SMART MAINTENANCE AND THE RAIL TRAVELLER EXPERIENCE

D5.3 Report on Dissemination and Exploitation Activities and Project reports achievements for future S2R activities

Due date of deliverable: 31/10/2019

Actual submission date: 19/12/2019

Leader/Responsible of this Deliverable: Marta Andreoni, UNIFE

Reviewed: Y

Document status		
Revision	Date	Description
1	15-10-2019	First release for WP5 partners' comments
2	25-10-2019	Input from HUD on WP2
3	29/10-2019	Input from UNIVLEES on WP3 dissemination activities
4	13-12-2019	Input from UNIVLEES on WP3 exploitation activities
5	20-12-2019	Final version approved by the coordinator

Project funded from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No 777627. This document 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.

Dissemination Level		
PU	Public	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

Start date of project: 01/09/2017 Duration: 26 months

REPORT CONTRIBUTORS

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Daniel Johnson	UNIVLEES	Revision and provision of missing input
Adam Bevan	HUD	Input to agreed structure

EXECUTIVE SUMMARY

This document provides a description of the SMaRTE dissemination and communication activities carried out during the whole duration of the project. The aim of this report is to provide a detailed description of the dissemination strategy and how this was implemented during the 26 months of project implementation, including the materials and strategies that have been used to facilitate the dissemination of the wide spread of information and knowledge of the results generated through the project. The dissemination of SMaRTE has been essential throughout the project's life and been carried out with the cooperation of all Work Packages.

First, materials and strategies for communicating and disseminating SMaRTE to railway stakeholders, the scientific community and the general public are presented. Those include: the creation of a project identity; the creation of a website; the production of two newsletters; the creation of a project brochure; the organization of dissemination events; the participation at conferences; and the publication of results in relevant journals. Moreover, this report describes how expert groups have interacted with the technical Work Packages and how the results have been disseminated to the Shift2Rail public-private partnership. Finally, a calendar of events is presented.

In addition, this document provides a description of the project results achieved over the duration of the project and how those results will contribute to the objectives/activities set up in the Shift2Rail Multi Annual Action Plan. The aim of this deliverable is to support the transfer of the knowledge gathered in the SMaRTE project to the Shift2Rail Joint Undertaking. The activities carried out in SMaRTE serve as input for the work implemented in the Cross-Cutting Activities of Shift2Rail.

The presentation of these results is structured with respect to the project's two thematic Work Streams, namely:

- Smart Maintenance
- Human Factors

Each section explains the work carried out, the main results and conclusions achieved so far, as well as the contributions of the results to the Cross-Cutting Activities of Shift2Rail plan.

ABBREVIATIONS AND ACRONYMS

CEN: European Committee for Standardization
CENELEC: European Committee for Electrotechnical Standardization
COMADEM: International Congress and Exhibition on Condition Monitoring and Diagnostic Engineering Management
EN: European Standard
ERA: European Railway Agency
EU: European Union
IWC: International Wheelset Congress
S2R: Shift2Rail
WP: Work Package

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1. INTRODUCTION

SMaRTE - Smart Maintenance and the Rail Traveller Experience - is a European research project within the Horizon 2020 programme of the European Commission.
SMaRTE brings together two related but distinct areas of research. Smart maintenance and human factors are both concerned with digitization 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.
SMaRTE has provided 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. On human factors, the final result of SMaRTE has been a set of quantified factors influencing rail usability, and recommendations on how to decrease the cognitive effort and onward mobility for rail journeys through a “Smart Journey Vision” and rail map of measures.

