NEWSLETTER

September 2019

INTRODUCTION

The general objective of S2R is to seek solutions to improve the performance of rail services across Europe, targeting a 50% reduction in the life-cycle cost of the rail transport system, a 100% increase in capacity, and a 50% increase in reliability and punctuality; and improving the customer experience.

Maintenance of rail vehicle systems is one of the biggest factors to achieve these performance targets. It has been demonstrated that Condition-Based Maintenance (CBM) is a reliable and cost-effective maintenance regime in the aerospace industry. In the railway industry, it is therefore reasonable to believe that a reliable CBM system, which manipulates the measured data or signals is able to identify the operational condition of vehicle system, diagnose the degradation of the critical component and even predicts future maintenance schedule.

Better understanding of the needs of passengers in accessing rail services, including the barriers and enablers to rail usage, taking into account the end-to-end journey, is crucial to delivering an improved passenger experience and in turn growing rail usage. Whilst extensive evidence exists on some factors influencing rail usage (e.g. reliability and crowding) the impact of some of the softer factors are much less well understood.

SMaRTE brings together these two related but distinct areas of research: Smart Maintenance and Human Factors. The relationship lies in the fact that both these areas are concerned with 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 interaction with other modes.

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The content of this publication reflects only the author's view and that the JU is not responsible for any use that may be made of the information it contains.

SMART MAINTENANCE FOR ROLLING STOCK

The aim of WP2 of SMaRTE is to **investigate the use of a Condition-Based Maintenance (CBM) approach for predictive and corrective maintenance in railway vehicle components/systems.** To achieve this aim we set out the following objectives:

- Build on experiences and knowledge of application of CBM from other industry sectors (T2.1)
- Intelligent analysis of condition and diagnostic data to identify trends and predict component degradation/failures (T2.2 and T2.3)
- Scheduling and planning (T2.3)
- Demonstrated on a range of vehicle components (T2.4)

D2.1 Applicability of Smart Maintenance Techniques Adopted in Aviation Industry

Over the past decades, significant improvement has taken place in the development of an applicable and effective Condition-Based Maintenance. One of the major developments has taken place in the aviation industry with the introduction of on-condition inspection/condition based maintenance through the Maintenance Steering Group (MSG-3) concept.

MSG-3 methodology implicitly incorporates the principles of Reliability Centered Maintenance (RCM) to justify task development and incorporates an efficient maintenance decision logic for the selection of an applicable and effective maintenance program.

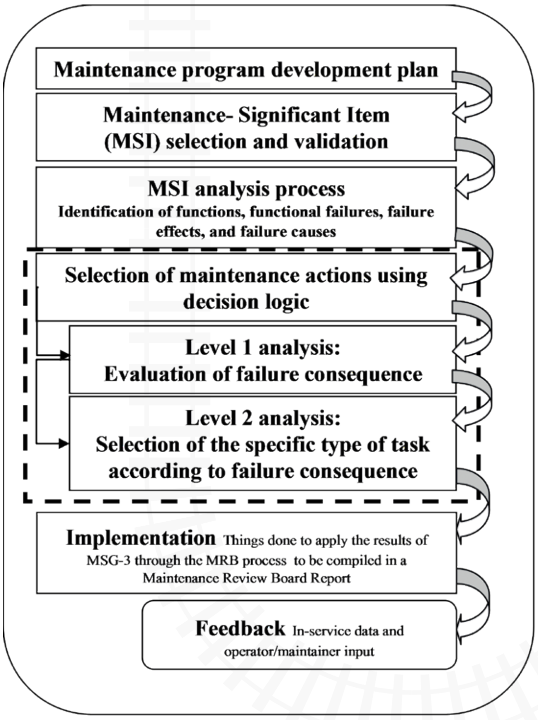


Figure 1 : MSG-3 process for Aircraft maintenance analysis

This deliverable provides a summary of the evolution of a scheduled CBM methodology within the aviation industry and provides an overview of the MSG-3 methodology. The advantages of the MSG-3 methodology is the application of on-condition inspection, CBM and the introduction of a risk-based approach to define maintenance requirements.

In rail industry, a risk-based RCM has been adopted and considered in the EU standard. The procedure for safety significance analysis is illustrated in figure 2 below.

