


NEWSLETTER

September 2018

INTRODUCTION

SMaRTE - Smart Maintenance and the Rail Traveller Experience - is one of the latest EU projects that answers the Cross-Cutting challenges proposed in the framework of Shift2Rail Programme.

SMaRTE brings together two complementary research areas. Smart maintenance and human factors are both practical aspects of digitisation and the use of information to enhance decision making, either by industry players in respect of maintenance decisions, or by users of the system in employing smart applications to navigate the rail system and its potential interactions with other modes and/or ancillary services.

SMaRTE will provide the methodology for implementation of a Condition Based Maintenance system which works for passenger railways and will result in reduced system costs and improved system reliability. Moreover, SMaRTE will identify and quantify a set of key factors influencing rail usability, proposing recommendations to enhance the attractiveness of the system in what is called a "Smart Journey Vision", e.g. recommendations addressing how to decrease the travellers' cognitive effort when moving.

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SMARTE CHALLENGES

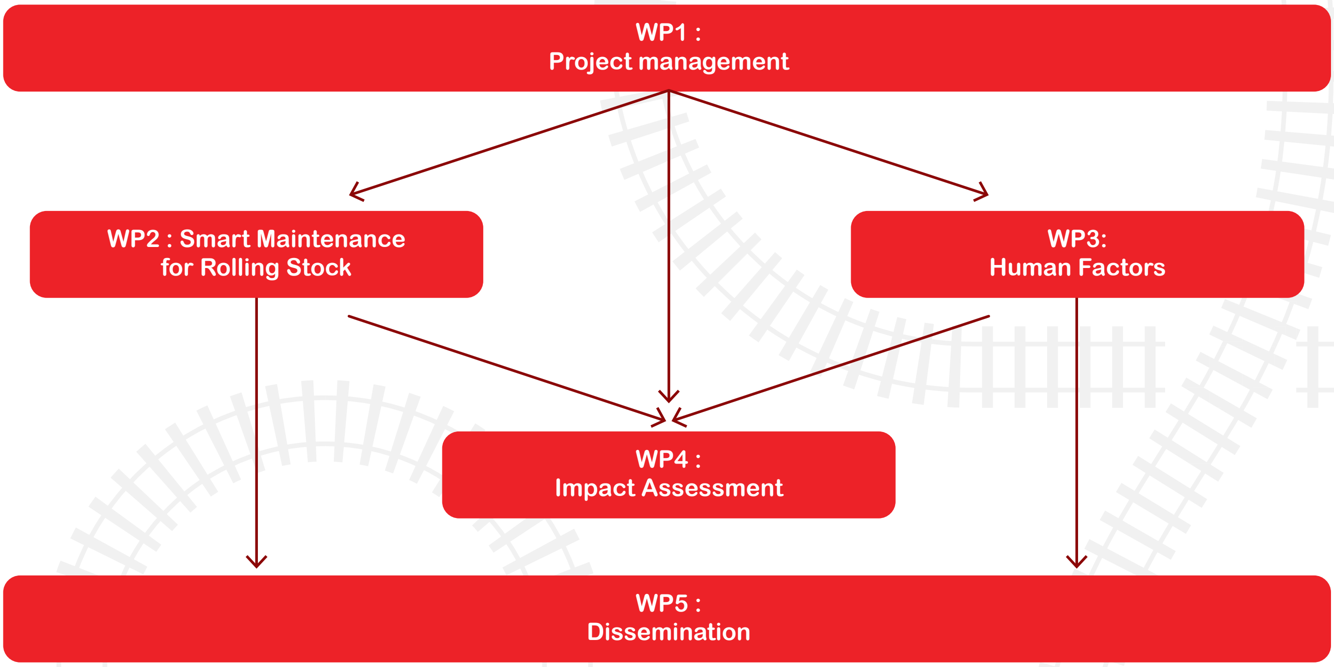

Figure 1: SMaRTE challenges

The structure of SMaRTE is two-fold: one set of tasks focused on the improvement of the maintenance of the rolling stock, the second set focused on a better understanding of the travel choice by potential passengers. These two work-streams will culminate in a joint impact assessment activity which ensure a full system approach. Other supporting activities such as dissemination, management and coordination are also considered as part of the regular project activities.

SMaRTE develops across two thematic Work Streams:

- Smart Maintenance: SMaRTE aims to improve current railway train maintenance systems, through the integration of predictive data analysis algorithms and online optimization tools within an improved Condition Based Maintenance (CBM) strategy

- Human Factors: SMaRTE aims to understand the current and future needs of rail passengers characterised by rapid advances in technology and demographic changes. SMaRTE will ensure a readjusted human centred design system by identifying the most relevant aspects of the travellers' experience which could be improved and simplified through information and mobility support.