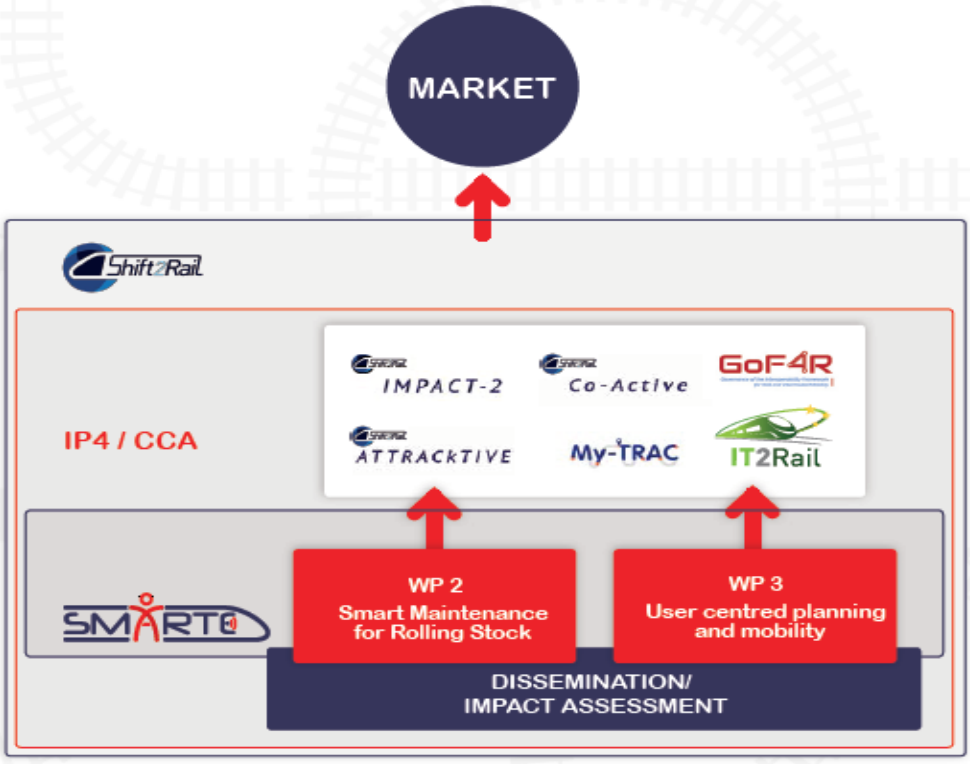

Figure 1: Project structure

The dissemination and exploitation of the project’s research activities and results are fundamental components of the SMaRTE project.

In order to address these priorities, the project has a dedicated Work Package (WP5), which coordinated and handled the dissemination activities of SMaRTE. UNIFE, UNIVLEEDS, HUD, FIT and UITP with the active collaboration of all partners, engaged in activities such as organising and participating in conferences, congresses and workshops as well as standardisation activities. WP5 with the collaboration of all the other partners also worked on the publication and distribution of material such as scientific publications, articles and brochures, press releases, newsletters and a website towards accomplishing dissemination of the project results to a wide range of audiences.

A widespread and targeted dissemination of project outputs was considered vital to the acceptance and implementation of the achievements developed. Therefore, SMaRTE established a detailed and clear strategy to reach the wider public and raise awareness of its main results. This report illustrates how this strategy was successfully implemented.

The research carried out in SMaRTE has provided valuable input for the work planned in Cross-Cutting Activities and it contributed in particular to the work of its corresponding CFM Project IMPACT-2.

In the two work areas, the project has provided a coordinated set of technical key contributions. These contributions are summarised hereunder, making reference to the work packages of the project in which they were derived:

WP2 - Smart Maintenance for Rolling Stock
Improvement of the current railway train maintenance systems, through the integration of predictive data analysis algorithms and online optimisation tools within an improved Condition Based Maintenance strategy. To this end the following lower level objectives have been targeted: • Review and benchmark of current CBM practices in other sectors, namely the aeronautical sector; • Development and integration of reliability ontology; • Development and integration of predictive tools for current and future condition of rolling stock components and systems; • Development of optimisation tools to support decision making; • Application of CBM models to real-world case studies on a range of rolling stock components.
WP3 - Human Factors: User Centred Planning and Mobility
Understanding of the current and future needs of passengers from the railway, and other transport systems characterised by rapid advances in technology and demographic change, and consider human centred design in identifying aspects of the customer experience which could be improved and simplified through information and mobility support. To this end the following lower level objectives have been targeted: • Review of demographical and societal factors affecting transport use, usability and attitudes towards transport. • Realize an Experience Map, which considers passengers as individuals behaving in the real context while performing the activities to reach their prefixed objectives. • Identification of the physical and planning factors and their relative importance in the journey to identify the resistance at each step of the journey, broken down by demographic groups and mode/journey purpose. • Estimation of attrition factors for each activity in the journey, again by mode/journey purpose and demographic groups, to quantify those potential customers lost at each step of the journey due to unfulfilled usability requirements. • Integrate the outcomes of the research into a ‘smart journey vision and roadmap of measures to simplify the end-user experience of planning and undertaking a trip that includes a rail journey.