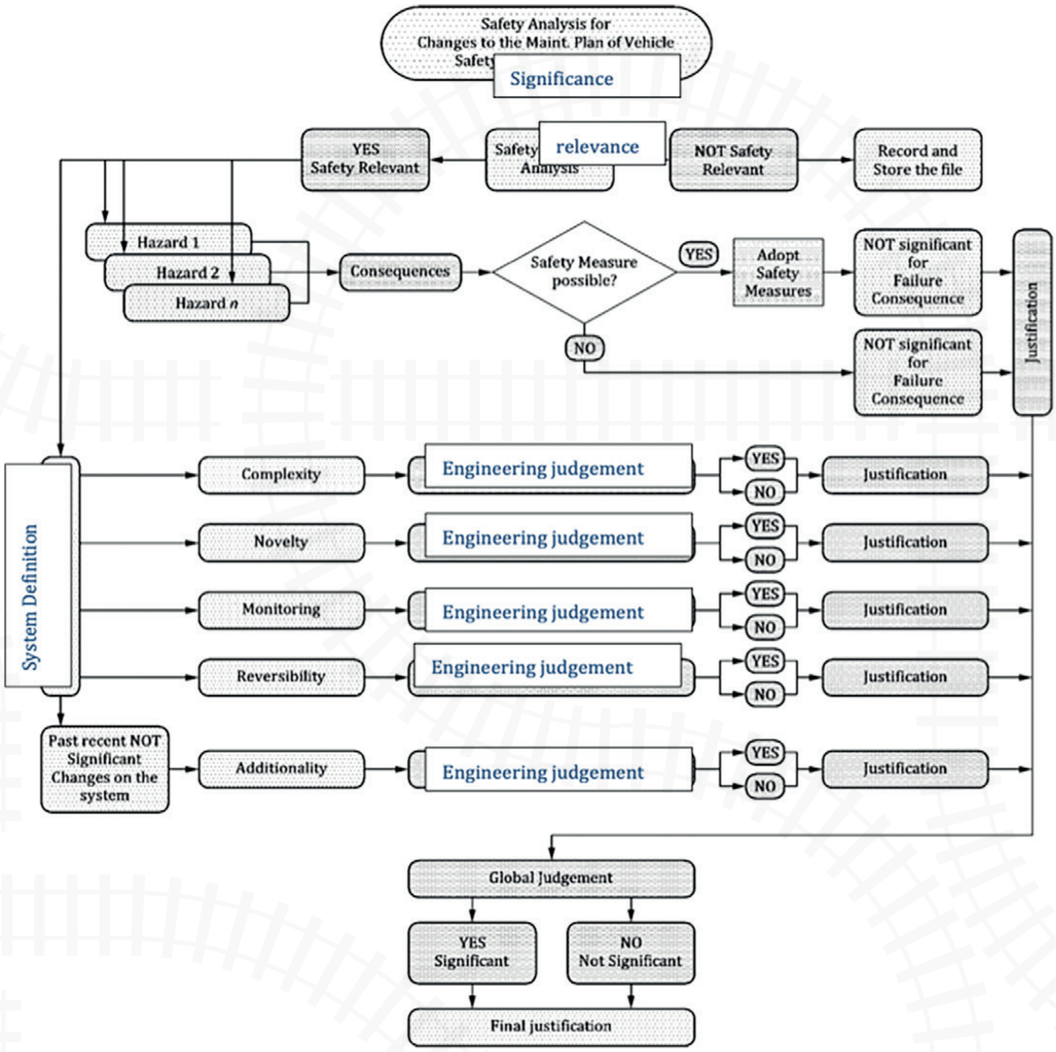


Figure 2 : Example of Safety Significance Analysis process in prEN17023

The process starts with a safety analysis for changes to the maintenance plan. If the changes are safety relevant, there should be an adequate safety assessment to identify safety hazards and evaluate the risks associated with these hazards in the context of system. And a significance analysis is needed.

Compared with MSG-3 method in the civil aviation industry, the approach to significance assessment in rail industry is determined by five criteria : failure consequence, innovation, complexity, reversibility and monitoring. Among these, failure consequence is the main criterion.

D2.2 Techniques to Support the Data-driven Maintenance of Rolling Stocks

The concept and methodology of MSG-3 was introduced in Deliverable D2.1 and an example case study to demonstrate how MSG-3 is applied to a typical system is provide in this deliverable. It has been shown that the MSG-3 methodology is able to provide a useful basis for the definition of appropriate maintenance actions to support the implementation of 'Smart Rolling Stock Maintenance'. The use of the MSG-3 decision logic helps to identify whether an interval- or condition-based maintenance approach is appropriate for each maintenance significant item.

In the process of CBM, data and feature extraction techniques required to support the maintenance decision-making system have been reviewed. The overall procedure of a CBM system can be conceptually modelled as two main tasks :

1. Condition monitoring (CM) - consists of data acquisition, data storage and transmission and data processing. During these tasks condition data is firstly collected and used to diagnose and identify the possible root causes of system failures.

2. Maintenance decision support – consists of the transfer the information produced in (1) to develop guidance and evidence for maintenance decisions. The trending, thresholds and maintenance decisions are connected in a loop to ensure continuous improvement within a decision-support system (DSS) and to follow the general maintenance process. In this task several mathematical models (e.g., Integer Linear Programming (ILP)) can be used to develop maintenance planning and scheduling models which take into account technical and operational constraints as illustrated in Figure 3 below.

Several techniques are proposed for the development of a CBM decision support system which are applied to a range of case studies in Deliverable 2.3.