SMaRTE INTERACTION WITH S2R

SMaRTE brings together two complementary research areas. The human factors work links to Work area 6 of the CCA-Cross Cutting Activities in the Shift2Rail programme called "Human Capital". This area aims to bridge the gap between the latest changes in the railway and other sectors imposed by rapid technological advances and substantial demographic changes.

Specifically this call links to customer oriented design of mobility. The smart maintenance work links to work area 3 of the CCA-Cross Cutting Activities, specifically sub work area 3.3, Smart Maintenance. An objective of this area includes the development of an overall maintenance concept featuring R&D activities for condition-based monitoring.

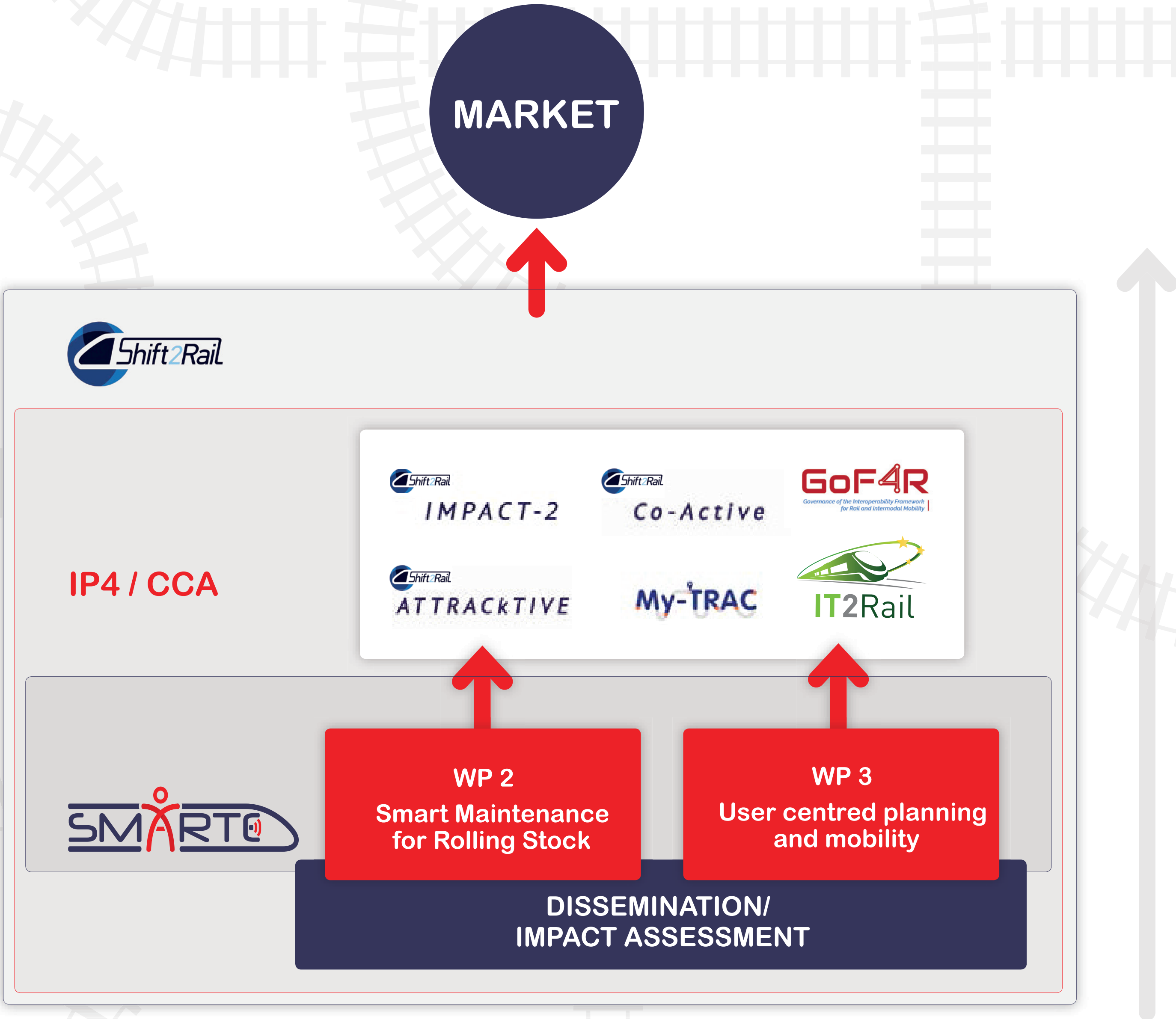

Figure 2: SMaRTE interaction with Shift2Rail

SMART MAINTENANCE FOR ROLLING STOCK

The research being conducted during WP2 is targeted towards the better use of information and modelled relationships to improve rolling stock maintenance based on the actual condition of a component or asset.

