NEWSLETTER JULY 2021

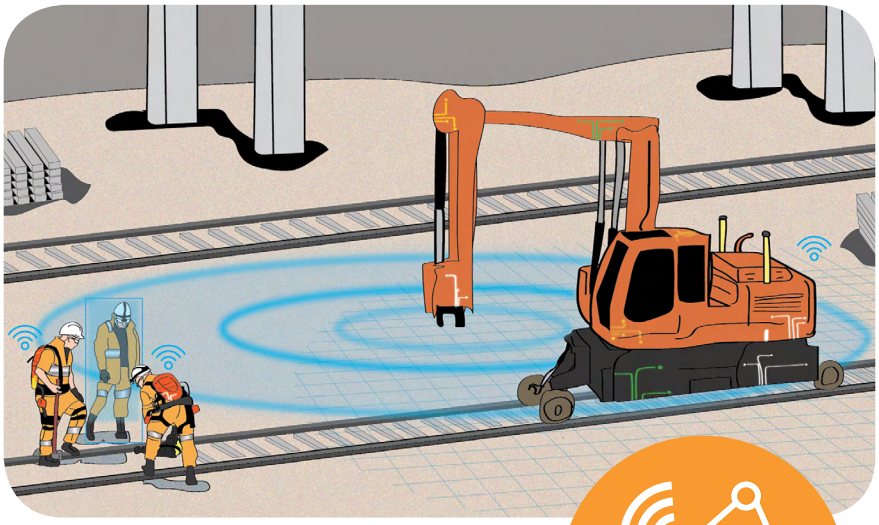
STREAM

CONTENT

FOREWORD/INTRODUCTION

In this 1st newsletter of the **STREAM** (Smart Tools for Railway work safEty and performAnce iMprovement) project, learn more about the current developments that the project has achieved in its first six months. Through the various developments described, you should also get an idea of what is to come in the next, until the project's completion at the end of May 2023, with biannual newsletters.

To learn more about STREAM and its goals, access the public deliverables, and get to know the project partners better, please visit our website at. https://streams2r.eu/



PROJECT SCOPE & STRUCTURE

The rail industry is facing important challenges as the average age of the workforce keeps growing while less young workers are interested in the physically demanding work required. Smart technologies can help to reduce work demands, avoid incidents and accidents, and support workers during heavy activities. STREAM support LEAN execution of intelligent maintenance process by introducing technologies that cause negligible modification of current working procedures, yet strongly improve operation planning, safety and performance. STREAM will develop two smart technologies employing environment perception and human intention principles enabling prevention and risk mitigation.

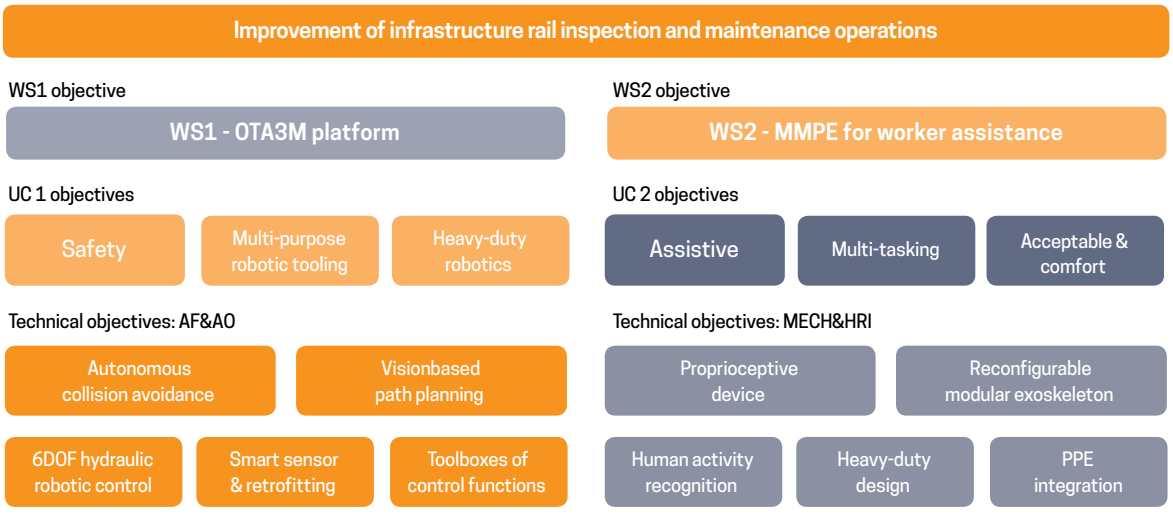
STREAM is a new collaborative project involving 7 partners from 5 EU Countries with the common goal to improve rail inspection and maintenance operations. The main ambition is to improve working methods by moderning and introducing robotic systems, but at the same time improve safety of workers, thus it also creates benefits in workers' health and quality of life at work. Funded by the European Union in the framework of Shift2Rail Joint Undertaking Programme, **STREAM** is coordinated by Istituto Italiano di Tecnologia (IIT).