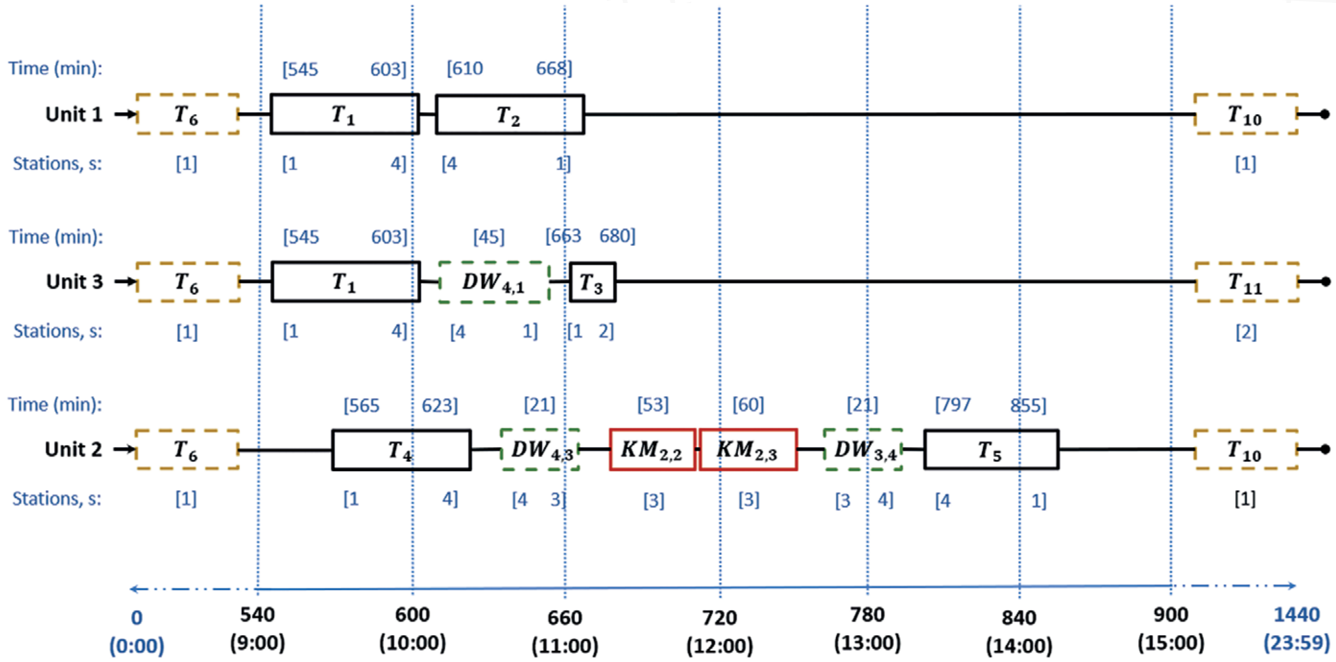


Figure 3: An example of 3-row-roster to cover timetable demand and maintenance requirements

D2.3 Preliminary Applications of CBM-model to Rolling Stock Components

The techniques identified within Deliverable D2.3 have been applied to the assessment of a range of rolling stock components/systems, including: wheelset, brake control unit and sliding door/step. These components/systems have been selected through consultation with project partners, Fertagus and LUL, along with close collaboration with the IMPACT-2 project.

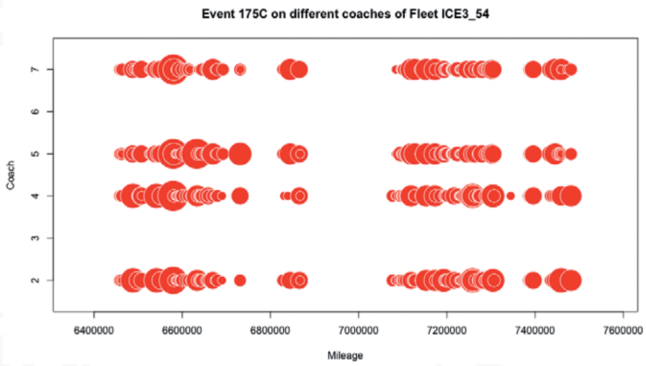
A range of data processing techniques have been applied to the data describing the conditions of the selected components/systems, including: data cleansing and integrity checking; statistical characteristics of variables (time interval and distance); correlation analysis on multiple variable and identification of trends. The outputs from this data processing have been used to develop prediction models of future component/subsystem condition for use in maintenance decision support tools.

The selected components/systems also provided the opportunity to assess two distinctly types of conditions data; (1) sensor or automated inspection data which provide a time/distance history of a physical quantity to describe the condition of the a component/system and (2) event (diagnosis) data which only provides a fault code and measured variable when a specific event occurs.

Diagnosis data analysis (IMPACT-2)

Trends in the type and occurrence of failure codes reported by the trains' on-board diagnosis systems have been analysed.

Correlation between different failure codes, condition variables and maintenance actions have also been made.



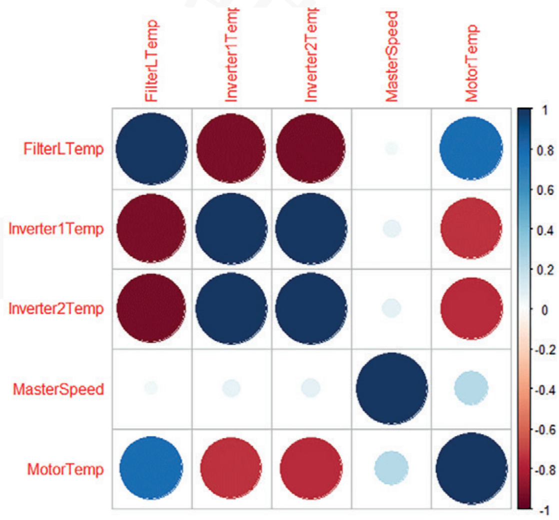
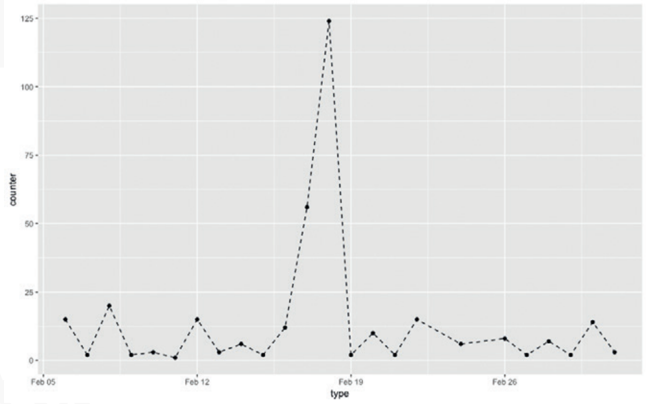


Figure 4: Occurrence of an event for different vehicles on a particular fleet (a) and correlation matrix of a set of condition variables (b).

The top figure shows an example of the occurrence of a particular failure on different coaches over a certain distance, and the bottom chart is the matrix shows that the correlation among various variables of the condition of a contraction control unit.