The aim of the smart maintenance research within the SMaRTE project is to investigate the use of a Condition-based Maintenance (CBM) approach to develop the most suitable solutions for predictive and corrective maintenance in railway vehicles. This will build on experiences and knowledge of the application CBM techniques from other industry sectors and will include intelligent data analytics to identify trends and predict component degradation/failures.

The developed approaches will be demonstrated on a range of vehicle components using real in-service data acquired from the industrial project partners and in-collaboration with the Shift2Rail CCA project, IMPACT-2. The outputs from WP2 will also support the Impact Assessment being conducted during WP4 which will demonstrate the impact of the approaches developed in the research.

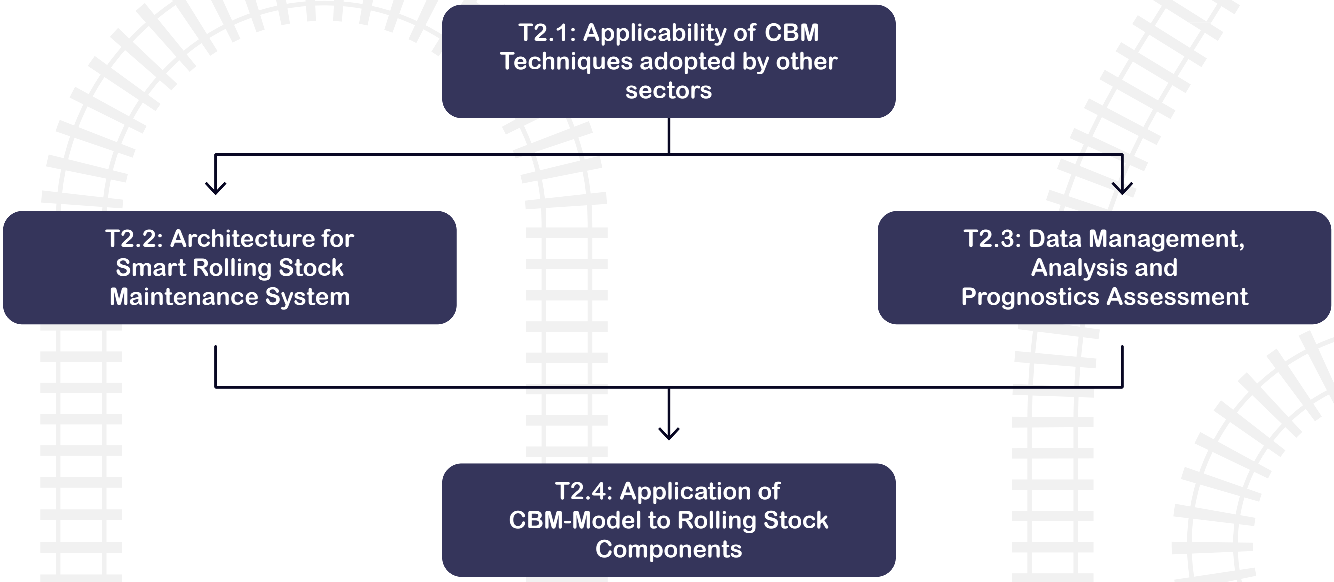

Figure 3: WP2 tasks for a better understanding of smart maintenance for rolling stock

Main achievements so far and next steps

T2.1: Applicability of CBM applications adopted by other sectors

This first task of WP2 reviews the CBM techniques applied to other technical systems, with a specific focus on the experiences from other industry sectors particularly with reference to the knowledge generated in the aerospace field.

The aim of Task 2.1 is to introduce the proven experience gained through the application of MSG-3 methodologies, in the development of a scheduled CBM based aircraft maintenance program. In particular the objective is to evaluate the potential benefit of a system such as MSG-3 to the railway industry for the development of an effective and efficient rolling stock maintenance programme. To achieve the purpose of this research, literature studies have been undertaken and empirical data and information have been collected through document studies, interviews, questionnaires, observations, combined with the published best practices from the aviation industry.

The deliverable for Task 2.1 describes the evolution of a scheduled CBM methodology within the aviation industry and provides an overview on the "aircraft maintenance program development" (Figure 4). The underlying concept, principles and processes of MSG-3 are presented and the details of each maintenance strategy is discussed with a specific focus on inspection/functional check. The current practices in the rolling stock industry for development of maintenance programs has also been reviewed and discussed. In addition, an assessment of current use of CBM in European train operating companies is provided.