STREAM activities will deliver two different technologies to improve competitiveness in railway maintenance and construction operations:

- The first technology (Work Stream 1) will consist on the development of a control platform aiming to convert traditional heavy-duty hydraulic machines (e.g. excavators) in robotic systems. These will be able to move and complete manipulation tasks autonomously. In addition, by introducing a level of robotic autonomy, digitalization and intelligence, the safety of On-track Autonomous Multi-purpose Mobile Manipulator (OTA3M) will be enhanced.
- The second technology (Work Stream 2) will be focused on the deployment of a Modular Multitasking Powered Exosketon (MMPE) to reduce the risk of injury due to physical overload. This exoskeleton will be worn by workers and will assist them in physically demanding activities, with the main feature of being a versatile exoskeleton that acts in accordance with the worker activities. Furthermore, the comfort, effectiveness and usability of these innovative devices will be studied and improved in order to positively influence the quality of life and safety of workers.

The ultimate goal of the **STREAM** project is to support the construction and maintenance processes of railway infrastructures by introducing smart technologies within the current working procedures, to improve them by optimizing their operation planning, safety and performance. This is aligned to the EU's worker policies of enhancing safety, to achieve permanent improvement basing it on the structural reduction of the probability of fatalities, injuries and damage.

STREAM will collaborate with main companies in the rail field and the IN2SMART2 CFM project, also part of the Shift2Rail community constituted by twenty large enterprises of the rail sector. In addition, **STREAM** is building a network of companies involved in the project as advisory board (End-User Board), to share experience and feedbacks to guide the technology development along the project life of the project.



USER, SAFETY, REGULATORY, ETHICAL, AND TECHNICAL REQUIREMENTS

In order to properly address the technical solutions for Work Package 1 (WP1) and WS2, the WP1 of **STREAM** has the objective of gathering the requirements, categorized into User Requirements, Safety and Regulatory Requirements, and Ethical Requirements for each of the two WSs.

Requirements & KPIs for generic On-Track Autonomous Multi-purpose Mobile Manipulator

Thanks to the cooperation of different roles in the End User Board partners, such as Acciona, Network Rail, Ferrovie Nord, Strukton Rail, ADIF, who participated in meetings and contributed to the questionnaire organized by the consortium, it has been possible to understand the needs and the most effective tasks to be automated. These needs have been also gathered from COMSA's internal data, with the main objective of increasing safety of workers and the economic impact. Then, starting from these needs, the relevant end user requirements have been derived.

From the analysis of standards, best practices and internal procedures used, Safety and Regulatory requirements have been collected. These requirements have been completed by the application of the Responsible Research and Innovation principles and by an ex-ante ethical assessment performed within Work Package 6 (WP6), that will have further developments in the next phases of the project. Some Ethical Requirements have been defined, focused on gender and diversity, stakeholders' engagement, and education. Then, as a result all the collected requirements, the main characteristics of the technical solution that will be developed within **STREAM** have been defined. Finally, the Key Performance Indicators (KPIs) that will be used to measure the final scenario with the OTA3M have been established.

