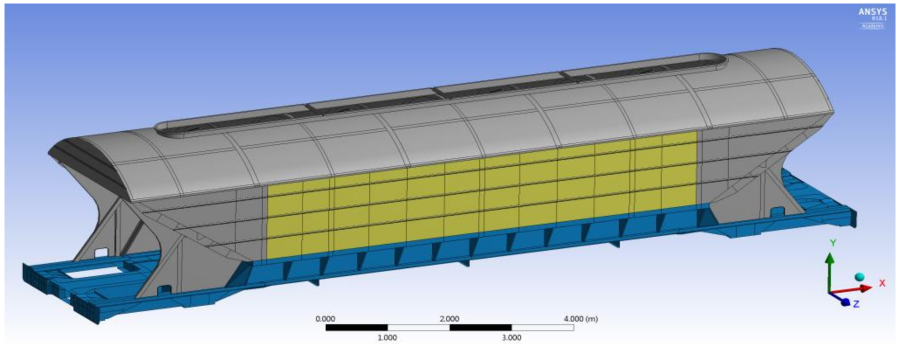


Figure 10: Lightweight cereal hopper wagon

Work Stream 3: Predictive Maintenance

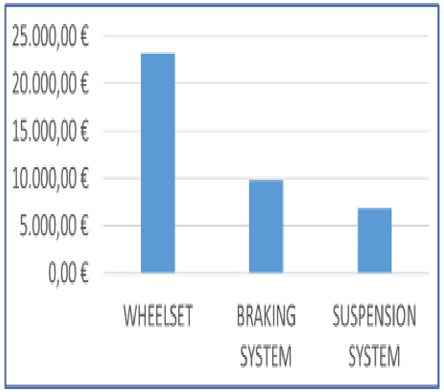
The development of approaches to support predictive maintenance on freight wagons materializes firstly in the **prioritisation of the failure modes** that could affect the wagon operation, and secondly in a tool able to integrate reliability and cost information for maintenance policy optimisation. This prioritisation of failure modes is performed through:

- a cost-driven analysis based on ***Life Cycle Cost*** (LCC)
- reliability-driven analysis based on ***Failure Mode and Effect Analysis*** (FMEA)

The results show that the most critical failure modes are the wheel flat and wheel out-of-roundness, followed by axle crack, broken helical coil spring and damage in bearings.

LCC application to component prioritisation and FMEA application to failure mode prioritisation

Net present value	WHEELSET	BRAKING SYSTEM	SUSPENSION SYSTEM
NPV	23.228,77 €	9.770,56 €	6.872,42 €
Critical components	1	2	3



Failure	GCU code	Nc (failure per 100 sub-assemblies)	Failure rate	Frequency rank	GCU class	GCU control criteria	Severity		Detectability		Frequency		Risk Priority Number (RPN)
axle crack	1.6.1.1	2	1.31E-06	4	5	VC	unsafe without warning	10	moderate	5	low: relatively few failures	3	200
wheel out of round	1.3.3; 1.7.2; 1.7.2.1	23	6.04E-06	6	4	M; VC/VC	very high	8	very low	7	moderate: often there are failures	6	336
wheel crack	1.3.5; 1.3.6; 1.5	4	3.50E-07	3	4	M; VC/VC	very high	8	very low	7	low: relative few failures	3	168
Wheel: build-up of material	1.3.4;	3	1.97E-06	4	4	M	very high	8	very low	7	moderate: seldom there are failures	4	224
wheel thermomechanical crack	1.3.5; 1.3.6; 1.5	4	3.50E-07	3	4	M; VC	very high	8	very low	7	low: relatively few failures	3	168

Figure 11: LCC appication to component and FMEA application to failure mode prioritization

The cost and reliability-driven analysis led to the development of a **Wizard Tool** (WT), whose backbone is the ***Proportional Hazards Model*** (PHM), able to integrate historical data with condition monitoring data. This is key for maintenance optimization policy. The tool is integrated by an LCC analysis to optimise the policy in a cost-effective manner. The WT provides info about improvement of both the inspection interval and the maintenance policy. It is empowered by a graphical user interface to provide practical support to the maintenance operator in data input and result visualisation. It is applied to the wheel flat failure mode scenario (the most critical failure mode), and the results show the potential for improvements to the maintenance policy. A graphic representation of the WT structure and of how the WT interface appears, is shown in the figure 12.