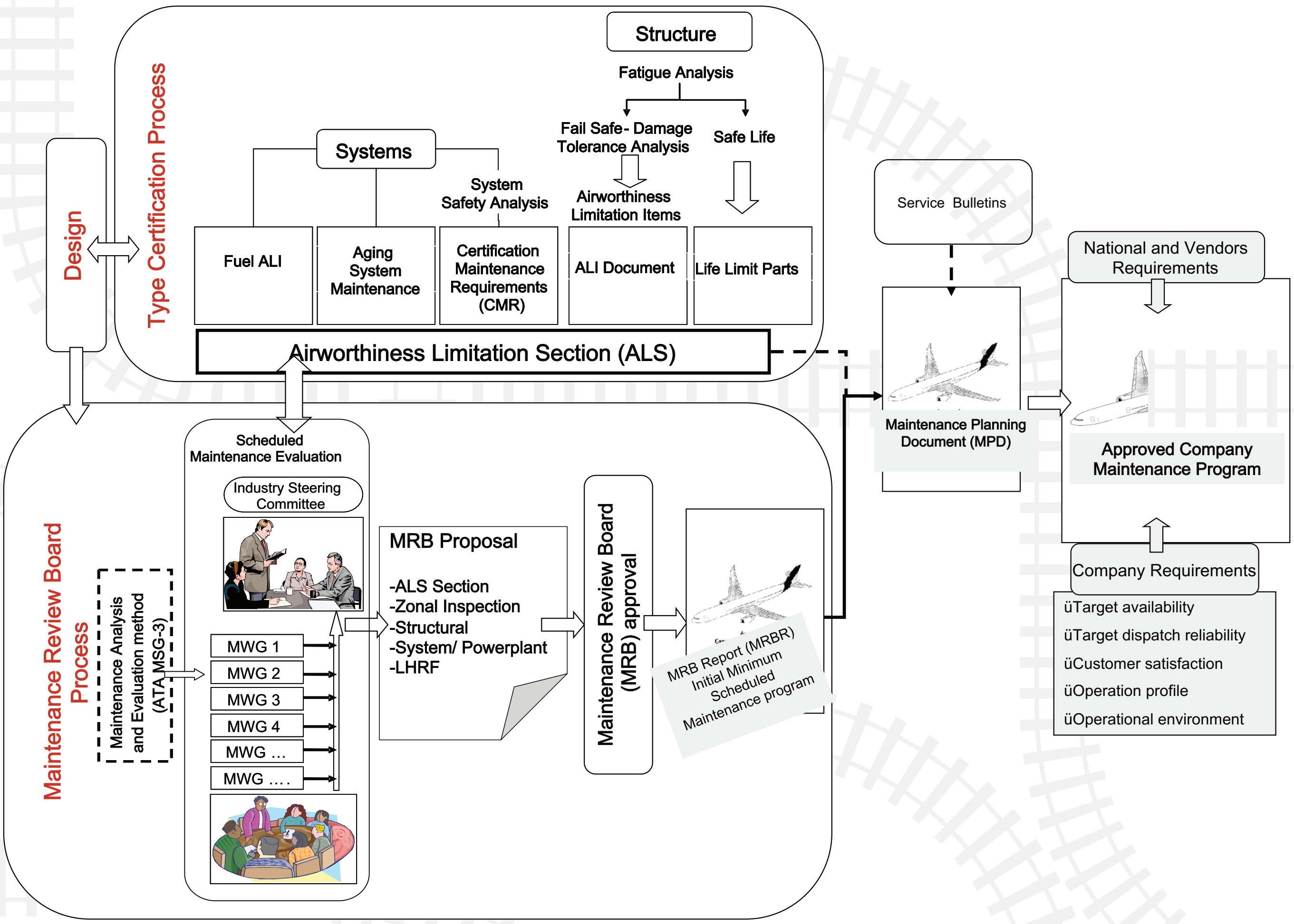

Figure 4: Process mapping of aircraft maintenance program development

This concluded that the current maintenance strategies for rolling stock are generally characterized by a combination of both corrective and preventive (interval-based) maintenance. However, the selection of an optimum strategy can often be subjective with little reference to scientific proof. The selection of an appropriate strategy will have a significant impact on the life cycle costs and benefits to the system and should be analysed in a scientific manner. Therefore, techniques and methods to find the optimum solutions need to be implemented in order to improve the maintenance of railway systems.