Table 1: SMaRTE technical key contributions

1.2 SHIFT2RAIL

S2R is the first public-private European rail technology partnership that aims at building the railway systems of tomorrow. This initiative is fully operational since 2016 and seeks focused research and innovation by accelerating the integration of new and advanced technologies into innovative rail product solutions. The work of Shift2Rail is structured around five Innovation Programmes (IPs) that cover all of the different structural and functional areas of the rail system as well as five cross-cutting activities (CCA). One of S2R's main outcomes will be the demonstration activities, such as technology developments in the lab to system prototype demonstrations in operational environments.

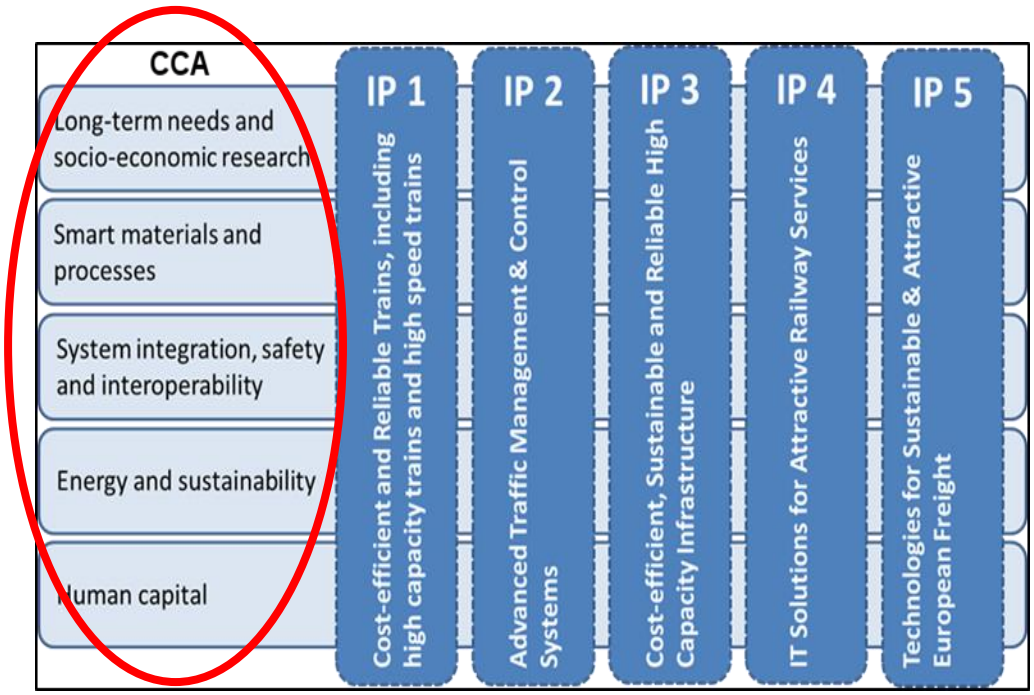

Figure 2: Overall structure of the S2R JU programme (Source: S2R MAAP, 2015)

2. EXTERNAL COMMUNICATION

External communication was of key importance for maximising SMaRTE's impact and for disseminating the project results. Communication of the project research activities involved reaching relevant railway stakeholders, the scientific community and creating awareness among the general public. This has been achieved through creating a project identity and a public website, attending conferences and relevant events and publishing articles in relevant journals.

2.1 PROJECT IDENTITY

A project identity has been set up at the beginning of the project including templates for presentations and reports, a project brochure as well as the SMaRTE logo. The project identity helped dissemination activities and ensured a consistent communication of the project concept,

objectives and results. The brochure has been distributed at project workshops and conferences, where project partners participated.