Analysis of the diagnostic data to identify patterns which can be used to predict the potential for future failures and enhance maintenance decisions.



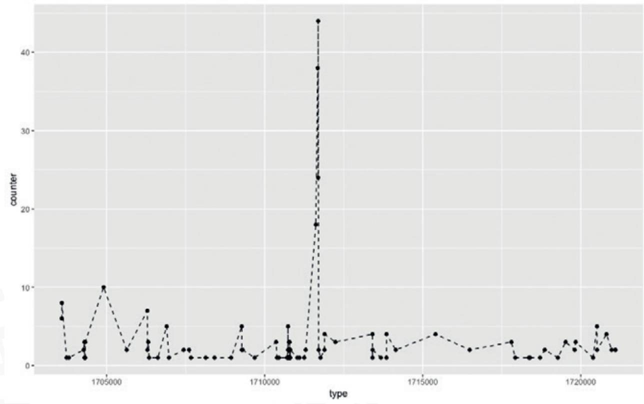


Figure 5: The occurrence of a failure over a period of time and a distance

In the case study, one of the most common failures in the vehicle is selected after analyzing the history of its appearance over a period of time and over a certain distance. Based on the historical data, a recurrent neural network (RNN) model is created to predict the failure in future. The results of the prediction are shown in Figure 6.

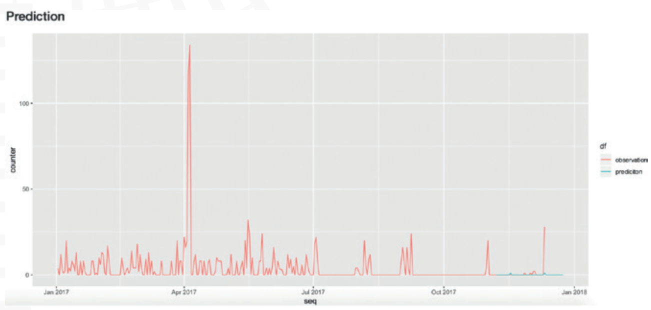


Figure 6: Prediction of the failure in next period

Wheelset degradation and survival analysis

Analysis of wheelset data demonstrates the variation in wheelset tread diameter due to wear with increasing running distance (km) since last re-profiling or renewal operation. This can be represented by a quadratic equation as illustrated in the figure below.

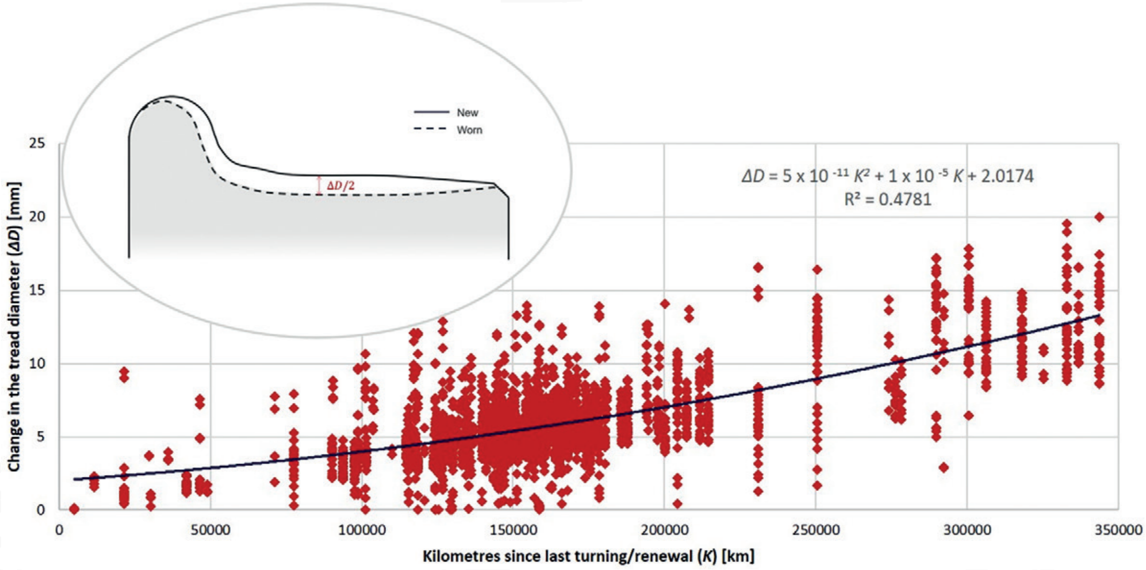


Figure 7: Change in the tread diameter due to wear with the kilometers since last turning/renewal operation

A survival analysis for the occurrence of wheelset damage has been performed considering historical wheelset data provided by project partner Fertagus. The observation time starts until damage occurs or a preventive wheel re-profiling operation is actioned. Survival curves have been estimated based on parametric and non-parametric models such as Kaplan-Meier curve.