Based on the results obtained through this study, it is highly recommended that a task force is established within the railway industry to harmonize the regulations among stakeholders and railway authorities, for development of rolling stock's inspection/CBM programs. In this process, the study also suggests that rolling stock stakeholders should establish a Maintenance Review Board to develop a specific maintenance program and share their data and experiences. Special attention should be given to the identification of Maintenance Significant Items, definition of applicability and effectiveness criteria and determination of maintenance intervals. It is also vital to implement a "maintenance reliability and surveillance programme" to evaluate and control the effectiveness of the developed maintenance program.

T2.2: Study of domain-specific architecture for smart rolling stock maintenance system and its semantic interoperability

The aim of this task is to propose a domain-specific architecture for a smart railway maintenance system which includes a unified railway-specific ontology model of maintenance management. This model will be a reliability/maintenance-driven ontology model, which can be seen as a bridge between data (e.g. historical and online monitored), derived component reliability information and maintenance information (e.g. maintenance tasks are performed for safety, operational, or economic reasons).

The initial work on this task has focused on a) exploring the feasibility of a systematic approach to establish the relationships between available data sets and system components and their common failure modes; b) the development of a schematic model for a process management system for rolling stock maintenance. This includes the identification of the parameters that have an influence on reliability and maintenance of specific system/components.

T2.3: Data management, analysis and prognostics assessment

The aim of this task is to explore and select a range of techniques of data management, analysis and failure prognostic for the assessment of rail vehicle component degradation and performance variations using the available condition data.

There are two main classes of prognostics assessment: data-driven prognostics (derived directly from routinely monitored system operation/health data) and model-based prognostics (prediction of a system's degradation via a series of simulations). Both of these approaches are built on a good understanding of the system model (including its functioning and failure logic models). Through collaboration with industry partners, the key parameters affecting a components reliability and maintenance have been identified using the systematic approach proposed in Task 2.2. The potential failure modes and their effects on the systems function and severity of the consequences for the system and its components have been established for a range of components/systems. The availability of condition data to monitor and model the specific failure modes has been reviewed.

The next step is to perform data analysis on the structured datasets. Techniques (e.g. signal processing, pattern recognition and statistical methods) for fault diagnosis, prognosis and feature extraction have been reviewed in the initial stages of this task. This includes fault diagnosis techniques to detect abnormal operating conditions, determine the component which is failing (or has failed) and estimate the nature and extent of the fault or failure.

As well as the development of the dynamic CBM techniques, longer-term tactical and shorter-term operational optimisation models have also been developed to have a better plan of preventive maintenance activities. These mathematical decision models (for example Analytic hierarchy process (AHP) and Mixed-Integer Linear Programming (MILP)) take all the constraints related to the preventive maintenance actions into account and seek a relative best solution to satisfy these operational constraints. The techniques will be validated using data provided by project partners Fertagus and London Underground.

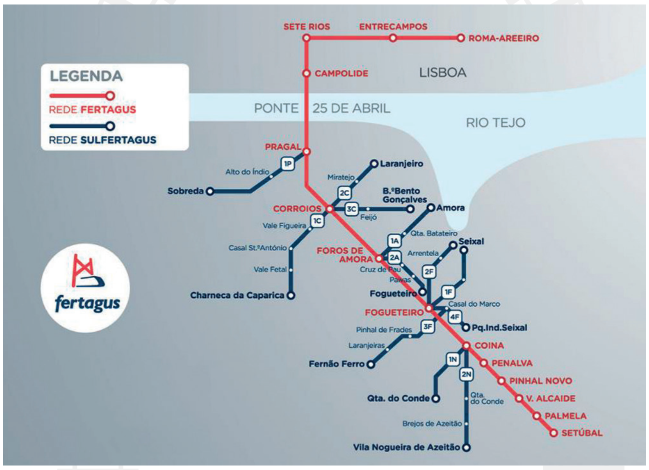

Figure 5: Fertagus rail map (source: Fertagus website)

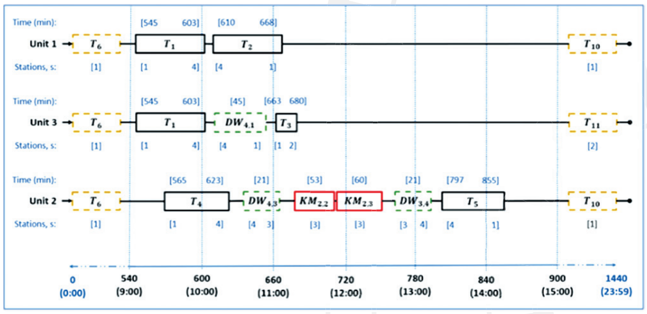

Figure 6: Summary of rolling stock tactical plan

T2. 4: Impact Assessment of introducing CBM in railway train maintenance

The final task of WP2 includes the application of the developed CBM techniques and architecture to a range of vehicle systems and components' using real data from specific train fleets. This will assess the impact and benefits of introducing a CBM-model into the railway industry and will initially include the following case studies:

- Vehicle systems and running gear
- Wheelset maintenance

These case studies will demonstrate the use of the CBM model and data analysis techniques within the rolling stock maintenance environment and provide important validation and guidance for future implementation. This will allow impact and benefits to be assessed in WP4 will be assessed using life-cycle techniques, such as life-cycle cost (LCC) and life-cycle assessment (LCA), to provide an overall socio-economic and environmental assessment of the shift towards a CBM regime.