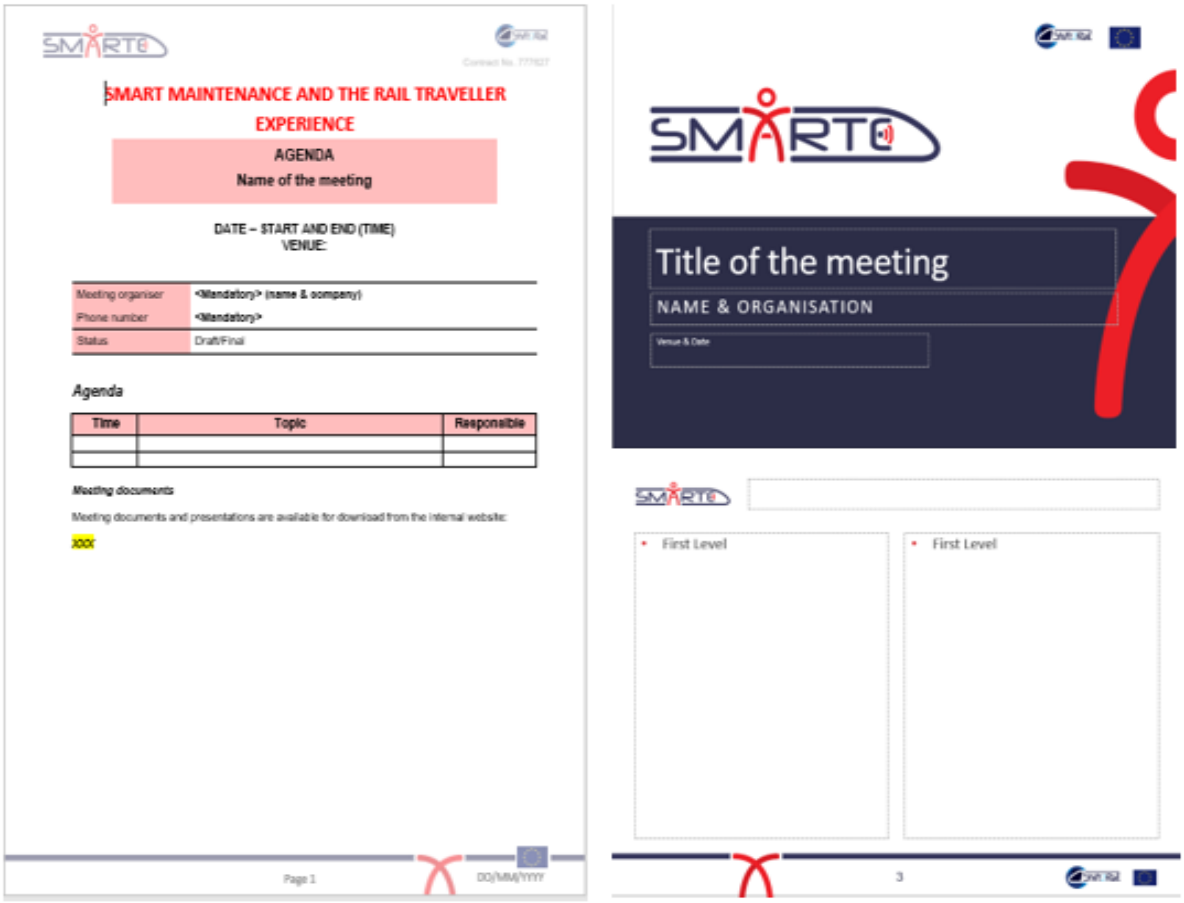

Figure 3 SMaRTE template samples (Agenda of the Meeting & PPT)

2.2 WEBSITE

A dedicated website was set up at the beginning of the project. The website (www.smarte-rail.eu) has been available throughout the whole project, with a section where visitors can register their interest. It is divided in two parts: the public portal and the private portal. The public portal displays the key project information, partners, Deliverables, news/events and links to the partners' institutions. All the public deliverables have been published on the website and are available for download. The project website will be available after its conclusion.

The webpage also lists all related projects including links to them. The webpage also offers links to the Shift2Rail website as well as to the websites of other projects such as IMPACT-2.