The specific uses cases for this work stream were also selected: ballast cleaning with one available track, ballast cleaning with two available parallel tracks and sleepers' replacement.

Requirements and KPIs for the Modular Multitasking Powered Exoskeleton

Thanks to the cooperation of several functions in the End User partner (COMSA), like workers, Construction/ Site managers, H&S managers, Project Managers, it has been possible to understand how an exoskeleton could help workers in heavy railway activities. The needs have been gathered both from the workers and organisational points of view. They focus on physical needs, such as the fatigue and discomfort workers can feel while performing heavy activities. On the one hand, the aim is to improve workers' experience in terms of safety, injuries, pain, and job satisfaction. On the other hand, **STREAM** also considers the needs for safety and relevant economic impact, including a reduction of sick leave days and absenteeism, for companies. Relevant end user requirements have been derived on this basis. In parallel, an analysis of international standards, best practices and internal procedures used by the End Users companies in the **STREAM** consortium has been conducted. Safety and Regulatory requirements have thus been collected. The requirements have been collected while applying the Responsible Research and Innovation principles, partly through stakeholder participation. Further efforts concerned ethics, with the completion of an ex-ante ethical assessment performed within Work Package 6 (WP6), which led to identifying ethical requirements focused on gender and diversity in general, and on the physical enhancement that a smart device could bring and the subsequent forms of use and misuse.

The Key Performance Indicators (KPIs), that will be used to measure the final scenario, have been defined.

Questionnaires for companies and for workers

Questionnaires completed by end-users have been created in order to address the requirements and needs. In a first stage, they have been fulfilled by COMSA, MER MEC STE, the end users of the **STREAM** consortium, and by the End-Users Board members.

Within WS1 a questionnaire for companies have been created, with questions relative to the technology, the activities that most affect workers physically, the operational needs and the investments.