HUMAN FACTORS: USER CENTRED PLANNING AND MOBILITY

SMaRTE “human factors” work-stream aims to have a better and updated understanding about the current and close-future needs of rail passengers. Thanks to its outcomes, this work stream will contribute to a friendlier human centered rail system by identifying the key aspects of the customer experience which could be improved and simplified through information and mobility support.

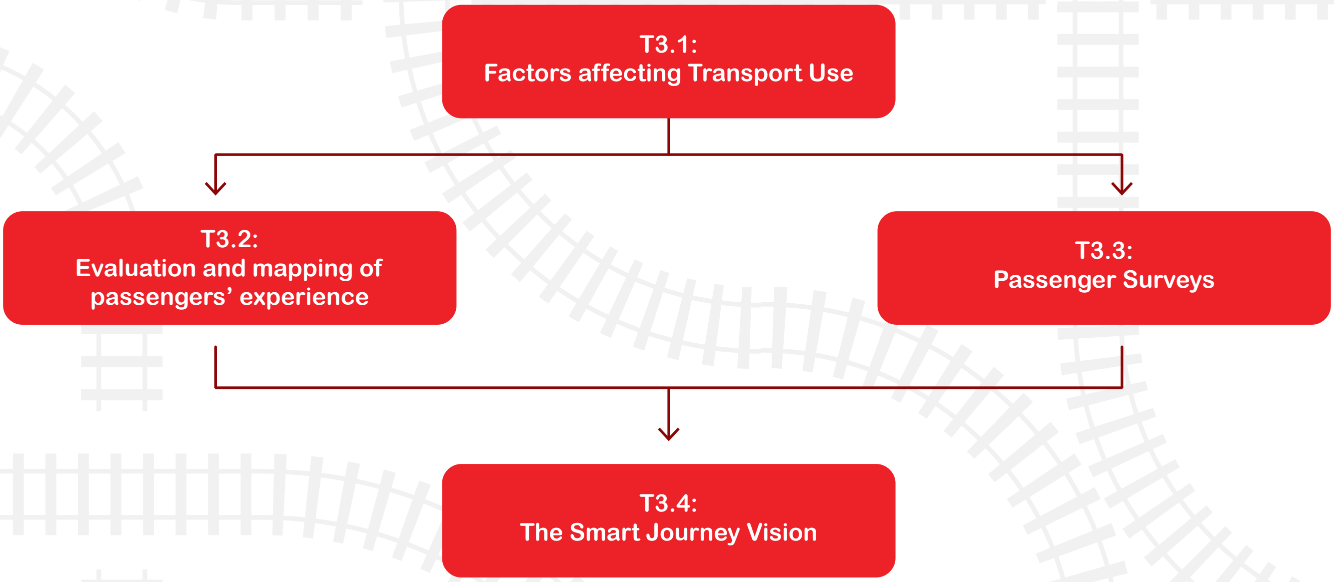

Figure 7: Tasks easing the path towards a deeper human factors understanding

Main achievements so far and next steps

T3.1: Factors affecting Train Use

The first task of the “human factors” Work package aims at identifying macro trends and factors influencing passengers’ choices and connected behaviours, as emerging from the literature survey. The review is performed to feed the subsequent definition of user profiles (personas) in Task 3.2 and the survey to be performed in Task 3.3. The review has identified macro trends affecting train use, from societal need for decarbonisation, to demographic evolution and lifestyle changes, autonomous driving systems evolution, climate change, ICT and IoT development and sharing economy.

The comprehensive literature survey led to the selection of 7 research project and 20 scientific papers regarding macro trends and rail use. The review outcome indicates which and how the surveyed societal trends influence the main aspects of the journey, with a particular emphasis on those within the control of train operators. The work is input for the composition of the Experience Map in Task 3.2.

T3.2: Evaluating and mapping passengers' experiences

Starting from Task 3.1 outcomes, Task 3.2 deepened the understanding of the factors affecting the perceived usability and passenger experience of rail services. The investigation consisted in activities leaded in three countries (i.e. Belgium, Italy, United Kingdom) both with key industry stakeholders (i.e. workshops) and rail services final users (i.e. focus groups).