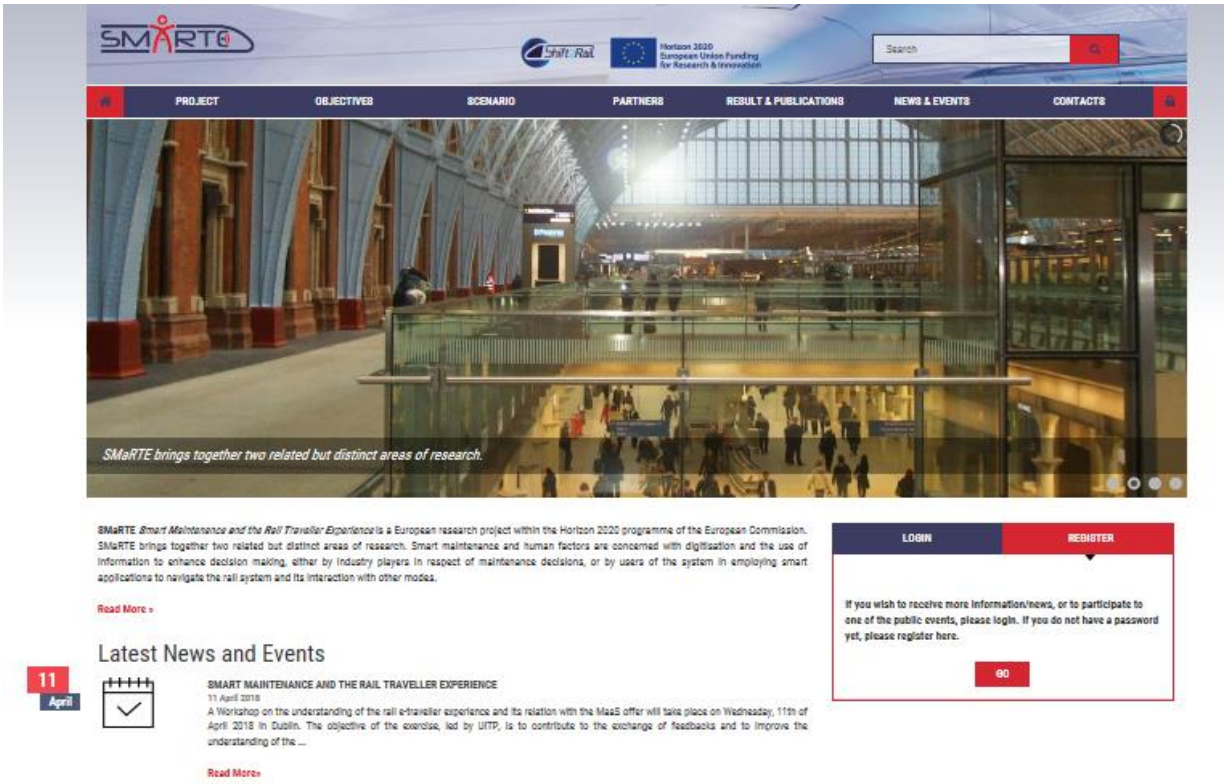

Figure 4: SMaRTE website

2.3 BROCHURE

During the first part of the project, a brochure was delivered. The main objective of this publication was to provide a wide audience with some preliminary information on the goals of the project, the structure and main planned activities and the members of the SMaRTE consortium. The brochure anticipated the newsletters and has been distributed at events and workshops.

Figure 5: Extract from SMaRTE brochure

2.4 NEWSLETTER

The project has produced two newsletters to provide up-to-date information on the status and achievements of the project.

The first newsletter was released in September 2018 and distributed for the first time at InnoTrans 2018 and then at IWC 2019. The second newsletter was produced toward the end of the project September 2019 in time to be distributed during important dissemination events such as COMADEM 2019.

The newsletters were also circulated via e-mailing lists and in a printed version that complements the project brochure. In order to ensure that the widest audience possible is reached, each partner has used its own mailing list. The newsletters are also uploaded on the project webpage and the printed copy has been distributed at events and workshops.

Figure 6: Two pages from the 1st and 2nd SMaRTE newsletters

2.5 EVENTS

SMaRTE partners promoted the project results during public events organised in Europe during the whole term of the project such as at TRA2018 (Vienna, April 2018), InnoTrans 2018 (Berlin, September 2018), UITP Global Public Transport Summit (Stockholm, June 2019), International Wheelset Congress (Venice, June 2019), COMADEM 2019 (Huddersfield, September 2019), University Transport Studies Group conference, July 2019. and other relevant occasions. A paper on WP3 results has been accepted for presentation at TRA 2019.