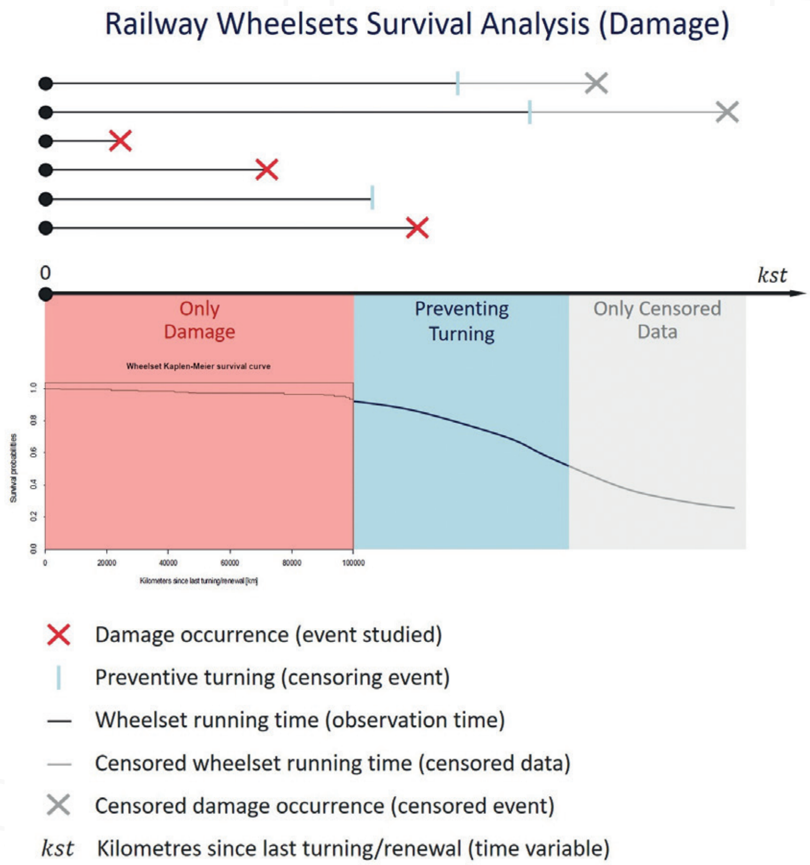


Figure 8: Railway wheelsets survival analysis (damage occurrence)

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.

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 macrotrends 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 macrotrends 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.

T3.2 : Evaluating and mapping passengers' experiences

Starting from the result of T3.1 literature review and of the T3.2 qualitative research activities (i.e. workshops with industry stakeholders and focus groups with rail services final users), held between April and September 2018, we proceeded with the support of a professional graphic designer to visually represent the elements emerged to be key for passengers' experience, through a diagram : the Rail Journey Experience Map.

The map is a synthetic, clear and multi-faceted, image of the context of use, the users' characteristics and needs, the possible usability issues and strong points of the rail travelling experience. Although it was conceived as an autonomous tool, it was accompanied by a report of T3.2 activities and results, the purpose of which was to further contextualize and complement the information shown in the map. Both the documents represent the link between T3.2 and T3.3 ; the goal of T3.3 was to perform surveys on a number of representative transport users, including non-rail users, to define the influence of key factors on the choice of a transport mode, including railway.