The result of these qualitative research activities is the creation of the Rail Journey Experience Map: a visual graphic representation of passengers' experiences while behaving in the real context, performing activities to reach their prefixed objectives. The core objective of the Experience Map is depicting all the elements which compose the passenger experience: the context of use, the users' characteristics and needs, the possible usability issues and strong points of the travelling experience.

Picture 1: 1st stakeholders' workshop (Dublin) on the understanding of the rail e-traveller experience

Picture 2: stakeholders' workshop (Leeds) on the understanding of the rail traveller experience

T3.3: Passenger Surveys

The goal of this task which is now underway is to perform surveys on a large number of representative transport users, including non-rail users, to define the influence of key factors on the choice of transport mode, including railway. Inputs to the survey design will be taken from Tasks 3.1 and 3.2. Through quantitative analysis of the collected data it will possible to measure passenger perceived usability of travel experience, overall satisfaction, effort in having a problem solved, loyalty to a service and attrition factors for each activity in the journey. The results will input into the re-positioning of the "Experience Map" as part of Task 3.4.

T3.4: The "Smart Journey" Vision

Based on the previous activities, the results and conclusions achieved will be re-studied and presented to the transport –in particular rail- stakeholders in an industry and policy facing "Smart Journey" vision. There, a collection of recommendations and technical solutions will be proposed so to define a realistic implementable 'Railmap'. This document will contribute to the further understanding of key measures to simplify the end-user experience of planning and undertaking a trip that includes a rail journey.

GLOBAL IMPACT ASSESSMENT

In order to ensure that the specific proposals developed in SMaRTE may sustain clear business and financial cases, with barriers to implementation identified and solutions proposed, the objectives of this activity are to:

- Develop metrics to demonstrate the impact of the outcomes developed in SMaRTE in line with achieving the relevant KPIs of the S2R JU. With respect to the call document and the MAAP, the proposals outlined in this project will primarily contribute towards cost reduction (KPI1 in the call; MP4 and MP5 in the MAAP), and increased reliability and availability of rolling stock and increased quality / attractiveness of the rail system / mode shift (KPI3 in the call and MP1, MP3 and MP6 in the MAAP);
- Establish the business case for the proposed innovations to demonstrate how they may generate an overall net benefit to society. The outputs will be expressed as a set of net present values;
- Establish the financial case to demonstrate the viability for the different parts of industry, considering a system approach where costs may be imposed on one part of the system, whereas benefits may accrue elsewhere.

The analysis will be conducted for the previous work-streams' outcomes, with extrapolations to yield high level estimates of impacts, assuming the solutions are rolled out more widely across Europe.

Figure 8: **Towards a global assessment of the two thematic Work Streams**

Main achievements so far and next steps

The Impact Assessment is structured into two main tasks:

- Task 4.1: Initial Statement of Methodology and Data Requirements – Deliverable 4.1 (completed in Month 4 of the project).
- Task 4.2: KPIs, Business and Financial Case Assessment – Deliverable 4.2 (to be completed in Month 24 of the project).

Task 4.1 was delivered on time (see Deliverable 4.1) and set out the methodology to be used in the impact assessment and the data requirements for smart maintenance and human factors.

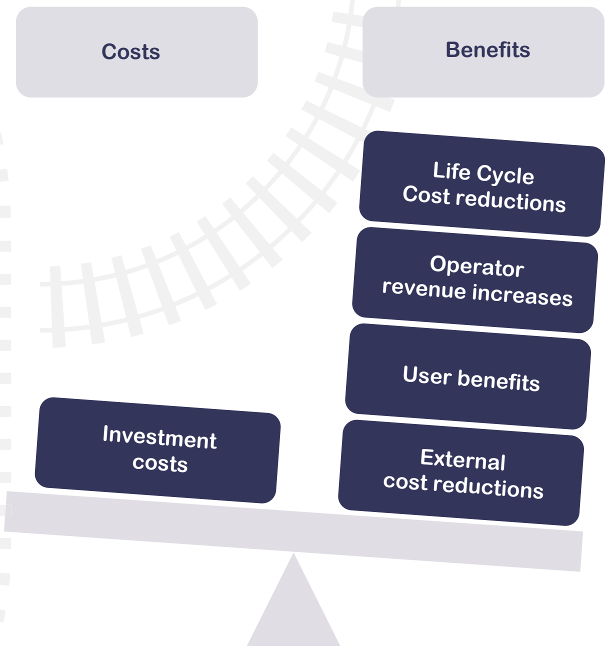

Figure 9: **Costs and Benefits in the impact assessment**

With respect to smart maintenance, WP4 assesses the CBM techniques and architecture proposed in WP2 using life-cycle techniques to provide an overall socio-economic and environmental assessment of the shift towards a CBM regime. The basic approach is to compare the Do-nothing scenario, which is characterised by periodic maintenance, versus the Do-something scenario, which is the proposed CBM. This latter approach will involve more frequent and tailored maintenance of some components (relatively low-cost activities); thus, requiring the more expensive/major maintenance activity to occur less frequently.