2.6 PRESENTATIONS AND PUBLICATIONS

Project results have been published in several specialized magazines, scientific journals and at relevant national and international conferences and workshops. SMaRTE has actively looked out for high profile academic and industrial events that are within the domain of interest of the project. At the end of the project, SMaRTE has been presented/published in the following events and press (an exhaustive list will be included in the Final Report):

Event/Publication	Title	Authors	Type of audience
Non-scientific and non-peer reviewed publications (popularized publications)			
Various (press-release)	More Effective Rolling Stock Maintenance	A. Bevan (HUD)	Non-technical
Project Repository Journal	SMaRTE project – overview and findings	Daniel Johnson, Adam Bevan	Non-technical
Scientific publications			
Proceedings of the 8th TRA, 2020	What the passenger really wants: Rail user centric planning and mobility	Daniel Johnson, Kate Pangbourne, Simone Lettieri, Simon Mastralangelo, Carlo Vaghi, Jeremy Shires	Academics, consultants, practitioners, operators, regulators
Participation to a conference			
Rolling Stock Maintenance Europe 2018	Better Use of Condition Data to Support Smart Rolling Stock Maintenance	X. Ge (HUD)	
COMADEM 2019	Condition Monitoring for Railways	A. Bevan (HUD)	
COMADEM 2019	Planning maintenance actions in train operating companies – a Portuguese case study	M. Méchain (IST) A. Andrade (IST) M. Gomes (IST)	
Rail Maintenance Middle East 2019 – Rolling Stock Predictive Maintenance & IoT	Vehicles Monitoring Vehicles – Feed Forward Neural Network Prediction	F. Balouchi (HUD)	
UITP Global Public Transport Summit	What the passenger really wants: rail centric planning and mobility – poster presentation	Daniel Johnson, Kate Pangbourne	Academics, consultants, practitioners,

			operators, regulators
UITP Global Public Transport Summit, Shift2Maas Workshop	SMaRTE project overview	Daniel Johnson	Academics, consultants, practitioners, operators, regulators
University Transport Studies Group conference	What the passenger really wants: Rail user centric planning and mobility	Daniel Johnson, Kate Pangbourne, Simone Lettieri, Simon Mastralangelo, Carlo Vaghi, Jeremy Shires	Academics, regulators
Participation to an event other than a conference or workshop			
Stand and poster at IWC 2019	• General overview of the project • Dissemination of results	M. Andreoni (UNIFE), S. Iwnicki (HUD)	Scientific Community, Industry, Policy Makers
Stand, poster and structured session at COMADEM 2019	• General overview of the project • Presentations from WP2 partners during structured session • Dissemination of results	A. Bevan (HUD) F. Balouchi (HUD) A. Andrade (IST)	Scientific Community, Industry, Policy Makers

Table 2: Targeted Publications and Conferences

2.7 ADVISORY GROUPS

In SMaRTE, research and technology uptakes were developed in parallel being followed by standardisation activities. The SMaRTE partners have supported this task by checking the viability and accuracy of the SMaRTE results with the developments in Regulation and Standardisation bodies in order to safeguard the project's services and conformance.

Since SMaRTE brings together two related but distinct areas of research, the discussion with the Advisory Group were carried out in separate calls.

On Smart Maintenance for Rolling Stock: An industry advisory group was establish to provide expert review of the outputs from WP2. This group included representatives from project partners Fertagus and LUL, along with other industry representative from outside the project including Unipart Rail and the IMPACT-2 partners (Siemens and DB). Separate virtual meetings were held with each of the advisory group members and presentations were also made at the relevant IMPACT-2 meetings. The comments received from the advisory group helped to ensure the techniques developed during the research were applicable to wider range of components/systems and highlight any issues/assumptions in the techniques.

On Human Factors: User Centred Planning and Mobility an Advisory was organized in Brussels on 24th January 2019, following the Consortium Plenary meeting the day before. External experts, such as a representative from ERA and from DB, was focused to discuss the main findings of D3.1 and how to liaise innovations within the projects with S2R innovations. We have also liaised with the Advisory Group informally over email to communicate our findings and sough and incorporated their guidance when devising the passenger survey.