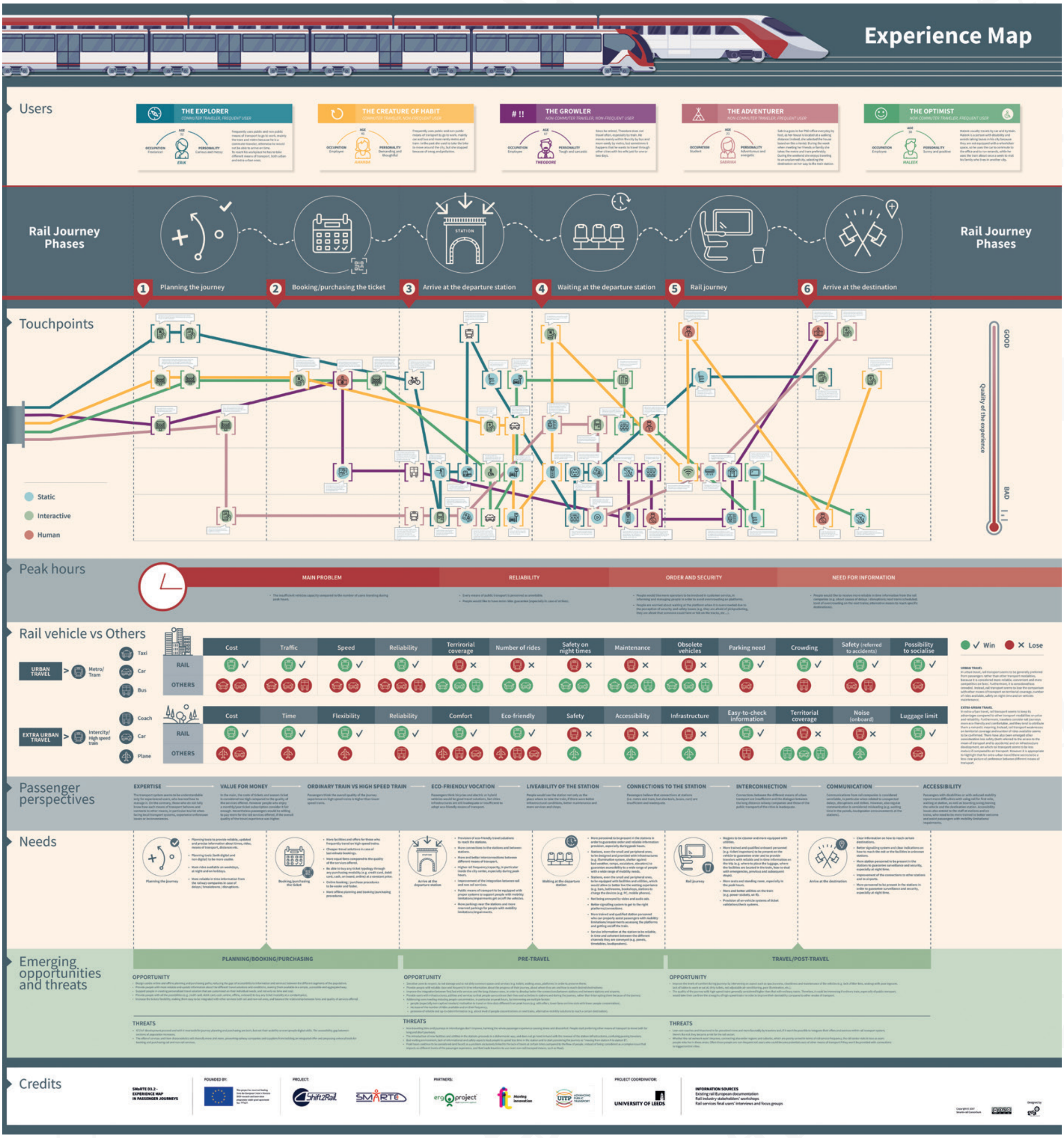


Figure 9: Rail Journey Experience Map

T3.3 : Passenger Surveys

This Task 3.3 is based on surveys of a representative number of transport users, including non-rail users, to define the influence of key factors behind the choice, or otherwise, of rail. Inputs to the survey design are taken from Tasks 3.1 and 3.2

Three European partner countries have been chosen as the basis of catchment areas, to allow the customisation of surveys and to enable partners to translate the surveys. It is also in line with other related activities in Work Package 3.

Using the large dataset we are able to cross compare results across different areas and user types. Therefore our findings enable us to make robust conclusions as to the key gaps in provision for rail passengers and barriers for non-rail passengers, having considered a large number of attributes to capture journey experience.

The findings here will form the basis of recommendations to feed into Task 3.4 (The Smart Journey Vision) and associated deliverable D3.4

The work is summarised in this poster presented at the UITP Summit in June 2019.

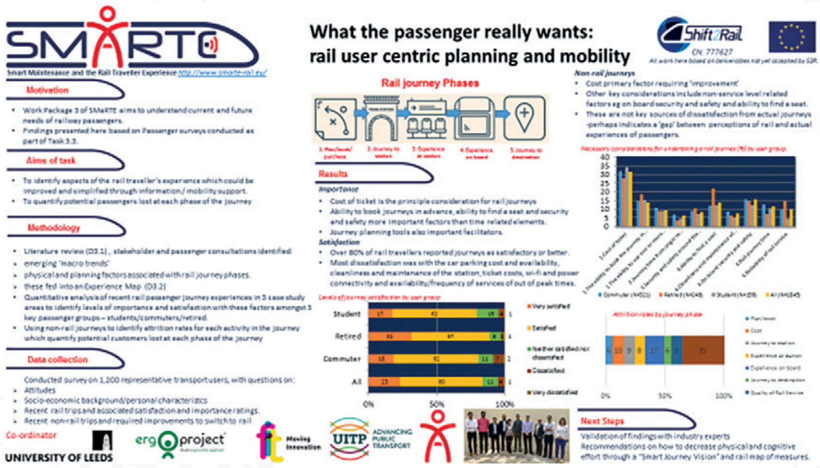


Figure 10 : SMaRTE results on human factors work-stream

T3.4 : The “Smart Journey” Vision

The objective of Task 3.4 is to seek expert opinion on improving the rail passenger journey experience through carrying out a Delphi survey. A group of experts, most of whom participated in Task 3.1 will be provided with selected information from the outputs of tasks 3.1-3.3 namely : 1) a high-level survey of demographic and societal factors affecting transport users at different journey stages (T3.1) ; 2) the Passenger Experience Map from Task 3.2 ; and 3) selected results from the large survey of rail users and non-users done in Task 3.3. Through the input of expert opinion and an iterative synthesis exercise, an industry and policy-facing “Smart Journey” vision will be produced, with a “Railmap” of prioritised recommendations for the industry aimed at simplifying 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, 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 11: 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.

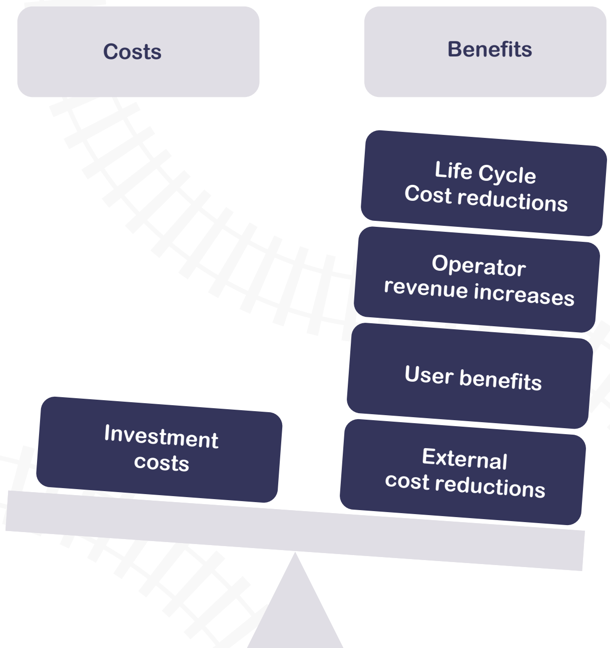


Figure 12 : Costs and Benefits in the impact assessment

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. This reflects that work needs to take place within WP2 and WP3 to outline the technical and passenger behavior research prior to quantifying the impacts. This activity will run to the end of the project. Relevant inputs have been developed in respect of the passenger behaviour element of the assessment (WP3) to feed in to the impact assessment. Links have been made to the simulations from WP2 to support the assessment of the assessment in respect of smart maintenance.