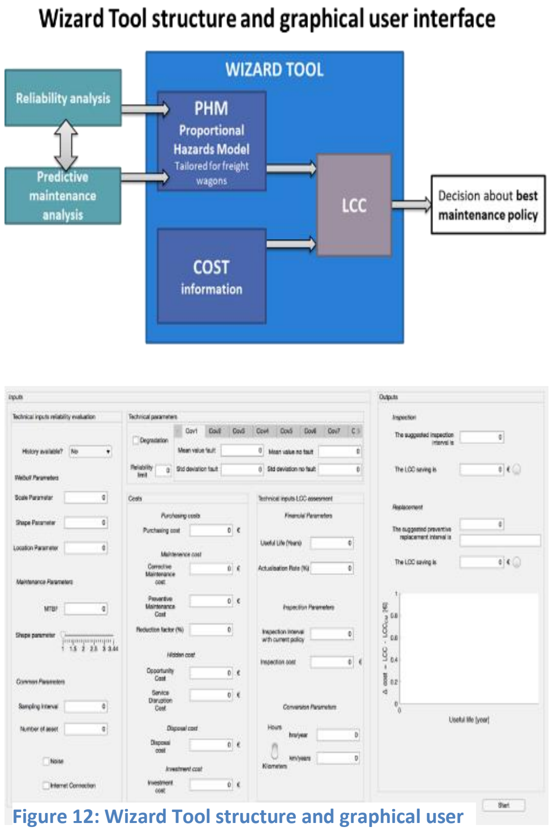


Figure 12: Wizard Tool structure and graphical user interface

INNOWAG Disseminaion Activities

In order to raise awareness on the INNOWAG findings and outcomes, ensuring their widest possible dissemination and uptake, several dissemination and communication activities have been performed throrought INNOWAG project lifetime. Objectives of these activities are: to disseminate and communicate the INNOWAG project progresses and achievements, in order to generate consensus and support building on the innovations and intelligent solutions in the three INNOWAG project WS; to develop and maintain a project website both as a dissemination tool open to the general public and as a cooperative intranet tool between partners. INNOWAG project outcomes have been disseminated and communicated to targeted audiences through appropriate tools, both virtual/interactive and physical. The support building was achieved through a comprehensive set of dissemination initiatives capable of catching the attention of targeted stakeholders, opinion leaders, academia, associations, research institutes, authorities, end users and general public at large. Dissemination activities increased awareness on the INNOWAG project and provided information on ongoing initiatives regarding the interested parties. Traditional tools for selected targets and web-based networking means for wider audiences have been used as regular working instruments for dissemination purposes, reaching instantaneously wide audiences. A **dissemination and communication plan** summarizing the dissemination tools to be utilized throrought INNOWAG project lifetime, with clear indication of the targeted addressed audiences was released at the project start. After the Kickoff meeting in Newcastle, a **press release** was distributed to more than 50 newspapers, magazines and press contacts. A project **logo** and a **website** was created. Three **newsletters** have been drafted and shared: one after the project start, one at TRA2018 and one at the project end. The second and third newsletters have been issued in a shape of **brochures** distributed at conferences and exhibitions. All this material was included in the *Transport News* international newsletter. Two **articles** were published on the specialized review *Baltic Transport Journal* and on *Railways2018*. Two **posters** and two **research papers** have been prepared for the international event TRA2018 in Vienna. An additional poster was prepared for the INNOWAG final event in Munich. A **flyer** was prepared and distributed during international events. INNOWAG partners shared the project outcomes and results, distributing dissemination material in several conferences, meetings, exhibitions&fairs, congresses, such as Transport&Logistics Munich 2017, Rail Industry Association Innovation Conference Hinkley 2017, F&L annual conferences Glasgow 2017 and Madrid 2018, TRA2018 Vienna, STECH 2018 Barcelona, Innotrans Berlin 2018, SmartRail Munich 2019. Workshops, lectures, seminars and meetings sharing INNOWAG outcomes have taken place In Hamburg, Berlin, Bremen, Dresden, Wiesbaden, London, Rome, Milan, Turin.

Figure 13: Dissemination at TRA2018 Vienna