3. INTERACTION WITH SHIFT2RAIL

SMaRTE brings together two related but distinct areas of research. The human factors work links to Work area 6 of the CCA-Cross Cutting Activities in the S2R MAAP, Human Capital, which aims to bridge the gap between changes in the railway and other sectors imposed by rapid technological advances and substantial demographic change. Specifically within this work programme 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. Therefore, the exploitation of the project's results to Work area 6 and 3 of the CCA-Cross Cutting Activities of Shift2Rail will be ensured. Knowledge-transfer discussions will be organised between the project WP leaders and relevant Shift2Rail TD leaders.

3.1 Overview of the Contribution of SMaRTE to Shift2Rail

In particular, SMaRTE has closely cooperated with its corresponding CFM project IMPACT2 - Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains – Phase 2 - coordinated by Trafikverket. A Collaboration Agreement between the two projects was signed at the beginning of the project.

3.2 WP2 - Smart Maintenance for Rolling Stock

3.2.1 Description of the Work

A number of synergies existed between WP6 of IMPACT-2 (specifically Tasks 6.3 – 6.5, CBM for passenger trains, reported in deliverable D6.4) and SMaRTE WP2 which were identified early in the project. As such Huddersfield were invited to participate on IMPACT-2 WP6 technical meetings and hosted a workshop with IMPACT-2 partners in Huddersfield.

The aim of the work was to develop a demonstrator for CBM activities and verify the benefits of the approaches through the use cases agreed in WP6. Data for the defined components (use cases) was collected by IMPACT-2 and analysed by Huddersfield to identify patterns in the data which would be suitability for CBM.

Huddersfield supported the transfer of data collected by IMPACT-2 partners by hosting a data transfer site which allowed each partner to upload rolling stock diagnosis, condition and maintenance data for further analysis. To facilitate this separate non-disclosure agreements between each IMPACT-2 sub-task leader and Huddersfield were signed.

The collected diagnosis data was analysed during the SMaRTE project to identify patterns that might reveal potential for maintenance or overhaul interval optimisation. This included statistical

analysis of the data and maintenance records, development of routines for failure prediction and exchange of results between all partners.

3.2.2 Contribution of the Results to Shift2Rail

The work conducted by Huddersfield in WP2 of SMaRTE, in close collaboration with IMPACT-2 partners, has had a direct contributed to the IMPACT-2 deliverable D6.4 (CBM Results for Rail Vehicles). This has included a review of data analysis and pattern recognition techniques (reported in SMaRTE deliverable D2.2) and application of these techniques to the analysis of diagnosis and maintenance data collected by IMPACT-2 for a range of components/system from regional, double-deck, high-speed and suburban EMUs (as reported in SMaRTE deliverable D2.3).

The outputs have helped to identify the suitability of the selected data to monitor the condition of components/system, support the diagnosis and prognosis of failures and the development of CBM-routines for future CBM activities. The investigations conducted have also identified challenges to for the future application of CBM, including: data access, data quality, cooperation from operator/maintainer, standardisation of data format, structure and interface as well as personnel skills for data analytics.

3.3 WP3 - Human Factors: User Centred Planning and Mobility

3.3.1 Description of the Work

- Reviewing demographical and societal factors affecting transport use, usability and attitudes towards transport.
- Defining behavioral use cases to be evaluated and deepened through passengers' experience mapping (Task 3.2) and a follow-up survey (Task 3.3).
- Implementing the Experience Map to simulate possible train trip experiences considering passengers as individuals behaving in the real context while performing the activities to reach their prefixed objectives.
- Conducting a passenger survey to identify physical and planning factors - and their relative importance - in the journey to identify the resistance at each step of the journey, broken down by demographic groups and mode/journey purpose.
- Identifying attrition factors for each activity in the journey, by mode/journey purpose and demographic groups, to quantify potential customers lost at each step of the journey due to unfulfilled usability requirements.
- Drafting the "Smart Journey Vision" and a roadmap (called 'railmap') of measures to simplify the end-user experience of planning and undertaking a trip that includes a rail journey

3.3.2 Description of the Work

Our findings have highlighted a number of areas for future research around a lack of clear evidence base regarding demand impact and valuation of the following aspects:

- ticket flexibility
- Utilization of digital tools to improve coordination between operators and integration of offerings into MaaS packages.
- Role of better tools for trip planning and information access.
- More understanding of the contribution of mechanisms for responding to customer needs and the role passengers can play in designing solutions.