PROJECT DISSEMINATION

SMaRTE at UITP Global Public Transport Summit (June 10th-12th, 2019)

This is the world's biggest event dedicated to sustainable mobility with stakeholders such as politicians operators, operations/network managers, business developers, marketing/finance managers and academics. Here we disseminated the findings from Work package 3 through a poster session and a MaaS technologies workshop.

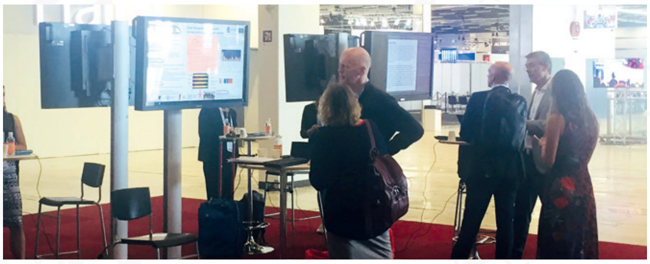


Figure 13: SMaRTE at UITP Global Public Transport Summit

SMaRTE at the International Wheelset Congress (June 16th-19th, 2019)

The 19th International Wheelset Congress (IWC) brought together stakeholders not only from the wheel and wheelset industry, but it also attracted key players across the globe, from system integrators, component manufacturers, operators and research institutions. The papers that were presented during the congress looked at various topics from the integrated design of wheelset components, to new maintenance approaches, materials development, performance enhancement, inspection methods, manufacturing processes, certification aspects and digitalisation. In this framework, the findings from Work package 2 were disseminated at a dedicated stand together with other Shift2Rail projects.

Figure 14: SMaRTE at IWC

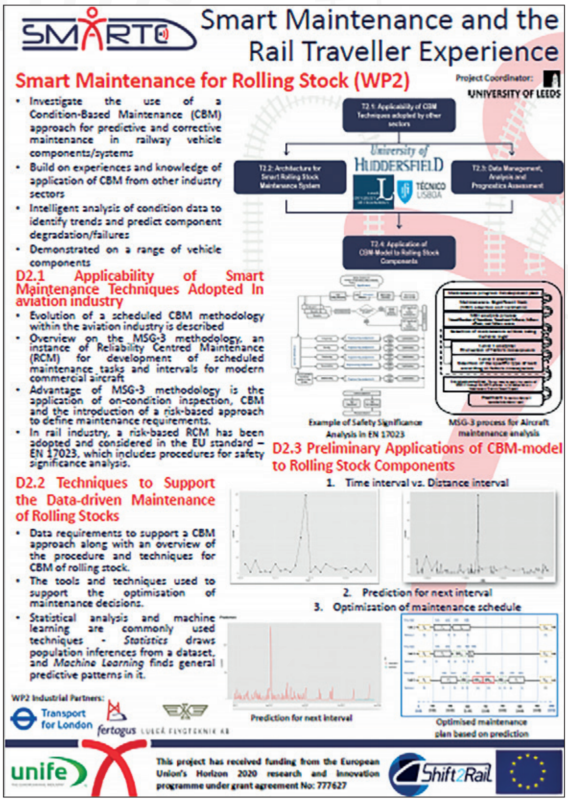


Figure 15: SMaRTE results on smart maintenance work-stream

SMaRTE at the Universities Transport Study Group Annual meeting (July 08th-10th 2019)

The Universities' Transport Study Group (UTSG) aims to promote transport teaching and research and to act as a focus for those involved in these activities in universities and institutions of higher education in the UK and Ireland. Over 100 departments from the UK and Ireland are involved in UTSG's activities, and over 70 academic institutions are represented on its list of overseas correspondents. Results from T3.3 were also presented here.