In particular, within the life of the asset, this approach may result in the removal of one or more major overhaul activities (i.e. pushing them beyond the end of the life of the train). It could also bring some reliability benefits resulting from reduced failures if faults are identified earlier, and improved availability of rolling stock as there is less need for the large maintenance activities that keep trains totally out of action for a long period. Note that most benefits of the CBM model will come from existing fleets, as newer fleets might already integrate/include better on-board sensors to feed a smart CBM approach, and new depots might include the flexibility to increase capacity when needed.

The impact assessment of the CBM model will be carried out in case studies specifically on "Wheelset maintenance" and "Vehicle systems and running gear" based on real data provided by Fertagus in Portugal and London Underground in the UK.

With respect to human factors, WP4 assesses the impact of perceived barriers (to be identified in Tasks 3.1-3.3) in terms of system loss at different points in the process or benefits added through addressing perceived barriers to rail travel. These measures can be expressed in number of passenger journeys, contributions to mode shift, generalized travel costs, consumer surplus, producer surplus, and environmental benefits associated with mode shift (collectively leading to an assessment of the impact on overall social welfare). Additionally, these measures will be evaluated in conjunction with the enhancement scenarios (to be framed in Task 3.4) to illustrate how impacts can be achieved though the scenarios' impact on attrition factors.

Table 1 below summarises the likely costs and benefits to be evaluated.

Benefit/Cost		Relevant to WP2	Relevant to WP3
Life cycle cost	Change in maintenance regime	√	
	Reduction in rolling stock maintenance costs	√	
	Reduction in up-front component costs	√	
	Reduction in component failure and replacement costs	√	
Operator revenue	Increase in revenue resulting from change in service (due to improved availability of rolling stock)	√	
	Increase in revenue resulting from demand growth		√
User benefits	Improved reliability (fewer delays / cancellations)	√	
	Improved accessibility		√
	Improved usability		√
	Improved comfort		√
	Reduction in generalised travel cost	√	√
External costs	Reduction in infrastructure cost of rail and competing modes	√	√
	Reduction in congestion in alternative modes		√
	Change in indirect tax revenue		√
	Reductions in environmental costs (i.e., air pollution, noise pollution, greenhouse gases)	√	√

Table 1: List of costs and benefits

Since the production of Deliverable 4.1, establishing the assessment framework, work has begun to collect the necessary data to complete the impact assessment.

PAST AND UPCOMING EVENTS

20/03/2018, London, UK – Wheelsets: More for Less, Institution of Mechanical Engineers Seminar

11/04/2018, Dublin, Ireland – 1st stakeholders' workshop on the understanding of the rail e-traveller experience

16-19/04/2018, Vienna, Austria – Transport Research Arena (TRA)

26/05/2018, Leeds, United Kingdom – 2nd stakeholders' workshop on the understanding of the rail traveller experience

25–27/06/2018, Bologna, Italy – EURO/ALIO on Combinatorial Optimization conference

12/07/2018, Rome, Italy – 1st passengers' workshop on the understanding of the rail e-traveller experience

18-20/07/2018, Leeds, United Kingdom – 2nd passengers' workshop on the understanding of the rail e-traveller experience

September 2018, Milan, Italy – 3rd stakeholders' workshop on the understanding of the rail e-traveller experience

18-21/09/2018, Berlin, Germany – InnoTrans

10-12/10/2018, Dublin, Ireland – European Transport Conference (ETC)

28/10-01/11/2019, Tokyo, Japan – 12th World Congress on Railway Research (WCRR)

FACTS AND FIGURES

TOTAL BUDGET
0.7 MILLION

PARTNERS
11

DURATION
24 MONTHS

PROJECT START DATE
01/09/2017

PROJECT END DATE
31/08/2019

GRANT AGREEMENT N°
777627

PARTNERS

PROJECT COORDINATOR

UNIVERSITY OF LEEDS

BENEFICIARIES

ergoproject – Studi ergonomici applicati

fertagus

fit – Moving innovation

University of Huddersfield

Técnico Lisboa

Luleå University of Technology

Transport for London

Luleå Flygteknik AB

UITP – Advancing Public Transport

unife – The European Rail Industry

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