Further, these will inform the survey work carried out in WP4 of Shift2Maas which we is led by the team from UNIVLEEDS involved in SMaRTE.

CONCLUSIONS

This report has provided an exhaustive list of all dissemination/communication activities carried out during the 26 months of project implementation. A large audience has been reached by SMaRTE messages and the project has at the same time ensured proper dissemination towards the Shift2Rail Joint Undertaking to ensure a smooth and effective transfer of results into the Shift2Rail projects.

Secondly, this report shows how the activities carried out in SMaRTE serve as input for the work implemented in the CCA of S2R. According to its aims, the work within the project SMaRTE was segmented into two work streams: Smart Maintenance For Rolling Stock, and Human Factors: User Centred Planning and Mobility. In these two areas, the solutions proposed by SMaRTE are shown to be "promising" in terms of impacts in general.

During the first case study of WP2 the feasibility of using a combination linear regression and neural network techniques to the analysis of on-train diagnostic data for prediction of impending failures (e.g. before the failure becomes terminal) were shown to provide some promising results. In the second case study a range of techniques were applied to wheelset condition data to demonstrate the potential for supporting maintenance decision making and optimisation. This included statistical modelling of wheelset degradation, survival modelling and a Markov decision process. These techniques were shown to provide a robust method for deriving a CBM strategy map for wheelset re-profiling and, when linked with maintenance planning models, can integrate the complexity of maintenance planning (including operational and technical constraint) in a medium term horizon.

Based on the WP2 stream of work, in WP4 a Fertagus case study was used to perform an impact assessment of moving towards more condition-based wheelset maintenance activities operationalised by relaxing the wheelset turning interval. In terms of the KPI1, long run cost reductions can be achieved up to 35% on preventive and corrective wheelset maintenance costs over the full life time of the wheelsets. In terms of total preventive maintenance costs annually up to 3% can be saved. Moreover, the potential for cost reductions depends on the rolling stock component under consideration. In an alternative analysis, cost reductions of annual preventive maintenance costs up to 1% were identified when the maintenance interval for sliding doors was relaxed.

Given the limited costs of installing CBM monitoring devices, there is a clear business and financial case to make use of smart maintenance methods. More importantly, we believe that larger cost reductions can be achieved when multiple condition based interventions are implemented jointly.

In WP3, through 1) a literature review; 2) stakeholder and passenger consultations and 3) a large scale passenger survey, a series of key aspects of the journey experience were identifies as a focus for improvements under different future scenarios. Recommendations included actions to improve affordability and ticket flexibility, improve safety and security and facilities around stations, rolling stock comfort and the development of trip planning tools. More costly recommendations included improving service reliability and frequency and improving first and last mile travel experience. Where supporting evidence permitted, in WP4 we investigated scenarios involving improvements of 10% in these attributes and found demand uplifts of between 20-40% depending on the type of rail network. Further welfare impacts were identified from improvements in consumer surplus.

Future exploitation activities have been identified as follows:

- Continued discussions with IMPACT-2 partners to further develop the most promising techniques trialled during the collaboration between SMaRTE WP2 and IMPACT-2 WP6.
- Outputs to be disseminated through the UK Rail Research Innovation Network (UKRRIN) Centre of Excellence in Rolling Stock, which is hosted at Institute of Railway Research (University of Huddersfield). Founding members who might benefit from the SMaRTE outputs include: Siemens, Bombardier, Hitachi and Unipart Rail.
- Outputs to be disseminated at Railway Industry Association (RIA) Unlocking Innovation event focused on Materials, Automation, Data and Energy (M.A.D.E) for Rolling Stock (December 2019, Huddersfield)
- New Shift2Rail IP5 open call project, LOCATE, will utilise the outputs from SMaRTE for the application to locomotive bogie condition maintenance.
- Presentation of WP3 results at TRA2020
- Exploitation of WP3 findings through participation in the Shift2Maas project where a passenger survey led by UNIV Leeds will feed into an impact assessment of digital enabling technologies and utilisation of travel apps