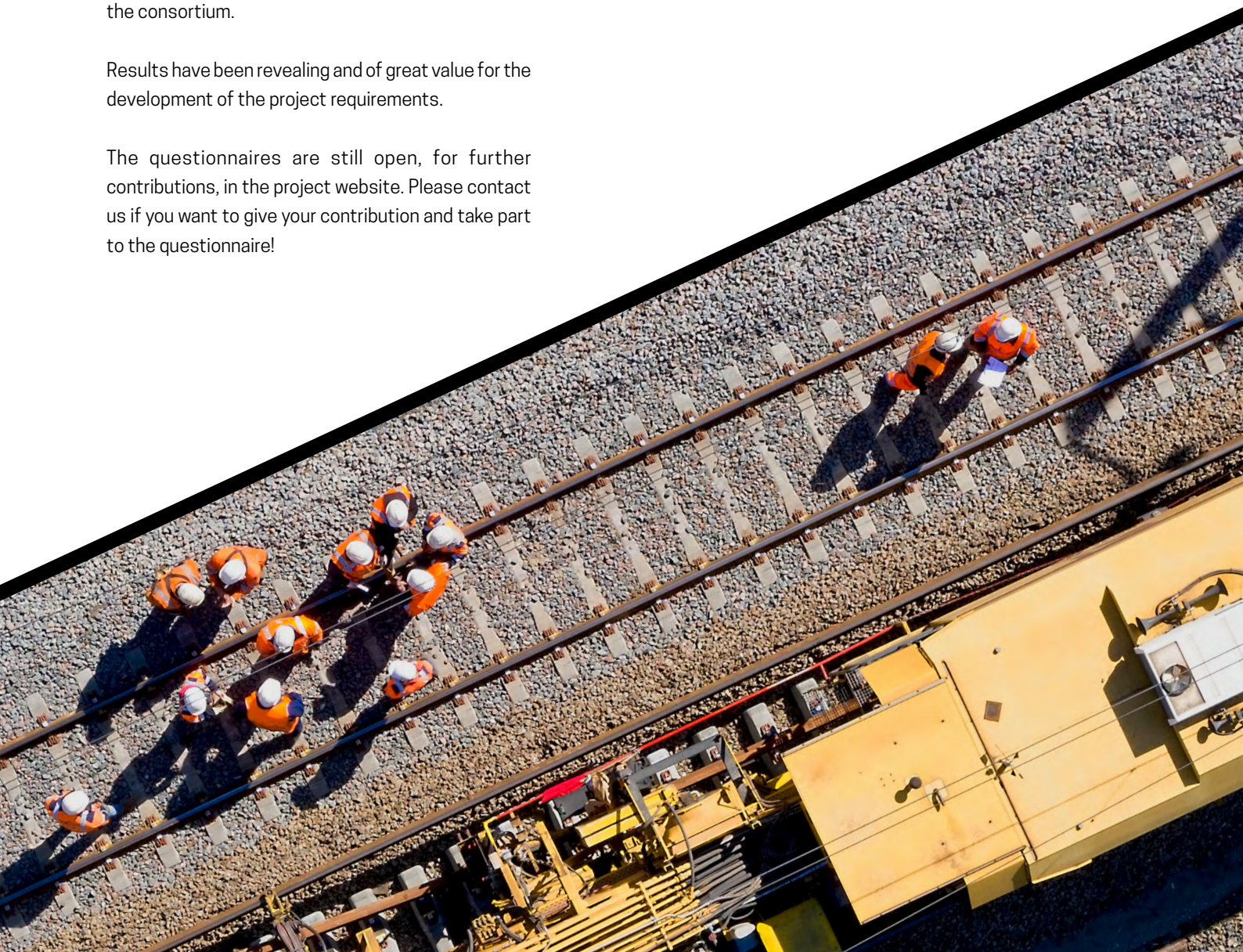
For WS2 two questionnaires have been created: one for companies, fulfilled by the managerial level of COMSA, MER MEC STE and End-Users Board; and another for workers, fulfilled by workers of the two End-Users of the consortium.

Results have been revealing and of great value for the development of the project requirements.

The questionnaires are still open, for further contributions, in the project website. Please contact us if you want to give your contribution and take part to the questionnaire!

Main achievements and next steps

STREAM released the first version of the requirements for the development of a control platform integrated in a current railway excavator (for WS1) and for the development of the exoskeleton (for WS2). The requirements will be refined thanks to the assessment with the alpha prototype produced in the first year of the project after the first cycle of problem definition, design solution, integration, and testing phases. A second version of requirements, for both WSs, will be released in summer 2022. The iterative methodology will be applied twice: the finalized version of requirements will lead to the development of the beta prototype, which will be the final outcome of the **STREAM** project.



OTA3M - AUTONOMY FUNCTIONS

Tampere University, together with Novatron, will develop the OTA3M control architecture, which is developed in a virtual development environment to enable safety focused and cost-effective development.

Supportive toolboxes are designed to provide required safety functions, such as a virtual working gauge and ARCC that will enable safe autonomous operations in railway applications.

From safety point-of-view, a point cloud-based environment perception system is designed, that can be utilized in later for the development of a collision avoidance system, and an automatic braking system is designed to stop the OTA3M safely.

Finally, OTA3M autonomous running mode is designed, where at first a path-following controller is developed to enable autonomous navigation of the OTA3M road-rail wheel system as a mobile robot problem.

Then, secondly, an exteroceptive safety certified laser scanner is used to detect obstacles on service tracks for avoiding collisions by stopping the OTA3M motion. STAM has the objective to develop efficient inspection and maintenance plans, respecting safety constraints and optimizing the activities and the tasks to be performed. The approach that will be followed envisages the creation of an agent-based model to simulate the working environment where autonomous machines and workers accomplish different tasks. Multiple configurations will be analysed in order to identify how to maximize the operation planning and performances of both autonomous machine and workers.