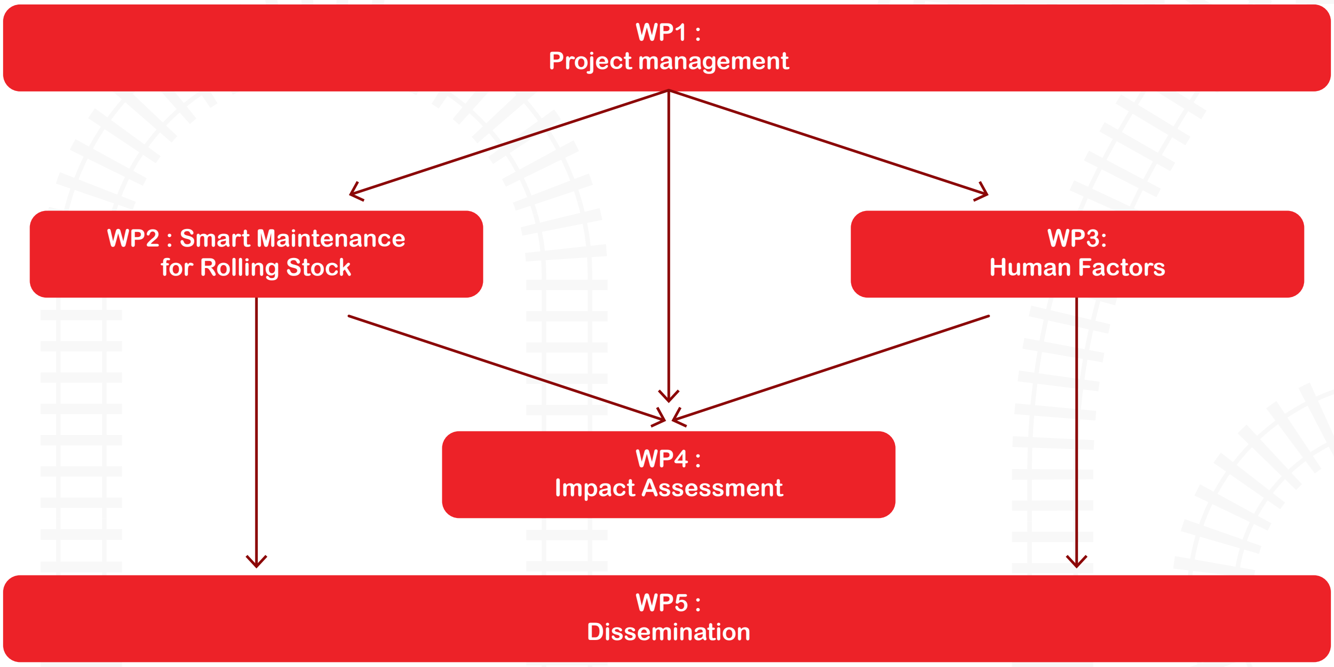
UPCOMING EVENTS

03-05/09/2019 Huddersfield, UK – COMADEM 2019

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

27-30/-4/2020 Helsinki, Sweden – TRA2020 : Rethinking transport - Towards clean and inclusive mobility

PROJECT STRUCTURE



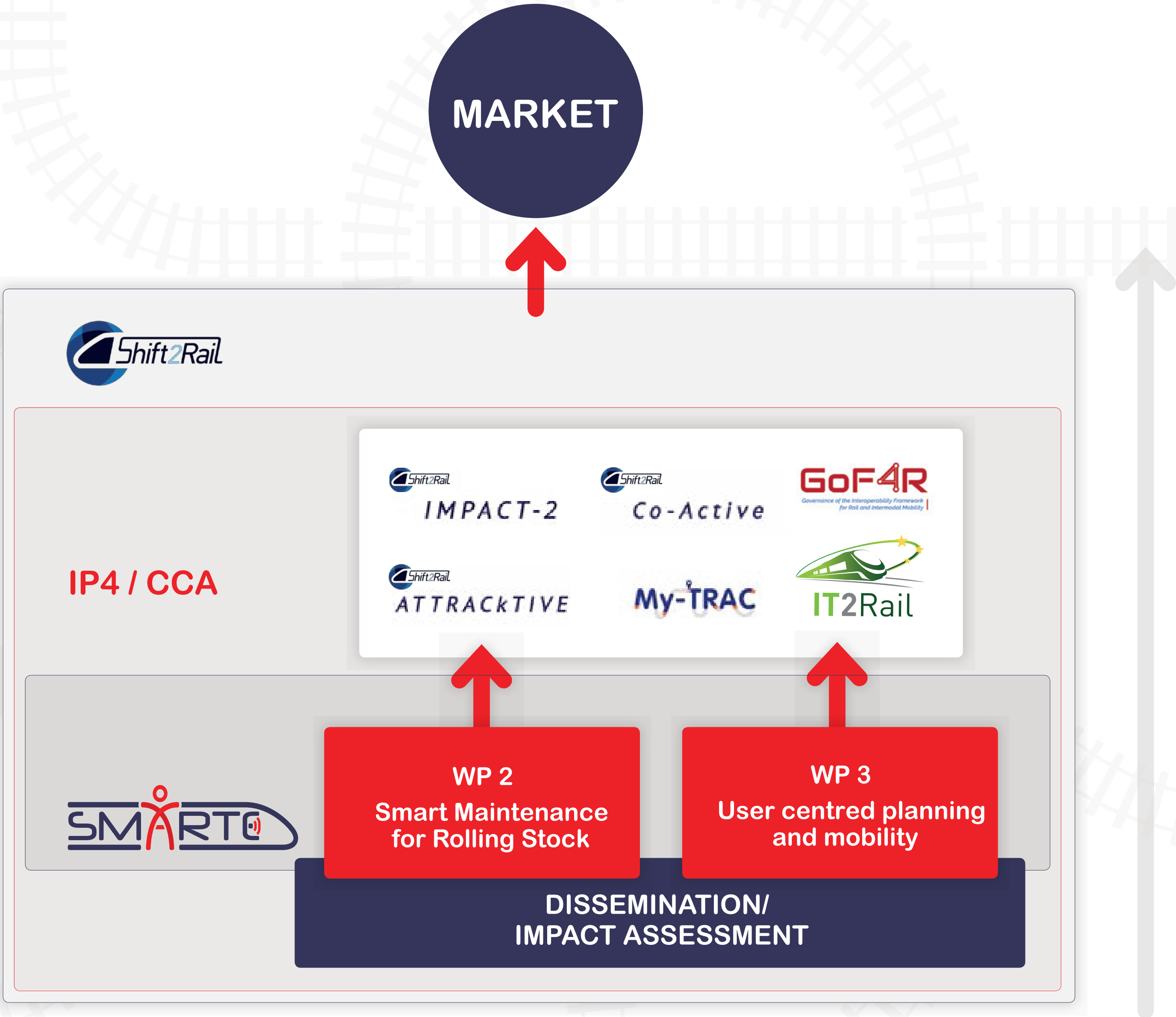
The structure of SMaRTE is two-fold : one set of tasks focused on the improvement of the maintenance of the rolling stock, the second set focused on a better understanding of the travel choice by potential passengers. These two work-streams will culminate in a joint impact assessment activity which ensure a full system approach. Other supporting activities such as dissemination, management and coordination are also consideredas 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 WITHIN THE S2R ENVIRONMENT



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, specifi cally 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.

FACTS AND FIGURES

TOTAL BUDGET

0.7 MILLION

PARTNERS

11

DURATION

26 MONTHS

PROJECT START DATE

1ST SEPTEMBER 2017

PROJECT END DATE

31ST OCTOBER 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

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