Different tasks will be performed to developed the OTA3M, as:

1. OTA3M platform design description and control architecture design
2. Safety function toolboxes for the OTA3M development and run-time safety
3. Perception system and model calibration toolbox for any-brand OTA3Ms
4. Controller designs for generic autonomous OTA3Ms in working and running modes
5. Development of the agent-based models

All this, will lead to design the robotic excavator arm, in 6DOF, fully equipped with a perception system (e.g. stereo cameras and lidar) for enabling autonomous collision avoidance while performing operations. Therefore, our main target is to develop a set of autonomous operations enabling the collaboration with the OTMs thanks to HMI principles.

The functionalities, embedded into the OTA3M, allow the autonomous control of both the motion of the excavator arm and road-rail wheel system.

In the first phase requirements for safe and efficient operations have been defined. Standards related to safety and autonomous operation on rail have been studied extensively to have the best possible requirements definition. Also, first virtual demonstrations have been carried out to demonstrate the improved safety functionalities.

WEARABLE ROBOT MECHATRONIC DESIGN

In WS2, by Istituto Italiano di Tecnologia (IIT) will develop a Modular Multitasking Powered Exoskeleton to assist rail track workers during inspection and maintenance operations. The occupational exoskeleton, will be able to understand the worker intention, and at the same time, to reduce the operational efforts by applying specific forces, synchronized with the musculoskeletal system. Human bio-functional aspects will be central to the design, as well directed on industrial hygiene and hazard process analysis as applied to occupational exposures.

For an effective assistive exoskeleton, the control is a vital characteristic. The controller will be developed with a multi-tier structure, where each level cooperates to accomplish a specific function, creating harmony in the overall behavior and motion of the robotic system. As already noted, the wearable device must be able to interpret human intentions, enabling the exoskeleton to control smoothly and effectively the wide range of different activities required by the working tasks (e.g. walking, holding, lifting, carrying, pushing and pulling). The project aims to deliver a MMPE paying particularly attention to the cost-benefit analysis aspect. This will encourage a fast-industrial take-up.

The objectives that Wearable Robot Mechatronic Design and Human-robot Interaction will address are:

1. Development of a modular multitasking powered exoskeleton.
2. Lightweight and heavy-duty design, using high-tech materials and components to develop an environmental robust, resilient device.
3. Development of a proprioceptive device through a functional sensing strategy enabling actuation control, and remote monitoring.
4. Development of a human activity recognition (HAR) algorithm able to autonomously select specific control strategies tailored to the workers and the task.
5. Maximization of the integration of typical rail worker PPEs improving device acceptability.

In the previous months, the requirements of the end users have been collected and the list of specifications for the exoskeleton has been defined. The next steps on the development of the **STREAM** project will consist in the selection of the sensors to be installed on the exoskeleton and the definition of the backend and frontend architecture in order to achieve the functionalities needed for the first release.

In detail, the starting idea provides the deployment on the Google Cloud Platform of the following interfaces:

1. Back-end written in java spring boot;
2. Front-end written in angular;
3. Database running an instance of MySQL

Moreover, the database instance will be deployed in a Cloud SQL service and the communication will be transmitted through API REST.

ASSESSMENT & DEMONSTRATION

The main objective of the work package on assessment and demonstration Work Package 6 (WP6) is to assess the developments carried out in Work Stream 1 (WS1) and Work Stream 2 (WS2) in an iterative way with the rest of the research and development Work Packages (i.e. Work Package 1 to Work Package 5 (WP1 to WP5) and to perform a final demonstration and validation of the developments by the end of the project.

Namely, the assessment of the developments shall include:

1. Validation of the requirements with emphasis on safety
2. Analysis of the performance against the baseline scenario in terms of KPIs
3. Ethical assessment, very important to the aim of this project and further described below
4. Cost Benefit Analysis

This work package is mainly managed by two partners, one of them is End-User (COMSA) and the University of Grenoble, with its expertise in the cost benefit assessment and in the Ethical field.

Technical demonstrations of both technologies on Italy and Spain

A first demonstration of the state-of-the art solutions has taken place at the beginning of 2021. In the case of WS1, it was a virtual reality demonstration carried out by Tampere University and Novatron, while for WS2, two physical demonstrations of the current IIT exoskeletons took place: one on January 27th 2021 as planned, to deploy the exoskeleton technology in some Italian End-User to assess the first prototype to show the background of IIT, as shown in the left picture below and another on February 17th 2021 at COMSA in Barcelona (Spain), as shown in the picture bellow.

A demonstration for WS1 (virtual reality demo) and WS2 (physical demo) is foreseen by early 2022 to check the developments carried during the first part of the project with regard to the OTA3M and MMPE, respectively, and in order to assess them against the requirements and KPIs.

The final demonstration is foreseen by the first half of 2023, before the end of the project, to test the developments of the project in WS1 and WS2 in a real environment.

ETHICAL ASSESSMENT AND COST-BENEFIT ANALYSIS

Cost-Benefit Analysis and Ethical assessment are of high relevance for the project. The first one which aims to assess the viability of both the robots and the exoskeletons on the market as S2R is moving towards higher technology readiness levels. The second one will take the shape of an ex-ante analysis and an analysis of issues occurring due to the interaction of users, technology, and work context.

Ethical Assessment

It will be focused on the observation of current practices and devices use and demonstration, through interviews of relevant stakeholders including users, their peers, managers, and union during the observations of current practices, technology tests, and usage in real environments.

The data collected will be used in order to assess ethical issues arising and communicate them during the process of development. It will also be used to design the next steps of the assessment.

Therefore, a Q-study with relevant stakeholders participating in each WS of the project will be performed. This will allow to understand what the most important issues for individuals, and to identify points of consensus and disagreement among them. In turn, this data will allow to identify types of users and points of vigilance to work on for future implementation plans.

Cost-Benefit Analysis (CBA)

Several scenarios will be studied, including scenarios where the devices are used, scenarios where the devices do not reach the market, and other alternative options. To be representative, the CBA will integrate the costs and benefits imputable to a wide variety of stakeholders and cover a wide variety of potential benefits and costs be they technical, environmental, financial, economic. Risks will be accounted for and mitigation measures will be presented.

A non-exhaustive list of the stakeholders to be involved consists of the consortium members creating the devices, the companies who will buy and use the devices, and in particular financial managers, managers for health and safety, line managers, users. This will allow capturing costs and benefits from a micro and meso perspective. External stakeholders such as public health services and agencies will be consulted in order to assess the impact of the devices at a macro level, allowing assessing the pressure on public finances. The CBA will be realized through interviews and continuous communications with stakeholders.

END-USERS BOARD (EUB)

STREAM project has created an End-User Board composed by 12 companies, end users of the technology, composed by Infrastructure Managers and Construction companies. Representatives in the End-Users Board are experts in the field on maintenance and construction, and in some cases, they are working with test pilots in different technologies related to the **STREAM** project.

The EUB of **STREAM** will contribute to the project in different tasks as:

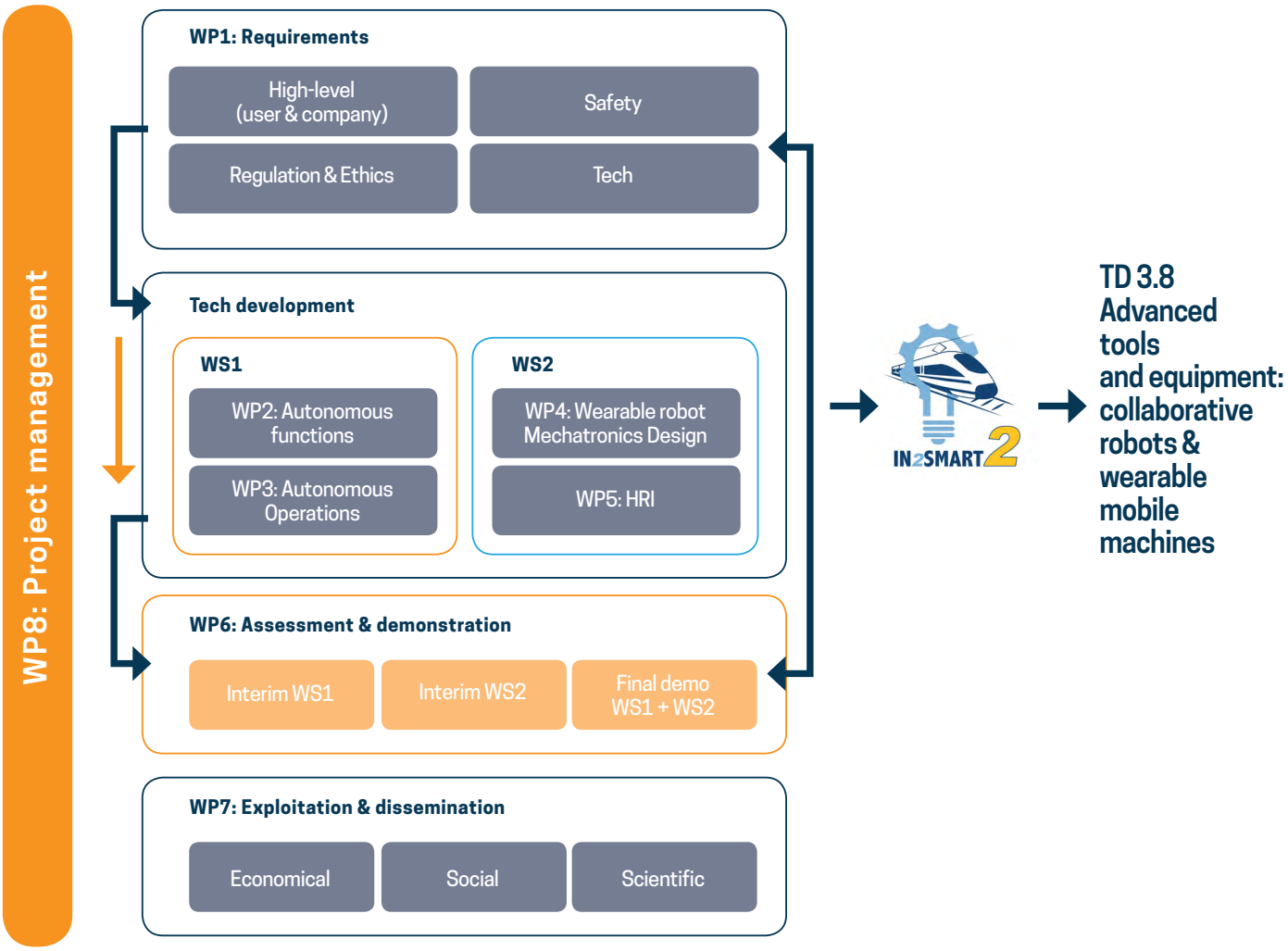
- Support in the definition of Technical Requirements of both Work Streams
- Contribution in specific use-cases
- Provide opinion and support in prototypes trials and the system evaluation
- Participation in the ethical assessment of the devices through participation in the acceptability Q-study
- Supporting capturing the costs and benefits from a micro and meso perspective

STREAM held its first End-Users Board (EUB) meeting on 16 April. The meeting provided a platform for experts to share their vision and expertise in the field of railway maintenance.

Click here to see the companies that compose the EUB of **STREAM.**

STREAM INTERACTION WITH SHIFT2RAIL

As depicted in the diagram below, the two Works Streams of **STREAM** are closely linked with IP3 project, IN2SMART2. In this respect the necessary collaboration has already been established during the beginning of the project and will continue until the end of the project.



FACTS AND FIGURES

Total Project Value
2.7M

7
Partners

Project Start Date
1 st Dec 2020

Project End Date
31 st May 2023

Topic
S2R-OC-IP3-03-2020

Complementary project IN2SMART2

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